**Table A-1. HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>Rupture of egg membrane.<br>Fatal injury or permanent auditory tissue damage limiting to survival.<br>Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey<br>Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. Likelihood of egg and alevin exposure is limited, as the majority of Chinook spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | <u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br><u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation.<br><u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure.<br><u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Likelihood of egg and alevin exposure is limited, as the majority of Chinook spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is highly likely. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles | <u>Eggs and alevins, juveniles</u>: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Likelihood of egg and alevin exposure is limited, as the majority of Chinook spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is highly likely. May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness. |

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## Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | Likelihood of egg and alevin exposure is limited, as the majority of Chinook spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is highly likely. See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | Likelihood of egg and alevin exposure is limited, as the majority of Chinook spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is highly likely. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |



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## Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Likelihood of egg and alevin exposure is limited, as the majority of Chinook spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, stressor may affect survival. May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles;<br>Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and productivity of juveniles and adults. |

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**Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Likelihood of egg and alevin exposure is limited, as the majority of Chinook spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, stressor may affect survival, growth, and fitness. May affect survival, growth, and fitness of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures) | Year-round, (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and survival. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. |

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Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Chinook dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, Chinook are known to utilize terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high quality habitat features. | May affect juvenile survival. |
| | Loss of groundwater input | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Chinook dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by waterlevel variability may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs predominantly during spring outmigration period through lakes) | Permanent | Continuous | Juveniles | Juveniles: Chinook are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |



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## Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival. |
| | Loss of groundwater input | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes) | Permanent | Continuous | Juveniles | Juveniles: Chinook dependence on groundwater inflow to nearshore lacustrine habitats is currently a data gap. | Avoid disturbance of vegetation along the shoreline. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, and reduced solar light penetration due to propeller-induced fine bubbles. | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. | | May affect juvenile survival. May affect adult growth and spawning productivity. |

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**Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.<br>Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | | May affect juvenile survival, growth, and fitness, as well as adult spawning productivity. |

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**Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile Chinook salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effects of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |

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## Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult Chinook salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adult Chinook will generally be less sensitive to these stressors. However, increased stress and delayed migration in the migratory corridor may reduce fitness and ultimately reduce spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | All exposed life-history stages: Jetties can fragment nearshore marine rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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## Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | All exposed life-history stages: Jetties can fragment nearshore lacustrine rearing habitats, forcing migrating and foraging salmonids to navigate offshore into deeper water environments. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and alevins; Juveniles; Adults | All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>Rupture of egg membrane.<br>Fatal injury or permanent auditory tissue damage limiting to survival.<br>Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey<br>Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. Likelihood of egg and alevin exposure is limited, as the majority of Chinook spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |



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## Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br><u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation.<br><u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure.<br><u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Likelihood of egg and alevin exposure is limited, as the majority of Chinook spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is highly likely. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles | <u>Eggs and alevins, juveniles</u>: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Likelihood of egg and alevin exposure is limited, as the majority of Chinook spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is highly likely. May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | <u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br><u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>Eggs and alevins</u>: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br><u>Juveniles</u>: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br><u>Adults</u>: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | <u>Juveniles</u>: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |

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### Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | Likelihood of egg and alevin exposure is limited, as the majority of Chinook spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is highly likely. See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Mortality or injury from entrainment.<br>Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | Likelihood of egg and alevin exposure is limited, as the majority of Chinook spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is highly likely. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success. |

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## Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Likelihood of egg and alevin exposure is limited, as the majority of Chinook spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, stressor may affect survival. May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles;<br>Adults | <u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and productivity of juveniles and adults. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br><u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Likelihood of egg and alevin exposure is limited, as the majority of Chinook spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, stressor may affect survival, growth, and fitness. May affect survival, growth, and fitness of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |

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**Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. | | May affect juvenile survival. May affect adult growth and spawning productivity. |

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**Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.<br>Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | | May affect juvenile survival, growth, and fitness, as well as adult spawning productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival.<br>Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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## Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile Chinook salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effects of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |

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## Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult Chinook salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adult Chinook will generally be less sensitive to these stressors. However, increased stress and delayed migration in the migratory corridor may reduce fitness and ultimately reduce spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |

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**Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| | **Lacustrine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |



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**Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and alevins; Juveniles; Adults | All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>Rupture of egg membrane.<br>Fatal injury or permanent auditory tissue damage limiting to survival.<br>Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey<br>Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Should exposure occur, direct mortality or injury is highly likely. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles | Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Should exposure occur, direct mortality or injury is highly likely. May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness. |

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of flow conditions to minimal area. | Should exposure occur, decreased survival is likely. May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Altered current and circulation conditions (marine and lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | Should exposure occur, direct mortality or injury is highly likely. See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |

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## Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Mortality or injury from entrainment.<br>Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | Should exposure occur, direct mortality or injury is highly likely. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Should exposure occur, stressor may affect survival. May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success. |
| | | Altered pH levels (freshwater only) | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles;<br>Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and productivity of juveniles and adults. |

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Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Should exposure occur, stressor may affect survival, growth, and fitness. May affect survival, growth, and fitness of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Direct mortality due to winter ice formation and scour.<br>Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns.<br>Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.<br>Adults: Decreased spawning fitness due to migration delays caused by thermal barriers. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Should exposure occur, stressor may affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity. |

**Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered stream bank and shoreline stability | Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools) | Year-round (with specific stressors prominent during high flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs and alevins; Juveniles; Adults | <u>Eggs/alevins:</u> Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification.<br><u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.<br><u>Adults:</u> Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Should exposure occur, stressor may affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs | Year-round | Permanent | Continuous | Juveniles | <u>Juveniles:</u> Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile rearing. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | <u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.<br><u>Adults:</u> Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced available suitable spawning habitat; reduced gravel dissolved oxygen | Year-round | Permanent | Continuous | Eggs and alevins; Adults | <u>Eggs and alevins</u>: Decreased incubation success.<br><u>Adults</u>: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success. | Avoid disturbance of vegetation along stream. | May affect survival of eggs and alevins, as well as adult spawning productivity. |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures) | Year-round, (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | <u>Juveniles</u>: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and survival. |



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**Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Chinook dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, Chinook are known to utilize terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high quality habitat features. | May affect juvenile survival. |
| | Loss of groundwater input | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Chinook dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input, and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. |



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**Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs predominantly during spring outmigration period through lakes) | Permanent | Continuous | Juveniles | Juveniles: Chinook are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival. |
| | Loss of groundwater input | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes) | Permanent | Continuous | Juveniles | Juveniles: Chinook dependence on groundwater inflow to nearshore lacustrine habitats is currently a data gap. | Avoid disturbance of vegetation along the shoreline. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. | | May affect juvenile survival. May affect adult growth and spawning productivity. |

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## Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles;<br>Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.<br>Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | | May affect juvenile survival, growth, and fitness, as well as adult spawning productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival.<br>Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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**Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile Chinook salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effects of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |

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**Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Juveniles; Adults | <u>Juveniles and adults</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult Chinook salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adult Chinook will generally be less sensitive to these stressors. However, increased stress and delayed migration in the migratory corridor may reduce fitness and ultimately reduce spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat; change in habitat structure, availability, and suitability; reduced food web complexity | Year-round | Permanent | Continuous | Eggs and alevins; Juveniles; Adults | <u>All exposed life-history stages</u>: Bank barbs and groins can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness. | Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |

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Table A-1 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chinook Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | All exposed life-history stages: Bank barbs and groins in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles;<br>Adults | All exposed life-history stages: Bank barbs and groins in lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-2. HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Fatal injury or permanent auditory tissue damage limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Likelihood of egg and alevin exposure is limited, as the majority of coho spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles | Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Likelihood of egg and alevin exposure is limited as the majority of coho spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity. |

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Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Streambed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Likelihood of egg and alevin exposure is limited, as the majority of coho spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and productivity at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | All exposed life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual-decadal | Eggs and alevins;<br>Juveniles;<br>Adults | All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | Likelihood of egg and alevin exposure is limited as the majority of coho spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual-decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual-decadal | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Mortality or injury from entrainment.<br>Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Likelihood of egg and alevin exposure is limited as the majority of coho spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |

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## Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles;<br>Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and fitness of juveniles and adults. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high-water temperature and current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Likelihood of egg and alevin exposure is limited as the majority of coho spawning habitat is located in areas unsuitable for jetty development. Should exposure occur stressor may affect survival, growth, and fitness. May affect survival, growth and fitness of juveniles and adults. |

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**Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures) | Year-round (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. This effect may be limited in magnitude, however, as juvenile coho use of littoral habitats is relatively limited. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and growth. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile coho use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and fitness. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Coho dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, coho are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival. |

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**Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Coho dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival, growth, and fitness. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival growth and fitness. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Coho dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, coho are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth, fitness, and survival. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile growth and fitness. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Coho dependence on groundwater inflow to littoral lacustrine habitats is currently a data gap. However, loss of groundwater may lead to reduction in shallow water thermal refuge, increased competition, and decreased foraging opportunity. | Avoid disturbance of vegetation along shoreline. | May affect juvenile survival, growth, and fitness. |

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**Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect juvenile survival, growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Alteration. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity. |
| | **Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | | May affect juvenile survival, growth, and fitness. |

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Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occuring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile coho. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect juvenile survival, growth, and fitness. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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## Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability. | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory coho salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect juvenile survival, growth, and fitness. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | All exposed life-history stages: Jetties can fragment nearshore marine rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |

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**Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles;<br>Adults | <u>All exposed life-history stages</u>: Jetties can fragment nearshore lacustrine rearing habitats, forcing migrating and foraging salmonids to navigate offshore into deeper water environments. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | <u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Fatal injury or permanent auditory tissue damage limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable. |

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## Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Likelihood of egg and alevin exposure is limited, as the majority of coho spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles | Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Likelihood of egg and alevin exposure is limited as the majority of coho spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity. |
| | | Streambed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Likelihood of egg and alevin exposure is limited, as the majority of coho spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and productivity at juvenile life-history stage. |

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**Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | All exposed life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual-decadal | Eggs and alevins; Juveniles; Adults | All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | Likelihood of egg and alevin exposure is limited as the majority of coho spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual-decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual-decadal | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Mortality or injury from entrainment.<br>Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Likelihood of egg and alevin exposure is limited as the majority of coho spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success. |

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**Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Likelihood of egg and alevin exposure is limited as the majority of coho spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, stressor may affect survival. May affect juvenile survival, growth, and fitness and adult survival, productivity, and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and fitness of juveniles and adults. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high-water temperature and current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Likelihood of egg and alevin exposure is limited as the majority of coho spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur stressor may affect survival, growth, and fitness. May affect survival, growth and fitness of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |

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## Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect juvenile survival, growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Alteration. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity. |

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**Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Site majority of facility offshore to limit grounding and prop wash effects. Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Design overwater structures and mooring buoys in accordance with USACE guidance to limit shading and anchor scour effects.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.<br>Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | | May affect juvenile survival, growth, and fitness, as well as adult spawning productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |

Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival.<br>Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile coho. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect juvenile survival, growth, and fitness. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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## Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability. | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory coho salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect juvenile survival, growth, and fitness. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |

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**Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Marine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| | **Lacustrine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Fatal injury or permanent auditory tissue damage limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Should exposure occur, direct mortality or injury is probable. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles | Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Should exposure occur, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success.<br>Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of flow conditions to minimal area. | Should exposure occur, decreased survival is likely. May affect survival during egg and alevin life-history stage, may affect adult spawning productivity. |

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Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered current and circulation conditions (marine and lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity. |
| | | Streambed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and productivity at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | All exposed life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual-decadal | Eggs and alevins;<br>Juveniles;<br>Adults | All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | Should exposure occur, direct mortality or injury is probable. See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual-decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual-decadal | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Mortality or injury from entrainment.<br>Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Should exposure occur, direct mortality or injury is probable. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |

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## Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and fitness of juveniles and adults. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high-water temperature and current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Should exposure occur stressor may affect survival, growth, and fitness. May affect survival, growth and fitness of juveniles and adults. |

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**Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Direct mortality due to winter ice formation and scour.<br>Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns.<br>Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.<br>Adults: Decreased spawning fitness due to migration delays caused by thermal barriers. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Should exposure occur, stressor may affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity. |
| | Altered stream bank and shoreline stability | Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools) | Year-round (with specific stressors prominent during high flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification.<br>Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.<br>Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Should exposure occur, stressor may affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs | Year-round | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile rearing. |

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## Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness.<br>Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile growth and survival, spawning success, and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced available suitable spawning habitat; reduced gravel dissolved oxygen | Year-round | Permanent | Continuous | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Decreased incubation success.<br>Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats.<br>Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success. | Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater recharge. Limit alteration of riparian vegetation to greatest extent practicable. | May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity. |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input, and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures) | Year-round (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. This effect may be limited in magnitude, however, as juvenile coho use of littoral habitats is relatively limited. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and growth. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile coho use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and fitness. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Coho dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, coho are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |

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## Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Coho dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival, growth, and fitness. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival growth and fitness. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Coho dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, coho are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth, fitness, and survival. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile growth and fitness. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Coho dependence on groundwater inflow to littoral lacustrine habitats is currently a data gap. However, loss of groundwater may lead to reduction in shallow water thermal refuge, increased competition, and decreased foraging opportunity. | Avoid disturbance of vegetation along shoreline. | May affect juvenile survival, growth, and fitness. |

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| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation codification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness. | Design: Site majority of facility offshore to limit grounding and prop wash effects. Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Design overwater structures and mooring buoys in accordance with USACE guidance to limit shading and anchor scour effects. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile survival, growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Alteration. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity. |
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Site majority of facility offshore to limit grounding and prop wash effects. Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Design overwater structures and mooring buoys in accordance with USACE guidance to limit shading and anchor scour effects. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | | May affect juvenile survival, growth, and fitness. |

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**Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs and alevins; Juveniles Adults | Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival.<br>Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity. Effects on spawning habitat are unlikely, however, as the cold water streams preferred by these species are unsuitable sites for groin and bank barb development. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of nonerodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Marine** | | | | | | | | |

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**Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile coho. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect juvenile survival, growth, and fitness. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |

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## Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability. | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory coho salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. profile characteristics where impacts are unavoidable. | May affect juvenile survival, growth, and fitness. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat; change in habitat structure, availability, and suitability; reduced food web complexity | Year-round | Permanent | Continuous | Eggs and alevins;<br>Juveniles;<br>Adults | All exposed life-history stages: Bank barbs and groins can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness. | Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |

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**Table A-2 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coho Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | All exposed life-history stages: Bank barbs and groins in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles;<br>Adults | All exposed life-history stages: Bank barbs and groins in lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-3. HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.**

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and alevins; Juveniles; Adults | All life-history stages: Stressor response dependent on noise magnitude; project specific environmental conditions may range from:<br>• Rupture of egg membrane.<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Likelihood of egg and alevin exposure is limited, as the majority of chum spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, and reduced growth and fitness, increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Likelihood of egg and alevin exposure is limited, as the majority of chum spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles | Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Likelihood of egg and alevin exposure is limited as the majority of chum spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness. |

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Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Streambed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Likelihood of egg and alevin exposure is limited, as the majority of chum spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Effects on chum salmon will be relatively minimal due to limited dependence on freshwater foraging. | Limit area of dewatering to the greatest extent practicable. | Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile chum salmon. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | Likelihood of egg and alevin exposure is limited as the majority of chum spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and alevins; Juveniles; Adults; | Eggs and alevins: Mortality or injury from entrainment.<br>Juveniles: Alteration of migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Likelihood of egg and alevin exposure is limited as the majority of chum spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |



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**Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.**

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Likelihood of egg and alevin exposure is limited as the majority of chum spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, stressor may affect survival. May affect juvenile survival, growth, and fitness, as well as adult survival, productivity, and spawning success. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Likelihood of egg and alevin exposure is limited as the majority of chum spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, stressor may affect survival, growth, and fitness. May affect survival, growth, and fitness of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |

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## Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures) | Year-round (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and growth. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and fitness. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduced organic matter inputs. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Chum dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, chum are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Chum dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |

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## Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, and reduced ambient light from fine bubble profusion. | May affect juvenile growth and fitness, potentially limiting subadult survival during ocean migration. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival. May affect adult growth and spawning productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile chum salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | <u>All exposed life-history stages</u>: Jetties can fragment nearshore marine rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Stressor response dependent on noise magnitude; project specific environmental conditions may range from:<br>• Rupture of egg membrane.<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Likelihood of egg and alevin exposure is limited, as the majority of chum spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. |

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| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short -term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, and reduced growth and fitness, increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Likelihood of egg and alevin exposure is limited, as the majority of chum spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles | Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Likelihood of egg and alevin exposure is limited as the majority of chum spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Streambed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Likelihood of egg and alevin exposure is limited, as the majority of chum spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Effects on chum salmon will be relatively minimal due to limited dependence on freshwater foraging. | Limit area of dewatering to the greatest extent practicable. | Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile chum salmon. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and alevins; Juveniles; Adults | <u>All life-history stages</u>: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | Likelihood of egg and alevin exposure is limited as the majority of chum spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | <u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and alevins; Juveniles; Adults; | <u>Eggs and alevins</u>: Mortality or injury from entrainment.<br><u>Juveniles</u>: Alteration of migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness.<br><u>All life-history stages</u>: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Likelihood of egg and alevin exposure is limited as the majority of chum spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | <u>Eggs and alevins:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen.<br><u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br><u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success. |

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## Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Likelihood of egg and alevin exposure is limited as the majority of chum spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, stressor may affect survival. May affect juvenile survival, growth, and fitness, as well as adult survival, productivity, and spawning success. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Likelihood of egg and alevin exposure is limited as the majority of chum spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, stressor may affect survival, growth, and fitness. May affect survival, growth, and fitness of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, and reduced ambient light from fine bubble profusion. | May affect juvenile growth and fitness, potentially limiting subadult survival during ocean migration. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival. May affect adult growth and spawning productivity. |

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## Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Riverine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | <u>Juveniles</u>: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | <u>Design</u>: Site majority of facility offshore to limit grounding and prop wash effects. Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Design overwater structures and mooring buoys in accordance with USACE guidance to limit shading and anchor scour effects.<br><u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.<br><u>Operation</u>: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles;<br>Adults | <u>Juveniles and adults</u>: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | <u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.<br><u>Adults:</u> Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | | May affect juvenile survival, growth, and fitness, as well as adult spawning productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs and alevins;<br>Juveniles;<br>Adults | <u>Eggs and alevins</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival.<br><u>Juveniles</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br><u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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## Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile chum salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |

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## Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and alevins; Juveniles; Adults | All life-history stages: Stressor response dependent on noise magnitude; project specific environmental conditions may range from:<br>• Rupture of egg membrane.<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |

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## Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, and reduced growth and fitness, increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Should exposure occur, direct mortality or injury is probable. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles | Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Should exposure occur, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Adults | Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of flow conditions to minimal area. | Should exposure occur, decreased survival is likely. May affect survival during egg and alevin life-history stage, may affect adult spawning productivity. |
| | | Altered current and circulation conditions (marine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Streambed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Effects on chum salmon will be relatively minimal due to limited dependence on freshwater foraging. | Limit area of dewatering to the greatest extent practicable. | Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile chum salmon. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | Should exposure occur, direct mortality or injury is probable. See effects for related stressors under Hydraulic and Geomorphic Modification. |

## Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and alevins; Juveniles; Adults; | Eggs and alevins: Mortality or injury from entrainment.<br>Juveniles: Alteration of migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Should exposure occur, direct mortality or injury is probable. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Should exposure occur, stressor may affect survival. May affect juvenile survival, growth, and fitness, as well as adult survival, productivity, and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and fitness of juveniles and adults |

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## Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Should exposure occur, stressor may affect survival, growth, and fitness. May affect survival, growth, and fitness of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Direct mortality due to winter ice formation and scour.<br>Juveniles: Potential delays in migration or alterations in migration behavior.<br>Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.<br>Adults: Decreased spawning fitness due to migration delays caused by thermal barriers. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Should exposure occur, stressor may affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity. |
| | Altered stream bank and shoreline stability | Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools) | Year-round (with specific stressors prominent during high-flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs and alevins; Juveniles; Adults | Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification.<br>Juveniles: Potential delays in migration or alteration in migration behavior, increased predation exposure.<br>Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Should exposure occur, stressor may affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity. |

Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction in organic matter inputs. | Year-round | Permanent | Continuous | Juveniles | Juveniles: Limited effects from food web alteration due to minimal dependence on freshwater forage resources. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Unlikely to affect juvenile rearing. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat, increased predation exposure.<br>Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile growth and survival, spawning success, and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced available suitable spawning habitat; reduced gravel dissolved oxygen; reduced thermal refuge | Year-round | Permanent | Continuous | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Decreased incubation success.<br>Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress and increased competition for suitable habitats.<br>Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success. | Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater recharge. Limit alteration of riparian vegetation to greatest extent practicable. | May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity. |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures) | Year-round (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and growth. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and fitness. |



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## Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduced organic matter inputs. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Chum dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, chum are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Chum dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile growth and fitness, potentially limiting subadult survival during ocean migration. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival. May affect adult growth and spawning productivity. |

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## Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Riverine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Chum dependence on autochthonous inputs from aquatic vegetation is limited, as this species does not forage in riverine and lacustrine environments. Therefore, effects on juvenile chum growth and fitness will be limited. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | Impact mechanism is unlikely to affect chum salmon. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability, potentially leading to altered migratory behavior and increased predation exposure. | | May affect juvenile survival. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival.<br>Juveniles: Altered channel geometry, flow velocity, substrate composition, and groundwater inputs can result in decreased refuge habitat suitability, potentially leading to changes in migratory behavior, increased stress, and increased predation exposure.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival at egg and alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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### Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile chum salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat; change in habitat structure, availability, and suitability; reduced food web complexity | Year-round | Permanent | Continuous | Eggs and alevins; Juveniles; Adults | All exposed life-history stages: Bank barbs and groins can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness. | Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |

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## Table A-3 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Chum Salmon.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | All exposed life-history stages: Bank barbs and groins in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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## Table A-4. HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Stressor response dependent on noise magnitude and project specific environmental conditions; may range from:<br>• Rupture of egg membrane.<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Likelihood of egg and alevin exposure is limited, as the majority of pink spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | <u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br><u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation.<br><u>Juveniles</u>: Increased competition once relocated, and reduced growth and fitness, increased predation exposure.<br><u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Likelihood of egg and alevin exposure is limited, as the majority of pink spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles | <u>Eggs, alevins, and juveniles</u>: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Likelihood of egg and alevin exposure is limited as the majority of pink spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | <u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br><u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |

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## Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth and fitness at juvenile life-history stage; may affect adult fitness and spawning productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Effects on pink salmon will be relatively minimal due to limited dependence on freshwater foraging. | Limit area of dewatering to the greatest extent practicable. | Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile pink salmon. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modifications. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | Likelihood of egg and alevin exposure is limited as the majority of pink spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and alevins;<br>Juveniles;<br>Adults; | Eggs and alevins: Mortality or injury from entrainment.<br>Juveniles: Alteration of migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Likelihood of egg and alevin exposure is limited as the majority of pink spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. May affect egg and alevin survival and productivity. May affect juvenile productivity and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |

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## Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Likelihood of egg and alevin exposure is limited as the majority of pink spawning habitat is located in areas unsuitable for marine or terminal development. Should exposure occur, stressor may affect survival. May affect juvenile survival, growth, and fitness, as well as adult survival and spawning productivity. |

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## Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br><u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Likelihood of egg and alevin exposure is limited as the majority of pink spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, stressor may affect survival, growth, and fitness. May affect survival, growth, and fitness of juveniles, and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures). | Year-round (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles | <u>Juveniles</u>: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and survival. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | <u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduced organic matter inputs. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | <u>Juveniles</u>: Pink salmon dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, pink are known to utilize terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |

## Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high quality habitat features. | May affect juvenile survival. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Pink dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |

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## Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced solar light penetration due to propeller-induced fine bubbles. | May affect juvenile growth and fitness, potentially limiting subadult survival during ocean migration. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. | | May affect juvenile survival. May affect adult growth and spawning productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occuring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile pink salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Altered current velocities | | Year-round (with variable effects depending on site specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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**Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | <u>All exposed life-history stages</u>: Jetties can fragment nearshore marine rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Stressor response dependent on noise magnitude and project specific environmental conditions; may range from:<br>• Rupture of egg membrane.<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Likelihood of egg and alevin exposure is limited, as the majority of pink spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | <u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |

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## Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, and reduced growth and fitness, increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Likelihood of egg and alevin exposure is limited, as the majority of pink spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles | Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Likelihood of egg and alevin exposure is limited as the majority of pink spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth and fitness at juvenile life-history stage; may affect adult fitness and spawning productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Effects on pink salmon will be relatively minimal due to limited dependence on freshwater foraging. | Limit area of dewatering to the greatest extent practicable. | Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile pink salmon. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modifications. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | Likelihood of egg and alevin exposure is limited as the majority of pink spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. See effects for related stressors under Hydraulic and Geomorphic Modification. |

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## Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and alevins;<br>Juveniles;<br>Adults; | Eggs and alevins: Mortality or injury from entrainment.<br>Juveniles: Alteration of migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Likelihood of egg and alevin exposure is limited as the majority of pink spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. May affect egg and alevin survival and productivity. May affect juvenile productivity and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Likelihood of egg and alevin exposure is limited as the majority of pink spawning habitat is located in areas unsuitable for marine or terminal development. Should exposure occur, stressor may affect survival. May affect juvenile survival, growth, and fitness, as well as adult survival and spawning productivity. |

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| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Likelihood of egg and alevin exposure is limited as the majority of pink spawning habitat is located in areas unsuitable for marine or terminal development. Should exposure occur, stressor may affect survival, growth, and fitness. May affect survival, growth, and fitness of juveniles, and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Decreased foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced solar light penetration due to propeller-induced fine bubbles. | May affect juvenile growth and fitness, potentially limiting subadult survival during ocean migration. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. | | May affect juvenile survival. May affect adult growth and spawning productivity. |
| | **Riverine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Site majority of facility offshore to limit grounding and prop wash effects. Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Design overwater structures and mooring buoys in accordance with USACE | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |

**Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.<br>Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | guidance to limit shading and anchor scour effects.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile survival, growth, and fitness, as well as adult spawning productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival.<br>Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile pink salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Altered current velocities | | Year-round (with variable effects depending on site specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |

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## Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and alevins; Juveniles; Adults | All life-history stages: Stressor response dependent on noise magnitude and project specific environmental conditions; may range from:<br>• Rupture of egg membrane.<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, and reduced growth and fitness, increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Should exposure occur, direct mortality or injury is probable. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles | Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Should exposure occur, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Adults | Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of flow conditions to minimal area. | Should exposure occur, decreased survival is likely. May affect survival during egg and alevin life-history stage; may affect adult spawning productivity. |



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## Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered current and circulation conditions (marine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth and fitness at juvenile life-history stage; may affect adult fitness and spawning productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Effects on pink salmon will be relatively minimal due to limited dependence on freshwater foraging. | Limit area of dewatering to the greatest extent practicable. | Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile pink salmon. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modifications. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | Should exposure occur, direct mortality or injury is probable. See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and alevins; Juveniles; Adults; | Eggs and alevins: Mortality or injury from entrainment. Juveniles: Alteration of migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Should exposure occur, direct mortality or injury is probable. May affect egg and alevin survival and productivity. May affect juvenile productivity and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |

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## Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Should exposure occur, stressor may affect survival. May affect juvenile survival, growth, and fitness, as well as adult survival and spawning productivity. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and fitness of juveniles and adults. |

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**Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br><u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Should exposure occur, stressor may affect survival, growth, and fitness. May affect survival, growth, and fitness of juveniles, and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Eggs and alevins;<br>Juveniles;<br>Adults | <u>Eggs and alevins:</u> Direct mortality due to winter ice formation and scour.<br><u>Juveniles</u>: Potential delays in migration or alterations in migration behavior.<br><u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.<br><u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Should exposure occur, stressor may affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity. |
| | Altered stream bank and shoreline stability | Increased suspended solids, decreased redd dissolved oxygen, decreased area of suitable spawning habitat, reduced habitat complexity (e.g., filling of pools) | Year-round (with specific stressors prominent during high-flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>Eggs/alevins:</u> Decreased incubation success due to decreased redd dissolved oxygen, as described for related stressor responses under Water Quality Modification.<br><u>Juveniles:</u> Potential delays in migration or alteration in migration behavior; increased predation exposure.<br><u>Adults:</u> Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival and productivity during egg and alevin, juvenile, and adult spawning life-history stages. |

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Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction in organic matter inputs | Year-round | Permanent | Continuous | Juveniles | Juveniles: Limited effects from food web alteration due to minimal dependence on freshwater forage resources. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Unlikely to affect juvenile rearing. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Decreased refuge habitat; increased predation exposure.<br>Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile growth and survival, spawning success, and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced available suitable spawning habitat; reduced gravel dissolved oxygen; reduced thermal refuge | Year-round | Permanent | Continuous | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Decreased incubation success.<br>Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress and increased competition for suitable habitats.<br>Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success. | Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater recharge. Limit alteration of riparian vegetation to greatest extent practicable. | May affect survival of eggs and alevins. May affect juvenile survival and productivity. May affect adult spawning productivity. |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures). | Year-round (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and survival. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduced organic matter inputs. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Pink salmon dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, pink are known to utilize terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high quality habitat features. | May affect juvenile survival. |

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**Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Pink dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile growth and fitness, potentially limiting subadult survival during ocean migration. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. | | May affect juvenile survival. May affect adult growth and spawning productivity. |
| | **Riverine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Pink salmon dependence on autochthonous inputs from aquatic vegetation is limited, as this species does not forage in riverine and lacustrine environments. Therefore, effects on juvenile pink growth and fitness will be limited. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | Impact mechanism is unlikely to affect pink salmon. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles;<br>Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability, potentially leading to altered migratory behavior and increased predation exposure. | | May affect juvenile survival. |

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**Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs and alevins;<br>Juveniles<br>Adults | Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival.<br>Juveniles: Altered channel geometry, flow velocity, substrate composition, and groundwater inputs can result in decreased refuge habitat suitability, potentially leading to changes in migratory behavior, increased stress, and increased predation exposure.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival at egg and alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile pink salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Altered current velocities | | Year-round (with variable effects depending on site specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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**Table A-4 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pink Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat; change in habitat structure, availability, and suitability; reduced food web complexity | Year-round | Permanent | Continuous | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All exposed life-history stages</u>: Bank barbs and groins can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness. | Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | <u>All exposed life-history stages</u>: Bank barbs and groins in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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# Table A-5. HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: Stressor response dependent on noise magnitude and project specific environmental conditions; may range from:<br>• Rupture of egg membrane.<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Likelihood of egg and alevin exposure is limited, as the majority of sockeye spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short -term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, reduced growth and fitness, increased predation exposure.<br>Adults: Delayed migration, resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Likelihood of egg and alevin exposure is limited, as the majority of sockeye spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness as well as adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles | Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Likelihood of egg and alevin exposure is limited as the majority of sockeye spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness as well as adult spawning productivity. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |

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| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect egg and alevin incubation success and survival; may affect growth and fitness at juvenile life-history stage; may affect adult spawning productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and productivity at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | Likelihood of egg and alevin exposure is limited, as the majority of sockeye spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Mortality or injury from entrainment.<br>Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Likelihood of egg and alevin exposure is limited as the majority of sockeye spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. May affect survival during egg and alevin life-history stage. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |

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**Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>Eggs and alevins:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen.<br><u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br><u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Likelihood of egg and alevin exposure is limited as the majority of sockeye spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, stressor may affect survival. May affect juvenile survival, growth, and fitness, as well as adult survival, productivity, and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles;<br>Adults | <u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and fitness of juveniles and adults. |

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## Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates. | Likelihood of egg and alevin exposure is limited as the majority of sockeye spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, stressor may affect survival, growth, and fitness. May affect survival, growth, and fitness of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures) | Year-round (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. Juvenile sockeye dependence on the nearshore marine environment is relatively limited. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and growth. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and fitness. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Sockeye dependence on allochthonous inputs from marine riparian vegetation is a data gap but is likely limited due to the lesser dependence of this species on the nearshore marine environment. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Potential effects resulting from this impact mechanism are unknown. |

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**Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Sockeye dependence on nearshore marine habitats is limited in comparison to other salmonids. Sockeye response to alteration of nearshore habitat complexity is currently a data gap.<br>Adults: Reduction in nearshore habitat complexity may affect availability of forage for returning adult sockeye, affecting growth and productivity during spawning. | Encourage project designs that limit permanent alteration of high-quality habitat features. | Potential effects on juvenile sockeye resulting from this impact mechanism are unknown. May affect adult growth and productivity. |
| | Altered groundwater surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Sockeye dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival, growth, and fitness. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Potential reduction in egg survival and incubation success (for beach spawning sockeye) due to increased sedimentation and turbidity, as described under Water Quality Modification.<br>Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.<br>Adults: May affect spawning habitat suitability, leading to decreased spawning productivity as described under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect egg and alevin survival. May affect juvenile survival and productivity. May affect adult spawning productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Sockeye dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. Sockeye are primarily planktonic feeders in the photic zone, so direct dependence on allochthonous inputs for prey is likely limited. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Potential effects resulting from this impact mechanism are unknown. |

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## Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Intermediate-term to permanent (dependent on nature of activity and time required for recovery) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival, growth, and fitness. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Decreased egg and alevin survival (beach-spawning sockeyes) due to lower dissolved oxygen levels in spawning substrate.<br>Juveniles: Sockeye dependence on groundwater inflow to nearshore habitats is currently a data gap.<br>Adults: Decreased suitable spawning habitat, leading to decreased spawning productivity. | Avoid disturbance of vegetation along shoreline. | May affect egg and alevin survival. May affect adult spawning productivity. Effects on juveniles are unknown. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Sockeye dependence on autochthonous inputs from marine littoral vegetation is a data gap but is likely limited due to the lesser dependence of this species on the nearshore marine environment. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from propeller wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | Potential effects resulting from this impact mechanism are unknown. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Sockeye dependence on nearshore marine habitats is limited in comparison to other salmonids. Sockeye response to alteration of nearshore habitat complexity is currently a data gap.<br>Adults: Reduction in nearshore habitat complexity may affect availability of forage for returning adult sockeye, affecting growth and productivity during spawning. | | Potential effects on juvenile sockeye resulting from this impact mechanism are unknown. May affect adult growth and productivity. |
| | **Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Alteration of aquatic vegetation may indirectly affect food web dynamics, potentially leading to decreased foraging opportunities. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile productivity. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles;<br>Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Alteration of aquatic vegetation may indirectly affect food web dynamics, potentially leading to decreased foraging opportunities. | | May affect juvenile survival. |

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**Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occuring in spring and summer when juveniles transit nearshore habitats) | Permanent | Continuous | Juveniles; Adults | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Juvenile sockeye have relatively limited dependence on nearshore marine habitats. However, alteration of habitat productivity in the nearshore may lead to alteration of food web dynamics in offshore environments, potentially affecting foraging opportunities, leading to decreased growth and productivity.<br>Adults: Alteration of nearshore habitat characteristics can demonstrably affect the productivity of forage species preyed upon by returning adult sockeye. Decreased foraging opportunity may lead to decreased growth and productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. May affect adult growth and productivity. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Yaer Round | Permanent | Continuous | | | | |

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**Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | <u>Eggs and alevins;</u><br>Juveniles;<br>Adults | <u>Eggs and alevins</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats. Alteration of nearshore lacustrine habitats may lead to direct mortality and decreased survival of eggs and alevins (beach-spawning sockeyes).<br><u>Juveniles</u>: Alteration of nearshore lacustrine rearing habitat may forcing migrating and foraging salmonids to navigate away from nearshore habitats. Alteration of habitat productivity in the nearshore may also lead to alteration of food web dynamics in offshore environments. This stressor may increase exposure to predation, increase stress and exertion, and potentially affect foraging opportunities affecting survival, growth, and fitness.<br><u>Adults</u>: Alteration of nearshore habitat parameters may alter the suitability of shoreline spawning habitats for beach spawning sockeye, leading to decreased spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect egg and alevin survival. May affect growth and fitness at juvenile life-history stage. May affect adult spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | <u>All exposed life-history stages</u>: Jetties can fragment nearshore marine rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | All exposed life-history stages: Jetties can fragment nearshore lacustrine rearing habitats, forcing migrating and foraging salmonids to navigate offshore into deeper water environments. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and alevins; Juveniles; Adults | All life-history stages: Stressor response dependent on noise magnitude and project specific environmental conditions; may range from:<br>• Rupture of egg membrane.<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Likelihood of egg and alevin exposure is limited, as the majority of sockeye spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |



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## Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short -term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, reduced growth and fitness, increased predation exposure.<br>Adults: Delayed migration, resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Likelihood of egg and alevin exposure is limited, as the majority of sockeye spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness as well as adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles | Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Likelihood of egg and alevin exposure is limited as the majority of sockeye spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness as well as adult spawning productivity. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect egg and alevin incubation success and survival; may affect growth and fitness at juvenile life-history stage; may affect adult spawning productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and productivity at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | Likelihood of egg and alevin exposure is limited, as the majority of sockeye spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. See effects for related stressors under Water Quality Modification. |

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## Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Likelihood of egg and alevin exposure is limited as the majority of sockeye spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. May affect survival during egg and alevin life-history stage. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Likelihood of egg and alevin exposure is limited as the majority of sockeye spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, stressor may affect survival. May affect juvenile survival, growth, and fitness, as well as adult survival, productivity, and spawning success. |

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**Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles;<br>Adults | <u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and fitness of juveniles and adults. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates. | Likelihood of egg and alevin exposure is limited as the majority of sockeye spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, stressor may affect survival, growth, and fitness. May affect survival, growth, and fitness of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | <u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | <u>Juveniles</u>: Sockeye dependence on autochthonous inputs from marine littoral vegetation is a data gap but is likely limited due to the lesser dependence of this species on the nearshore marine environment. | <u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br><u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.<br><u>Operation</u>: Enforce vessel operation rules to limit submerged aquatic vegetation damage from propeller wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | Potential effects resulting from this impact mechanism are unknown. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | <u>Juveniles</u>: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | <u>Juveniles:</u> Sockeye dependence on nearshore marine habitats is limited in comparison to other salmonids. Sockeye response to alteration of nearshore habitat complexity is currently a data gap.<br><u>Adults</u>: Reduction in nearshore habitat complexity may affect availability of forage for returning adult sockeye, affecting growth and productivity during spawning. | | Potential effects on juvenile sockeye resulting from this impact mechanism are unknown. May affect adult growth and productivity. |

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## Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Alteration of aquatic vegetation may indirectly affect food web dynamics, potentially leading to decreased foraging opportunities. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile productivity. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles;<br>Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Alteration of aquatic vegetation may indirectly affect food web dynamics, potentially leading to decreased foraging opportunities. | | May affect juvenile survival. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival.<br>Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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**Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles transit nearshore habitats) | Permanent | Continuous | Juveniles; Adults | <u>Juveniles</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Juvenile sockeye have relatively limited dependence on nearshore marine habitats. However, alteration of habitat productivity in the nearshore may lead to alteration of food web dynamics in offshore environments, potentially affecting foraging opportunities, leading to decreased growth and productivity.<br><u>Adults</u>: Alteration of nearshore habitat characteristics can demonstrably affect the productivity of forage species preyed upon by returning adult sockeye. Decreased foraging opportunity may lead to decreased growth and productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. For example: | May affect survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. May affect adult growth and productivity. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-Round | Permanent | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Eggs and alevins; Juveniles; Adults | <u>Eggs and alevins</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats. Alteration of nearshore lacustrine habitats may lead to direct mortality and decreased survival of eggs and alevins (beach-spawning sockeyes).<br><u>Juveniles</u>: Alteration of nearshore lacustrine rearing habitat may forcing migrating and foraging salmonids to navigate away from nearshore habitats. Alteration of habitat productivity in the nearshore may also lead to alteration of food web dynamics in offshore | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. For example: | May affect egg and alevin survival. May affect growth and fitness at juvenile life-history stage. May affect adult spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |

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Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | environments. This stressor may increase exposure to predation, increase stress and exertion, and potentially affect foraging opportunities affecting survival, growth, and fitness.<br>Adults: Alteration of nearshore habitat parameters may alter the suitability of shoreline spawning habitats for beach spawning sockeye, leading to decreased spawning productivity. | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| | **Lacustrine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |

**Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: Stressor response dependent on noise magnitude and project specific environmental conditions; may range from:<br>• Rupture of egg membrane.<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short -term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, reduced growth and fitness, increased predation exposure.<br>Adults: Delayed migration, resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Should exposure occur, direct mortality or injury is probable. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness as well as adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles | Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Should exposure occur, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness as well as adult spawning productivity. |

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Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success.<br>Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of flow conditions to minimal area. | Should exposure occur, decreased survival is likely. May affect survival during egg and alevin life-history stage; may affect adult spawning productivity. |
| | | Altered current and circulation conditions (marine and lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect egg and alevin incubation success and survival; may affect growth and fitness at juvenile life-history stage; may affect adult spawning productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and productivity at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | Should exposure occur, direct mortality or injury is probable. See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Mortality or injury from entrainment.<br>Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Should exposure occur, direct mortality or injury is probable. May affect survival during egg and alevin life-history stage. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |

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**Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Should exposure occur, stressor may affect survival. May affect juvenile survival, growth, and fitness, as well as adult survival, productivity, and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles;<br>Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and fitness of juveniles and adults. |

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## Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br><u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Should exposure occur, stressor may affect survival, growth, and fitness. May affect survival, growth, and fitness of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered riparian shading | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Eggs and alevins;<br>Juveniles;<br>Adults | <u>Eggs and alevins:</u> Direct mortality due to winter ice formation and scour.<br><u>Juveniles</u>: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns.<br><u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.<br><u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Should exposure occur, stressor may affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity. |
| | Altered ambient air temperature regime | | | | | | | | |

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**Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered stream bank and shoreline stability | Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools) | Year-round (with specific stressors prominent during high-flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs and alevins;<br>Juveniles;<br>Adults | <u>Eggs/alevins:</u> Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification.<br><u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.<br><u>Adults:</u> Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Should exposure occur, stressor may affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs | Year-round | Permanent | Continuous | Juveniles | <u>Juveniles:</u> Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile rearing. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | <u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.<br><u>Adults:</u> Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile growth and survival, spawning success, and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced available suitable spawning habitat; reduced gravel dissolved oxygen | Year-round | Permanent | Continuous | Eggs and alevins;<br>Juveniles;<br>Adults | <u>Eggs and alevins</u>: Decreased incubation success.<br><u>Juveniles</u>: Decreased availability of thermal refuge habitat, resulting in increased thermal stress and increased competition for suitable habitats.<br><u>Adults</u>: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success. | Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater recharge. Limit alteration of riparian vegetation to greatest extent practicable. | May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity. |

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**Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Marine** | | | | | | | | |
| | Altered shading, solar input, and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures) | Year-round (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. Juvenile sockeye dependence on the nearshore marine environment is relatively limited. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and growth. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and fitness. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Sockeye dependence on allochthonous inputs from marine riparian vegetation is a data gap but is likely limited due to the lesser dependence of this species on the nearshore marine environment. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Potential effects resulting from this impact mechanism are unknown. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Sockeye dependence on nearshore marine habitats is limited in comparison to other salmonids. Sockeye response to alteration of nearshore habitat complexity is currently a data gap.<br>Adults: Reduction in nearshore habitat complexity may affect availability of forage for returning adult sockeye, affecting growth and productivity during spawning. | Encourage project designs that limit permanent alteration of high-quality habitat features. | Potential effects on juvenile sockeye resulting from this impact mechanism are unknown. May affect adult growth and productivity. |
| | Altered groundwater surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Sockeye dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival, growth, and fitness. |

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## Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Potential reduction in egg survival and incubation success (for beach spawning sockeye) due to increased sedimentation and turbidity, as described under Water Quality Modification.<br>Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.<br>Adults: May affect spawning habitat suitability, leading to decreased spawning productivity as described under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect egg and alevin survival. May affect juvenile survival and productivity. May affect adult spawning productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Sockeye dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. Sockeye are primarily planktonic feeders in the photic zone, so direct dependence on allochthonous inputs for prey is likely limited. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Potential effects resulting from this impact mechanism are unknown. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Intermediate-term to permanent (dependent on nature of activity and time required for recovery) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival, growth, and fitness. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Decreased egg and alevin survival (beach-spawning sockeyes) due to lower dissolved oxygen levels in spawning substrate.<br>Juveniles: Sockeye dependence on groundwater inflow to nearshore habitats is currently a data gap.<br>Adults: Decreased suitable spawning habitat, leading to decreased spawning productivity. | Avoid disturbance of vegetation along shoreline. | May affect egg and alevin survival. May affect adult spawning productivity. Effects on juveniles are unknown. |


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**Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Sockeye dependence on autochthonous inputs from marine littoral vegetation is a data gap but is likely limited due to the lesser dependence of this species on the nearshore marine environment. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | Potential effects resulting from this impact mechanism are unknown. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Sockeye dependence on nearshore marine habitats is limited in comparison to other salmonids. Sockeye response to alteration of nearshore habitat complexity is currently a data gap.<br>Adults: Reduction in nearshore habitat complexity may affect availability of forage for returning adult sockeye, affecting growth and productivity during spawning. | | Potential effects on juvenile sockeye resulting from this impact mechanism are unknown. May affect adult growth and productivity. |
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Alteration of aquatic vegetation may indirectly affect food web dynamics, potentially leading to decreased foraging opportunities. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile productivity. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles;<br>Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Alteration of aquatic vegetation may indirectly affect food web dynamics, potentially leading to decreased foraging opportunities. | | May affect juvenile survival. |

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**Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased refuge habitat during migration to lacustrine rearing environments, and increased predation exposure. Juvenile river rearing sockeye may also experience decreased foraging opportunity, leading to increased competition and decreased growth and fitness. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival, growth, and fitness at egg, alevin, and juvenile life-history stages (river rearing sockeye). May affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles transit nearshore habitats) | Permanent | Continuous | Juveniles; Adults | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater input are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Juvenile sockeye have relatively limited dependence on nearshore marine habitats. However, alteration of habitat productivity in the nearshore may lead to alteration of food web dynamics in offshore environments, potentially affecting foraging opportunities, leading to decreased growth and productivity. Adults: Alteration of nearshore habitat characteristics can demonstrably affect the productivity of forage species preyed upon by returning adult sockeye. Decreased foraging opportunity may lead to decreased growth and productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. May affect adult growth and productivity. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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## Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats. Alteration of nearshore lacustrine habitats may lead to direct mortality and decreased survival of eggs and alevins (beach-spawning sockeyes).<br>Juveniles: Alteration of nearshore lacustrine rearing habitat may forcing migrating and foraging salmonids to navigate away from nearshore habitats. Alteration of habitat productivity in the nearshore may also lead to alteration of food web dynamics in offshore environments. This stressor may increase exposure to predation, increase stress and exertion, and potentially affect foraging opportunities affecting survival, growth, and fitness.<br>Adults: Alteration of nearshore habitat parameters may alter the suitability of shoreline spawning habitats for beach spawning sockeye, leading to decreased spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect egg and alevin survival. May affect growth and fitness at juvenile life-history stage. May affect adult spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-Round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat; change in habitat structure, availability, and suitability; reduced food web complexity | Year-round | Permanent | Continuous | Eggs and alevins; Juveniles; Adults | All exposed life-history stages: Bank barbs and groins can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness. | Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |

**Table A-5 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Sockeye Salmon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | All exposed life-history stages: Bank barbs and groins in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles;<br>Adults | All exposed life-history stages: Bank barbs and groins in lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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## Table A-6. HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and alevins; Juveniles; Adults | All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>• Rupture of egg membrane.<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Likelihood of egg and alevin exposure is limited, as the majority of steelhead spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles, Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, reduced growth and fitness, increased predation exposure.<br>Adults: Delayed migration, resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Likelihood of egg and alevin exposure is limited, as the majority of steelhead spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles | Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Likelihood of egg and alevin exposure is limited as the majority of steelhead spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity. |

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**Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | <u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br><u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering). | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | <u>Eggs and alevins</u>: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br><u>Juveniles</u>: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br><u>Adults</u>: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Likelihood of egg and alevin exposure is limited, as the majority of steelhead spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | <u>Juveniles</u>: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and productivity at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | <u>All life-history stages</u>: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and alevins; Juveniles; Adults | <u>All life-history stages</u>: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | Likelihood of egg and alevin exposure is limited as the majority of steelhead spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | <u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and alevins; Juveniles; Adults | <u>Eggs and alevins</u>: Mortality or injury from entrainment.<br><u>Juveniles</u>: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness.<br><u>All life-history stages</u>: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Likelihood of egg and alevin exposure is limited as the majority of steelhead spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, however, direct mortality or injury is probable. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |

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## Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness as well as adult productivity and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Likelihood of egg and alevin exposure is limited as the majority of steelhead spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, stressor may affect survival. May affect juvenile survival, growth, and fitness as well as adult survival, productivity, and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and fitness of juveniles and adults. |

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## Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates. | Likelihood of egg and alevin exposure is limited as the majority of steelhead spawning habitat is located in areas unsuitable for jetty development. Should exposure occur, stressor may affect survival, growth, and fitness. May affect survival, growth, and fitness of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered riparian shading | Expansion of thermal regime (i.e., increased summer temperatures) | Year-round (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. The extent of nearshore habitat use by juvenile steelhead is currently a data gap. However, juveniles trapped by tidal exchange in specific habitats, such as pocket estuaries, may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival and growth. |
| | Altered ambient air temperature regime | | | | | | | | |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile steelhead use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival and fitness. |



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| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Steelhead dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, steelhead are known to use terrestrial insect resources recruited from the riparian zone in freshwater environments, so exploitation of these resources in marine environments is possible. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival, growth, and fitness. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Steelhead dependence on nearshore habitat complexity is currently a data gap. Altered habitat complexity may lead to decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival, growth, and fitness. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Steelhead dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival, growth, and fitness. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and fitness. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Steelhead dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, steelhead are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth, fitness, and productivity. |

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| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival and fitness, spawning success, and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Steelhead dependence on groundwater inflow to littoral lacustrine habitats is currently a data gap. However, loss of groundwater may lead to reduction in shallow water thermal refuge, increased competition, and decreased foraging opportunity. | Avoid disturbance of vegetation along shoreline. | May affect juvenile survival and fitness. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival and productivity. May affect adult growth and spawning productivity. |
| | **Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile productivity. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. | | May affect juvenile survival and productivity. |



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**Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.**

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability. | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles; Adults | <u>Juveniles</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile steelhead. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.<br><u>Adults</u>: Subadult and returning adult steelhead forage in nearshore environments. Alteration in nearshore ecosystem processes may decrease foraging opportunity, affecting growth and fitness. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at juvenile life-history stage. May affect adult growth and productivity. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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## Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult steelhead. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adult steelhead will generally be less sensitive to these stressors. However, increased stress and delayed migration may reduce fitness and ultimately reduce spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | All exposed life-history stages: Jetties can fragment nearshore marine rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

**Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles;<br>Adults | All exposed life-history stages: Jetties can fragment nearshore lacustrine rearing habitats, forcing migrating and foraging salmonids to navigate offshore into deeper water environments. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>• Rupture of egg membrane.<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Likelihood of egg and alevin exposure is limited, as the majority of steelhead spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles, Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |

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## Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, reduced growth and fitness, increased predation exposure.<br>Adults: Delayed migration, resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Likelihood of egg and alevin exposure is limited, as the majority of steelhead spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles | Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Likelihood of egg and alevin exposure is limited as the majority of steelhead spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering). | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Likelihood of egg and alevin exposure is limited, as the majority of steelhead spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and productivity at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |



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| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and alevins; Juveniles; Adults | <u>All life-history stages</u>: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | Likelihood of egg and alevin exposure is limited as the majority of steelhead spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | <u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and alevins; Juveniles; Adults | <u>Eggs and alevins</u>: Mortality or injury from entrainment.<br><u>Juveniles</u>: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness.<br><u>All life-history stages</u>: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Likelihood of egg and alevin exposure is limited as the majority of steelhead spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, however, direct mortality or injury is probable. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | <u>Eggs and alevins:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen.<br><u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br><u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness as well as adult productivity and spawning success. |

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## Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | <u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Likelihood of egg and alevin exposure is limited as the majority of steelhead spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, stressor may affect survival. May affect juvenile survival, growth, and fitness as well as adult survival, productivity, and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | <u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and fitness of juveniles and adults. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and alevins; Juveniles; Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates. | Likelihood of egg and alevin exposure is limited as the majority of steelhead spawning habitat is located in areas unsuitable for breakwater development. Should exposure occur, stressor may affect survival, growth, and fitness. May affect survival, growth, and fitness of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins; Juveniles; Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | <u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | |

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## Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival and productivity. May affect adult growth and spawning productivity. |
| | **Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile productivity. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. | | May affect juvenile survival and productivity. |

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## Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival.<br>Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival, growth, and fitness at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | Alteration in the magnitude, volume, and timing of peak flows | During storm events (predominantly from fall through spring) | Permanent | Common | Eggs and alevins; Juveniles; Adults | All life-history stages: Because the amount of impervious surface associated with breakwaters is a relatively inconsequential component of the overall drainage area of the larger river systems that would support this type of development, the magnitude of the hydrologic modification stressor is expected to be negligible. As such, this stressor is not expected to significantly affect the riverine environment, and there will be no response to the stressor. | Encourage facilities to employ modern low-impact development and stormwater treatment technology. | Impervious surface at anticipated scale would not produce stressors of sufficient magnitude to adversely affect steelhead at any life-history stage. |

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## Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability. | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles; Adults | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile steelhead. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.<br>Adults: Subadult and returning adult steelhead forage in nearshore environments. Alteration in nearshore ecosystem processes may decrease foraging opportunity, affecting growth and fitness. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at juvenile life-history stage. May affect adult growth and productivity. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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## Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult steelhead. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adult steelhead will generally be less sensitive to these stressors. However, increased stress and delayed migration may reduce fitness and ultimately reduce spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |

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**Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| | **Lacustrine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | <u>Juveniles</u>: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and alevins; Juveniles; Adults | <u>All life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>• Rupture of egg membrane.<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable. |

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Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles, Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, reduced growth and fitness, increased predation exposure.<br>Adults: Delayed migration, resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | Should exposure occur, direct mortality or injury is probable. May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles | Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | Should exposure occur, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success.<br>Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of flow conditions to minimal area. | Should exposure occur, decreased survival is likely. May affect survival during egg and alevin life-history stages, may affect adult spawning productivity. |
| | | Altered current and circulation conditions (marine and lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering). | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable. |

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## Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and productivity at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and alevins; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | Should exposure occur, direct mortality or injury is probable. See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Mortality or injury from entrainment.<br>Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Should exposure occur, direct mortality or injury is probable. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness as well as adult productivity and spawning success. |

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## Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. | Avoid sediment pulses. | Should exposure occur, stressor may affect survival. May affect juvenile survival, growth, and fitness as well as adult survival, productivity, and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and fitness of juveniles and adults. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Should exposure occur, stressor may affect survival, growth, and fitness. May affect survival, growth, and fitness of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and alevins; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |

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### Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Direct mortality due to winter ice formation and scour.<br>Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns.<br>Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.<br>Adults: Decreased spawning fitness due to migration delays caused by thermal barriers. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Should exposure occur, stressor may affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity. |
| | Altered stream bank and shoreline stability | Increased suspended solids; decreased redd dissolved oxygen, decreased area of suitable spawning habitat, reduced habitat complexity (e.g., filling of pools) | Year-round (with specific stressors prominent during high-flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs and alevins; Juveniles; Adults | Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen, as described for related stressor responses under Water Quality Modification.<br>Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.<br>Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Should exposure occur, stressor may affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs | Year-round | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile rearing. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.<br>Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile growth and survival; spawning success; and overall population productivity |

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## Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered groundwater–surface water exchange | Reduced available suitable spawning habitat; reduced gravel dissolved oxygen | Year-round | Permanent | Continuous | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Decreased incubation success.<br>Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats.<br>Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success. | Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater recharge. Limit alteration of riparian vegetation to greatest extent practicable. | May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity. |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures). | Year-round (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. The extent of nearshore habitat use by juvenile steelhead is currently a data gap. However, juveniles trapped by tidal exchange in specific habitats, such as pocket estuaries, may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival and growth. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile steelhead use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival and fitness. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Steelhead dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, steelhead are known to use terrestrial insect resources recruited from the riparian zone in freshwater environments, so exploitation of these resources in marine environments is possible. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival, growth, and fitness. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Steelhead dependence on nearshore habitat complexity is currently a data gap. Altered habitat complexity may lead to decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival, growth, and fitness. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Steelhead dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |

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## Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival, growth, and fitness. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and fitness. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Steelhead dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, steelhead are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth, fitness, and productivity. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival and fitness, spawning success, and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Steelhead dependence on groundwater inflow to littoral lacustrine habitats is currently a data gap. However, loss of groundwater may lead to reduction in shallow water thermal refuge, increased competition, and decreased foraging opportunity. | Avoid disturbance of vegetation along shoreline. | May affect juvenile survival and fitness. |

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**Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. .<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles | Juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival and productivity. May affect adult growth and spawning productivity. |
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile productivity. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. | | May affect juvenile survival and productivity. |

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## Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs and alevins; Juveniles; Adults | Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival.<br>Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival, growth, and fitness at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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## Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability. | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles; Adults | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile steelhead. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.<br>Adults: Subadult and returning adult steelhead forage in nearshore environments. Alteration in nearshore ecosystem processes may decrease foraging opportunity, affecting growth and fitness. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at juvenile life-history stage. May affect adult growth and productivity. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult steelhead. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adult steelhead will generally be less sensitive to these stressors. However, increased stress and delayed migration may reduce fitness and ultimately reduce spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. For example: | May affect survival, growth, and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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**Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat; change in habitat structure, availability, and suitability; reduced food web complexity | Year-round | Permanent | Continuous | Eggs and alevins;<br>Juveniles;<br>Adults | All exposed life-history stages: Bank barbs and groins can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness. | Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | All exposed life-history stages: Bank barbs and groins in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-6 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Steelhead.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles;<br>Adults | All exposed life-history stages: Bank barbs and groins in lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-7. HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality or injury and/or affect survival, growth, and fitness of exposed life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect juvenile survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. May affect adult fitness due to decreased foraging success. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated; reduced growth and fitness; increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May cause direct mortality or injury to affected life-history stages. May affect survival, growth, and fitness at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows. Avoid use when juveniles are present. | May affect survival, growth, and fitness at juvenile life-history stage. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. | May affect juvenile growth and fitness; may affect adult spawning productivity. |

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Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Adults and juveniles: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Juveniles; Adults | Adults and juveniles: See responses described under Hydraulic and Geomorphic Modifications. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Adults and juveniles: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Juveniles; Adults | Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness.<br>Adults and juveniles: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to Interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Decreased spawning success resulting from reduced fitness. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Mortality in acute low dissolved oxygen events due to asphyxiation. Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Avoid sediment pulses. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |

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**Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to Interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Juveniles; Adults | Adults and juveniles: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Juveniles; Adults | Adults and juveniles: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival, growth, and fitness. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and productivity. |

**Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Cutthroat trout dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, cutthroat trout are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth, fitness, and productivity. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival and productivity, spawning success, and overall population productivity. |
| | Altered freshwater inflow | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Cutthroat trout dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along stream. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and productivity. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Cutthroat trout dependence on allochthonous inputs from riparian vegetation is a data gap. However, cutthroat trout are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth, fitness, and productivity. |

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**Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival and productivity, spawning success, and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Cutthroat trout dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along stream. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. | May affect juvenile productivity. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Adults and juveniles: See related stressor responses under Water Quality Modification. | Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, and reduced ambient light from fine bubble profusion. | May affect juvenile survival and productivity. May affect adult growth and spawning productivity. |
| | **Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. | May affect juvenile productivity. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile survival and productivity. |

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## Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that comprise the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile coastal cutthroat trout. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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**Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Juveniles; Adults | Adults and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult coastal cutthroat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.<br>Adults: Adult cutthroat trout will generally be less sensitive to these stressors. However, increased stress and delayed migration may reduce fitness and ultimately reduce spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round, with variable effects by season (e.g., circulation patterns) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | All exposed life-history stages: Jetties can fragment nearshore marine rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | <u>All exposed life-history stages</u>: Jetties can fragment nearshore lacustrine rearing habitats, forcing migrating and foraging salmonids to navigate offshore into deeper water environments. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | <u>Adults and juveniles</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality or injury and/or affect survival, growth, and fitness of exposed life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | <u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect juvenile survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. May affect adult fitness due to decreased foraging success. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation.<br><u>Juveniles</u>: Increased competition once relocated; reduced growth and fitness; increased predation exposure.<br><u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May cause direct mortality or injury to affected life-history stages. May affect survival, growth, and fitness at juvenile and adult life-history stages. |

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## Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows. Avoid use when juveniles are present. | May affect survival, growth, and fitness at juvenile life-history stage. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Adults and juveniles: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Juveniles; Adults | Adults and juveniles: See responses described under Hydraulic and Geomorphic Modifications. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Adults and juveniles: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Juveniles; Adults | Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness.<br>Adults and juveniles: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |

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Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to Interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Decreased spawning success resulting from reduced fitness. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Mortality in acute low dissolved oxygen events due to asphyxiation. Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Avoid sediment pulses. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to Interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |

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## Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Juveniles; Adults | Adults and juveniles: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Juveniles; Adults | Adults and juveniles: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, and reduced ambient light from fine bubble profusion. | May affect juvenile productivity. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Adults and juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival and productivity. May affect adult growth and spawning productivity. |

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## Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile productivity. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | | May affect juvenile survival and productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect juvenile survival, growth, and fitness. May affect adult spawning fitness. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round (with stressor exposure occurring during juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | Alteration in the magnitude, volume, and timing of peak flows | During storm events (predominantly from fall through spring) | Permanent | Common | Juveniles; Adults | Adults and juveniles: Because the amount of impervious surface associated with breakwaters is a relatively inconsequential component of the overall drainage area of the larger river systems that would support this type of development, the magnitude of the hydrologic modification stressor is expected to be negligible. As such, this stressor is not expected to significantly affect the riverine environment, and there will be no response to the stressor. | Encourage facilities to employ modern low-impact development and stormwater treatment technology. | Impervious surface at anticipated scale would not produce stressors of sufficient magnitude to adversely affect cutthroat trout at any life-history stage. |

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# Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that comprise the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile coastal cutthroat trout. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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## Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Juveniles; Adults | Adults and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult coastal cutthroat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.<br>Adults: Adult cutthroat trout will generally be less sensitive to these stressors. However, increased stress and delayed migration may reduce fitness and ultimately reduce spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round, with variable effects by season (e.g., circulation patterns) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |



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Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| | **Lacustrine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality or injury and/or affect survival, growth, and fitness of exposed life-history stages, depending on project-specific noise intensity and receptor exposure. |

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## Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect juvenile survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. May affect adult fitness due to decreased foraging success. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated; reduced growth and fitness; increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May cause direct mortality or injury to affected life-history stages. May affect survival, growth, and fitness at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows. Avoid use when juveniles are present. | May affect survival, growth, and fitness at juvenile life-history stage. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of flow conditions to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Altered current and circulation conditions (marine and lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Adults and juveniles: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Juveniles; Adults | Adults and juveniles: See responses described under Hydraulic and Geomorphic Modifications. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Adults and juveniles: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |

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## Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Juveniles; Adults | Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. Adults and juveniles: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to Interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Decreased spawning success resulting from reduced fitness. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Mortality in acute low dissolved oxygen events due to asphyxiation. Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Avoid sediment pulses. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to Interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Juveniles; Adults | Adults and juveniles: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Juveniles; Adults | Adults and juveniles: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures). | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles; Adults | Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.<br>Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns.<br>Adults: Decreased spawning fitness due to migration delays caused by thermal barriers. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered stream bank and shoreline stability | Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools) | Year-round (with specific stressors prominent during high-flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.<br>Adults: Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |

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## Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs | Year-round | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of juveniles. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness.<br>Adults: Increased mortality and decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered groundwater-surface water exchange | Reduced available suitable spawning habitat; reduced gravel dissolved oxygen | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress; increased competition for suitable habitats.<br>Adults: Decrease in suitable habitat, increased competition, decreased spawning fitness and success. | Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater recharge. Limit alteration of riparian vegetation to greatest extent practicable. | May affect juvenile survival, growth, and fitness. May affect adult spawning productivity. |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival, growth, and fitness. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Cutthroat trout dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, cutthroat trout are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth, fitness, and productivity. |

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## Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival and productivity, spawning success, and overall population productivity. |
| | Altered freshwater inflow | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Cutthroat trout dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along stream. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and productivity. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Cutthroat trout dependence on allochthonous inputs from riparian vegetation is a data gap. However, cutthroat trout are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth, fitness, and productivity. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival and productivity, spawning success, and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Cutthroat trout dependence on groundwater inflow to nearshore lacustrine habitats is currently a data gap. | Avoid disturbance of vegetation along stream. | Effects of the action resulting from this impact mechanism are unknown. |

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Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile productivity. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Adults and juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival and productivity. May affect adult growth and spawning productivity. |
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile productivity. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | | May affect juvenile survival and productivity. |

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**Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect juvenile survival, growth, and fitness. May affect adult spawning fitness. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round (with stressor exposure occurring during juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Juveniles | Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that comprise the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile coastal cutthroat trout. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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## Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Juveniles; Adults | Adults and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult coastal cutthroat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.<br>Adults: Adult cutthroat trout will generally be less sensitive to these stressors. However, increased stress and delayed migration may reduce fitness and ultimately reduce spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater–surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat; change in habitat structure, availability, and suitability; reduced food web complexity | Year-round | Permanent | Continuous | Eggs and alevins; Juveniles; Adults | All exposed life-history stages: Bank barbs and groins can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness. | Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | All exposed life-history stages: Bank barbs and groins in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |

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**Table A-7 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Coastal Cutthroat Trout.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | All exposed life-history stages: Bank barbs and groins in lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-8. HPA HCP Shoreline Modification Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Stressor response dependent on noise magnitude, project-specific environmental conditions; may range from:<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality or injury and/or affect survival, growth, and fitness of exposed life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect juvenile survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. May affect adult fitness due to decreased foraging success. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated; reduced growth and fitness, and increased predation exposure.<br>Adults: Decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May cause direct mortality or injury to affected life-history stages. May affect survival, growth, and fitness at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work window. Avoid use when juveniles are present. | May affect survival, growth, and fitness at juvenile life-history stage. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. | May affect growth and fitness at juvenile life-history stage; may affect adult spawning productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at juvenile life-history stage. |

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## Table A-8 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Adults and juveniles: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual-decadal | Juveniles; Adults | Adults and juveniles: See responses described under Hydraulic and Geomorphic Modifications. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual-decadal | Juveniles; Adults | Adults and juveniles: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual-decadal | Juveniles; Adults | Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness.<br>Adults and juveniles: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Decreased spawning success resulting from reduced fitness. | Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Mortality in acute low dissolved oxygen events due to asphyxiation. Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Avoid sediment pulses. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |

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Table A-8 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Juveniles; Adults | Adults and juveniles: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated-wood particulates. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Juveniles; Adults | Adults and juveniles: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles; Adults | Adults and juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Native trout dependence on allochthonous inputs from riparian vegetation is a data gap. However, native trout are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth, fitness, and productivity. |

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## Table A-8 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival and productivity, spawning success, and overall population productivity. |
| | Altered groundwater-surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Native trout dependence on groundwater inflow to nearshore habitats is currently a data gap. | Avoid disturbance of vegetation along stream. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile productivity. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Adults and juveniles: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. | | May affect juvenile survival and productivity. |

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Table A-8 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Juveniles; Adults | <u>Adults and juveniles</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult native trout. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and fitness, and direct mortality.<br><u>Adults</u>: Adult native trout will generally be less sensitive to these stressors. However, increased stress and inhibited movement may reduce fitness and ultimately reduce spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | <u>All exposed life-history stages</u>: Jetties can fragment nearshore lacustrine rearing habitats, forcing migrating and foraging salmonids to navigate offshore into deeper water environments. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |

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## Table A-8 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Stressor response dependent on noise magnitude, project-specific environmental conditions; may range from:<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality or injury and/or affect survival, growth, and fitness of exposed life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect juvenile survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. May affect adult fitness due to decreased foraging success. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated; reduced growth and fitness, and increased predation exposure.<br>Adults: Decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May cause direct mortality or injury to affected life-history stages. May affect survival, growth, and fitness at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work window. Avoid use when juveniles are present. | May affect survival, growth, and fitness at juvenile life-history stage. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. | May affect growth and fitness at juvenile life-history stage; may affect adult spawning productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Adults and juveniles: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |

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## Table A-8 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual-decadal | Juveniles; Adults | Adults and juveniles: See responses described under Hydraulic and Geomorphic Modifications. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual-decadal | Juveniles; Adults | Adults and juveniles: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual-decadal | Juveniles; Adults | Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness.<br>Adults and juveniles: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Decreased spawning success resulting from reduced fitness. | Ensure that project design avoids and/or minimizes habitat alterations leading to chronic shoreline instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Mortality in acute low dissolved oxygen events due to asphyxiation. Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Avoid sediment pulses. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |

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| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Juveniles; Adults | Adults and juveniles: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated-wood particulates. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Juveniles; Adults | Adults and juveniles: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. | May affect juvenile productivity. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Adults and juveniles: See related stressor responses under Water Quality Modification. | Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. | | May affect juvenile survival and productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced rearing habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect juvenile survival, growth and fitness. May affect adult spawning fitness. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |

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| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered groundwater-surface water exchange | | Year-round (with stressor exposure occurring during juvenile rearing) | Permanent | Continuous | | success. | | |
| | Addition of impervious surface | Alteration in the magnitude, volume, and timing of peak flows | During storm events (predominantly from fall through spring) | Permanent | Common | Juveniles;<br>Adults | Adults and juveniles: Because the amount of impervious surface associated with breakwaters is a relatively inconsequential component of the overall drainage area of the larger river systems that would support this type of development, the magnitude of the hydrologic modification stressor is expected to be negligible. As such, this stressor is not expected to significantly affect the riverine environment, and there will therefore be no response to the stressor. | Encourage facilities to employ modern low-impact development and stormwater treatment technology. | Impervious surface at anticipated scale would not produce stressors of sufficient magnitude to adversely affect native trout at any life-history stage. |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Juveniles;<br>Adults | Adults and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult native trout. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and fitness, and direct mortality.<br>Adults: Adult native trout will generally be less sensitive to these stressors. However, increased stress and inhibited movement may reduce fitness and ultimately reduce spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. For example: | May affect survival and productivity at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round) | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Lacustrine** | | | | | | | | |

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### Table A-8 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Stressor response dependent on noise magnitude, project-specific environmental conditions; may range from:<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality or injury and/or affect survival, growth, and fitness of exposed life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect juvenile survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. May affect adult fitness due to decreased foraging success. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated; reduced growth and fitness, and increased predation exposure.<br>Adults: Decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May cause direct mortality or injury to affected life-history stages. May affect survival, growth, and fitness at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work window. Avoid use when juveniles are present. | May affect survival, growth, and fitness at juvenile life-history stage. |

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Table A-8 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Increased stress; decreased spawning fitness. | Limit alteration of flow conditions to minimal area. | May affect juvenile growth and fitness; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. | May affect growth and fitness at juvenile life-history stage; may affect adult spawning productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Adults and juveniles: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual-decadal | Juveniles; Adults | Adults and juveniles: See responses described under Hydraulic and Geomorphic Modifications. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual-decadal | Juveniles; Adults | Adults and juveniles: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual-decadal | Juveniles; Adults | Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. Adults and juveniles: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |

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### Table A-8 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Decreased spawning success resulting from reduced fitness. | Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Juveniles; Adults | Adults and juveniles: Mortality in acute low dissolved oxygen events due to asphyxiation. Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Avoid sediment pulses. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Juveniles; Adults | Adults and juveniles: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated-wood particulates. Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect juvenile and adult survival, growth, and fitness. Reduced adult fitness may affect spawning success. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Juveniles; Adults | Adults and juveniles: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |

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**Table A-8 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered riparian shading<br><br>Altered ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles;<br>Adults | Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.<br>Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns.<br>Adults: Decreased spawning fitness due to inhibited or delayed movement caused by thermal barriers. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered stream bank and shoreline stability | Increased suspended solids; reduced habitat complexity (e.g., filling of pools) | Year-round (with specific stressors prominent during high-flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles;<br>Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.<br>Adults: Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs | Year-round | Permanent | Continuous | Juveniles | Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of juveniles. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.<br>Adults: Increased mortality and decreased fitness and spawning success due to decreased availability of suitable habitat. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered groundwater surface water exchange | Reduced available suitable habitat; reduced gravel dissolved oxygen | Year-round | Permanent | Continuous | Juveniles;<br>Adults | Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress; increased competition for suitable habitats.<br>Adults: Decrease in suitable habitat, increased competition, decreased spawning fitness and success. | Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater recharge. Limit alteration of riparian vegetation to greatest extent practicable. | May affect juvenile survival, growth, and fitness. May affect adult spawning productivity. |

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**Table A-8 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered riparian shading | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles; Adults | Adults and juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered ambient air temperature regime | | | | | | | | |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Native trout dependence on allochthonous inputs from riparian vegetation is a data gap. However, native trout are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth, fitness, and productivity. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival and productivity, spawning success, and overall population productivity. |
| | Altered groundwater-surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Native trout dependence on groundwater inflow to nearshore habitats is currently a data gap. | Avoid disturbance of vegetation along stream. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. | May affect juvenile productivity. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Adults and juveniles: See related stressor responses under Water Quality Modification. | Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. | | May affect juvenile survival and productivity. |

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### Table A-8 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced rearing habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect juvenile survival, growth and fitness. May affect adult spawning fitness. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round (with stressor exposure occurring during juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Juveniles; Adults | Adults and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult native trout. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and fitness, and direct mortality.<br>Adults: Adult native trout will generally be less sensitive to these stressors. However, increased stress and inhibited movement may reduce fitness and ultimately reduce spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. For example: | May affect survival and productivity at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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## Table A-8 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat; change in habitat structure, availability, and suitability; reduced food web complexity | Year-round | Permanent | Continuous | Eggs and alevins;<br>Juveniles;<br>Adults | <u>All exposed life-history stages</u>: Bank barbs and groins can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness. | Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles;<br>Adults | <u>All exposed life-history stages</u>: Bank barbs and groins in lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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### Table A-9. HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | All life-history stages: Stressor response, dependent on noise magnitude, project-specific environmental conditions, may range from:<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work window. Use double confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden piles where practicable. | Activity may cause direct mortality or injury, and/or affect survival, growth, and fitness, of exposed life-history stages depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect juvenile survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.<br>May affect adult fitness due to decreased foraging success. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May cause direct mortality or injury to affected life-history stages. May affect survival, growth, and fitness at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work window. Avoid use when juveniles are present. | May affect survival and fitness at juvenile life-history stage |
| | | Altered current and circulation conditions (marine and lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal depending on activity frequency | Juveniles;<br>Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity. |

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Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal depending on activity frequency | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work window. Avoid work during egg incubation periods. | May affect egg and alevin incubation success and survival; may affect growth and fitness at juvenile life-history stage; may affect adult spawning fitness. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal depending on activity frequency | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, and decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal depending on activity frequency | Juveniles;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual-decadal | Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual-decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual-decadal | Juveniles;<br>Adults | Juveniles: Altered migratory behavior; decreased foraging opportunity due to short-term reduction in prey availability; decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Juveniles;<br>Adults | Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival, growth, and fitness at all life-history stages. Reduced adult fitness may affect spawning success. |

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### Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles;<br>Adults | <u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation.<br><u>Juveniles and adults</u>: Stress and other physiological responses to levels outside optimal thresholds causing mortality or injury leading to reduced fitness. | Avoid sediment pulses. | Egg and alevin exposure is unlikely as bull trout and Dolly Varden spawning habitat is typically in areas unsuitable for jetty development. May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | | Altered pH levels. | Dependent on contributing mechanism of impact | Temporary to short-term depending on contributing mechanism of impact | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Juveniles;<br>Adults | <u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | Egg and alevin exposure is unlikely as bull trout and Dolly Varden spawning habitat is typically in areas unsuitable for jetty development. May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Use of creosote-treated Wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water.<br>Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Juveniles;<br>Adults | <u>Adults and juveniles</u>: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br><u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Egg and alevin exposure is unlikely as bull trout and Dolly Varden spawning habitat is typically in areas unsuitable for jetty development. May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Use of ACZA and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Juveniles;<br>Adults | <u>Adults and juveniles</u>: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |

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## Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased localized summer temperatures) | Year-round (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles; Adults | Adults and juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, adult char trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence have been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles; Adults | Adults and juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduced organic matter inputs. Reduced large woody debris recruitment affecting habitat complexity (see below) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles; Adults | Adults and juveniles: Char dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, the dependence on terrestrial insect fall as a food source may be limited as adult char are primarily piscivorous. Indirect effects on food web productivity may decrease foraging opportunities, leading to decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered groundwater surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles; Adults | | Avoid disturbance of vegetation along stream. | |

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Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles; Adults | Adults and juveniles: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. | May affect growth and fitness at juvenile and adult life-history stages. Reduced adult fitness may affect spawning success. |
| | Altered habitat complexity | Reduced food web productivity, foraging opportunity, available cover, and available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Adult and juveniles: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from propeller wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect survival, growth, and fitness at juvenile and adult life-history stages. Reduced adult fitness may affect spawning success. |
| | **Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles; Adults | Adults and juveniles: Char dependence on littoral lacustrine vegetation is relatively limited as this species tends to occupy cold water river habitats and deepwater lacustrine habitats in the photic or profundal zone where aquatic vegetation is limited or non-existent. Therefore, modification of aquatic vegetation may have limited direct effects on this species. However, such alterations may limit the productivity of prey species for native char, leading to decreased foraging opportunity and decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from propeller wash, grounding and anchoring. | May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | | | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | | | |

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**Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round, with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of foraging habitats for adult char. This may occur through a number of specific stressors, including change in current and wave energy patterns, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and fitness, and potentially decreased survival due to predation exposure. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Altered current velocities | | Year-round, with variable effects depending on site-specific current dynamics and project configuration | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round, with seasonally variable effects depending on site-specific, geography and bathymetry and project configuration | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round, beginning with project installation and becoming more pronounced over time | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round, beginning with project installation and becoming more pronounced over time (e.g., due to accumulation of shell hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round, with predominant effects from fall through spring when wind driven waves are most pronounced | Permanent | Continuous | Juveniles: Adults | Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats. Use of these habitats by adult char is limited, as these species tend to utilize cold, deepwater habitats in the photic and profundal zone. However, reduction in nearshore habitat productivity may affect abundance of potential prey species, reducing adult foraging opportunity and leading to decreased growth and fitness. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival at juvenile life-history stage. May affect result in decreased growth and fitness at adult life-history stage. |
| | Altered current velocities | | Year-round, with effects more predominant in reservoirs versus natural lakes | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round, with variable effects by season (e.g., circulation patterns) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | All exposed life-history stages: Jetties can fragment nearshore marine rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles;<br>Adults | All exposed life-history stages: Jetties can fragment nearshore lacustrine rearing habitats, forcing migrating and foraging salmonids to navigate offshore into deeper water environments. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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## Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | All life-history stages: Stressor response, dependent on noise magnitude, project-specific environmental conditions, may range from:<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work window. Use double confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden piles where practicable. | Activity may cause direct mortality or injury, and/or affect survival, growth, and fitness, of exposed life-history stages depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect juvenile survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. May affect adult fitness due to decreased foraging success. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May cause direct mortality or injury to affected life-history stages. May affect survival, growth, and fitness at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work window. Avoid use when juveniles are present. | May affect survival and fitness at juvenile life-history stage |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of flow conditions to minimal area. | May affect survival, growth, and fitness during egg and alevin life-history stage; may affect juvenile growth and fitness; may affect adult spawning fitness. |
| | | Altered current and circulation conditions (marine and lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal depending on activity frequency | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity. |

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Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal depending on activity frequency | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work window. Avoid work during egg incubation periods. | May affect egg and alevin incubation success and survival; may affect growth and fitness at juvenile life-history stage; may affect adult spawning fitness. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal depending on activity frequency | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, and decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal depending on activity frequency | Juveniles;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual-decadal | Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual-decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual-decadal | Juveniles;<br>Adults | Juveniles: Altered migratory behavior; decreased foraging opportunity due to short-term reduction in prey availability; decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Juveniles;<br>Adults | Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival, growth, and fitness at all life-history stages. Reduced adult fitness may affect spawning success. |

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**Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins; Juveniles;<br>Adults | <u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation.<br><u>Juveniles and adults</u>: Stress and other physiological responses to levels outside optimal thresholds causing mortality or injury leading to reduced fitness. | Avoid sediment pulses. | Egg and alevin exposure is unlikely as bull trout and Dolly Varden spawning habitat is typically in areas unsuitable for breakwater development May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term depending on contributing mechanism of impact | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Juveniles;<br>Adults | <u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | Egg and alevin exposure is unlikely as bull trout and Dolly Varden spawning habitat is typically in areas unsuitable for breakwater development. May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Use of creosote-treated Wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water.<br>Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Juveniles;<br>Adults | <u>Adults and juveniles</u>: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br><u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | Egg and alevin exposure is unlikely as bull trout and Dolly Varden spawning habitat is typically in areas unsuitable for breakwater development. May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Use of ACZA and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Juveniles;<br>Adults | <u>Adults and juveniles</u>: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |

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**Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.<br>Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | | May affect juvenile survival, growth, and fitness, as well as adult spawning productivity. |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles; Adults | Adults and juveniles: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from propeller wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect growth and fitness at juvenile and adult life-history stages. Reduced adult fitness may affect spawning success. |
| | Altered habitat complexity | Reduced food web productivity, foraging opportunity, available cover, and available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Adults and juveniles: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect survival, growth, and fitness at juvenile and adult life-history stages. Reduced adult fitness may affect spawning success. |
| | **Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles; Adults | Adults and juveniles: Char dependence on littoral lacustrine vegetation is relatively limited as this species tends to occupy cold water river habitats and deepwater lacustrine habitats in the photic or profundal zone where aquatic vegetation is limited or non-existent. Therefore, modification of aquatic vegetation may have limited direct effects on this species. However, such alterations may limit the productivity of prey species for native char, leading to decreased foraging opportunity and decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from propeller wash, grounding and anchoring. | May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | | | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | | | |

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Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles<br>Adults | Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect juvenile survival, growth, and fitness. May affect adult spawning fitness. Effects on spawning and freshwater rearing habitat are unlikely, however, as the cold water streams preferred by these species are unsuitable sites for breakwater development. |
| | Altered flow velocity | | Year-round, with stressor exposure occurring during high flow events, fall through spring | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round, with stressor exposure occurring during egg incubation and juvenile rearing | Permanent | Continuous | | | | |
| | Addition of impervious surface | Alteration in the magnitude, volume, and timing of peak flows | During storm events, predominantly from fall through spring | Permanent | Common | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: Because the amount of impervious surface associated with breakwaters is a relatively inconsequential component of the overall drainage area of the larger river systems that would support this type of development, the magnitude of the hydrologic modification stressor is expected to be negligible. As such, this stressor is not expected to significantly affect the riverine environment, and there will therefore be no response to the stressor.<br>Also see Water Quality Modification above. | Encourage facilities to employ modern low impact development and stormwater treatment technology. | Impervious surface at anticipated scale would not produce stressors of sufficient magnitude to adversely affect char at any life-history stage. Effects on spawning and freshwater rearing habitat are also unlikely as the cold water streams preferred by these species are unsuitable sites for breakwater development. |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round, with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing | Permanent | Continuous | Juveniles;<br>Adults | Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of foraging habitats for adult char. This may occur through a number of specific stressors, including change in current and wave energy patterns, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and fitness, and potentially decreased survival due to predation exposure. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect juvenile and adult survival and growth. |
| | Altered current velocities | | Year-round, with variable effects depending on site-specific current dynamics and project configuration | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round, with seasonally variable effects depending on site-specific, geography and bathymetry and project configuration | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round, beginning with project installation and becoming more pronounced over time | Permanent | Continuous | | | | |

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**Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered substrate composition | | Year-round, beginning with project installation and becoming more pronounced over time (e.g., due to accumulation of shell hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching) | Permanent | Continuous | | | | |
| | Altered groundwater – surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round, with predominant effects from fall through spring when wind driven waves are most pronounced | Permanent | Continuous | Juveniles:<br>Adults | Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats. Use of these habitats by adult char is limited, as these species tend to utilize cold, deepwater habitats in the photic and profundal zone. However, reduction in nearshore habitat productivity may affect abundance of potential prey species, reducing adult foraging opportunity and leading to decreased growth and fitness. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect juveniles and adult growth and fitness. |
| | Altered current velocities | | Year-round, with effects more predominant in reservoirs versus natural lakes | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round, with variable effects by season (e.g., circulation patterns) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |

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## Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| | **Lacustrine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles | Juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile salmonids in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | All life-history stages: Stressor response, dependent on noise magnitude, project-specific environmental conditions, may range from:<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work window. Use double confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden piles where practicable. | Activity may cause direct mortality or injury, and/or affect survival, growth, and fitness, of exposed life-history stages depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect juvenile survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. May affect adult fitness due to decreased foraging success. |

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## Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May cause direct mortality or injury to affected life-history stages. May affect survival, growth, and fitness at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work window. Avoid use when juveniles are present. | May affect survival and fitness at juvenile life-history stage |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of flow conditions to minimal area. | May affect survival, growth, and fitness during egg and alevin life-history stage; may affect juvenile growth and fitness; may affect adult spawning fitness. |
| | | Altered current and circulation conditions (marine and lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal depending on activity frequency | Juveniles;<br>Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal depending on activity frequency | Eggs and alevins;<br>Juveniles;<br>Adults | Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance.<br>Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work window. Avoid work during egg incubation periods. | May affect egg and alevin incubation success and survival; may affect growth and fitness at juvenile life-history stage; may affect adult spawning fitness. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal depending on activity frequency | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, and decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal depending on activity frequency | Juveniles;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual-decadal | Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual-decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |

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Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual-decadal | Juveniles;<br>Adults | Juveniles: Altered migratory behavior; decreased foraging opportunity due to short-term reduction in prey availability; decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Juveniles;<br>Adults | Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival, growth, and fitness at all life-history stages. Reduced adult fitness may affect spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and alevins;<br>Juveniles;<br>Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.<br>Juveniles and adults: Stress and other physiological responses to levels outside optimal thresholds causing mortality or injury leading to reduced fitness. | Avoid sediment pulses. | May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | | Altered pH levels. | Dependent on contributing mechanism of impact | Temporary to short-term depending on contributing mechanism of impact | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Juveniles;<br>Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |

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## Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated Wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water.<br>Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Juveniles;<br>Adults | Adults and juveniles: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Use of ACZA and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Juveniles;<br>Adults | Adults and juveniles: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles;<br>Adults | Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.<br>Juveniles: Altered growth and fitness caused by temperatures outside optimal growth range, and alteration of food web patterns.<br>Adults: Decreased spawning fitness due to migration delays caused by thermal barriers. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered streambank and shoreline stability | Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools) | Year-round (with specific stressors prominent during high-flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles;<br>Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.<br>Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction in organic matter inputs. | Year-round | Permanent | Continuous | Juveniles | Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of juveniles. |

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## Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality, and decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect survival, growth, and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered groundwater-surface water exchange | Reduced available suitable spawning habitat; reduced gravel dissolved oxygen | Year-round | Permanent | Continuous | Adults | Adults: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, and increased competition for suitable habitats. | Avoid permitting of projects that disturb groundwater inflow areas with springs, seeps, or sources of significant groundwater recharge. Limit alteration of riparian vegetation to greatest extent practicable. | May affect adult survival, growth, and fitness. Reduced fitness may affect spawning success. |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased localized summer temperatures) | Year-round (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles; Adults | Adults and juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, adult char trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence have been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles; Adults | Adults and juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduced organic matter inputs. Reduced large woody debris recruitment affecting habitat complexity (see below) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles; Adults | Adults and juveniles: Char dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, the dependence on terrestrial insect fall as a food source may be limited as adult char are primarily piscivorous. Indirect effects on food web productivity may decrease foraging opportunities, leading to decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |

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**Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered groundwater surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles; Adults | Juveniles and Adults: Char dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along stream. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Modification. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.<br>Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | | May affect juvenile survival, growth, and fitness, as well as adult spawning productivity. |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles; Adults | Adults and juveniles: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect growth and fitness at juvenile and adult life-history stages. Reduced adult fitness may affect spawning success. |
| | Altered habitat complexity | Reduced food web productivity, foraging opportunity, available cover, and available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Adult juveniles: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect survival, growth, and fitness at juvenile and adult life-history stages. Reduced adult fitness may affect spawning success. |
| | **Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles; Adults | Adults and juveniles: Char dependence on littoral lacustrine vegetation is relatively limited as this species tends to occupy cold water river habitats and deepwater lacustrine habitats in the photic or profundal zone where aquatic vegetation is limited or non-existent. Therefore, modification of aquatic vegetation may have limited direct effects on this species. However, such alterations may limit the productivity of prey species for native char, leading to decreased foraging opportunity and decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | | | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | | | |



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## Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles<br>Adults | Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect juvenile survival, growth, and fitness. May affect adult spawning fitness. |
| | Altered flow velocity | | Year-round, with stressor exposure occurring during high flow events, fall through spring | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round, with stressor exposure occurring during egg incubation and juvenile rearing | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round, with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing | Permanent | Continuous | Juveniles;<br>Adults | Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of foraging habitats for adult char. This may occur through a number of specific stressors, including change in current and wave energy patterns, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and fitness, and potentially decreased survival due to predation exposure. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect juvenile and adult survival and growth. |
| | Altered current velocities | | Year-round, with variable effects depending on site-specific current dynamics and project configuration | Permanent | Intermittent | | | | |
| | Altered sediment supply | | Year-round, beginning with project installation and becoming more pronounced over time | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round, beginning with project installation and becoming more pronounced over time (e.g., due to accumulation of shell hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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### Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round, with predominant effects from fall through spring when wind driven waves are most pronounced | Permanent | Continuous | Juveniles:<br>Adults | Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats. Use of these habitats by adult char is limited, as these species tend to utilize cold, deepwater habitats in the photic and profundal zone. However, reduction in nearshore habitat productivity may affect abundance of potential prey species, reducing adult foraging opportunity and leading to decreased growth and fitness. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect juveniles and adult growth and fitness. |
| | Altered current velocities | | Year-round, with effects more predominant in reservoirs versus natural lakes | Permanent | Common | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat; change in habitat structure, availability, and suitability; reduced food web complexity | Year-round | Permanent | Continuous | Eggs and alevins;<br>Juveniles;<br>Adults | All exposed life-history stages: Bank barbs and groins can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness. | Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles | All exposed life-history stages: Bank barbs and groins in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |

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**Table A-9 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Loss of LWD recruitment | Reduced availability of LWD from drift.<br>Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs<br>Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles;<br>Adults | <u>All exposed life-history stages</u>: Bank barbs and groins in lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-10. HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and larvae; Juveniles; Adults | All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>• Rupture of egg membrane.<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles, Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitations to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation.<br>Juveniles: Increased competition once relocated, reduced growth and fitness, increased predation exposure.<br>Adults: Delayed local migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May affect survival and productivity at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | May affect survival and fitness at juvenile life-history stage. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect survival and productivity during egg and larvae life-history stage, may affect juvenile productivity; may affect adult spawning productivity. |

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**Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and larvae; Juveniles; Adults | Eggs and larvae: Potential decreased egg incubation success and larvae survival due to turbidity exposure and substrate disturbance.<br>Juveniles and adults: Stress and behavioral modifications by juveniles and adults exposed to sediment pulses, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth at all life-history stages. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and productivity at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and larvae; Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and larvae; Juveniles; Adults | All life-history stages: See responses described above under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and larvae; Juveniles; Adults | Juveniles and Adults: Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May affect juvenile productivity and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and larvae; Juveniles; Adults | Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success. |

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**Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.**

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and larvae; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.(dissolved oxygen levels should be >5 ppm).<br>Juveniles and adults: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Avoid sediment pulses. | May affect juvenile survival and adult survival, and spawning productivity. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and larvae; Juveniles; Adults | All life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid sediment pulses. | May affect survival of all life-history stages. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and larvae; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival of all life-history stages. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and larvae; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |

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### Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Riparian and Shoreline Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures). Pygmy whitefish depend on cold water of 50°F or less. Therefore, increased temperatures will limit suitable habitat. | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of currents, wind conditions, and other factors. However, juveniles trapped in habitats with isolated water level changes may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Pygmy whitefish are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival and productivity, spawning success, and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Whitefish dependence upon groundwater inflow is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |

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**Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.**

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile productivity. |
| | | Altered DO levels due to reduced photosynthesis. | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Alteration. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | | May affect juvenile survival and adult spawning productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Eggs and larvae; Juveniles; Adults | All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially leading to direct mortality and decreased survival of eggs and larvae (lacustrine spawning whitefish) and decreasing the suitability of rearing habitat for juvenile and adult whitefish. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, fitness, and productivity, as well as direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May decrease survival of eggs and larvae. May affect survival and productivity at juvenile life-history stage. Decreased adult fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |

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Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles | <u>Juveniles</u>: Jetties can fragment nearshore lacustrine habitats. Larval and juvenile pygmy whitefish are known to occur in these habitat types, but knowledge of dependence on these habitats is limited. Given prevalence in these habitat types, however, stressor exposure may affect juvenile survival, growth, and fitness if habitat access is impaired. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival, growth, and fitness. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and larvae; Juveniles; Adults | <u>All life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>• Rupture of egg membrane.<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. Effects on incubating eggs are unlikely as spawning occurs in habitats that are unsuitable for breakwater development. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles, Adults | <u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitations to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. |



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**Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation.<br><u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, increased predation exposure.<br><u>Adults</u>: Delayed local migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May affect survival and productivity at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | <u>Juveniles</u>: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | May affect survival and fitness at juvenile life-history stage. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and larvae; Juveniles; Adults | <u>Eggs and larvae</u>: Potential substrate scour/or sedimentation, resulting in decreased incubation success.<br><u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br><u>Adults</u>: Delayed migration to spawning stream, increased stress, decreased spawning fitness. | Limit alteration of flow conditions to minimal area. | May affect survival and productivity during egg and juvenile life-history stages, may affect adult spawning productivity. |
| | | Altered current and circulation conditions (lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | <u>Eggs and larvae</u>: Potential decreased egg incubation success and larvae survival due to altered current and circulation conditions.<br><u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br><u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect survival and productivity during egg and larvae life-history stage, may affect juvenile productivity; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and larvae; Juveniles; Adults | <u>Eggs and larvae</u>: Potential decreased egg incubation success and larvae survival due to turbidity exposure and substrate disturbance.<br><u>Juveniles and adults</u>: Stress and behavioral modifications by juveniles and adults exposed to sediment pulses, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth at all life-history stages. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | <u>Juveniles</u>: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and productivity at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and larvae; Juveniles; Adults | <u>All life-history stages</u>: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and larvae; Juveniles; Adults | <u>All life-history stages</u>: See responses described above under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |

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### Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and larvae; Juveniles; Adults | Eggs and larvae: Mortality or injury from entrainment. Juveniles and Adults: Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May affect juvenile productivity and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and larvae; Juveniles; Adults | Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect juvenile growth and fitness and adult productivity and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and larvae; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.(dissolved oxygen levels should be >5 ppm). Juveniles and adults: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Avoid sediment pulses. | May affect juvenile survival and adult survival, and spawning productivity. |



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**Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.**

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and larvae; Juveniles; Adults | <u>All life-history stages:</u> Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid sediment pulses. | May affect survival of juveniles and adults. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and larvae; Juveniles; Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br><u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and larvae; Juveniles; Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | <u>Juveniles</u>: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | <u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br><u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.<br><u>Operation</u>: Enforce vessel operation rules to limit submerged | May affect juvenile productivity. |
| | | Altered DO levels due to reduced photosynthesis. | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | <u>Juveniles and adults</u>: See related stressor responses under Water Quality Alteration. | | See effects for related stressors under Water Quality Modification. |

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**Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.**

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile survival and adult spawning productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs and larvae Juveniles Adults | Eggs and larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased egg incubation success and survival. Pygmy whitefish dependence on groundwater inflow for incubation success is currently a data gap. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of spawning areas) if potential spawning habitat is affected | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival and productivity at egg, larvae, and juvenile life-history stages. May affect spawning productivity. Note that stressor exposure is unlikely to occur, as riverine habitats used by this species are typically unsuitable for breakwater development. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | Alteration in the magnitude, volume, and timing of peak flows | During storm events (predominantly from fall through spring) | Permanent | Common | Eggs and larvae; Juveniles; Adults | All life-history stages: Because the amount of impervious surface associated with breakwaters is a relatively inconsequential component of the overall drainage area of the larger river systems that would support this type of development, the magnitude of the hydrologic modification stressor is expected to be negligible. As such, this stressor is not expected to significantly affect the riverine environment, and there will be no response to the stressor. | Encourage facilities to employ modern low-impact development and stormwater treatment technology. | Depending on the size of the additional impervious surface, the additional amount of impervious surface may not affect the streamflow at a scale to become a stressor for whitefish. |



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**Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.**

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Eggs and larvae; Juveniles; Adults | All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially leading to direct mortality and decreased survival of eggs and larvae (lacustrine spawning whitefish) and decreasing the suitability of rearing habitat for juvenile and adult whitefish. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, fitness, and productivity, as well as direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns | May decrease survival of eggs and larvae. May affect survival and productivity at juvenile life-history stage. Decreased adult fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | NA | NA | NA | NA | NA | NA | NA |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | NA | NA | NA | NA | NA | NA | NA |
| | **Lacustrine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for whitefish in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile and adult survival. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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### Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and larvae; Juveniles; Adults | <u>All life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>• Rupture of egg membrane.<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | <u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitations to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation.<br><u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, increased predation exposure.<br><u>Adults</u>: Delayed local migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May affect survival and productivity at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | <u>Juveniles</u>: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present. | May affect survival and fitness at juvenile life-history stage. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and larvae; Juveniles; Adults | <u>Eggs and larvae</u>: Potential substrate scour/or sedimentation, resulting in decreased incubation success.<br><u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br><u>Adults</u>: Delayed migration to spawning stream, increased stress, decreased spawning fitness. | Limit alteration of flow conditions to minimal area. | May affect survival and productivity during egg and juvenile life-history stages, may affect adult spawning productivity. |

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| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered current and circulation conditions (lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, decreased spawning fitness. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | May affect survival and productivity during egg and larvae life-history stage, may affect juvenile productivity; may affect adult spawning productivity. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and larvae; Juveniles; Adults | Eggs and larvae: Potential decreased egg incubation success and larvae survival due to turbidity exposure and substrate disturbance.<br>Juveniles and adults: Stress and behavioral modifications by juveniles and adults exposed to sediment pulses, reduced foraging opportunities, and increased predation risk. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect growth at all life-history stages. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and productivity at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and larvae; Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and larvae; Juveniles; Adults | All life-history stages: See responses described above under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and larvae; Juveniles; Adults | Juveniles and Adults: Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May affect juvenile productivity and fitness. See effects for related stressors under Water Quality Modification. |



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**Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and larvae; Juveniles; Adults | Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May lead to direct mortality and decreased survival of eggs and larvae.<br>May affect juvenile growth and fitness and adult productivity and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and larvae; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.(dissolved oxygen levels should be >5 ppm).<br>Juveniles and adults: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Avoid sediment pulses. | May affect juvenile survival and adult survival, and spawning productivity. |

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## Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and larvae; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and larvae; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian and Shoreline Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Eggs and larvae; Juveniles; Adults | Eggs and larvae: Direct mortality due to winter ice formation and scour.<br>Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns (optimal range 50°F or less).<br>Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.<br>Adults: Decreased spawning fitness due to migration delays caused by thermal barriers. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect larval, juvenile, and adult growth and fitness. |

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**Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered stream bank and shoreline stability | Increased suspended solids; decreased dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools) | Year-round (with specific stressors prominent during high flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs and larvae; Juveniles; Adults | <u>Eggs and larvae:</u> Decreased incubation success due to decreased dissolved oxygen as described for related stressor responses under Water Quality Modification.<br><u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.<br><u>Adults:</u> Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival during incubation, rearing, and spawning. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs | Year-round | Permanent | Continuous | Juveniles | Pygmy whitefish dependency upon allochthonous input is a data gap. However, Pygmy whitefish feed on zooplankton and aquatic insects that could be associated with terrestrial riparian inputs. Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile rearing growth and fitness. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat. | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Larvae; Juveniles; Adults | <u>Larvae and juveniles:</u> Decreased foraging opportunities, leading to increased competition and resulting effects on growth and fitness.<br><u>Adults:</u> Increased mortality; decreased fitness and spawning success due to decreased pool availability and availability of suitable spawning habitat. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect larval and juvenile survival, growth, and productivity. May affect adult spawning productivity. |
| | Altered groundwater–surface water exchange | Reduced available suitable spawning habitat; reduced gravel dissolved oxygen | Year-round | Permanent | Continuous | Eggs and larvae; Adults | <u>Eggs and larvae</u>: Decreased incubation success.<br><u>Adults</u>: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success. | Avoid disturbance of vegetation along stream. | May affect survival of eggs and larvae and adult spawning productivity. |

**Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered riparian shading<br>Altered ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures). Pygmy whitefish depend on cold water of 50°F or less. Therefore, increased temperatures will limit suitable habitat. | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of currents, wind conditions, and other factors. However, juveniles trapped in habitats with isolated water level changes may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Pygmy whitefish are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Larvae; Juveniles; Adults | Larvae and juveniles: Decreased foraging opportunities, leading to increased competition and resulting effects on growth and fitness.<br>Adults: Increased mortality; decreased fitness and spawning success due to decreased pool availability and availability of suitable spawning habitat. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect larval and juvenile survival and productivity, spawning success, and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Eggs and larvae; Juveniles | Juveniles: Whitefish dependence upon groundwater inflow is currently a data gap. However, may result in a decrease in incubation success and a decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |

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## Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile productivity. |
| | | Altered DO levels due to reduced photosynthesis. | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Alteration. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.<br>Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat. | | May affect juvenile survival and adult spawning productivity. |

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Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs and larvae; Juveniles; Adults | Eggs and larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased egg incubation success and survival. Pygmy whitefish dependence on groundwater inflow for incubation success is currently a data gap.<br>Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of spawning areas) if potential spawning habitat is affected | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival and productivity at egg, larvae, and juvenile life-history stages. May affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Eggs and larvae; Juveniles; Adults | All life-history stages Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially leading to direct mortality and decreased survival of eggs and larvae (lacustrine spawning whitefish) and decreasing the suitability of rearing habitat for juvenile and adult whitefish. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May decrease survival of eggs and larvae. May affect survival and productivity at juvenile life-history stage. Decreased adult fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |

**Table A-10 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pygmy Whitefish.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, fitness, and productivity, as well as direct mortality. | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat; change in habitat structure, availability, and suitability; reduced food web complexity | Year-round | Permanent | Continuous | Larvae; Adults | Larvae and adults: Bank barbs and groins can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor is unlikely to significantly affect pygmy whitefish, which spawn in the mainstems of small, swift rivers and the larvae are transported to oligotrophic lakes for rearing to adulthood. | Require assessment of the hydraulic effects of the project before permitting and avoid permitting designs that lead to disconnection of floodplain habitat. | Stressor may affect larval and adult pygmy whitefish, but is unlikely to adversely affect these species. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles | Juveniles: Bank barbs and groins can fragment nearshore lacustrine habitats. Larval and juvenile pygmy whitefish are known to occur in these habitat types, but knowledge of dependence on these habitats is limited. Given prevalence in these habitat types, however, stressor exposure may affect juvenile survival, growth, and fitness if habitat access is impaired. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival, growth, and fitness. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-11. HPA HCP Shoreline Modification Exposure and Response Matrix for Olympic Mudminnow.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | NA | NA | NA | This species does not occur in habitats suitable for jetty development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | NA | NA | NA | |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Altered current and circulation conditions (lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Increased suspended solids. | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | Navigation/ maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual-decadal | NA | NA | NA | |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | NA | NA | NA | |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | NA | NA | NA | |

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### Table A-11 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympic Mudminnow.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | NA | NA | NA | This species does not occur in habitats suitable for jetty development; therefore, there is no potential for exposure to related water quality modification impact mechanisms and stressors. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | NA | NA | NA | |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | NA | NA | NA | |
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in freshwater. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | NA | NA | NA | |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | NA | NA | | |

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**Table A-11 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympic Mudminnow.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered riparian shading | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures). | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | NA | NA | NA | This species does not occur in habitats suitable for jetty development, therefore there is no potential for exposure to related riparian vegetation modification impact mechanisms and stressors. |
| | Altered ambient air temperature regime | | | | | | | | |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | NA | NA | NA | |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | NA | NA | NA | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | NA | NA | NA | |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | NA | NA | NA | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | NA | NA | NA | This species does not occur in habitats suitable for jetty development; therefore, there is no potential for exposure to related aquatic vegetation modification impact mechanisms and stressors. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | NA | NA | | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | NA | NA | | |

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**Table A-11 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympic Mudminnow.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | NA | NA | NA | This species does not occur in habitats suitable for jetty development; therefore, there is no potential for exposure to related hydraulic and geomorphic modification impact mechanisms and stressors. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | NA | NA | NA | NA | NA | NA | NA |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | NA | NA | NA | NA | NA | NA | NA |

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## Table A-11 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympic Mudminnow.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | NA | NA | NA | This species does not occur in habitats suitable for breakwater development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | NA | NA | NA | |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Altered current and circulation conditions (lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Increased suspended solids. | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | Navigation/ maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual-decadal | NA | NA | NA | |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | NA | NA | NA | |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | NA | NA | NA | |

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**Table A-11 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympic Mudminnow.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | NA | NA | NA | This species does not occur in habitats suitable for breakwater development; therefore, there is no potential for exposure to related water quality modification impact mechanisms and stressors. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | NA | NA | NA | |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | NA | NA | NA | |
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in freshwater. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | NA | NA | NA | |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | NA | NA | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | NA | NA | NA | This species does not occur in habitats suitable for breakwater development; therefore, there is no potential for exposure to related aquatic vegetation modification impact mechanisms and stressors. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | NA | NA | | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | NA | NA | | |

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**Table A-11 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympic Mudminnow.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | NA | NA | NA | This species does not occur in habitats suitable for breakwater development; therefore, there is no potential for exposure to related hydraulic and geomorphic modification impact mechanisms and stressors. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | NA | NA | NA | NA | NA | NA | NA |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | NA | NA | NA | NA | NA | NA | NA |
| | **Lacustrine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | NA | NA | NA | NA | NA | NA | NA |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | NA | NA | NA | NA | NA | NA | NA |

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**Table A-11 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympic Mudminnow.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | NA | NA | NA | This species does not occur in habitats suitable for groin and bank barb development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | NA | NA | NA | |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Altered current and circulation conditions (lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | | Increased suspended solids. | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | NA | NA | NA | |
| | Navigation/ maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual-decadal | NA | NA | NA | |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | NA | NA | NA | |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | NA | NA | NA | |

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**Table A-11 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympic Mudminnow.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | NA | NA | NA | This species does not occur in habitats suitable for groin and bank barb development; therefore, there is no potential for exposure to related water quality modification impact mechanisms and stressors. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | NA | NA | NA | |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | NA | NA | NA | |
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in freshwater. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | NA | NA | NA | |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | NA | NA | | |

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## Table A-11 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympic Mudminnow.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Riparian and Shoreline Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered riparian shading<br>Altered ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | NA | NA | NA | This species does not occur in habitats suitable for groin and bank barb development; therefore, there is no potential for exposure to related riparian vegetation modification impact mechanisms and stressors. |
| | Altered stream bank and shoreline stability | Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools) | Year-round (with specific stressors prominent during high flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | NA | NA | NA | |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs | Year-round | Permanent | Continuous | NA | NA | NA | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | NA | NA | NA | |
| | Altered groundwater–surface water exchange | Reduced available suitable spawning habitat; reduced gravel dissolved oxygen | Year-round | Permanent | Continuous | NA | NA | NA | |
| | **Lacustrine** | | | | | | | | |
| | Altered riparian shading<br>Altered ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures). | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | NA | NA | NA | This species does not occur in habitats suitable for groin and bank barb development, therefore there is no potential for exposure to related riparian vegetation modification impact mechanisms and stressors. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | NA | NA | NA | |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | NA | NA | NA | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | NA | NA | NA | |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | NA | NA | NA | |

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**Table A-11 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympic Mudminnow.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | NA | NA | NA | This species does not occur in habitats suitable for groin and bank barb development; therefore, there is no potential for exposure to related aquatic vegetation modification impact mechanisms and stressors. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | NA | NA | | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | NA | NA | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | NA | NA | NA | This species does not occur in habitats suitable for groin and bank barb development; therefore, there is no potential for exposure to related hydraulic and geomorphic modification impact mechanisms and stressors. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat; change in habitat structure, availability, and suitability; reduced food web complexity | NA | NA | NA | NA | NA | NA | NA |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | NA | NA | NA | NA | NA | NA | NA |

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**Table A-11 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympic Mudminnow.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | NA | NA | NA | NA | NA | NA | NA |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | NA | NA | NA | NA | NA | NA | NA |

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Table A-12. HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs, Juveniles;<br>Adults | All life-history stages: Stressor response dependent on noise magnitude; project-specific environmental conditions may range from:<br>▪ Egg mortality due to membrane rupture.<br>▪ Barotraumas causing fatality or permanent auditory tissue damage leading to impairment limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.<br>Note that specific data on the noise sensitivity of these species are limited; therefore, the effects of stressor exposure are uncertain. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality at all life-history stages. May affect survival, growth, and fitness at all life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles,<br>Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, as well as potentially decreased foraging success and increased predation exposure. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Juveniles;<br>Adults | Eggs: Mortality due to dewatering.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Small juvenile dace may be difficult to capture and relocate, leading to higher incidence of mortality. Increased competition once relocated, and reduced growth and fitness; increased predation exposure. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May cause direct mortality and injury. May affect survival, growth, and fitness at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Juveniles | Eggs and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present. | May cause direct mortality or injury. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Juveniles;<br>Adults | Eggs: Potential substrate scour/or sedimentation, resulting in decreased incubation success.<br>Juveniles and adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. | Limit alteration of flow conditions to minimal area. | May affect survival, growth, and fitness during egg and juvenile life-history stages. May affect adult spawning growth and fitness. |
| | | Altered current and circulation conditions (lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Juvenile and adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | May affect juvenile and adult survival, growth, and productivity. |

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# Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Streambed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs;<br>Juveniles;<br>Adults | Eggs: Potential decreased survival due to turbidity exposure and substrate disturbance.<br>Juveniles and adults: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, reduced foraging opportunities, and increased predation risk, leading to decreased survival, growth, and fitness. See responses to related stressors under Water Quality Modification. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect egg survival. May affect juvenile and adult survival, growth, and fitness. See effects of related stressor exposure under Water Quality Modification. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Juveniles and adults: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect juvenile and adult growth and fitness. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Juveniles;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |
| | Construction/ maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modifications. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs;<br>Juveniles;<br>Adults; | Eggs and juveniles: Eggs and immobile juveniles entrained during dredging may experience direct mortality or injury.<br>Juveniles and adults: Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid dredging in shallow water margin areas preferred by these species. | May affect juvenile productivity and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Daily, temporary, or short-term (dependent on contributing mechanism of impact) | Daily to intermittent and interannual–decadal (dependent on contributing mechanism of impact) | Eggs;<br>Juveniles;<br>Adults | Eggs: Turbidity sufficient to cause fine sediment embeddedness may lead to egg burial, causing decreased survival.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses), leading to increased territoriality, reduced foraging opportunity, increased predation exposure. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness. |

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### Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered dissolved oxygen and temperature levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs; Juveniles; Adults | All exposed life-history stages: Alteration of water temperatures leading to increases or decreases beyond optimal ranges may affect growth and fitness of dace and sucker. Optimal temperatures range from 59–64°F for dace and 55–70°F for mountain sucker. Exposure to higher temperatures may lead to direct mortality or sufficient stress to affect survival. Acute low dissolved oxygen events may cause direct mortality of eggs, juveniles, and adults by asphyxiation. Juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities. | Avoid sediment pulses. | May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term depending on contributing mechanism of impact | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs; Juveniles; Adults | All exposed life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. Mobile juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | May cause direct mortality or physiological injury in acute events. May affect survival of eggs and immobile juveniles. May affect juvenile and adult growth and fitness. |
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs; Juveniles; Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br><br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May cause direct mortality. May affect survival, growth, and fitness across all life-history stages. Reduced fitness may affect adult spawning productivity. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs; Juveniles; Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures). Therefore, increased temperatures will limit suitable habitat | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a relatively minor effect on deep lacustrine water temperatures relative to the dominant influence of currents, wind conditions, and other factors. However, protected nearshore habitats favored by dace may be sensitive to temperature extremes. Lack of suitable thermal refuge habitat may lead to decreased survival. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness at all life-history stages. Mountain sucker prefer deeper water environments and are likely to be less sensitive to these effects. |

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**Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs (dace);<br>Juveniles;<br>Adults | Eggs: Dace may experience decreased egg survival in lacustrine spawning environments due to turbidity effects.<br>Juveniles and adults: Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect dace egg survival. See effects for related stressors under Water Quality Modification. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles;<br>Adults | Juveniles and adults: Dace and suckers prey upon terrestrial insects recruited from riparian zone. Alteration of vegetation will result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect growth, fitness, and productivity. |
| | Altered habitat complexity | Reduced recruitment of large woody debris. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles and adults: Alteration of habitat complexity may affect the suitability of spawning, rearing, and refuge habitat for dace and suckers, leading to reduced survival, growth, and fitness. Reduced habitat complexity may affect the availability of suitable spawning habitats for dace. Likelihood of effects on sucker spawning habitat is more limited due to preference for shallow riffle habitats unsuitable for jetty development. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect survival, growth, and fitness during juvenile and adult life-history stages. Reduced habitat complexity may affect spawning productivity. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Dependence on groundwater–surface water exchange by these fish species is a data gap. However, lack of suitable thermal refuge habitat may lead to decreased survival during temperature extremes. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | Effects resulting from this impact mechanism are uncertain, as dace and sucker sensitivity to stressor exposure is currently a data gap. However, lack of suitable thermal refuge habitat may affect dace survival. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles;<br>Adults | Juveniles and adults: Reduced foraging opportunities due to decreased food web productivity, leading to decreased growth and fitness. Primary forage for suckers includes algae and aquatic invertebrates, which may be affected by decreased autochthonous production. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect survival, growth, and productivity of juvenile and adult life-history stages. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, increased predation exposure, and resulting effects on survival, growth, and fitness. | | May affect survival, growth, and productivity of juvenile and adult life-history stages. |

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Eggs (dace);<br>Juveniles;<br>Adults | All exposed life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juveniles and adults. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness, or mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at all exposed life-history stages. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered groundwater – surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Eggs (dace);<br>Juveniles (dace and mountain suckers);<br>Adults (dace and mountain suckers) | Eggs: Adult dace spawning habitat availability may be limited by the structural footprint of jetties, and by limitations on movement in the nearshore zone. Increased egg density may in turn increase potential egg losses from predation, localized water quality impacts, or other mechanisms, limiting egg survival and/or incubation success.<br>Juveniles and adults: Jetties can fragment nearshore lacustrine habitats, forcing juvenile fish moving along the shoreline to migrate into deeper water. Dace, which prefer shallow water habitats, would experience increased predation exposure and increased stress and exertion as a result. Concentration in nearshore habitats due to restricted movement may limit foraging opportunities. Exposure to these stressors may limit survival, growth, and fitness. Reduced adult fitness may affect spawning productivity. Juvenile and adult suckers will experience similar stressor exposure but are less prone to the resulting effects due to their benthic orientation.<br>Margined sculpins are found predominantly in small rivers and streams in the Tucannon and Walla Walla River drainages. The likelihood of occurrence in lakes is limited, which in turn limits the potential for stressor exposure in lacustrine environments. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile and adult survival, growth, and fitness. May affect egg survival and/or incubation success. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles;<br>Adults | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs, Juveniles; Adults | All life-history stages: Stressor response dependent on noise magnitude; project-specific environmental conditions may range from:<br>▪ Egg mortality due to membrane rupture.<br>▪ Barotraumas causing fatality or permanent auditory tissue damage leading to impairment limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.<br>Note that specific data on the noise sensitivity of these species are limited; therefore, the effects of stressor exposure are uncertain. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality at all life-history stages. May affect survival, growth, and fitness at all life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles, Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, as well as potentially decreased foraging success and increased predation exposure. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs; Juveniles; Adults | Eggs: Mortality due to dewatering.<br>Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Small juvenile dace may be difficult to capture and relocate, leading to higher incidence of mortality. Increased competition once relocated, and reduced growth and fitness; increased predation exposure. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May cause direct mortality and injury. May affect survival, growth, and fitness at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs; Juveniles | Eggs and juveniles: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present. | May cause direct mortality or injury. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs; Juveniles; Adults | Eggs: Potential substrate scour/or sedimentation, resulting in decreased incubation success.<br>Juveniles and adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. | Limit alteration of flow conditions to minimal area. | May affect survival, growth, and fitness during egg and juvenile life-history stages. May affect adult spawning growth and fitness. |
| | | Altered current and circulation conditions (lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juvenile and adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | May affect juvenile and adult survival, growth, and productivity. |

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Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Streambed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs;<br>Juveniles;<br>Adults | Eggs: Potential decreased survival due to turbidity exposure and substrate disturbance.<br>Juveniles and adults: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, reduced foraging opportunities, and increased predation risk, leading to decreased survival, growth, and fitness. See responses to related stressors under Water Quality Modification. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect egg survival. May affect juvenile and adult survival, growth, and fitness. See effects of related stressor exposure under Water Quality Modification. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Juveniles and adults: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect juvenile and adult growth and fitness. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Juveniles;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |
| | Construction/ maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modifications. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs;<br>Juveniles;<br>Adults; | Eggs and juveniles: Eggs and immobile juveniles entrained during dredging may experience direct mortality or injury.<br>Juveniles and adults: Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid dredging in shallow water margin areas preferred by these species. | May affect juvenile productivity and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Daily, temporary, or short-term (dependent on contributing mechanism of impact) | Daily to intermittent and interannual–decadal (dependent on contributing mechanism of impact) | Eggs;<br>Juveniles;<br>Adults | Eggs: Turbidity sufficient to cause fine sediment embeddedness may lead to egg burial, causing decreased survival.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses), leading to increased territoriality, reduced foraging opportunity, increased predation exposure. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness. |

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### Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered dissolved oxygen and temperature levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs; Juveniles; Adults | All exposed life-history stages: Alteration of water temperatures leading to increases or decreases beyond optimal ranges may affect growth and fitness of dace and sucker. Optimal temperatures range from 59–64°F for dace and 55–70°F for mountain sucker. Exposure to higher temperatures may lead to direct mortality or sufficient stress to affect survival. Acute low dissolved oxygen events may cause direct mortality of eggs, juveniles, and adults by asphyxiation. Juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities. | Avoid sediment pulses. | May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term depending on contributing mechanism of impact | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs; Juveniles; Adults | All exposed life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. Mobile juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | May cause direct mortality or physiological injury in acute events. May affect survival of eggs and immobile juveniles. May affect juvenile and adult growth and fitness. |
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs; Juveniles; Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May cause direct mortality. May affect survival, growth, and fitness across all life-history stages. Reduced fitness may affect adult spawning productivity. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs; Juveniles; Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Reduced foraging opportunities due to decreased food web productivity, leading to decreased growth and fitness. Primary forage for suckers includes algae and aquatic invertebrates, which may be affected by decreased autochthonous production. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect survival, growth, and productivity of juvenile and adult life-history stages. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, increased predation exposure, and resulting effects on survival, growth, and fitness. | | May affect survival, growth, and productivity of juvenile and adult life-history stages. |

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**Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs;<br>Juveniles;<br>Adults | Eggs: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased egg incubation success and survival. Likelihood of sucker exposure to these stressors is limited, given preference for spawning in areas unsuitable for breakwater development.<br>Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. Dace are associated with low to moderate flows, which may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival, growth, and fitness at egg and juvenile life-history stages. May affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Eggs (dace);<br>Juveniles;<br>Adults | All exposed life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juveniles and adults. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness, or mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at all exposed life-history stages. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |

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**Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles;<br>Adults (dace) | Juveniles and adults (dace): Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile suckers and juvenile and adult dace in the vicinity of the structure, leading to decreased survival.<br>Margined sculpins do not occur in riverine environments suitable for breakwaters, therefore there is no potential for stressor exposure. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival of suckers. May affect juvenile and adult survival of dace. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Lacustrine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles;<br>Adults (dace and lake chub) | Juveniles and adults (dace): Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for juvenile suckers and juvenile and adult dace and lake chub in the vicinity of the structure, leading to decreased survival.<br>Margined sculpins do not occur in lacustrine environments therefore there is no potential for stressor exposure. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile survival of suckers. May affect juvenile and adult survival of dace and lake chub. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles;<br>Adults | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs, Juveniles; Adults | <u>All life-history stages</u>: Stressor response dependent on noise magnitude; project-specific environmental conditions may range from:<br>▪ Egg mortality due to membrane rupture.<br>▪ Barotraumas causing fatality or permanent auditory tissue damage leading to impairment limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.<br>Note that specific data on the noise sensitivity of these species are limited; therefore, the effects of stressor exposure are uncertain. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality at all life-history stages. May affect survival, growth, and fitness at all life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles, Adults | <u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, as well as potentially decreased foraging success and increased predation exposure. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs; Juveniles; Adults | <u>Eggs:</u> Mortality due to dewatering.<br><u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. Small juvenile dace may be difficult to capture and relocate, leading to higher incidence of mortality. Increased competition once relocated, and reduced growth and fitness; increased predation exposure. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May cause direct mortality and injury. May affect survival, growth, and fitness at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs; Juveniles | <u>Eggs and juveniles</u>: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present. | May cause direct mortality or injury. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs; Juveniles; Adults | <u>Eggs</u>: Potential substrate scour/or sedimentation, resulting in decreased incubation success.<br><u>Juveniles and adults</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. | Limit alteration of flow conditions to minimal area. | May affect survival, growth, and fitness during egg and juvenile life-history stages. May affect adult spawning growth and fitness. |
| | | Altered current and circulation conditions (lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | <u>Juvenile and adults</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | May affect juvenile and adult survival, growth, and productivity. |

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**Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Streambed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs;<br>Juveniles;<br>Adults | <u>Eggs</u>: Potential decreased survival due to turbidity exposure and substrate disturbance.<br><u>Juveniles and adults</u>: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, reduced foraging opportunities, and increased predation risk, leading to decreased survival, growth, and fitness. See responses to related stressors under Water Quality Modification. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect egg survival. May affect juvenile and adult survival, growth, and fitness. See effects of related stressor exposure under Water Quality Modification. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | <u>Juveniles and adults</u>: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect juvenile and adult growth and fitness. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |
| | Construction/ maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: See responses described under Hydraulic and Geomorphic Modifications. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles;<br>Adults | <u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs;<br>Juveniles;<br>Adults; | <u>Eggs and juveniles:</u> Eggs and immobile juveniles entrained during dredging may experience direct mortality or injury.<br><u>Juveniles and adults</u>: Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness.<br><u>All life-history stages</u>: See responses described for related stressors under Water Quality Modification. | Avoid dredging in shallow water margin areas preferred by these species. | May affect juvenile productivity and fitness. See effects for related stressors under Water Quality Modification. |

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## Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Daily, temporary, or short-term (dependent on contributing mechanism of impact) | Daily to intermittent and interannual–decadal (dependent on contributing mechanism of impact) | Eggs;<br>Juveniles;<br>Adults | Eggs: Turbidity sufficient to cause fine sediment embeddedness may lead to egg burial, causing decreased survival.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses), leading to increased territoriality, reduced foraging opportunity, increased predation exposure. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness. |
| | | Altered dissolved oxygen and temperature levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs; Juveniles;<br>Adults | All exposed life-history stages: Alteration of water temperatures leading to increases or decreases beyond optimal ranges may affect growth and fitness of dace and sucker. Optimal temperatures range from 59–64°F for dace and 55–70°F for mountain sucker. Exposure to higher temperatures may lead to direct mortality or sufficient stress to affect survival. Acute low dissolved oxygen events may cause direct mortality of eggs, juveniles, and adults by asphyxiation. Juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities. | Avoid sediment pulses. | May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term depending on contributing mechanism of impact | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs;<br>Juveniles;<br>Adults | All exposed life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. Mobile juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | May cause direct mortality or physiological injury in acute events. May affect survival of eggs and immobile juveniles. May affect juvenile and adult growth and fitness. |
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs;<br>Juveniles;<br>Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May cause direct mortality. May affect survival, growth, and fitness across all life-history stages. Reduced fitness may affect adult spawning productivity. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs;<br>Juveniles;<br>Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |

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**Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Riparian and Shoreline Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Eggs;<br>Juveniles;<br>Adults | Eggs: High water temperatures may decrease egg survival.<br>Juveniles: Reduced growth and fitness caused by temperatures outside optimal growth range, and alteration of food web patterns.<br>Adults and juveniles: May reduce the availability of suitable refuge and foraging habitat, leading to reduced survival, growth, and fitness.<br>Adults: Spawning is temperature dependent; alteration of nearshore temperature may affect spawning success and productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness at all life-history stages. Mountain sucker prefer deeper water environments and are likely to be less sensitive to these effects. |
| | Altered stream bank and shoreline stability | Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools) | Year-round (with specific stressors prominent during high-flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs; Juveniles;<br>Adults | Eggs: Decreased incubation success due to turbidity effects as described for related stressor responses under Water Quality Modification.<br>Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.<br>Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness at all life-history stages |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs | Year-round | Permanent | Continuous | Juveniles;<br>Adults | Juveniles and adults: Dace feed on terrestrial insects. While less dependent, suckers are opportunistic feeders dependent on overall food web productivity. Reduced allochthonous inputs may affect food web productivity, leading to decreased foraging opportunities and decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect growth and fitness at juvenile and adult life-history stages. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles and adults: Decreased availability of suitable foraging and refuge habitat, leading to decreased foraging opportunities, increased competition, increased predation exposure, collectively affecting survival, growth, and fitness. Reduction in suitable spawning habitat area may affect spawning productivity. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile and adult survival, growth, and fitness. May affect adult spawning productivity. |
| | Altered groundwater–surface water exchange | Reduced available thermal refuge habitat | Year-round | Permanent | Continuous | Eggs;<br>Juveniles;<br>Adults | All exposed life-history stages: Dace and sucker dependency on groundwater is currently a data gap. However, decreased availability of thermal refuge may affect survival during temperature extremes. | Avoid disturbance of vegetation along stream. | Effects resulting from this impact mechanism are uncertain, as dace and sucker sensitivity to stressor exposure is currently a data gap. However, lack of suitable thermal refuge habitat may affect dace survival. |

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**Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures). Therefore, increased temperatures will limit suitable habitat | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a relatively minor effect on deep lacustrine water temperatures relative to the dominant influence of currents, wind conditions, and other factors. However, protected nearshore habitats favored by dace may be sensitive to temperature extremes. Lack of suitable thermal refuge habitat may lead to decreased survival. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness at all life-history stages. Mountain sucker prefer deeper water environments and are likely to be less sensitive to these effects. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs (dace);<br>Juveniles;<br>Adults | Eggs: Dace may experience decreased egg survival in lacustrine spawning environments due to turbidity effects.<br>Juveniles and adults: Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect dace egg survival. See effects for related stressors under Water Quality Modification. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles;<br>Adults | Juveniles and adults: Dace and suckers prey upon terrestrial insects recruited from riparian zone. Alteration of vegetation will result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect growth, fitness, and productivity. |
| | Altered habitat complexity | Reduced recruitment of large woody debris. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles and adults: Alteration of habitat complexity may affect the suitability of spawning, rearing, and refuge habitat for dace and suckers, leading to reduced survival, growth, and fitness. Reduced habitat complexity may affect the availability of suitable spawning habitats for dace. Likelihood of effects on sucker spawning habitat is more limited due to preference for shallow riffle habitats unsuitable for groin and bank barb development. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect survival, growth, and fitness during juvenile and adult life-history stages. Reduced habitat complexity may affect spawning productivity. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Dependence on groundwater–surface water exchange by these fish species is a data gap. However, lack of suitable thermal refuge habitat may lead to decreased survival during temperature extremes. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | Effects resulting from this impact mechanism are uncertain, as dace and sucker sensitivity to stressor exposure is currently a data gap. However, lack of suitable thermal refuge habitat may affect dace survival. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles;<br>Adults | Juveniles and adults: Reduced foraging opportunities due to decreased food web productivity, leading to decreased growth and fitness. Primary forage for suckers includes algae and aquatic invertebrates, which may be affected by decreased autochthonous production. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect survival, growth, and productivity of juvenile and adult life-history stages. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, increased predation exposure, and resulting effects on survival, growth, and fitness. | | May affect survival, growth, and productivity of juvenile and adult life-history stages. |

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**Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs;<br>Juveniles;<br>Adults | Eggs: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased egg incubation success and survival.<br>Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. Dace are associated with low to moderate flows, which may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations, egg burial, etc.) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival, growth, and fitness at egg and juvenile life-history stages. May affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Eggs (dace);<br>Juveniles;<br>Adults | All exposed life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juveniles and adults. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness, or mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at all exposed life-history stages. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered groundwater Inputs | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |

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## Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat; change in habitat structure, availability, and suitability; reduced food web complexity | Year-round | Permanent | Continuous | Eggs (dace);<br>Juveniles;<br>Adults | Eggs: Adult dace spawning habitat availability may be limited by the structural footprint of groins and bank barbs, and by limitations on movement in the nearshore zone. Increased egg density may in turn increase potential egg losses from predation, localized water quality impacts, or other mechanisms, limiting egg survival and/or incubation success.<br>Juveniles: Disconnection of floodplain habitats can lead to decreased availability and suitability of rearing habitat, and changes in food web complexity. Moderate gradient stream systems preferred by sculpins may limit the extent of suitable habitat area. Disconnection of sloughs and similar slow-flowing floodplain habitats in lower gradient systems may limit habitat area preferred by dace and juvenile suckers. These stressors may thereby result in decreased foraging opportunities and increased competition for suitable habitats, affecting survival, growth, and fitness.<br>Adults: Disconnection of sloughs and similar slow-water rearing habitats may limit the availability of suitable foraging and spawning habitat for dace. In moderate gradient habitats, disconnection of floodplain habitats may limit the availability and suitability of spawning habitat for mountain sucker, and foraging and spawning habitat for margined sculpins. These stressors may thereby result in decreased foraging opportunities, and increased competition for suitable habitats, affecting survival, growth, fitness, and by extension, spawning productivity. | Require assessment of the hydraulic effects of the project before permitting and avoid permitting designs that lead to disconnection of floodplain habitat. | May affect egg survival. May affect juvenile and adult survival, growth, and fitness. May affect adult spawning productivity. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |

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**Table A-12 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Eggs (dace);<br>Juveniles (dace and mountain suckers);<br>Adults (dace and mountain suckers) | Eggs: Adult dace spawning habitat availability may be limited by the structural footprint of groins and bank barbs, and by limitations on movement in the nearshore zone. Increased egg density may in turn increase potential egg losses from predation, localized water quality impacts, or other mechanisms, limiting egg survival and/or incubation success.<br>Juveniles and adults: Bank barbs and groins can fragment nearshore habitats, forcing juvenile fish moving along the shoreline to migrate into deeper water. Dace, which prefer shallow water habitats, would experience increased predation exposure and increased stress and exertion as a result. Concentration in nearshore habitats due to restricted movement may limit foraging opportunities. Exposure to these stressors may limit survival, growth, and fitness. Reduced adult fitness may affect spawning productivity. Juvenile and adult suckers will experience similar stressor exposure but are less prone to the resulting effects due to their benthic orientation.<br>Margined sculpins are found predominantly in small rivers and streams in the Tucannon and Walla Walla River drainages. The likelihood of occurrence in lakes is limited, which in turn limits the potential for stressor exposure in lacustrine environments. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile and adult survival, growth, and fitness. May affect egg survival and/or incubation success. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles;<br>Adults | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-13. HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Ammocoetes;<br>Transforming adults;<br>Adults | All life-history stages: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Little is known about the effects of anthropogenic sounds on lamprey. |
| | Construction vessel operation | Increased or altered ambient noise levels. | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Transforming adults,<br>Adults | Adults and transforming adults: Very little is known of the effects of anthropogenic sounds on lamprey at any life-history stage. | Although little is known about the effects of anthropogenic sounds on lamprey, it is prudent to avoid/ minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | Little is known about the effects of anthropogenic sounds on lamprey. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Ammocoetes;<br>Transforming adults;<br>Adults | Ammocoetes: Mortality, injury, and stress, during dewatering (when buried in riverine sediments).<br>Adults and transforming adults: Mortality, injury, or stress from capture, handling, and relocation.<br>Transforming adults: Increased competition once relocated, and reduced growth and fitness; increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May affect survival, growth, and fitness at ammocoete, transforming adult, and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Transforming adults | Transforming adults: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when transforming adults are present. | May affect survival and fitness at transforming adult life-history stage. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Ammocoetes;<br>Transforming adults;<br>Adults | Ammocoetes: Potential nest scour and/or sedimentation, resulting in decreased incubation success.<br>Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, and decreased spawning fitness. | Limit alteration of flow conditions to minimal area. | May affect survival during ammocoete life-history stages; may affect transforming adult growth and fitness; may affect adult spawning success. |
| | | Altered current and circulation conditions (marine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Transforming adults;<br>Adults | Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, and decreased spawning fitness. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | May affect transforming adult survival, growth, and fitness. May affect adult spawning fitness. |

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**Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering). | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Ammocoetes; Transforming adults; Adults | Ammocoetes: Potential decreased ammocoete survival due to turbidity exposure and substrate disturbance.<br>Transforming adults and adults: For Pacific and river lamprey, decreased populations of host fish such as salmon could decrease available habitat. | Adhere to system-specific in-water work windows. Avoid work during ammocoete stages. | May affect survival of ammocoetes. May affect growth and fitness at transforming adult and adult life-history stages. |
| | | Localized alteration in host fish abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Transforming adults | Transforming adults and adults: For Pacific and river lamprey, short-term reductions in host fish due to increased competition, decreased growth, and fitness are expected to affect growth and survival for these life-stages. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at transforming adult life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Ammocoetes; Transforming adults; Adults | All life-history-stages: See responses to related stressors under Water Quality Modification. Water quality effects to ammocoetes are a data gap. However, as Pacific and river lamprey feed on host fish, effects of suspended solids on host fish could affect them. As western brook lamprey are filter feeders, this may not be a stressor for transforming adults and adults. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Ammocoetes; Transforming adults; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modifications. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Transforming adults; Adults | Transforming adults and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Ammocoetes; Transforming adults; Adults | Ammocoetes: Ammocoetes of Pacific and river lamprey mature buried in fine substrates in the lower reaches and estuaries of larger rivers for extended periods and are therefore vulnerable to direct injury and mortality from dredging entrainment.<br>Transforming adults: Decreased foraging opportunity due to short-term reduction in prey availability.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May cause direct mortality or injury to ammocoetes. May affect transforming adult growth and fitness. See effects for related stressors under Water Quality Modification. |

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Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Ammocoetes;<br>Transforming adults;<br>Adults | Ammocoetes: Turbidity sufficient to cause fine sediment embeddedness or increased burial depth may lead to direct mortality and decreased survival of ammocoetes.<br>Transforming adults and adults: Not a direct stressor to the lamprey. For Pacific and river lamprey, responses depend on stressor magnitude to host fish, which may include the following: unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of ammocoetes. May affect transforming adult growth and fitness, as well as adult fitness and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Ammocoetes; Transforming adults;<br>Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects on host fish are stressors to Pacific and river lamprey.<br>Transforming adults and adults: A physiological response to exposure at toxic levels causing mortality or injury leading to reduced fitness is a data gap. However, effects on host fish are known and would affect Pacific and river lamprey. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. This is a data gap. | Avoid sediment pulses. | May affect survival of ammocoetes. May affect transforming adult survival, growth, and fitness, as well as adult survival, productivity, and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Transforming adults;<br>Adults | Transforming adults and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness of host fish for Pacific and river lamprey. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | May affect survival, growth, and fitness of transforming adults and adults. |

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| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Ammocoetes; Transforming adults; Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness for Pacific and river lamprey. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival, growth, and fitness of all exposed life-history stages. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Ammocoetes; Transforming adults; Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian and Shoreline Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Transforming adults; Adults | Transforming adults: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, transforming adult Pacific and river lamprey trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress. Similar effects on Pacific and river lamprey host fish may affect foraging success.<br>Adults: River lamprey adults are found in nearshore environments and may experience similar effects as described above. Similar effects on river lamprey host fish may affect foraging success, leading to decreased growth and spawning fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of transforming adult Pacific and river lamprey, as well as adult river lamprey. |

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Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Transforming adults;<br>Adults | Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness of Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.<br>Adults: River lamprey adults are found in nearshore environments and may experience similar effects as described above. Similar effects on river lamprey host fish may affect foraging success, leading to decreased growth and spawning fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of transforming adult Pacific and river lamprey, as well as adult river lamprey. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduced organic matter inputs. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Transforming adults;<br>Adults | Transforming adults: Pacific and river lamprey host fish depend on allochthonous inputs from marine riparian vegetation. Effects on host fish survival growth and fitness may in turn affect lamprey growth and fitness. Those host fish that feed on benthic organisms (such as mollusks and amphipods) are likely linked to allochthonous material inputs.<br>Adults: Adult river lamprey experience same effects as above. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | For Pacific and river lamprey, effects would be related only to host fish dependence on allochthonous inputs. Western brook lamprey have no marine life-history stage. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Transforming adults;<br>Adults | Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness of host fish for Pacific and river lamprey.<br>Adults: Adult river lamprey experience same effects as above. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect transforming adult survival, growth, and fitness; adult spawning success; and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Transforming adults;<br>Adults | Transforming adults and adults (river lamprey): Lamprey dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Ammocoetes;<br>Transforming adults;<br>Adults | Ammocoetes: Larval western brook, river, and potentially Pacific lamprey are found in sheltered nearshore lacustrine habitats, buried in substrates. Altered water temperatures due to riparian modification could limit habitat suitability, affecting survival, growth, and fitness.<br>Adults and transforming adults: Adult lamprey dependence on nearshore lacustrine habitats is currently a data gap. However, transforming adult host fish of Pacific and river lamprey may become trapped in isolated habitats, which may increase temperatures and potentially lead to mortality or increased thermal stress and decreased fitness of host fish, affecting foraging opportunities for adults and transforming adults. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect ammocoete survival, growth, and fitness. May affect growth and fitness of adults and transforming adults. |

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## Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Ammocoetes;<br>Transforming adults;<br>Adults | <u>Ammocoetes</u>: Larval western brook, river, and potentially Pacific lamprey are found in sheltered nearshore lacustrine habitats, buried in substrates. Alteration of shoreline stability could lead to increased sedimentation and burial, affecting larval survival.<br><u>Adults and transforming adults:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness for Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect ammocoete survival. May affect growth and fitness of adults and transforming adults. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Ammocoetes;<br>Transforming adults;<br>Adults | <u>All life-history stages</u>: Lamprey dependence on allochthonous inputs from shoreline riparian vegetation is a data gap. However, Pacific and river lamprey ammocoete benthic filter feeding stage and the filter feeding of the western brook lamprey could be affected. This could be a stressor to the extent the host fish is stressed by this mechanism of impact. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect ammocoete, transforming adult, and adult growth and fitness, depending on species. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Ammocoetes;<br>Transforming adults;<br>Adults | <u>Ammocoetes</u>: Decrease in availability of suitable rearing habitat, leading to decreased survival, growth, and fitness.<br><u>Transforming adults and adults:</u> Decreased refuge habitat availability and foraging opportunities for host fish, potentially leading to decreased foraging opportunities for Pacific and river lamprey with resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect ammocoete survival, growth, and fitness. May affect adult growth, fitness, and spawning productivity due to effects on host fish. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Ammocoetes;<br>Transforming adults;<br>Adults | <u>All life-history stages</u>: Lamprey dependence on groundwater inflow in lacustrine habitats is currently a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | Effects of the action resulting from this impact mechanism are unknown. |

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Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Transforming adults;<br>Adults | Transforming adults and adults: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness of Pacific and river lamprey host fish. Effects on host fish in nearshore habitats would also affect adult river lamprey forage opportunities. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect river lamprey transforming adult and adult growth and fitness, as well as productivity of Pacific and river lamprey host fish. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Transforming adults;<br>Adults | Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness of Pacific and river lamprey host fish.<br>Adults: Decreased foraging opportunity due to decreased food web productivity, with resulting decreased growth and reproductive fitness of Pacific and river lamprey. River lamprey use nearshore habitats during this life-history phase, but dependence on habitat complexity remains a data gap. | | May affect transforming adult survival and productivity. May affect adult growth and spawning productivity of Pacific and river lamprey host fish. Other effects on adult river lamprey are a data gap. |
| | **Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity. | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Ammocoetes;<br>Transforming adults | Ammocoetes and transforming adults: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness of Pacific and river lamprey host fish, and decreased prey resources for filter-feeding Western brook lamprey and ammocoete stages of Pacific and river lamprey. Altered prey resource effects to lamprey ammocoete life-history stages are a data gap. Although effects of altered autochthonous inputs for western brook lamprey are a data gap, alterations could be expected to affect prey resource availability. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect ammocoete and transforming adult growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Transforming adults;<br>Adults | Transforming adults and adults: See related stressor responses under Water Quality Alteration. Effects are related to host fish effects for both Pacific and river lamprey. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Ammocoetes;<br>Transforming adults;<br>Adults | All exposed life-history stages: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness of Pacific and river lamprey host fish, and decreased prey resources for filter feeding Western brook lamprey and ammocoete stages of Pacific and river lamprey. Altered prey resource effects to lamprey ammocoete life-history stages are a data gap. Although effects of altered autochthonous inputs on Western brook lamprey are a data gap, alterations could be expected to affect prey resource availability. | | Lamprey dependence on habitat complexity provided by freshwater aquatic vegetation is a data gap. |

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### Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when transforming adults occupy nearshore habitats for rearing) | Permanent | Continuous | Transforming adults;<br>Adults (river lamprey) | <u>Transforming adults and adults</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for lamprey host fish, leading to decreased foraging opportunities for transforming adult Pacific and river lamprey, and adult river lamprey. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect growth and fitness at transforming adult life-history stages through effects on host fish. River lamprey are also known to use nearshore habitats during the adult life-history stage and will be subject to these effects during this period. Direct dependence on nearshore habitat characteristics for both species is a data gap. Decreased growth and fitness may affect survival and productivity during ocean migration life-history phase for both species. Western brook lamprey are non-anadromous and will not be exposed to these stressors. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |

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**Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Ammocoetes; Transforming adults; Adults | Ammocoetes: Rearing lamprey ammocoetes are found buried in nearshore lacustrine sediments. Modification of hydraulic and geomorphic conditions may alter habitat suitability, leading to limitations on the amount of available habitat and affecting survival, growth, and fitness at this life-history stage. Transforming adults and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for host fish, leading to decreased foraging opportunities for adults and transforming adults. Decreased foraging opportunities may cause decreased growth and fitness, affecting survival during marine migration and spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at ammocoete life-history stage. Effects on host fish may decrease survival, growth, and fitness of transforming adult and adult lamprey, and spawning productivity of adult lamprey. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered groundwater Inputs | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Transforming adults; Adults | All exposed life-history stages: Jetties can fragment nearshore marine habitat, forcing migrating and foraging river lamprey to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. Pacific lamprey exposure to these stressors is minimal, as they primarily reside in offshore habitats during the transforming adult and adult life-history stages. Brook lamprey do not occur in the marine environment. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at transforming adult life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Transforming adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect transforming adult survival. |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Ammocoetes; Transforming adults; Adults | All exposed life-history stages: Jetties can fragment nearshore lacustrine rearing habitat, potentially affecting transport to and the suitability of these habitats for Pacific and river lamprey ammocoetes. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. Western brook lamprey do not typically occur in lacustrine environments; therefore, the likelihood of stressor exposure is limited. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival, growth, and fitness at ammocoete life-history stage. Effects on host fish may decrease survival, growth, and fitness of transforming adult and adult lamprey, and spawning productivity of adult lamprey. |

**Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Transforming adults;<br>Adults | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect survival of transforming adult growth and survival, as well as spawning success and overall population productivity. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and ammocoetes;<br>Transforming adults;<br>Adults | All life-history stages: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Little is known about the effects of anthropogenic sounds on lamprey. |
| | Construction vessel operation | Increased or altered ambient noise levels. | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Transforming adults,<br>Adults | Adults and transforming adults: Very little is known of the effects of anthropogenic sounds on lamprey at any life-history stage. | Although little is known about the effects of anthropogenic sounds on lamprey, it is prudent to avoid/ minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | Little is known about the effects of anthropogenic sounds on lamprey. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Ammocoetes;<br>Transforming adults;<br>Adults | Ammocoetes: Mortality, injury, and stress, during dewatering (when buried in riverine sediments).<br>Adults and transforming adults: Mortality, injury, or stress from capture, handling, and relocation.<br>Transforming adults: Increased competition once relocated, and reduced growth and fitness; increased predation exposure.<br>Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May affect survival, growth, and fitness at ammocoete, transforming adult, and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Transforming adults | Transforming adults: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when transforming adults are present. | May affect survival and fitness at transforming adult life-history stage. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and ammocoetes;<br>Transforming adults;<br>Adults | Eggs and ammocoetes: Potential nest scour and/or sedimentation, resulting in decreased incubation success.<br>Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.<br>Adults: Delayed migration, increased stress, and decreased spawning fitness. | Limit alteration of flow conditions to minimal area. | May affect survival during egg and ammocoete life-history stages; may affect transforming adult growth and fitness; may affect adult spawning success. |

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Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Altered current and circulation conditions (marine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Transforming adults; Adults | Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, and decreased spawning fitness. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | May affect transforming adult survival, growth, and fitness. May affect adult spawning fitness. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering). | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and ammocoetes; Transforming adults; Adults | Eggs and ammocoetes: Potential decreased egg incubation success and ammocoete survival due to turbidity exposure and substrate disturbance. Transforming adults and adults: For Pacific and river lamprey, decreased populations of host fish such as salmon could decrease available habitat. | Adhere to system-specific in-water work windows. Avoid work during egg incubation and ammocoete stages. | May affect survival of eggs and ammocoetes. May affect growth and fitness at transforming adult and adult life-history stages. |
| | | Localized alteration in host fish abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Transforming adults | Transforming adults and adults: For Pacific and river lamprey, short-term reductions in host fish due to increased competition, decreased growth, and fitness are expected to affect growth and survival for these life-stages. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at transforming adult life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and ammocoetes; Transforming adults; Adults | All life-history-stages: See responses to related stressors under Water Quality Modification. Water quality effects to ammocoetes are a data gap. However, as Pacific and river lamprey feed on host fish, effects of suspended solids on host fish could affect them. As western brook lamprey are filter feeders, this may not be a stressor for transforming adults and adults. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and ammocoetes; Transforming adults; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modifications. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Transforming adults; Adults | Transforming adults and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and ammocoetes; Transforming adults; Adults | Ammocoetes: Ammocoetes of Pacific and river lamprey mature buried in fine substrates in the lower reaches and estuaries of larger rivers for extended periods and are therefore vulnerable to direct injury and mortality from dredging entrainment. Transforming adults: Decreased foraging opportunity due to short-term reduction in prey availability. All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May cause direct mortality or injury to ammocoetes. May affect transforming adult growth and fitness. See effects for related stressors under Water Quality Modification. |

**Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and ammocoetes;<br>Transforming adults;<br>Adults | Eggs and ammocoetes: Turbidity sufficient to cause fine sediment embeddedness or increased burial depth may lead to direct mortality and decreased survival of eggs and ammocoetes.<br>Transforming adults and adults: Not a direct stressor to the lamprey. For Pacific and river lamprey, responses depend on stressor magnitude to host fish, which may include the following: unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and ammocoetes. May affect transforming adult growth and fitness, as well as adult fitness and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and ammocoetes; Transforming adults;<br>Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects on host fish are stressors to Pacific and river lamprey.<br>Transforming adults and adults: A physiological response to exposure at toxic levels causing mortality or injury leading to reduced fitness is a data gap. However, effects on host fish are known and would affect Pacific and river lamprey. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. This is a data gap. | Avoid sediment pulses. | May affect survival of incubating eggs and ammocoetes. May affect transforming adult survival, growth, and fitness, as well as adult survival, productivity, and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Transforming adults;<br>Adults | Transforming adults and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness of host fish for Pacific and river lamprey. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | May affect survival, growth, and fitness of transforming adults and adults. |

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Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and ammocoetes;<br>Transforming adults;<br>Adults | <u>All exposed life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness for Pacific and river lamprey. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br><u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival, growth, and fitness of all exposed life-history stages. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and ammocoetes;<br>Transforming adults;<br>Adults | <u>All exposed life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Transforming adults;<br>Adults | <u>Transforming adults and adults</u>: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness of Pacific and river lamprey host fish. Effects on host fish in nearshore habitats would also affect adult river lamprey forage opportunities. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect river lamprey transforming adult and adult growth and fitness, as well as productivity of Pacific and river lamprey host fish. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Transforming adults;<br>Adults | <u>Transforming adults:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness of Pacific and river lamprey host fish.<br><u>Adults</u>: Decreased foraging opportunity due to decreased food web productivity, with resulting decreased growth and reproductive fitness of Pacific and river lamprey. River lamprey use nearshore habitats during this life-history phase, but dependence on habitat complexity remains a data gap. | | May affect transforming adult survival and productivity. May affect adult growth and spawning productivity of Pacific and river lamprey host fish. Other effects on adult river lamprey are a data gap. |

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**Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity. | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Ammocoetes;<br>Transforming adults | Ammocoetes and transforming adults: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness of Pacific and river lamprey host fish, and decreased prey resources for filter-feeding Western brook lamprey and ammocoete stages of Pacific and river lamprey. Altered prey resource effects to lamprey ammocoete life-history stages are a data gap. Although effects of altered autochthonous inputs for western brook lamprey are a data gap, alterations could be expected to affect prey resource availability. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect ammocoete and transforming adult growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Transforming adults;<br>Adults | Transforming adults and adults: See related stressor responses under Water Quality Alteration. Effects are related to host fish effects for both Pacific and river lamprey. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Ammocoetes;<br>Transforming adults;<br>Adults | All exposed life-history stages: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness of Pacific and river lamprey host fish, and decreased prey resources for filter feeding Western brook lamprey and ammocoete stages of Pacific and river lamprey. Altered prey resource effects to lamprey ammocoete life-history stages are a data gap. Although effects of altered autochthonous inputs on Western brook lamprey are a data gap, alterations could be expected to affect prey resource availability. | | Lamprey dependence on habitat complexity provided by freshwater aquatic vegetation is a data gap. |

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**Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability. | Year-round | Permanent | Continuous | Eggs and ammocoetes;<br>Transforming adults;<br>Adults | Eggs and ammocoetes: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and ammocoete survival. Pacific and river lamprey ammocoetes are particularly vulnerable to impact mechanisms that cause scour, deposition, or other forms of substrate modification when buried in fine substrates during rearing periods, which can last for several years.<br>Transforming adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, as well as changes in food web complexity. These may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival, growth, and fitness at egg and ammocoete stages and egg and transforming adult life-history stages for host fish of Pacific and river lamprey. May also affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposures occurring during high flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round, with stressor exposure occurring during egg incubation and transforming adult rearing. | Permanent | Continuous | | | | |
| | Addition of impervious surface | Alteration in the magnitude, volume, and timing of peak flows | During storm events, (predominantly from fall through spring) | Permanent | Common | Eggs and ammocoetes;<br>Transforming adults;<br>Adults | All life-history stages: Because the amount of impervious surface associated with marinas is a relatively inconsequential component of the overall drainage area of the larger river systems that would support this type of development, the magnitude of the hydrologic modification stressor is expected to be negligible. As such, this stressor is not expected to significantly affect the riverine environment, and there will be no response to the stressor. | Encourage facilities to employ modern low-impact development and stormwater treatment technology. | Impervious surface at anticipated scale should not produce stressors of sufficient magnitude to adversely affect lamprey at any life-history stage. |

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## Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when transforming adults occupy nearshore habitats for rearing) | Permanent | Continuous | Transforming adults;<br>Adults (river lamprey) | Transforming adults and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for lamprey host fish, leading to decreased foraging opportunities for transforming adult Pacific and river lamprey, and adult river lamprey. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect growth and fitness at transforming adult life-history stages through effects on host fish. River lamprey are also known to use nearshore habitats during the adult life-history stage and will be subject to these effects during this period. Direct dependence on nearshore habitat characteristics for both species is a data gap. Decreased growth and fitness may affect survival and productivity during ocean migration life-history phase for both species. Western brook lamprey are non-anadromous and will not be exposed to these stressors. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Ammocoetes;<br>Transforming adults;<br>Adults | Ammocoetes: Rearing lamprey ammocoetes are found buried in nearshore lacustrine sediments. Modification of hydraulic and geomorphic conditions may alter habitat suitability, leading to limitations on the amount of available habitat and affecting survival, growth, and fitness at this life-history stage.<br>Transforming adults and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for host fish, leading to decreased foraging opportunities for adults and transforming adults. Decreased foraging opportunities may cause decreased growth and fitness, affecting survival during marine migration and spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at ammocoete life-history stage. Effects on host fish may decrease survival, growth, and fitness of transforming adult and adult lamprey, and spawning productivity of adult lamprey. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered groundwater Inputs | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |

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**Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Ammocoetes | Ammocoetes: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for Pacific and river lamprey ammocoetes in the vicinity of the structure, leading to decreased survival.<br>Western brook lamprey do not occur in habitats suitable for breakwater development, therefore they have effectively no risk of stressor exposure. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect ammocoete survival. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Transforming adults;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect survival of transforming adult growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Transforming adults;<br>Adults | Transforming adults, adults: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for transforming adult Pacific and river lamprey in the vicinity of the structure, leading to decreased survival. Adult river lamprey utilize nearshore habitats and may experience similar exposure (however they may also experience increased foraging opportunities as well). Pacific lamprey adults primarily occur in offshore habitats and are unlikely to experience stressor exposure. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival of transforming adult Pacific and river lamprey. May affect survival (negatively), growth and productivity (positively) of adult river lamprey. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Transforming adults;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect survival of transforming adult growth and survival, as well as spawning success and overall population productivity. |
| | **Lacustrine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Ammocoetes | Ammocoetes: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for Pacific and river lamprey ammocoetes in the vicinity of the structure, leading to decreased survival.<br>Western brook lamprey do not occur in habitats suitable for breakwater development, therefore they have effectively no risk of stressor exposure. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect ammocoete survival. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Transforming adults;<br>Adults | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect survival of transforming adult growth and survival, as well as spawning success and overall population productivity. |

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**Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs and ammocoetes; Transforming adults; Adults | All life-history stages: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Little is known about the effects of anthropogenic sounds on lamprey. |
| | Construction vessel operation | Increased or altered ambient noise levels. | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Transforming adults, Adults | Adults and transforming adults: Very little is known of the effects of anthropogenic sounds on lamprey at any life-history stage. | Although little is known about the effects of anthropogenic sounds on lamprey, it is prudent to avoid/ minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | Little is known about the effects of anthropogenic sounds on lamprey. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Ammocoetes; Transforming adults; Adults | Ammocoetes: Mortality, injury, and stress, during dewatering (when buried in riverine sediments). Adults and transforming adults: Mortality, injury, or stress from capture, handling, and relocation. Transforming adults: Increased competition once relocated, and reduced growth and fitness; increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May affect survival, growth, and fitness at ammocoete, transforming adult, and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Transforming adults | Transforming adults: Injury or mortality from entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when transforming adults are present. | May affect survival and fitness at transforming adult life-history stage. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and ammocoetes; Transforming adults; Adults | Eggs and ammocoetes: Potential nest scour and/or sedimentation, resulting in decreased incubation success. Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, and decreased spawning fitness. | Limit alteration of flow conditions to minimal area. | May affect survival during egg and ammocoete life-history stages; may affect transforming adult growth and fitness; may affect adult spawning success. |
| | | Altered current and circulation conditions (marine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Transforming adults; Adults | Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, and decreased spawning fitness. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | May affect transforming adult survival, growth, and fitness. May affect adult spawning fitness. |

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## Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stream bed disturbance, increased turbidity (associated with site rewatering). | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and ammocoetes; Transforming adults; Adults | Eggs and ammocoetes: Potential decreased egg incubation success and ammocoete survival due to turbidity exposure and substrate disturbance. Transforming adults and adults: For Pacific and river lamprey, decreased populations of host fish such as salmon could decrease available habitat. | Adhere to system-specific in-water work windows. Avoid work during egg incubation and ammocoete stages. | May affect survival of eggs and ammocoetes. May affect growth and fitness at transforming adult and adult life-history stages. |
| | | Localized alteration in host fish abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Transforming adults | Transforming adults and adults: For Pacific and river lamprey, short-term reductions in host fish due to increased competition, decreased growth, and fitness are expected to affect growth and survival for these life-stages. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at transforming adult life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and ammocoetes; Transforming adults; Adults | All life-history-stages: See responses to related stressors under Water Quality Modification. Water quality effects to ammocoetes are a data gap. However, as Pacific and river lamprey feed on host fish, effects of suspended solids on host fish could affect them. As western brook lamprey are filter feeders, this may not be a stressor for transforming adults and adults. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs and ammocoetes; Transforming adults; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modifications. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Transforming adults; Adults | Transforming adults and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and ammocoetes; Transforming adults; Adults | Ammocoetes: Ammocoetes of Pacific and river lamprey mature buried in fine substrates in the lower reaches and estuaries of larger rivers for extended periods and are therefore vulnerable to direct injury and mortality from dredging entrainment. Transforming adults: Decreased foraging opportunity due to short-term reduction in prey availability. All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May cause direct mortality or injury to ammocoetes. May affect transforming adult growth and fitness. See effects for related stressors under Water Quality Modification. |

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Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and ammocoetes;<br>Transforming adults;<br>Adults | Eggs and ammocoetes: Turbidity sufficient to cause fine sediment embeddedness or increased burial depth may lead to direct mortality and decreased survival of eggs and ammocoetes.<br>Transforming adults and adults: Not a direct stressor to the lamprey. For Pacific and river lamprey, responses depend on stressor magnitude to host fish, which may include the following: unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs and ammocoetes. May affect transforming adult growth and fitness, as well as adult fitness and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and ammocoetes;<br>Transforming adults;<br>Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects on host fish are stressors to Pacific and river lamprey.<br>Transforming adults and adults: A physiological response to exposure at toxic levels causing mortality or injury leading to reduced fitness is a data gap. However, effects on host fish are known and would affect Pacific and river lamprey. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. This is a data gap. | Avoid sediment pulses. | May affect survival of incubating eggs and ammocoetes. May affect transforming adult survival, growth, and fitness, as well as adult survival, productivity, and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Transforming adults;<br>Adults | Transforming adults and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness of host fish for Pacific and river lamprey. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | May affect survival, growth, and fitness of transforming adults and adults. |



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**Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and ammocoetes;<br>Transforming adults;<br>Adults | <u>All exposed life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness for Pacific and river lamprey. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br><u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival, growth, and fitness of all exposed life-history stages. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and ammocoetes;<br>Transforming adults;<br>Adults | <u>All exposed life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered riparian shading<br>Altered ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Eggs and ammocoetes;<br>Transforming adults;<br>Adults | <u>Eggs and ammocoetes:</u> Direct mortality when exposed to temperatures over 68°F for continuous periods.<br><u>Transforming adults</u>: Altered growth and fitness when exposed to temperatures outside optimal growth range, and alteration of food web patterns, including food web supporting Pacific and river lamprey host fish.<br><u>Adults and transforming adults</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.<br><u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness during incubation, rearing, and spawning. Likelihood of stressor exposure is limited, however, as most settings suitable for groin and bank barb development are in larger river environments where riparian vegetation has less effect on temperature conditions. |

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## Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered stream bank and shoreline stability | Increased suspended solids and burial of benthic ammocoetes or eggs. | Year-round (with specific stressors prominent during high-flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs and ammocoetes; Transforming adults; Adults | Eggs and ammocoetes: Decreased incubation success due to burial or scour of eggs and rearing ammocoetes. Decreased availability of host fish for Pacific and river lamprey. Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness for Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Potential effects on migration and spawning productivity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness during incubation and transforming adult and adult fitness of host fish for Pacific and river lamprey. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction in organic matter inputs. | Year-round | Permanent | Continuous | Ammocoetes; Transforming adults | Transforming adults and ammocoetes: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect growth and fitness of ammocoetes and transforming adults. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Transforming adults; Adults | Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness of host fish for Pacific and river lamprey. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat for host fish of Pacific and river lamprey. Decreased suitable lamprey spawning habitat. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect growth and fitness of transforming adults. May affect adult spawning success. |
| | Altered groundwater–surface water exchange | Decreased thermal refuge, decreased substrate dissolved oxygen | Year-round | Permanent | Continuous | Eggs and ammocoetes; Adults | Lamprey responses to groundwater exchange are a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Lamprey dependence on groundwater exchange is currently a data gap. Therefore, the effects of stressor exposure are unknown. |

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**Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Marine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Transforming adults;<br>Adults | Transforming adults: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, transforming adult Pacific and river lamprey trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress. Similar effects on Pacific and river lamprey host fish may affect foraging success.<br>Adults: River lamprey adults are found in nearshore environments and may experience similar effects as described above. Similar effects on river lamprey host fish may affect foraging success, leading to decreased growth and spawning fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of transforming adult Pacific and river lamprey, as well as adult river lamprey. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Transforming adults;<br>Adults | Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness of Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.<br>Adults: River lamprey adults are found in nearshore environments and may experience similar effects as described above. Similar effects on river lamprey host fish may affect foraging success, leading to decreased growth and spawning fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of transforming adult Pacific and river lamprey, as well as adult river lamprey. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduced organic matter inputs. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Transforming adults;<br>Adults | Transforming adults: Pacific and river lamprey host fish depend on allochthonous inputs from marine riparian vegetation. Effects on host fish survival growth and fitness may in turn affect lamprey growth and fitness. Those host fish that feed on benthic organisms (such as mollusks and amphipods) are likely linked to allochthonous material inputs.<br>Adults: Adult river lamprey experience same effects as above. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | For Pacific and river lamprey, effects would be related only to host fish dependence on allochthonous inputs. Western brook lamprey have no marine life-history stage. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Transforming adults;<br>Adults | Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness of host fish for Pacific and river lamprey.<br>Adults: Adult river lamprey experience same effects as above. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect transforming adult survival, growth, and fitness; adult spawning success; and overall population productivity. |

## Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Transforming adults;<br>Adults | Transforming adults and adults (river lamprey): Lamprey dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Ammocoetes;<br>Transforming adults;<br>Adults | Ammocoetes: Larval western brook, river, and potentially Pacific lamprey are found in sheltered nearshore lacustrine habitats, buried in substrates. Altered water temperatures due to riparian modification could limit habitat suitability, affecting survival, growth, and fitness.<br>Adults and transforming adults: Adult lamprey dependence on nearshore lacustrine habitats is currently a data gap. However, transforming adult host fish of Pacific and river lamprey may become trapped in isolated habitats, which may increase temperatures and potentially lead to mortality or increased thermal stress and decreased fitness of host fish, affecting foraging opportunities for adults and transforming adults. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect ammocoete survival, growth, and fitness. May affect growth and fitness of adults and transforming adults. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Ammocoetes;<br>Transforming adults;<br>Adults | Ammocoetes: Larval western brook, river, and potentially Pacific lamprey are found in sheltered nearshore lacustrine habitats, buried in substrates. Alteration of shoreline stability could lead to increased sedimentation and burial, affecting larval survival.<br>Adults and transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness for Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect ammocoete survival. May affect growth and fitness of adults and transforming adults. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Ammocoetes;<br>Transforming adults;<br>Adults | All life-history stages: Lamprey dependence on allochthonous inputs from shoreline riparian vegetation is a data gap. However, Pacific and river lamprey ammocoete benthic filter feeding stage and the filter feeding of the western brook lamprey could be affected. This could be a stressor to the extent the host fish is stressed by this mechanism of impact. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect ammocoete, transforming adult, and adult growth and fitness, depending on species. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Ammocoetes;<br>Transforming adults;<br>Adults | Ammocoetes: Decrease in availability of suitable rearing habitat, leading to decreased survival, growth, and fitness.<br>Transforming adults and adults: Decreased refuge habitat availability and foraging opportunities for host fish, potentially leading to decreased foraging opportunities for Pacific and river lamprey with resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect ammocoete survival, growth, and fitness. May affect adult growth, fitness, and spawning productivity due to effects on host fish. |

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## Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Ammocoetes;<br>Transforming adults;<br>Adults | <u>All life-history stages</u>: Lamprey dependence on groundwater inflow in lacustrine habitats is currently a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine Littoral** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Transforming adults;<br>Adults | <u>Transforming adults and adults</u>: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness of Pacific and river lamprey host fish. Effects on host fish in nearshore habitats would also affect adult river lamprey forage opportunities. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect river lamprey transforming adult and adult growth and fitness, as well as productivity of Pacific and river lamprey host fish. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Transforming adults;<br>Adults | <u>Transforming adults:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness of Pacific and river lamprey host fish.<br><u>Adults</u>: Decreased foraging opportunity due to decreased food web productivity, with resulting decreased growth and reproductive fitness of Pacific and river lamprey. River lamprey use nearshore habitats during this life-history phase, but dependence on habitat complexity remains a data gap. | | May affect transforming adult survival and productivity. May affect adult growth and spawning productivity of Pacific and river lamprey host fish. Other effects on adult river lamprey are a data gap. |

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**Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity. | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Ammocoetes;<br>Transforming adults | <u>Ammocoetes and transforming adults</u>: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness of Pacific and river lamprey host fish, and decreased prey resources for filter-feeding Western brook lamprey and ammocoete stages of Pacific and river lamprey. Altered prey resource effects to lamprey ammocoete life-history stages are a data gap. Although effects of altered autochthonous inputs for western brook lamprey are a data gap, alterations could be expected to affect prey resource availability. | <u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br><u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect ammocoete and transforming adult growth and fitness. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Transforming adults;<br>Adults | <u>Transforming adults and adults</u>: See related stressor responses under Water Quality Alteration. Effects are related to host fish effects for both Pacific and river lamprey. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Ammocoetes;<br>Transforming adults;<br>Adults | <u>All exposed life-history stages</u>: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness of Pacific and river lamprey host fish, and decreased prey resources for filter feeding Western brook lamprey and ammocoete stages of Pacific and river lamprey. Altered prey resource effects to lamprey ammocoete life-history stages are a data gap. Although effects of altered autochthonous inputs on Western brook lamprey are a data gap, alterations could be expected to affect prey resource availability. | | Lamprey dependence on habitat complexity provided by freshwater aquatic vegetation is a data gap. |

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Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability. | Year-round | Permanent | Continuous | Eggs and ammocoetes;<br>Transforming adults;<br>Adults | <u>Eggs and ammocoetes</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and ammocoete survival. Pacific and river lamprey ammocoetes are particularly vulnerable to impact mechanisms that cause scour, deposition, or other forms of substrate modification when buried in fine substrates during rearing periods, which can last for several years.<br><u>Transforming adults</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, as well as changes in food web complexity. These may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br><u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival, growth, and fitness at egg and ammocoete stages and egg and transforming adult life-history stages for host fish of Pacific and river lamprey. May also affect spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposures occurring during high flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round, with stressor exposure occurring during egg incubation and transforming adult rearing. | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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**Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when transforming adults occupy nearshore habitats for rearing) | Permanent | Continuous | Transforming adults;<br>Adults (river lamprey) | Transforming adults and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for lamprey host fish, leading to decreased foraging opportunities for transforming adult Pacific and river lamprey, and adult river lamprey. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect growth and fitness at transforming adult life-history stages through effects on host fish. River lamprey are also known to use nearshore habitats during the adult life-history stage and will be subject to these effects during this period. Direct dependence on nearshore habitat characteristics for both species is a data gap. Decreased growth and fitness may affect survival and productivity during ocean migration life-history phase for both species. Western brook lamprey are non-anadromous and will not be exposed to these stressors. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Ammocoetes;<br>Transforming adults;<br>Adults | Ammocoetes: Rearing lamprey ammocoetes are found buried in nearshore lacustrine sediments. Modification of hydraulic and geomorphic conditions may alter habitat suitability, leading to limitations on the amount of available habitat and affecting survival, growth, and fitness at this life-history stage.<br>Transforming adults and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for host fish, leading to decreased foraging opportunities for adults and transforming adults. Decreased foraging opportunities may cause decreased growth and fitness, affecting survival during marine migration and spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at ammocoete life-history stage. Effects on host fish may decrease survival, growth, and fitness of transforming adult and adult lamprey, and spawning productivity of adult lamprey. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered groundwater Inputs | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |

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Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat; change in habitat structure, availability, and suitability; reduced food web complexity | Year-round | Permanent | Continuous | Eggs and Ammocoetes;<br>Transforming adults;<br>Adults | All exposed life-history stages: Bank barbs and groins can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and larval rearing habitat for lamprey species. Depending on configuration, these structures may also affect the transport of lamprey ammocoetes to suitable rearing habitats, potentially affecting ammocoete survival. Decreased habitat availability may lead to density-dependent effects on adult spawning success. Adult brook lamprey may also be affected by decreased availability of suitable foraging habitat. | Require assessment of the hydraulic effects of the project before permitting and avoid permitting designs that lead to disconnection of floodplain habitat. | May affect survival at egg, ammocoete, and transforming adult life-history stages. May affect spawning productivity. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Transforming adults;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect transforming adult growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Transforming adults;<br>Adults | All exposed life-history stages: Bank barbs and groins in the marine environment can fragment nearshore habitat, forcing migrating and foraging river lamprey to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. Pacific lamprey exposure to these stressors is minimal, as they primarily reside in offshore habitats during the transforming adult and adult life-history stages. Brook lamprey do not occur in the marine environment. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at transforming adult life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Transforming adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect transforming adult survival. |

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Table A-13 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Transforming adults;<br>Adults | All exposed life-history stages: Bank barbs and groins in lacustrine environments can fragment nearshore rearing habitat, potentially affecting transport to and the suitability of nearshore rearing habitats for Pacific and river lamprey ammocoetes. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. Western brook lamprey do not typically occur in lacustrine environments; therefore, the likelihood of stressor exposure is limited. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at transforming adult life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Transforming adults; | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect Transforming adult survival. |

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## Table A-14. HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Fatal injury or permanent auditory tissue damage caused by barotraumas limiting to larval, juvenile, and adult survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness<br>Note that actual sound sensitivity of primitive fish species such as sturgeon is currently a data gap, so actual harm thresholds are unknown. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | May cause direct mortality or injury at all life-history stages. May affect survival, growth, and fitness at the juvenile life-history stage. Actual effects are uncertain as the sensitivity of these species to noise related stressors is currently a data gap. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Juveniles: Auditory masking may affect ability to avoid predators, leading to effects on survival. Behavioral responses may lead to habitat avoidance, affecting growth and fitness.<br>Adults: May cause avoidance behavior.<br>Note: While these responses are possible, very little is known of the effects of anthropogenic sounds on sturgeon at any life-history stage, so the actual effects of stressor exposure are uncertain. | Although, little is known about the effects of anthropogenic sounds on sturgeon, it is prudent to avoid/ minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect juvenile survival due to avoidance behavior, decreased foraging success, and increased predation risk. May cause adult avoidance behavior. Actual effects are unknown as stressor sensitivity is currently a data gap. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles | Juveniles and larvae: Mortality, injury, or stress from capture, handling, and relocation. Sturgeon larvae may be too small to capture effectively, leading to mortality or injury from asphyxiation. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May cause direct mortality or injury to larvae and juveniles. Stress from relocation may affect survival, growth, and fitness. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles | Larvae and juveniles: Injury or mortality from pump entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present. | May cause direct mortality of larvae and juveniles. |

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**Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juvenile (over 1 ft length-[marine]) and adults: Because of the limited temporal and spatial extent of alteration to sturgeon marine habitat, project effects on marine circulation are a relatively inconsequential component. Therefore, the magnitude of project hydrologic modification is expected to be negligible. As such, this stressor is not expected to significantly affect the marine environment, and there will be no response to the stressor. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | Effects from exposure to this stressor are expected to be insignificant and discountable. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: May cause avoidance behavior, potentially delaying migration. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect juvenile survival, growth, and productivity. May cause adult avoidance behavior, potentially delaying migration and limiting spawning productivity; however, actual sensitivity to these stressors is a data gap. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Juveniles; Adults | All life-history stages: See responses under Hydraulic and Geomorphic Modifications. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: Decreased growth and fitness due to stress and exertion caused by avoidance behavior and decreased foraging opportunity caused by short-term reduction in prey availability.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May affect juvenile and adult growth and fitness. See effects for related stressors under Water Quality Modification. |

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Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to reduced foraging opportunity, increased predation exposure, and altered migration behavior. | Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect juvenile productivity and adult productivity and spawning success. May cause direct mortality or injury in acute events. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.<br>Juveniles and adults: Physiological responses to exposure at levels exceeding tolerance thresholds, causing mortality or injury leading to reduced fitness. Avoidance behavior during subacute events. | Avoid sediment pulses. | May affect juvenile and adult survival, growth, and fitness. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Prevent in-water curing of concrete and discharge of concrete leachate to surface waters. | May affect survival and productivity of juveniles and adults. |

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## Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in freshwater. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Juveniles; Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. Due to their long lifespan and high age at maturity, adult sturgeon are at risk from adverse effects from bioaccumulation of contaminants. Chronic exposure to contaminants may affect adult survival, growth, fitness, and spawning productivity. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates. | May affect survival, growth, and fitness of all exposed life-history stages. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Juveniles; Adults | | Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Adults | Adults: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. Adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Adults | Adults: Adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Adults | Adults: Sturgeon dependence on allochthonous inputs from marine riparian vegetation is a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap; therefore, the effects of the action from this impact mechanism are unknown. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Adults | Adults: Adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur. | Encourage project designs that limit permanent alteration of high-quality habitat features. | Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable. |
| | Altered freshwater input | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Adults | Adult: Sturgeon dependence on groundwater inflow to nearshore marine habitats is currently a data gap. However, adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap; therefore, the effects of the action from this impact mechanism are unknown. |

**Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered riparian shading<br><br>Altered ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of turnover time, stratification patterns, wind conditions, and other factors. However, the suitability of some protected habitats such as isolated embayments may be affected, leading to decreased rearing habitat availability and increased competition, leading to decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Sturgeon dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. However, juvenile sturgeon are opportunistic feeders. Loss of terrestrial insect-fall could lead to decreased foraging opportunities, affecting growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile growth and fitness. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Sturgeon dependence on groundwater inflow to nearshore lacustrine habitats is currently a data gap. However, juveniles are dependent on water temperatures less than 75°F (24°C) for optimal growth. Reduction in thermal refuge habitat may lead to avoidance behavior, decreased growth, and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | Effects of action resulting from this impact mechanism are unknown, as sturgeon dependence on lacustrine groundwater inflow is a data gap. However, loss of thermal refuge habitat may affect juvenile growth and fitness. |

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### Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Adults | Adults: Adult sturgeon dependence on nearshore aquatic vegetation is a data gap. However, this species feeds on mollusks, fish, and invertebrate species dependent on nearshore food web productivity. Therefore, this stressor could indirectly affect adult growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect adult growth and fitness. However, localized effects are likely to be insignificant. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Adults | Adults: Adult sturgeon dependence on nearshore habitat complexity is limited. However, effects on habitat complexity may limit the availability and productivity of prey species; therefore, this stressor could indirectly affect adult growth and fitness. Given the extended marine foraging habitats used by sturgeon, localized effects are likely to be insignificant. | | |
| | **Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Juvenile sturgeon are known to feed opportunistically upon benthic prey organisms and fish dependent upon autochthonous material; reducing autochthonous production may decrease foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile productivity. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Reduced aquatic habitat complexity may limit the availability of suitable refuge and foraging habitat, leading to increased predation exposure and decreased foraging opportunities, affecting survival, growth, and fitness. | | May affect juvenile survival, growth, and fitness. |

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Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occuring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Adults | Adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing marine food web productivity and availability of prey species. This could lead to decreased adult growth and fitness, however incremental effects may not be significant considering the wide ranging marine habitats of adult sturgeon. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect adult growth and fitness. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |

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## Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Larvae; Juveniles; Adults | Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of juvenile rearing habitat. This may occur through increased predation exposure, food web alterations, and decreased foraging opportunity. Alteration of current and circulation patterns may prevent larvae transport to suitable rearing environments. The combined effect of these stressors can result in decreased survival, growth, and fitness at larval and juvenile life-history stages.<br>Adults: Adult sturgeon are generally less sensitive to these stressors. However, food web productivity in large reservoir environments may be affected by these impact mechanisms. This could lead to reduced adult foraging opportunities in residualized populations, and decreased growth, fitness, and spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival at larval life-history stage. May affect growth and fitness at juvenile life-history stage. May affect adult growth and fitness, and adult spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoir versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Adults | All exposed life-history stages: Jetties can fragment nearshore rearing and foraging habitats. Sturgeon dependence on these habitat types is currently a data gap; therefore, the effects of this stressor are unknown. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | Sensitivity to stressor exposure is currently a data gap; therefore, the effects of the action from this impact mechanism are unknown. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable. |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | All exposed life-history stages: Jetties can fragment nearshore lacustrine habitat, forcing foraging larval and juvenile sturgeon to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | <u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Egg mortality due to membrane rupture.<br>▪ Fatal injury or permanent auditory tissue damage caused by barotraumas limiting to larval, juvenile, and adult survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness<br>Note that actual sound sensitivity of primitive fish species such as sturgeon is currently a data gap, so actual harm thresholds are unknown. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | May cause direct mortality or injury at all life-history stages. May affect survival, growth, and fitness at larval and juvenile life-history stages. Actual effects are uncertain as the sensitivity of these species to noise related stressors is currently a data gap. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | <u>Juveniles</u>: Auditory masking may affect ability to avoid predators, leading to effects on survival. Behavioral responses may lead to habitat avoidance, affecting growth and fitness.<br><u>Adults</u>: May cause avoidance behavior.<br>Note: While these responses are possible, very little is known of the effects of anthropogenic sounds on sturgeon at any life-history stage, so the actual effects of stressor exposure are uncertain. | Although, little is known about the effects of anthropogenic sounds on sturgeon, it is prudent to avoid/ minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect juvenile survival due to avoidance behavior, decreased foraging success, and increased predation risk. May cause adult avoidance behavior. Actual effects are unknown as stressor sensitivity is currently a data gap. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles | <u>Juveniles and larvae</u>: Mortality, injury, or stress from capture, handling, and relocation. Sturgeon larvae may be too small to capture effectively, leading to mortality or injury from asphyxiation. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May cause direct mortality or injury to larvae and juveniles. Stress from relocation may affect survival, growth, and fitness. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles | <u>Larvae and juveniles</u>: Injury or mortality from pump entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present. | May cause direct mortality of larvae and juveniles. |

**Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juvenile (over 1 ft length [marine]) and adults: Because of the limited temporal and spatial extent of alteration to sturgeon marine habitat, project effects on marine circulation are a relatively inconsequential component. Therefore, the magnitude of project hydrologic modification is expected to be negligible. As such, this stressor is not expected to significantly affect the marine environment, and there will be no response to the stressor. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | Effects from exposure to this stressor are expected to be insignificant and discountable. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and larvae; Juveniles; Adults | Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity.<br>Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: May cause avoidance behavior, potentially delaying migration. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect survival during egg and larval life-history stages. May affect juvenile survival, growth, and productivity. May cause adult avoidance behavior, potentially delaying migration and limiting spawning productivity; however, actual sensitivity to these stressors is a data gap. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and larvae; Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs; Larvae; Juveniles; Adults | All life-history stages: See responses above under Hydraulic and Geomorphic Modifications. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and larvae; Juveniles; Adults | Eggs and larvae: Non-mobile eggs and larvae may experience injury or mortality from dredge entrainment.<br>Juveniles and adults: Decreased growth and fitness due to stress and exertion caused by avoidance behavior and decreased foraging opportunity caused by short-term reduction in prey availability.<br>All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May cause direct injury or mortality of eggs and larvae. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |

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**Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and larvae;<br>Juveniles;<br>Adults | Eggs and larvae: Turbidity may lead to direct mortality and decreased survival of eggs and larvae. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to reduced foraging opportunity, increased predation exposure, and altered migration behavior. | Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of eggs and larvae. May affect juvenile productivity and adult productivity and spawning success. May cause direct mortality or injury in acute events. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and larvae;<br>Juveniles;<br>Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.<br>Juveniles and adults: Physiological responses to exposure at levels exceeding tolerance thresholds, causing mortality or injury leading to reduced fitness. Avoidance behavior during subacute events. | Avoid sediment pulses. | May affect survival of incubating eggs and larvae. May affect juvenile and adult survival, growth, and fitness. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles;<br>Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Prevent in-water curing of concrete and discharge of concrete leachate to surface waters. | May affect survival and productivity of juveniles and adults. |

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| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in freshwater. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and larvae; Juveniles; Adults | <u>All exposed life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. Due to their long lifespan and high age at maturity, adult sturgeon are at risk from adverse effects from bioaccumulation of contaminants. Chronic exposure to contaminants may affect adult survival, growth, fitness, and spawning productivity. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates. | May affect survival, growth, and fitness of all exposed life-history stages. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and larvae; Juveniles; Adults | | <u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Adults | <u>Adults</u>: Adult sturgeon dependence on nearshore aquatic vegetation is a data gap. However, this species feeds on mollusks, fish, and invertebrate species dependent on nearshore food web productivity. Therefore, this stressor could indirectly affect adult growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect adult growth and fitness. However, localized effects are likely to be insignificant. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Adults | <u>Adults</u>: Adult sturgeon dependence on nearshore habitat complexity is limited. However, effects on habitat complexity may limit the availability and productivity of prey species; therefore, this stressor could indirectly affect adult growth and fitness. Given the extended marine foraging habitats used by sturgeon, localized effects are likely to be insignificant. | | |
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | <u>Juveniles</u>: Juvenile sturgeon are known to feed opportunistically upon benthic prey organisms and fish dependent upon autochthonous material; reducing autochthonous production may decrease foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | <u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br><u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.<br><u>Operation</u>: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile productivity. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | <u>Juveniles:</u> Reduced aquatic habitat complexity may limit the availability of suitable refuge and foraging habitat, leading to increased predation exposure and decreased foraging opportunities, affecting survival, growth, and fitness. | | May affect juvenile survival, growth, and fitness. |

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**Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs and larvae; Juveniles Adults | Eggs and larvae: Sturgeon are believed to spawn in swift current environments in part because the high velocities protect eggs from predation. Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success, and potentially increased predation exposure. Changes in flow regime may cause larvae to be transported to environments unfavorable for survival.<br>Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Juvenile dependence on groundwater exchange is a data gap; however, loss of thermal refuge may decrease the availability of suitable rearing habitat, leading to decreased growth and fitness.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations) if potential spawning habitat is affected | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival at egg and larval life-history stages. May affect juvenile growth and fitness. May affect adult spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposures occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round, with stressor exposure occurring during egg incubation and juvenile rearing. | Permanent | Continuous | | | | |
| | Addition of impervious surface | Alteration in the magnitude, volume, and timing of peak flows. | During storm events, predominantly from fall through spring. | Permanent | Common | Eggs and larvae; Juveniles Adults | All life-history stages: Because the amount of impervious surface associated with breakwaters is a relatively inconsequential component of the overall drainage area of the larger river systems that would support this type of development, the magnitude of the hydrologic modification stressor is expected to be negligible. As such, this stressor is not expected to significantly affect the riverine environment, and there will therefore be no response to the stressor. | Encourage facilities to employ modern low impact development and stormwater treatment technology. | Impervious surface at anticipated scale would not produce stressors of sufficient magnitude to adversely affect sturgeon at any life-history stage. |

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### Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Adults | Adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing marine food web productivity and availability of prey species. This could lead to decreased adult growth and fitness, however incremental effects may not be significant considering the wide ranging marine habitats of adult sturgeon. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. For example:<br>Permeable breakwaters that maintain longshore drift patterns<br>Suggest alternative designs for projects that fragment sources of sediment recruitment and groundwater supply<br>Require beach nourishment to maintain substrate and beach profile characteristics where impacts are unavoidable | May affect adult growth and fitness. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |

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**Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Larvae;<br>Juveniles;<br>Adults | <u>Larvae and juveniles</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of juvenile rearing habitat. This may occur through increased predation exposure, food web alterations, and decreased foraging opportunity. Alteration of current and circulation patterns may prevent larvae transport to suitable rearing environments. The combined effect of these stressors can result in decreased survival, growth, and fitness at larval and juvenile life-history stages.<br><br><u>Adults</u>: Adult sturgeon are generally less sensitive to these stressors. However, food web productivity in large reservoir environments may be affected by these impact mechanisms. This could lead to reduced adult foraging opportunities in residualized populations, and decreased growth, fitness, and spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival at larval life-history stage. May affect growth and fitness at juvenile life-history stage. May affect adult growth and fitness, and adult spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoir versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Larvae;<br>Juveniles | <u>Larvae and juveniles</u>: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for sturgeon larvae and smaller juveniles in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect larval and juvenile survival. |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | NA | NA | NA | NA | Sturgeon in the marine environment occur as sub-adults and adults, which are not vulnerable to predation by the typical range of lie-in-wait predators that associate with breakwaters and similar structures. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | The effects of exposure to this stressor are considered insignificant and discountable. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable. |

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## Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Larvae;<br>Juveniles | Larvae and juveniles: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators, potentially increasing predation exposure for sturgeon larvae and smaller juveniles in the vicinity of the structure, leading to decreased survival. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect larval and juvenile survival. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Egg mortality due to membrane rupture.<br>▪ Fatal injury or permanent auditory tissue damage caused by barotraumas limiting to larval, juvenile, and adult survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness<br>Note that actual sound sensitivity of primitive fish species such as sturgeon is currently a data gap, so actual harm thresholds are unknown. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable. | May cause direct mortality or injury at all life-history stages. May affect survival, growth, and fitness at larval and juvenile life-history stages. Actual effects are uncertain as the sensitivity of these species to noise related stressors is currently a data gap. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Juveniles: Auditory masking may affect ability to avoid predators, leading to effects on survival. Behavioral responses may lead to habitat avoidance, affecting growth and fitness.<br>Adults: May cause avoidance behavior.<br>Note: While these responses are possible, very little is known of the effects of anthropogenic sounds on sturgeon at any life-history stage, so the actual effects of stressor exposure are uncertain. | Although, little is known about the effects of anthropogenic sounds on sturgeon, it is prudent to avoid/ minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | May affect juvenile survival due to avoidance behavior, decreased foraging success, and increased predation risk. May cause adult avoidance behavior. Actual effects are unknown as stressor sensitivity is currently a data gap. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles | Juveniles and larvae: Mortality, injury, or stress from capture, handling, and relocation. Sturgeon larvae may be too small to capture effectively, leading to mortality or injury from asphyxiation. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May cause direct mortality or injury to larvae and juveniles. Stress from relocation may affect survival, growth, and fitness. |

## Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles | Larvae and juveniles: Injury or mortality from pump entrainment or impingement. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present. | May cause direct mortality of larvae and juveniles. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | Larvae: May affect settlement, leading to decreased larval survival.<br>Juveniles and adults: Sturgeon feed opportunistically on benthic organisms, such as aquatic insect larvae and fish. Substrate effects on these prey organisms could affect prey availability, resulting in decreased growth and fitness. | Limit alteration of flow conditions to minimal area. | May affect survival during larval life-history stage. May affect juvenile and adult growth and fitness. |
| | | Altered current and circulation conditions (marine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles;<br>Adults | Juvenile (over 1 ft length-[marine]) and adults: Because of the limited temporal and spatial extent of alteration to sturgeon marine habitat, project effects on marine circulation are a relatively inconsequential component. Therefore, the magnitude of project hydrologic modification is expected to be negligible. As such, this stressor is not expected to significantly affect the marine environment, and there will be no response to the stressor. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | Effects from exposure to this stressor are expected to be insignificant and discountable. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs and larvae;<br>Juveniles;<br>Adults | Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity.<br>Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk.<br>Adults: May cause avoidance behavior, potentially delaying migration. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | May affect survival during egg and larval life-history stages. May affect juvenile survival, growth, and productivity. May cause adult avoidance behavior, potentially delaying migration and limiting spawning productivity; however, actual sensitivity to these stressors is a data gap. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. | Limit area of dewatering to the greatest extent practicable. | May affect growth and fitness at juvenile life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs and larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses under Hydraulic and Geomorphic Modifications. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles;<br>Adults | Juveniles and adults: See responses under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |

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## Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs and larvae; Juveniles; Adults | Eggs and larvae: Non-mobile eggs and larvae may experience injury or mortality from dredge entrainment. Juveniles and adults: Decreased growth and fitness due to stress and exertion caused by avoidance behavior and decreased foraging opportunity caused by short-term reduction in prey availability. All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May cause direct injury or mortality of eggs and larvae. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and larvae; Juveniles; Adults | Eggs and larvae: Turbidity may lead to direct mortality and decreased survival of eggs and larvae. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to reduced foraging opportunity, increased predation exposure, and altered migration behavior. | Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of eggs and larvae. May affect juvenile productivity and adult productivity and spawning success. May cause direct mortality or injury in acute events. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and larvae; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Physiological responses to exposure at levels exceeding tolerance thresholds, causing mortality or injury leading to reduced fitness. Avoidance behavior during subacute events. | Avoid sediment pulses. | May affect survival of incubating eggs and larvae. May affect juvenile and adult survival, growth, and fitness. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Prevent in-water curing of concrete and discharge of concrete leachate to surface waters. | May affect survival and productivity of juveniles and adults. |

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## Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in freshwater. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs and larvae; Juveniles; Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. Due to their long lifespan and high age at maturity, adult sturgeon are at risk from adverse effects from bioaccumulation of contaminants. Chronic exposure to contaminants may affect adult survival, growth, fitness, and spawning productivity. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival, growth, and fitness of all exposed life-history stages. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs and larvae; Juveniles; Adults | | | |
| | **Riparian and Shoreline Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures). | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Eggs and larvae; Juveniles; Adults | Eggs and larvae: Direct mortality of embryos at temperatures in excess of 68°F (20°C).<br>Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Decreased growth when exposed to temperatures in excess of 75°F (24°C).<br>Adults: Exposure to thermal barriers is unlikely as spawning migrations occur in mid- to late-winter and spawning occurs in turbulent river mainstems. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness during incubation, rearing, and spawning. Likelihood of stressor exposure is limited, however, as most settings suitable for groin and bank barb development are in larger river environments where riparian vegetation has less effect on temperature conditions. |
| | Altered stream bank and shoreline stability | Increased suspended solids and burial of benthic organisms (juvenile prey) or eggs attached to coarse substrate | Year-round (with specific stressors prominent during high flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs and larvae; Juveniles; | Eggs and larvae: Decreased incubation success and larval survival due to effects of turbidity exposure as described above under Water Quality Modification.<br>Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival during incubation larval dispersal, as well as survival, growth, and fitness during juvenile rearing. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs | Year-round | Permanent | Continuous | Juveniles | Juveniles: Juvenile sturgeon are opportunistic feeders and may utilize allochthonous inputs in the form of terrestrially insect-fall. Reduced foraging opportunities due to decreased food web productivity may lead to decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |

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**Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival, growth, and fitness. |
| | Altered groundwater–surface water exchange | Reduced thermal refuge, reduced substrate dissolved oxygen, altered food web productivity | Year-round | Permanent | Continuous | Juveniles | Juveniles: Sturgeon dependence on groundwater exchange is currently a data gap. However, juveniles are dependent on water temperatures less than 75°F (24°C) for optimal growth. Reduction in thermal refuge habitat may lead to avoidance behavior, decreased growth, and decreased fitness. | Avoid disturbance of vegetation along stream. | Effects of action resulting from this impact mechanism are unknown, as sturgeon dependence on groundwater-surface water exchange is a data gap. However, loss of thermal refuge habitat may affect juvenile growth and fitness. |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Adults | Adults: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. Adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Adults | Adults: Adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Adults | Adults: Sturgeon dependence on allochthonous inputs from marine riparian vegetation is a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap; therefore, the effects of the action from this impact mechanism are unknown. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Adults | Adults: Adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur. | Encourage project designs that limit permanent alteration of high-quality habitat features. | Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable. |
| | Altered freshwater input | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Adults | Adult: Sturgeon dependence on groundwater inflow to nearshore marine habitats is currently a data gap. However, adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap; therefore, the effects of the action from this impact mechanism are unknown. |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of turnover time, stratification patterns, wind conditions, and other factors. However, the suitability of some protected habitats such as isolated embayments may be affected, leading to decreased rearing habitat availability and increased competition, leading to decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |

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## Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Sturgeon dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. However, juvenile sturgeon are opportunistic feeders. Loss of terrestrial insect-fall could lead to decreased foraging opportunities, affecting growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile growth and fitness. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Sturgeon dependence on groundwater inflow to nearshore lacustrine habitats is currently a data gap. However, juveniles are dependent on water temperatures less than 75°F (24°C) for optimal growth. Reduction in thermal refuge habitat may lead to avoidance behavior, decreased growth, and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | Effects of action resulting from this impact mechanism are unknown, as sturgeon dependence on lacustrine groundwater inflow is a data gap. However, loss of thermal refuge habitat may affect juvenile growth and fitness. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Adults | Adults: Adult sturgeon dependence on nearshore aquatic vegetation is a data gap. However, this species feeds on mollusks, fish, and invertebrate species dependent on nearshore food web productivity. Therefore, this stressor could indirectly affect adult growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect adult growth and fitness. However, localized effects are likely to be insignificant. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Adults | Adults: Adult sturgeon dependence on nearshore habitat complexity is limited. However, effects on habitat complexity may limit the availability and productivity of prey species; therefore, this stressor could indirectly affect adult growth and fitness. Given the extended marine foraging habitats used by sturgeon, localized effects are likely to be insignificant. | | |

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## Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Juvenile sturgeon are known to feed opportunistically upon benthic prey organisms and fish dependent upon autochthonous material; reducing autochthonous production may decrease foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile productivity. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Reduced aquatic habitat complexity may limit the availability of suitable refuge and foraging habitat, leading to increased predation exposure and decreased foraging opportunities, affecting survival, growth, and fitness. | | May affect juvenile survival, growth, and fitness. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability<br>. | Year-round | Permanent | Continuous | Eggs and larvae;<br>Juveniles<br>Adults | Eggs and larvae: Sturgeon are believed to spawn in swift current environments in part because the high velocities protect eggs from predation. Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success, and potentially increased predation exposure. Changes in flow regime may cause larvae to be transported to environments unfavorable for survival.<br>Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Juvenile dependence on groundwater exchange is a data gap; however, loss of thermal refuge may decrease the availability of suitable rearing habitat, leading to decreased growth and fitness.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations) if potential spawning habitat is affected | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival at egg and larval life-history stages. May affect juvenile growth and fitness. May affect adult spawning productivity. |
| | Altered flow velocity | | Year-round (with stressor exposures occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round, with stressor exposure occurring during egg incubation and juvenile rearing. | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

**Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Adults | Adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing marine food web productivity and availability of prey species. This could lead to decreased adult growth and fitness, however incremental effects may not be significant considering the wide ranging marine habitats of adult sturgeon. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect adult growth and fitness. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced) | Permanent | Continuous | Larvae;<br>Juveniles;<br>Adults | Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of juvenile rearing habitat. This may occur through increased predation exposure, food web alterations, and decreased foraging opportunity. Alteration of current and circulation patterns may prevent larvae transport to suitable rearing environments. The combined effect of these stressors can result in decreased survival, growth, and fitness at larval and juvenile life-history stages.<br>Adults: Adult sturgeon are generally less sensitive to these stressors. However, food web productivity in large reservoir environments may be affected by these impact mechanisms. This could lead to reduced adult foraging opportunities in residualized populations, and decreased growth, fitness, and spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival at larval life-history stage. May affect growth and fitness at juvenile life-history stage. May affect adult growth and fitness, and adult spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoir versus natural lakes) | Permanent | Common | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |

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## Table A-14 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Green and White Sturgeon.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat; change in habitat structure, availability, and suitability; reduced food web complexity | Year-round | Permanent | Continuous | Eggs and alevins; Juveniles; Adults | All exposed life-history stages: Bank barbs and groins can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of larval sturgeon rearing habitat. Decreased habitat availability may lead to density-dependent effects on larval and juvenile survival, growth, and fitness. | Require assessment of the hydraulic effects of the project before permitting, and avoid permitting designs that lead to disconnection of floodplain habitat. | May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. . |
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Adults | All exposed life-history stages: Bank barbs and groins in the marine environment can fragment nearshore habitat. Sturgeon dependence on these habitat types is currently a data gap; therefore, the effects of this stressor are unknown. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | Sensitivity to stressor exposure is currently a data gap; therefore, the effects of the action from this impact mechanism are unknown. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable. |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | All exposed life-history stages: Bank barbs and groins in lacustrine environments can fragment nearshore habitat, forcing foraging larval and juvenile sturgeon to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-15. HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs and larvae: Noise of sufficient magnitude may cause direct mortality of eggs and larval smelt or permanent injury leading to decreased survival and fitness.<br>Adults and juveniles: Stressor response, depending on noise magnitude and project-specific environmental conditions, may range from:<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to system-specific in-water work windows to avoid stressor exposure during spawning, incubation, and larval dispersal (November to April, depending on system). If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning, incubation, and larval dispersal. The potential for juvenile exposure is less well known. Except for the landlocked Lake Washington population of longfin smelt, juvenile habitat use by these species is poorly understood. Subadults are known to migrate to offshore areas on the continental shelf. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults. | Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning disruptions. Exposure to stressor may affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Juveniles (Lake Washington longfin smelt);<br>Adults | Eggs and larvae: Channel dewatering will cause egg mortality.<br>Juveniles: Juvenile smelt are generally believed to migrate offshore and will therefore not likely be exposed to dewatering. Lake Washington longfin smelt are an exception; potential nearshore habitat use by this population is currently a data gap.<br>Adults: Capture, handling, and relocation are likely to cause mortality or injury and stress leading to mortality or decreased spawning fitness. Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults. | Unlikely to affect eggs, larvae, and adults if activities are conducted during in-water work windows. Capture and removal of eggs, larvae, and juveniles is impractical, meaning that activities occurring during incubation and emigration periods may affect survival during these life-history stages. Capture and removal of adults are likely to affect survival and spawning productivity. |

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## Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | Eggs, larvae, and juveniles: Pump entrainment is highly likely to cause mortality of larvae and drifting eggs. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles.<br>Adults: Impingement is likely to cause adult mortality. | Adhere to system-specific in-water work windows; avoid use of dewatering pumps during spawning, incubation, and larval dispersal. | Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted within in-water work windows. If activities are permitted outside in-water work windows, activity may affect adult and egg and larval survival. The potential for effects on juvenile smelt survival in marine habitats and Lake Washington are unknown because habitat use by this life-history stage is a data gap. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Nearshore habitat use by smelt is currently a data gap, so the potential for exposure to this stressor is unknown. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | The potential for this mechanism to affect juvenile smelt is currently unknown because dependence on nearshore circulation patterns is currently a data gap. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering). | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Adults | Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance.<br>Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, increased predation exposure, decreased spawning habitat suitability. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | Unlikely to affect egg survival and adult spawning productivity when activities are conducted during in-water work windows. May affect these parameters if activities occur during spawning and incubation. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: With the exception of the Lake Washington longfin population, smelt do not feed on benthic organisms in freshwater systems and will be unaffected by this stressor. In Lake Washington and in marine systems, smelt are planktonic feeders that are not likely to be affected by temporary decreases in benthic invertebrate abundance. | Limit area of dewatering to the greatest extent practicable. | Not likely to affect smelt at any life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual-decadal | Eggs;<br>Larvae;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modifications. | Avoid fill or if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual-decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |

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Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual-decadal | Eggs; Larvae; Juveniles; Adults | Eggs and larvae: Incubating eggs entrained during dredging will suffer high mortality. Juveniles: The potential for juvenile exposure to these stressors is unknown because habitat use is currently a data gap. All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Unlikely to affect survival of eggs and larvae if activities are conducted during in-water work windows. Likely to affect egg survival and larval survival and productivity if exposure occurs. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | Eggs and larvae: Turbidity sufficient to cause burial or coating of eggs may lead to direct mortality. Increased turbidity may decrease larval foraging success, resulting in decreased growth and fitness. Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs. May affect juvenile productivity, adult productivity, and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved events due to asphyxiation. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness. | Avoid sediment pulses. | May affect survival of incubating eggs. May affect juvenile survival and productivity and adult survival, productivity, and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing direct mortality or injury leading to reduced fitness. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and productivity of eggs and larvae, juveniles, and adults |

Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs;<br>Larvae;<br>Juveniles | Eggs and larvae, juveniles: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival and productivity of eggs, larvae, and juveniles |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn), | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs;<br>Larvae;<br>Juveniles; | Eggs and larvae, juveniles: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Larvae;<br>Juveniles | Larvae and juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. Dependence of larval and juvenile longfin smelt and eulachon on these habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high-wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Larvae;<br>Juveniles | Larvae and juveniles: Dependence of larval and juvenile longfin smelt and eulachon on these habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Larvae;<br>Juveniles | Larvae and juveniles: Longfin smelt and eulachon dependence on allochthonous inputs from marine riparian vegetation is a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Larvae;<br>Juveniles | Larvae and juveniles: Dependence of larval and juvenile smelt on these habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |



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## Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered groundwater-surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Larvae;<br>Juveniles | Larvae and juveniles: Dependence of larval and juvenile smelt on surface water and groundwater exchange in nearshore habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures). | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | Larvae, juveniles, and adults: Riparian shade and ambient temperature has a relatively minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade. Dependence of juvenile longfin smelt on these habitats is currently a data gap Therefore the potential for exposure to these stressors is unknown. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | Potential effects resulting from this impact mechanism are unknown. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation). | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | Larvae, juveniles, and adults: Potential habitat avoidance and/or injury/mortality caused by excessive turbidity, potential for decreased foraging success leading to decreased growth and fitness as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile and adult survival and productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | Larvae, juveniles, and adults: Longfin smelt dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. Therefore the potential for exposure to these stressors is unknown. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | Potential effects resulting from this impact mechanism are unknown. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | Larvae, juveniles, and adults: Dependence of larval, juvenile, and adult longfin smelt on these habitats is currently a data gap, Therefore the potential for exposure to these stressors is unknown. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | Potential effects resulting from this impact mechanism are unknown. |
| | Altered groundwater surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | Larvae, juveniles, and adults: Longfin smelt dependence on groundwater inflow to nearshore lacustrine habitats is currently a data gap. Therefore the potential for exposure to these stressors is unknown. | Avoid disturbance of vegetation along stream | Potential effects resulting from this impact mechanism are unknown. |



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Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Larvae; Juveniles; Adults | All exposed life-history stages: Longfin smelt and eulachon dependence on marine littoral vegetation and the nearshore marine environment is currently a data gap. Therefore, the potential for exposure to these stressors is unknown. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, and reduced ambient light from fine bubble profusion. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity. | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Lake Washington longfin smelt. Eggs; Larvae; Adults | All exposed life-history stages: Smelt dependence on freshwater submerged aquatic vegetation is currently a data gap. Therefore, the potential for exposure to these stressors is unknown. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | | | | |



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## Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round, with stressor exposure occurring in spring and summer when larvae and juveniles occupy nearshore habitats for rearing | Permanent | Continuous | Larvae;<br>Juveniles;<br>Adults | Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Longfin smelt and eulachon dependence on these habitats is currently a data gap. However, alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment.<br>Adults: Alteration of nearshore habitat parameters may affect survival and foraging opportunities at larval and juvenile life-history stages, leading to decreased adult fitness, decreased survival, and decreased spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at the larval and juvenile life-history stages. Decreased fitness may affect survival and productivity during ocean migration life-history phase, and may affect spawning productivity. |
| | Altered current velocities | | Year-round, with variable effects depending on site-specific current dynamics and project configuration | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round, with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round, beginning with project installation and becoming more pronounced over time | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round, beginning with project installation and becoming more pronounced over time (e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching) | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round, with predominant effects from fall through spring when wind-driven waves are most pronounced | Permanent | Continuous | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | Larvae, juveniles, and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, with concomitant food web effects throughout the lacustrine ecosystem. Therefore, alteration of these parameters may affect foraging opportunities for longfin smelt at larval and juvenile life-history stages, leading to decreased adult fitness and decreased spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect productivity at larval and juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round, with effects more predominant in reservoirs versus natural lakes | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round, with variable effects by season (e.g., circulation patterns) | Permanent | Seasonal | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |

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## Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Larvae;<br>Juvenile;<br>Adult | All exposed life-history stages: Jetties fragment nearshore marine habitat. Eulachon and longfin smelt are known to use these habitat types during juvenile and adult life-history stages, and are likely to occur as larvae as well. Jetties may alter migration of adults toward spawning habitats, larval dispersal, and juvenile foraging, affecting survival, growth, and fitness at all life-history stages. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Larvae;<br>Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | All exposed life-history stages: Longfin smelt dependence on nearshore habitats in Lake Washington is currently a data gap. Therefore the effects of this stressor are unknown. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | Potential effects resulting from this impact mechanism are unknown. |

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Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs and larvae: Noise of sufficient magnitude may cause direct mortality of eggs and larval smelt or permanent injury leading to decreased survival and fitness.<br>Adults and juveniles: Stressor response, depending on noise magnitude and project-specific environmental conditions, may range from:<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to system-specific in-water work windows to avoid stressor exposure during spawning, incubation, and larval dispersal (November to April, depending on system). If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning, incubation, and larval dispersal. The potential for juvenile exposure is less well known. Except for the landlocked Lake Washington population of longfin smelt, juvenile habitat use by these species is poorly understood. Subadults are known to migrate to offshore areas on the continental shelf. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults. | Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning disruptions. Exposure to stressor may affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Juveniles (Lake Washington longfin smelt);<br>Adults | Eggs and larvae: Channel dewatering will cause egg mortality.<br>Juveniles: Juvenile smelt are generally believed to migrate offshore and will therefore not likely be exposed to dewatering. Lake Washington longfin smelt are an exception; potential nearshore habitat use by this population is currently a data gap.<br>Adults: Capture, handling, and relocation are likely to cause mortality or injury and stress leading to mortality or decreased spawning fitness. Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults. | Unlikely to affect eggs, larvae, and adults if activities are conducted during in-water work windows. Capture and removal of eggs, larvae, and juveniles is impractical, meaning that activities occurring during incubation and emigration periods may affect survival during these life-history stages. Capture and removal of adults are likely to affect survival and spawning productivity. |



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## Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae; Juveniles; Adults | Eggs, larvae, and juveniles: Pump entrainment is highly likely to cause mortality of larvae and drifting eggs. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles. Adults: Impingement is likely to cause adult mortality. | Adhere to system-specific in-water work windows; avoid use of dewatering pumps during spawning, incubation, and larval dispersal. | Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted during in-water work windows. If activities are permitted outside in-water work windows, activity may affect adult and egg and larval survival. The potential for effects on juvenile smelt survival in marine habitats and Lake Washington are unknown because habitat use by this life-history stage is a data gap. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: Nearshore habitat use by smelt is currently a data gap, so the potential for exposure to this stressor is unknown. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | The potential for this mechanism to affect juvenile smelt is currently unknown because dependence on nearshore circulation patterns is currently a data gap. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering). | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs; Larvae; Adults | Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, increased predation exposure, decreased spawning habitat suitability. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | Unlikely to affect egg survival and adult spawning productivity when activities are conducted during in-water work windows. May affect these parameters if activities occur during spawning and incubation. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | Juveniles: With the exception of the Lake Washington longfin population, smelt do not feed on benthic organisms in freshwater systems and will be unaffected by this stressor. In Lake Washington and in marine systems, smelt are planktonic feeders that are not likely to be affected by temporary decreases in benthic invertebrate abundance. | Limit area of dewatering to the greatest extent practicable. | Not likely to affect smelt at any life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs; Larvae; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual-decadal | Eggs; Larvae; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modifications. | Avoid fill or if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual-decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |

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## Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual-decadal | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | <u>Eggs and larvae</u>: Incubating eggs entrained during dredging will suffer high mortality.<br><u>Juveniles</u>: The potential for juvenile exposure to these stressors is unknown because habitat use is currently a data gap.<br><u>All life-history stages</u>: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Unlikely to affect survival of eggs and larvae if activities are conducted during in-water work windows. Likely to affect egg survival and larval survival and productivity if exposure occurs. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | <u>Eggs and larvae:</u> Turbidity sufficient to cause burial or coating of eggs may lead to direct mortality. Increased turbidity may decrease larval foraging success, resulting in decreased growth and fitness.<br><u>Juveniles</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness.<br><u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs. May affect juvenile productivity, adult productivity, and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Mortality in acute low dissolved events due to asphyxiation.<br><u>Juveniles and adults</u>: Avoidance behavior and increased stress, leading to reduced growth and fitness. | Avoid sediment pulses. | May affect survival of incubating eggs. May affect juvenile survival and productivity and adult survival, productivity, and spawning success. |

### Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing direct mortality or injury leading to reduced fitness. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and productivity of eggs and larvae, juveniles, and adults |
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs;<br>Larvae;<br>Juveniles | Eggs and larvae, juveniles: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival and productivity of eggs, larvae, and juveniles |
| | Use of ACZA and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs;<br>Larvae;<br>Juveniles; | Eggs and larvae, juveniles: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |

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**Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Larvae; Juveniles; Adults | <u>All exposed life-history stages</u>: Longfin smelt and eulachon dependence on marine littoral vegetation and the nearshore marine environment is currently a data gap. Therefore, the potential for exposure to these stressors is unknown. | <u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br><u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.<br><u>Operation</u>: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, and reduced ambient light from fine bubble profusion. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | | | | |
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity. | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Eggs; Larvae; Adults | <u>All exposed life-history stages</u>: Smelt dependence on freshwater submerged aquatic vegetation is currently a data gap. Therefore, the potential for exposure to these stressors is unknown. | <u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br><u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.<br><u>Operation</u>: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | | | | |

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**Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival.<br>Larvae and juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival at egg and larval life-history stages. May affect spawning productivity. |
| | Altered flow velocity | | Year-round, with stressor exposure occurring during high flow events, fall through spring | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round, with stressor exposure occurring during egg incubation and juvenile rearing | Permanent | Continuous | | | | |
| | Addition of impervious surface | Alteration in the magnitude, volume, and timing of peak flows | During storm events, predominantly fall through spring | Permanent | Common | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: Because the amount of impervious surface associated with breakwaters is a relatively inconsequential component of the overall drainage area of the larger river systems that would support this type of development, the magnitude of the hydrologic modification stressor is expected to be negligible. As such, this stressor is not expected to significantly affect the riverine environment, and there will therefore be no response to the stressor. | Encourage facilities to employ modern low impact development and stormwater treatment technology. | Impervious surface at anticipated scale would not produce stressors of sufficient magnitude to adversely affect longfin smelt and eulachon at any life-history stage. |

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**Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round, with stressor exposure occurring in spring and summer when larvae and juveniles occupy nearshore habitats for rearing | Permanent | Continuous | Larvae;<br>Juveniles;<br>Adults | Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Longfin smelt and eulachon dependence on these habitats is currently a data gap. However, alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment.<br>Adults: Alteration of nearshore habitat parameters may affect survival and foraging opportunities at larval and juvenile life-history stages, leading to decreased adult fitness, decreased survival, and decreased spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at the larval and juvenile life-history stages. Decreased fitness may affect survival and productivity during ocean migration life-history phase, and may affect spawning productivity. |
| | Altered current velocities | | Year-round, with variable effects depending on site-specific current dynamics and project configuration | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round, with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round, beginning with project installation and becoming more pronounced over time | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round, beginning with project installation and becoming more pronounced over time (e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round, with predominant effects from fall through spring when wind-driven waves are most pronounced | Permanent | Continuous | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | Larvae, juveniles, and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, with concomitant food web effects throughout the lacustrine ecosystem. Therefore, alteration of these parameters may affect foraging opportunities for longfin smelt at larval and juvenile life-history stages, leading to decreased adult fitness and decreased spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect productivity at larval and juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round, with effects more predominant in reservoirs versus natural lakes | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round, with variable effects by season (e.g., circulation patterns) | Permanent | Seasonal | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Larvae;<br>Adults | Larvae and adults: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators. However, these life history stages typically occur in large enough abundance that the related predation exposure would be insignificant relative to typical natural mortality levels. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | The effects of exposure to this stressor are considered insignificant and discountable. |

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## Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Juveniles; Adults | All exposed life history stages: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators. Juvenile and adult eulachon and smelt may be exposed to increased predation exposure. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile and adult survival. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Larvae; Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | **Lacustrine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Lake Washington longfin smelt Larvae; Juveniles; Adults | All exposed life history stages: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators. Juvenile and adult Lake Washington longfin smelt may be exposed to increased predation exposure. Larval longfin smelt may experience similar exposure, but increased predation rates are most likely insignificant relative to natural mortality. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile and adult survival. May affect larval survival, but effects will be insignificant relative to natural mortality. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Lake Washington longfin smelt. Larvae; Juveniles; Adults | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | Potential effects resulting from this impact mechanism are unknown. |

**Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | <u>Eggs and larvae</u>: Noise of sufficient magnitude may cause direct mortality of eggs and larval smelt or permanent injury leading to decreased survival and fitness.<br><u>Adults and juveniles</u>: Stressor response, depending on noise magnitude and project-specific environmental conditions, may range from:<br>• Fatal injury or permanent auditory tissue damage limiting to survival.<br>• Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>• Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to system-specific in-water work windows to avoid stressor exposure during spawning, incubation, and larval dispersal (November to April, depending on system). If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning, incubation, and larval dispersal. The potential for juvenile exposure is less well known. Except for the landlocked Lake Washington population of longfin smelt, juvenile habitat use by these species is poorly understood. Subadults are known to migrate to offshore areas on the continental shelf. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | <u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults. | Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning disruptions. Exposure to stressor may affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Juveniles (Lake Washington longfin smelt);<br>Adults | <u>Eggs and larvae</u>: Channel dewatering will cause egg mortality.<br><u>Juveniles</u>: Juvenile smelt are generally believed to migrate offshore and will therefore not likely be exposed to dewatering. Lake Washington longfin smelt are an exception; potential nearshore habitat use by this population is currently a data gap.<br><u>Adults</u>: Capture, handling, and relocation are likely to cause mortality or injury and stress leading to mortality or decreased spawning fitness. Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults. | Unlikely to affect eggs, larvae, and adults if activities are conducted during in-water work windows. Capture and removal of eggs, larvae, and juveniles is impractical, meaning that activities occurring during incubation and emigration periods may affect survival during these life-history stages. Capture and removal of adults are likely to affect survival and spawning productivity. |



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**Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | <u>Eggs, larvae, and juveniles</u>: Pump entrainment is highly likely to cause mortality of larvae and drifting eggs. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles.<br><u>Adults</u>: Impingement is likely to cause adult mortality. | Adhere to system-specific in-water work windows; avoid use of dewatering pumps during spawning, incubation, and larval dispersal. | Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted during in-water work windows. If activities are permitted outside the in-water work windows, activity may affect adult and egg and larval survival. The potential for effects on juvenile smelt survival in marine habitats and Lake Washington are unknown because habitat use by this life-history stage is a data gap. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Adults | <u>Eggs and larvae</u>: Potential scour of spawning substrate and/or sedimentation, resulting in decreased incubation success. Potential larval dispersal to unfavorable habitats, decreasing larval survival and productivity.<br><u>Adults</u>: Decreased availability of suitable spawning sites; decreased spawning success. | Adhere to system-specific in-water work windows, avoid use during spawning, incubation, and larval dispersal. Limit alteration of flow conditions to minimal area. | Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted during in-water work windows. If activities are permitted during in-water work windows, activity may affect adult spawning productivity and egg and larval survival. |
| | | Altered current and circulation conditions (marine and lacustrine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | <u>Juveniles</u>: Nearshore habitat use by smelt is currently a data gap, so the potential for exposure to this stressor is unknown. | Limit alteration of current and circulation patterns to greatest extent practicable to minimal area. | The potential for this mechanism to affect juvenile smelt is currently unknown because dependence on nearshore circulation patterns is currently a data gap. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering). | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Adults | <u>Eggs and larvae</u>: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance.<br><u>Adults</u>: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, increased predation exposure, decreased spawning habitat suitability. | Adhere to system-specific in-water work windows. Avoid work during egg incubation periods. | Unlikely to affect egg survival and adult spawning productivity when activities are conducted during in-water work windows. May affect these parameters if activities occur during spawning and incubation. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles | <u>Juveniles</u>: With the exception of the Lake Washington longfin population, smelt do not feed on benthic organisms in freshwater systems and will be unaffected by this stressor. In Lake Washington and in marine systems, smelt are planktonic feeders that are not likely to be affected by temporary decreases in benthic invertebrate abundance. | Limit area of dewatering to the greatest extent practicable. | Not likely to affect smelt at any life-history stage. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Adults | <u>All life-history stages</u>: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual-decadal | Eggs;<br>Larvae;<br>Adults | <u>All life-history stages</u>: See responses described under Hydraulic and Geomorphic Modifications. | Avoid fill or if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |

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**Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual-decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual-decadal | Eggs; Larvae; Juveniles; Adults | Eggs and larvae: Incubating eggs entrained during dredging will suffer high mortality. Juveniles: The potential for juvenile exposure to these stressors is unknown because habitat use is currently a data gap. All life-history stages: See responses described for related stressors under Water Quality Modification. | Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Unlikely to affect survival of eggs and larvae if activities are conducted during in-water work windows. Likely to affect egg survival and larval survival and productivity if exposure occurs. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | Eggs and larvae: Turbidity sufficient to cause burial or coating of eggs may lead to direct mortality. Increased turbidity may decrease larval foraging success, resulting in decreased growth and fitness. Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating eggs. May affect juvenile productivity, adult productivity, and spawning success. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved events due to asphyxiation. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness. | Avoid sediment pulses. | May affect survival of incubating eggs. May affect juvenile survival and productivity and adult survival, productivity, and spawning success. |

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**Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Physiological responses to pH levels outside of optimal thresholds, causing direct mortality or injury leading to reduced fitness. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and productivity of eggs and larvae, juveniles, and adults |
| | Use of creosote-treated wood | Leaching of polyaromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs;<br>Larvae;<br>Juveniles | <u>Eggs and larvae, juveniles</u>: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br><u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival and productivity of eggs, larvae, and juveniles |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn), | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs;<br>Larvae;<br>Juveniles; | <u>Eggs and larvae, juveniles</u>: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Adults | <u>Adults</u>: Decreased spawning productivity and fitness due to migration delays caused by low water temperatures. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect spawning productivity. |
| | Altered stream bank and shoreline stability | Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., alteration of spawning substrate) | Year-round (with specific stressors prominent during high-flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs;<br>Larvae;<br>Adults | <u>Eggs and larvae:</u> Decreased incubation success due to smothering of eggs as described for related stressor responses under Water Quality Modification.<br><u>Adults:</u> Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival during egg incubation; may affect spawning fitness and productivity. |
| | Altered allochthonous inputs | Reduced aquatic food web productivity due to reduction in organic matter inputs | Year-round | Permanent | Continuous | Larvae | <u>Larvae:</u> Larval longfin smelt and eulachon feed on forage on riverine plankton following emergence and transport to estuarine and marine habitats. Reduced allochthonous inputs may affect food web productivity, leading to decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect larval growth and fitness. |

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## Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Adults | <u>Adults:</u> Reduced habitat complexity may affect the availability of suitable spawning habitat leading to decreased spawning productivity. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect adult spawning productivity. |
| | Altered groundwater-surface water exchange | Reduced available suitable spawning habitat; reduced gravel dissolved oxygen | Year-round | Permanent | Continuous | Unknown | Longfin smelt and eulachon dependence on groundwater exchange is currently a data gap. | Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater recharge. Limit alteration of riparian vegetation to greatest extent practicable. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | **Marine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Larvae; Juveniles | <u>Larvae and juveniles</u>: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. Dependence of larval and juvenile longfin smelt and eulachon on these habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high-wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Larvae; Juveniles | <u>Larvae and juveniles</u>: Dependence of larval and juvenile longfin smelt and eulachon on these habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Larvae; Juveniles | <u>Larvae and juveniles</u>: Longfin smelt and eulachon dependence on allochthonous inputs from marine riparian vegetation is a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Larvae; Juveniles | <u>Larvae and juveniles</u>: Dependence of larval and juvenile smelt on these habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | Altered freshwater inputs | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Larvae; Juveniles | <u>Larvae and juveniles</u>: Dependence of larval and juvenile smelt on surface water and groundwater exchange in nearshore habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |

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**Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures). | Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | Larvae, juveniles, and adults: Riparian shade and ambient temperature has a relatively minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade. Dependence of juvenile longfin smelt on these habitats is currently a data gap. Therefore the potential for exposure to these stressors is unknown. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | Potential effects resulting from this impact mechanism are unknown. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation). | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | Larvae, juveniles, and adults: Potential habitat avoidance and/or injury/mortality caused by excessive turbidity, potential for decreased foraging success leading to decreased growth and fitness as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile and adult survival and productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | Larvae, juveniles, and adults: Longfin smelt dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. Therefore the potential for exposure to these stressors is unknown. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | Potential effects resulting from this impact mechanism are unknown. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | Larvae, juveniles, and adults: Dependence of larval, juvenile, and adult longfin smelt on these habitats is currently a data gap, Therefore the potential for exposure to these stressors is unknown. | Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible. | Potential effects resulting from this impact mechanism are unknown. |
| | Altered groundwater surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | Larvae, juveniles, and adults: Longfin smelt dependence on groundwater inflow to nearshore lacustrine habitats is currently a data gap. Therefore the potential for exposure to these stressors is unknown. | Avoid disturbance of vegetation along stream | Potential effects resulting from this impact mechanism are unknown. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Larvae;<br>Juveniles;<br>Adults | All exposed life-history stages: Longfin smelt and eulachon dependence on marine littoral vegetation and the nearshore marine environment is currently a data gap. Therefore, the potential for exposure to these stressors is unknown. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | | | | |

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### Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Riverine and Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity. | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Eggs; Larvae; Adults | All exposed life-history stages: Smelt dependence on freshwater submerged aquatic vegetation is currently a data gap. Therefore, the potential for exposure to these stressors is unknown. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability | Year-round | Permanent | Continuous | Eggs; Larvae; Juveniles; Adults | Eggs: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Larvae and juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival at egg and larval life-history stages. May affect spawning productivity. |
| | Altered flow velocity | | Year-round, with stressor exposure occurring during high flow events, fall through spring | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round, with stressor exposure occurring during egg incubation and juvenile rearing | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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**Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round, with stressor exposure occurring in spring and summer when larvae and juveniles occupy nearshore habitats for rearing | Permanent | Continuous | Larvae; Juveniles; Adults | Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Longfin smelt and eulachon dependence on these habitats is currently a data gap. However, alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Adults: Alteration of nearshore habitat parameters may affect survival and foraging opportunities at larval and juvenile life-history stages, leading to decreased adult fitness, decreased survival, and decreased spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at the larval and juvenile life-history stages. Decreased fitness may affect survival and productivity during ocean migration life-history phase, and may affect spawning productivity. |
| | Altered current velocities | | Year-round, with variable effects depending on site-specific current dynamics and project configuration | Permanent | Intermittent | | | | |
| | Altered sediment supply | | Year-round, beginning with project installation and becoming more pronounced over time | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round, beginning with project installation and becoming more pronounced over time (e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round, with predominant effects from fall through spring when wind-driven waves are most pronounced | Permanent | Continuous | Lake Washington longfin smelt. Larvae; Juveniles; Adults | Larvae, juveniles, and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, with concomitant food web effects throughout the lacustrine ecosystem. Therefore, alteration of these parameters may affect foraging opportunities for longfin smelt at larval and juvenile life-history stages, leading to decreased adult fitness and decreased spawning success. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect productivity at larval and juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round, with effects more predominant in reservoirs versus natural lakes | Permanent | Common | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat; change in habitat structure, availability, and suitability; reduced food web complexity | Year-round | Permanent | Continuous | Adults | Adults: Bank barbs and groins can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor is unlikely to significantly affect mainstem spawning eulachon and longfin smelt. Planktonic larvae are carried downstream to estuarine habitats, and are not dependent on floodplain habitats. | Require assessment of the hydraulic effects of the project before permitting, and avoid permitting designs that lead to disconnection of floodplain habitat. | Unlikely to significantly affect mainstem spawning eulachon and longfin smelt |

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### Table A-15 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Loss of LWD recruitment | Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect juvenile growth and survival, as well as spawning success and overall population productivity. |
| | **Marine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Larvae;<br>Juvenile;<br>Adult | <u>All exposed life-history stages</u>: Bank barbs and groins in the marine environment can fragment nearshore habitat. Eulachon and longfin smelt are known to use these habitat types during juvenile and adult life-history stages, and are likely to occur as larvae as well. Groins and bank barbs may alter migration of adults toward spawning habitats, larval dispersal, and juvenile foraging, affecting survival, growth, and fitness at all life-history stages. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles. | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | <u>All exposed life-history stages</u>: Longfin smelt dependence on nearshore habitats in Lake Washington is currently a data gap. Therefore the effects of this stressor are unknown. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Lake Washington longfin smelt.<br>Larvae;<br>Juveniles;<br>Adults | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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## Table A-16. HPA HCP Shoreline Modification Exposure and Response Matrix for Surf Smelt and Sand Lance.

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| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Larvae;<br>Juveniles;<br>Adults | <u>Larvae</u>: Noise of sufficient magnitude may cause direct mortality of larvae, or permanent injury leading to decreased survival and fitness. Eggs are unlikely to be exposed to pile driving noise due to position in intertidal environment.<br><u>Adults and juveniles</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Fatal injury or permanent auditory tissue damage limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Where possible, avoid stressor exposure during site-specific spawn timing, incubation, and larval dispersal. Require review of available data and/or site surveys to avoid exposure of spawners to stressor. If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | May affect survival and productivity during larval, juvenile, and adult life-history stages. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | <u>Adults and juveniles</u>: May cause avoidance behavior leading to increased stress and decreased foraging opportunity. Auditory masking or temporary hearing threshold effects may increase risk of predation due to decreased ability to sense predators. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults. | May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | <u>Larvae and juveniles</u>: These life-history stages will be difficult to capture and relocate effectively.<br><u>Adults</u>: Capture, handling, and relocation is likely to cause mortality, or injury and stress leading to mortality or decreased spawning fitness. Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Require review of available data and/or site surveys to reduce likelihood of stressor exposure. | Capture/removal of larvae and juveniles is impractical, meaning that these activities are likely to affect larval and juvenile survival. Capture and removal of adults is likely to affect survival and spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | <u>Larvae and juveniles</u>: Pump entrainment is likely to cause mortality of drifting larvae. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles.<br><u>Adults</u>: Impingement is likely to cause adult mortality. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Require review of available data and/or site surveys to reduce likelihood of stressor exposure. | May cause injury and mortality of larvae, juveniles, and adults. Effects are less likely to occur if activities are conducted outside of spawning season. |

**Table A-16 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Surf Smelt and Sand lance.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification.<br>Juveniles: Nearshore habitat use by smelt is currently a data gap, so the potential for exposure to this stressor is unknown. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | See effects for related stressors under Hydraulic and Geomorphic Modification.<br>The potential for this mechanism to affect juvenile smelt is currently unknown because dependence on nearshore circulation patterns is a data gap. |
| | | Bottom disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | Larvae: Potential decreased larval foraging success due to turbidity exposure and substrate disturbance, leading to decreased growth and fitness.<br>Adults and juveniles: Stress caused by avoidance behavior; decreased foraging success due to increased turbidity levels. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May affect larval productivity. May affect juvenile and adult survival and productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | All life-history stages: Surf smelt and sand lance dependence on benthic invertebrates for forage is likely limited but is currently a data gap. Therefore, the potential effects of stressor exposure are unknown. | Limit area of dewatering to the greatest extent practicable. | Potential effects resulting from this impact mechanism are unknown. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Larvae;<br>Juveniles;<br>Adults | All life-history stages: Entrainment of smelt and sand lance during dredging is likely to cause mortality or injury, leading to decreased survival. See responses described for related stressors under Water Quality Modification. | Require review of available data and/or site surveys to reduce likelihood of larval and adult stressor exposure. Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Unlikely to affect survival of larvae and adults if activities are conducted during in-water work windows. Likely to affect survival at any life-history stage if exposure occurs. See effects for related stressors under Water Quality Modification. |

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**Table A-16 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Surf Smelt and Sand lance.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Larvae;<br>Juveniles;<br>Adults | <u>Larvae</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness.<br><u>Adults and juveniles</u>: Same effects as above, as well as increased stress and decreased foraging opportunity due to avoidance behavior. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival and productivity at larval, juvenile, and adult life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation.<br><u>Juveniles and adults</u>: Avoidance behavior and increased stress, leading to reduced growth and fitness. | Avoid sediment pulses. | May affect larval, juvenile, and adult survival and productivity. Reduced adult fitness may affect spawning productivity. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br><u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival and productivity of eggs, larvae, juveniles, and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs;<br>Larvae;<br>Larvae;<br>Juveniles | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |

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**Table A-16 (continued).  HPA HCP Shoreline Modification Exposure and Response Matrix for Surf Smelt and Sand lance.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Eggs | Eggs:  Surf smelt and sand lance incubation success is demonstrably affected by microclimate conditions in the nearshore environment that are influenced by riparian vegetation.  Alteration of riparian vegetation has been demonstrated to reduce egg survival and incubation success. | Avoid/minimize disturbance of riparian vegetation.  Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect egg survival, decreasing population productivity. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs:  Smothering of incubating eggs or alteration of substrate composition may decrease egg survival.<br>Larvae and juveniles:  See responses to increased turbidity exposure described under Water Quality Modification.<br>Adults:  Potential reduction of suitable spawning habitat, leading to decreased spawning productivity. | Avoid/minimize disturbance of riparian vegetation.  Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect egg survival.  May affect growth and fitness at larval and juvenile life-history stages.  May affect adult spawning fitness and productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs:  Leaf litter and other detritus may influence microclimate conditions in spawning substrates.  Reduction in leaf litter may cause reduced incubation success.<br>Larvae, juveniles, and adults:  Dependence on allochthonous inputs from marine riparian vegetation is a data gap. | Avoid/minimize disturbance of riparian vegetation.  Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival of incubating eggs.  Potential effects resulting from this impact mechanism on remaining life-history stages are unknown. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate.  Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Larvae;<br>Juveniles;<br>Adults | All life-history stages:  Altered habitat complexity is likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation.  Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap for these species; the potential effects resulting from this impact mechanism are unknown. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs:  Groundwater inflow demonstrably affects substrate temperatures, creating favorable conditions for egg incubation.<br>Larvae and juveniles:  Dependence of larval and juvenile forage fish on surface water and groundwater exchange in nearshore habitats is currently a data gap; the potential for exposure to these stressors is unknown.<br>Adults: Altered groundwater inflow may affect spawning habitat suitability, leading to decreased spawning success. | Avoid/minimize disturbance of riparian vegetation.  Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect egg survival and adult spawning productivity.  Potential effects resulting from this impact mechanism on larvae and juveniles are unknown. |

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## Table A-16 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Surf Smelt and Sand lance.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs: Alteration or reduction of submerged aquatic vegetation component of beach wrack may affect microclimate conditions in spawning substrates, decreasing egg survival (particularly during spring and summer spawning).<br>All life-history stages: Altered autochthonous production and habitat complexity are likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect growth and fitness at egg, larval, juvenile, and adult life-history stages. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | | | | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when larvae and juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Egg incubation success may be affected by alteration in wave energy patterns and groundwater inputs. Alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Therefore, alteration of these parameters may affect foraging opportunities for at larval and juvenile life-history stages, leading to decreased adult fitness, decreased survival, and decreased spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect egg incubation success, May affect survival at the larval and juvenile life-history stages. May affect juvenile and adult growth and fitness. Decreased fitness may affect spawning productivity. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |

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Table A-16 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Surf Smelt and Sand lance.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Larvae;<br>Juveniles;<br>Adults | Larvae and juveniles: Jetties fragment nearshore marine rearing habitat, forcing larval and juvenile surf-smelt and sandlance to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion. These stressors may affect survival, growth, and fitness.<br>Adults: The physical footprint of jetties and their geomorphic effects on the upper intertidal zone may eliminate or decrease the suitability of spawning habitat, potentially limiting the spawning productivity of affected populations. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect larval and juvenile survival, growth, and fitness. May affect adult survival, fitness, and spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Larvae;<br>Juveniles;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | Sensitivity to stressor exposure is currently a data gap for these species; the potential effects resulting from this impact mechanism are unknown. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Larvae;<br>Juveniles;<br>Adults | Larvae: Noise of sufficient magnitude may cause direct mortality of larvae, or permanent injury leading to decreased survival and fitness. Eggs are unlikely to be exposed to pile driving noise due to position in intertidal environment.<br>Adults and juveniles: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Fatal injury or permanent auditory tissue damage limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Where possible, avoid stressor exposure during site-specific spawn timing, incubation, and larval dispersal. Require review of available data and/or site surveys to avoid exposure of spawners to stressor. If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | May affect survival and productivity during larval, juvenile, and adult life-history stages. |

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## Table A-16 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Surf Smelt and Sand lance.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | <u>Adults and juveniles</u>: May cause avoidance behavior leading to increased stress and decreased foraging opportunity. Auditory masking or temporary hearing threshold effects may increase risk of predation due to decreased ability to sense predators. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults. | May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | <u>Larvae and juveniles</u>: These life-history stages will be difficult to capture and relocate effectively.<br><u>Adults</u>: Capture, handling, and relocation is likely to cause mortality, or injury and stress leading to mortality or decreased spawning fitness. Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Require review of available data and/or site surveys to reduce likelihood of stressor exposure. | Capture/removal of larvae and juveniles is impractical, meaning that these activities are likely to affect larval and juvenile survival. Capture and removal of adults is likely to affect survival and spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | <u>Larvae and juveniles</u>: Pump entrainment is likely to cause mortality of drifting larvae. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles.<br><u>Adults</u>: Impingement is likely to cause adult mortality. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Require review of available data and/or site surveys to reduce likelihood of stressor exposure. | May cause injury and mortality of larvae, juveniles, and adults. Effects are less likely to occur if activities are conducted outside of spawning season. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: See responses described under Hydraulic and Geomorphic Modification.<br><u>Juveniles</u>: Nearshore habitat use by smelt is currently a data gap, so the potential for exposure to this stressor is unknown. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | See effects for related stressors under Hydraulic and Geomorphic Modification.<br>The potential for this mechanism to affect juvenile smelt is currently unknown because dependence on nearshore circulation patterns is a data gap. |
| | | Bottom disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | <u>Larvae</u>: Potential decreased larval foraging success due to turbidity exposure and substrate disturbance, leading to decreased growth and fitness.<br><u>Adults and juveniles</u>: Stress caused by avoidance behavior; decreased foraging success due to increased turbidity levels. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May affect larval productivity. May affect juvenile and adult survival and productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Surf smelt and sand lance dependence on benthic invertebrates for forage is likely limited but is currently a data gap. Therefore, the potential effects of stressor exposure are unknown. | Limit area of dewatering to the greatest extent practicable. | Potential effects resulting from this impact mechanism are unknown. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |

**Table A-16 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Surf Smelt and Sand lance.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Larvae; Juveniles; Adults | All life-history stages: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Larvae; Juveniles; Adults | All life-history stages: Entrainment of smelt and sand lance during dredging is likely to cause mortality or injury, leading to decreased survival. See responses described for related stressors under Water Quality Modification. | Require review of available data and/or site surveys to reduce likelihood of larval and adult stressor exposure. Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Unlikely to affect survival of larvae and adults if activities are conducted during in-water work windows. Likely to affect survival at any life-history stage if exposure occurs. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Larvae; Juveniles; Adults | Larvae: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness.<br>Adults and juveniles: Same effects as above, as well as increased stress and decreased foraging opportunity due to avoidance behavior. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival and productivity at larval, juvenile, and adult life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.<br>Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness. | Avoid sediment pulses. | May affect larval, juvenile, and adult survival and productivity. Reduced adult fitness may affect spawning productivity. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to | May affect survival and productivity of eggs, larvae, juveniles, and adults. |

## Table A-16 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Surf Smelt and Sand lance.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs; Larvae; Larvae; Juveniles | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | avoid fragmentation and release of treated wood particulates. Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Eggs; Larvae; Juveniles; Adults | Eggs: Alteration or reduction of submerged aquatic vegetation component of beach wrack may affect microclimate conditions in spawning substrates, decreasing egg survival (particularly during spring and summer spawning). All life-history stages: Altered autochthonous production and habitat complexity are likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect growth and fitness at egg, larval, juvenile, and adult life-history stages. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | | | | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when larvae and juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Eggs; Larvae; Juveniles; Adults | All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Egg incubation success may be affected by alteration in wave energy patterns and groundwater inputs. Alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Therefore, alteration of these parameters may affect foraging opportunities for at larval and juvenile life- | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival at the larval and juvenile life-history stages. May affect juvenile and adult growth and fitness. Decreased fitness may affect spawning productivity. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |

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**Table A-16 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Surf Smelt and Sand lance.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | history stages, leading to decreased adult fitness, decreased survival, and decreased spawning productivity. | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Larvae;<br>Juveniles;<br>Adults | <u>All exposed life history stages</u>: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators. Juvenile and adult Lake surf smelt and sand lance may be exposed to increased predation exposure. Larvae may experience similar exposure, but increased predation rates are most likely insignificant relative to natural mortality. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile and adult survival. May affect larval survival, but effects will be insignificant relative to natural mortality. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Larvae;<br>Juveniles;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | Sensitivity to stressor exposure is currently a data gap for these species; the potential effects resulting from this impact mechanism are unknown. |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Larvae;<br>Juveniles;<br>Adults | <u>Larvae</u>: Noise of sufficient magnitude may cause direct mortality of larvae, or permanent injury leading to decreased survival and fitness. Eggs are unlikely to be exposed to pile driving noise due to position in intertidal environment.<br><u>Adults and juveniles</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Fatal injury or permanent auditory tissue damage limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Where possible, avoid stressor exposure during site-specific spawn timing, incubation, and larval dispersal. Require review of available data and/or site surveys to avoid exposure of spawners to stressor. If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | May affect survival and productivity during larval, juvenile, and adult life-history stages. |

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**Table A-16 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Surf Smelt and Sand lance.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: May cause avoidance behavior leading to increased stress and decreased foraging opportunity. Auditory masking or temporary hearing threshold effects may increase risk of predation due to decreased ability to sense predators. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults. | May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | Larvae and juveniles: These life-history stages will be difficult to capture and relocate effectively.<br>Adults: Capture, handling, and relocation is likely to cause mortality, or injury and stress leading to mortality or decreased spawning fitness. Delayed migration resulting in decreased fitness and spawning success. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Require review of available data and/or site surveys to reduce likelihood of stressor exposure. | Capture/removal of larvae and juveniles is impractical, meaning that these activities are likely to affect larval and juvenile survival. Capture and removal of adults is likely to affect survival and spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | Larvae and juveniles: Pump entrainment is likely to cause mortality of drifting larvae. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles.<br>Adults: Impingement is likely to cause adult mortality. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Require review of available data and/or site surveys to reduce likelihood of stressor exposure. | May cause injury and mortality of larvae, juveniles, and adults. Effects are less likely to occur if activities are conducted outside of spawning season. |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification.<br>Juveniles: Nearshore habitat use by smelt is currently a data gap, so the potential for exposure to this stressor is unknown. | To greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | See effects for related stressors under Hydraulic and Geomorphic Modification.<br>The potential for this mechanism to affect juvenile smelt is currently unknown because dependence on nearshore circulation patterns is a data gap. |
| | | Bottom disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | Larvae: Potential decreased larval foraging success due to turbidity exposure and substrate disturbance, leading to decreased growth and fitness.<br>Adults and juveniles: Stress caused by avoidance behavior; decreased foraging success due to increased turbidity levels. | Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. | May affect larval productivity. May affect juvenile and adult survival and productivity. |
| | | Localized alteration in invertebrate abundance | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | All life-history stages: Surf smelt and sand lance dependence on benthic invertebrates for forage is likely limited but is currently a data gap. Therefore, the potential effects of stressor exposure are unknown. | Limit area of dewatering to the greatest extent practicable. | Potential effects resulting from this impact mechanism are unknown. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |

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## Table A-16 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Surf Smelt and Sand lance.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Larvae;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Larvae;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Entrainment of smelt and sand lance during dredging is likely to cause mortality or injury, leading to decreased survival. See responses described for related stressors under Water Quality Modification. | Require review of available data and/or site surveys to reduce likelihood of larval and adult stressor exposure. Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Unlikely to affect survival of larvae and adults if activities are conducted during in-water work windows. Likely to affect survival at any life-history stage if exposure occurs. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual-decadal (dependent on contributing mechanism of impact) | Larvae;<br>Juveniles;<br>Adults | <u>Larvae</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness.<br><u>Adults and juveniles</u>: Same effects as above, as well as increased stress and decreased foraging opportunity due to avoidance behavior. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival and productivity at larval, juvenile, and adult life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation.<br><u>Juveniles and adults</u>: Avoidance behavior and increased stress, leading to reduced growth and fitness. | Avoid sediment pulses. | May affect eggs, larval, juvenile, and adult survival and productivity. Reduced adult fitness may affect spawning productivity. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to | May affect survival and productivity of larvae, juveniles, and adults. |

**Table A-16 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Surf Smelt and Sand lance.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs;<br>Larvae;<br>Larvae;<br>Juveniles | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | avoid fragmentation and release of treated wood particulates.<br><u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input, ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Eggs | <u>Eggs</u>: Surf smelt and sand lance incubation success is demonstrably affected by microclimate conditions in the nearshore environment that are influenced by riparian vegetation. Alteration of riparian vegetation has been demonstrated to reduce egg survival and incubation success. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect egg survival, decreasing population productivity. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | <u>Eggs</u>: Smothering of incubating eggs or alteration of substrate composition may decrease egg survival.<br><u>Larvae and juveniles</u>: See responses to increased turbidity exposure described under Water Quality Modification.<br><u>Adults</u>: Potential reduction of suitable spawning habitat, leading to decreased spawning productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect egg survival. May affect growth and fitness at larval and juvenile life-history stages. May affect adult spawning fitness and productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | <u>Eggs</u>: Leaf litter and other detritus may influence microclimate conditions in spawning substrates. Reduction in leaf litter may cause reduced incubation success.<br><u>Larvae, juveniles, and adults</u>: Dependence on allochthonous inputs from marine riparian vegetation is a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival of incubating eggs. Potential effects resulting from this impact mechanism on remaining life-history stages are unknown. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Larvae;<br>Juveniles;<br>Adults | <u>All life-history stages</u>: Altered habitat complexity is likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Sensitivity to stressor exposure is currently a data gap for these species; the potential effects resulting from this impact mechanism are unknown. |

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## Table A-16 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Surf Smelt and Sand lance.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs: Groundwater inflow demonstrably affects substrate temperatures, creating favorable conditions for egg incubation.<br>Larvae and juveniles: Dependence of larval and juvenile forage fish on surface water and groundwater exchange in nearshore habitats is currently a data gap; the potential for exposure to these stressors is unknown.<br>Adults: Altered groundwater inflow may affect spawning habitat suitability, leading to decreased spawning success. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect egg survival and adult spawning productivity. Potential effects resulting from this impact mechanism on larvae and juveniles are unknown. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs: Alteration or reduction of submerged aquatic vegetation component of beach wrack may affect microclimate conditions in spawning substrates, decreasing egg survival (particularly during spring and summer spawning).<br>All life-history stages: Altered autochthonous production and habitat complexity are likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect growth and fitness at egg, larval, juvenile, and adult life-history stages. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | | | | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring in spring and summer when larvae and juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Egg incubation success may be affected by alteration in wave energy patterns and groundwater inputs. Alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Therefore, alteration of these parameters may affect foraging opportunities for at larval and juvenile life-history stages, leading to decreased adult fitness, decreased survival, and decreased spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival at the egg, larval and juvenile life-history stages. May affect juvenile and adult growth and fitness. Decreased fitness may affect spawning productivity. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |

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**Table A-16 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Surf Smelt and Sand lance.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Larvae;<br>Juveniles;<br>Adults | Larvae and juveniles: Bank barbs and groins in the marine environment can fragment nearshore rearing habitat, forcing larval and juvenile surf-smelt and sandlance to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion. These stressors may affect survival, growth, and fitness.<br>Adults: The physical footprint of groins and bank barbs and their geomorphic effects on the upper intertidal zone may eliminate or decrease the suitability of spawning habitat, potentially limiting the spawning productivity of affected populations. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect larval and juvenile survival, growth, and fitness. May affect adult survival, fitness, and spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Larvae;<br>Juveniles;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | Sensitivity to stressor exposure is currently a data gap for these species; the potential effects resulting from this impact mechanism are unknown. |

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## Table A-17. HPA HCP Shoreline Modifications Exposure and Response Matrix for Pacific Herring.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs and larvae: Noise of sufficient magnitude may cause direct mortality of eggs and larvae, or permanent injury leading to decreased survival and fitness.<br>Adults and juveniles: Stressor response, dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Fatal injury or permanent auditory tissue damage limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Where possible, avoid stressor exposure during site-specific spawn timing, incubation, and larval dispersal. Require review of available data and/or site surveys to determine if spawning adults or rearing larvae are likely to be present, and time activities to avoid stressor exposure. If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | May affect survival during egg, larval, juvenile, and adult life-history stages. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: May cause avoidance behavior leading to increased stress and decreased foraging opportunity. Auditory masking or temporary hearing threshold effects may increase risk of predation due to decreased ability to sense predators. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. Limit activities to in-water work windows where practicable. | May affect growth, fitness, and survival due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs: Extended dewatering may lead to egg desiccation or thermal exposure, causing mortality, or larval abnormalities limiting to survival.<br>Larvae and juveniles: Dewatering is likely to lead to mortality, as larval and juvenile herring will be difficult to capture and relocate effectively.<br>Adults: Capture, handling, and relocation are likely to cause mortality, or injury and stress, leading to mortality or decreased spawning fitness. | Limit activities to in-water work windows where practicable. | Dewatering and fish removal in marine habitats is an unlikely requirement for jetty development. However, in the event that such activities are required, adverse effects on exposed life-history stages should be expected. Capture and removal of larvae and juveniles is impractical, meaning that these activities are likely to affect larval and juvenile survival. Capture and removal of adults is likely to affect survival and spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | Larvae and juveniles: Pump entrainment is likely to cause mortality of drifting larvae. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles.<br>Adults: Impingement is likely to cause adult mortality. | Adhere to in-water work windows; avoid use during spawning, incubation, and larval dispersal. | May cause injury and mortality of larvae, juveniles, and adults. Effects are less likely to occur if activities are conducted outside of spawning season. |

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### Table A-17 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pacific Herring.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae | Larvae: Alteration of nearshore current and circulation patterns may cause larvae to be transported offshore or into habitats with increased predation risk and reduced foraging opportunity, limiting survival, growth, and fitness. | To the greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | May affect larval survival, growth, and fitness. |
| | | Bottom disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Larvae: Potential decreased larval foraging success due to turbidity exposure and substrate disturbance, leading to decreased growth and fitness.<br>Adults and juveniles: Stress caused by avoidance behavior; decreased foraging success due to increased turbidity levels.<br>Adults: Decreased availability of spawning substrate due to sedimentation effects on submerged aquatic vegetation.<br>All life-history stages: See responses to related stressors under Water Quality Modification. | Adhere to in-water work windows; avoid activity during spawning, incubation, and larval dispersal. | The likely stressor is increased suspended solids. May affect larval growth and survival. May affect juvenile and adult survival. May affect adult spawning productivity. |
| | | Localized alteration in invertebrate abundance | NA | NA | NA | NA | NA | NA | NA |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Larvae;<br>Juveniles;<br>Adults | All life-history stages: Entrainment of larval herring during dredging is likely to cause mortality or injury, leading to decreased survival. See responses described for related stressors under Water Quality Modification. | Require review of available data and/or site surveys to determine if spawning adults or rearing larvae are likely to be present, and time activities to avoid stressor exposure. Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Increased suspended solids and resuspension of contaminated sediments would be the likely stressors. Unlikely to affect survival of larvae and adults if activities are conducted during in-water work windows. Likely to affect survival at any life-history stage if exposure occurs. See effects for related stressors under Water Quality Modification. |

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**Table A-17 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pacific Herring.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | Eggs: Effects of suspended sediments on incubating herring eggs is currently a data gap. Larvae: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. Adults and juveniles: Same effects as above, as well as increased stress and decreased foraging opportunity due to avoidance behavior. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bluff/bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival and productivity at egg, larval, juvenile, and adult life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness. | Avoid sediment resuspension. | Decreased spawning habitat area. May affect egg, larval, juvenile, and adult survival and productivity. Reduced adult fitness may affect spawning productivity. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. Herring eggs are at an increased risk of exposure due to herring tendency to lay eggs directly on pilings and other vertical structures in the nearshore environment. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates. Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival and productivity of eggs, larvae, juveniles, and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. Herring eggs are at an increased risk of exposure due to herring tendency to lay eggs directly on pilings and other vertical structures in the nearshore environment. | | |

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## Table A-17 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pacific Herring.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures) | Pronounced in summer during solar radiation and ambient temperature extremes | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Eggs | Eggs: The influence of marine riparian shading on herring incubation is likely limited due to the typical elevation of herring spawn in the upper subtidal zone. However, the effects of this stressor are currently a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Potential effects resulting from this impact mechanism are unknown. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs, larvae, and juveniles: See responses to increased turbidity exposure described under Water Quality Modification.<br>Adults: Potential reduction of suitable spawning habitat, leading to decreased spawning productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect egg survival. May affect productivity at larval and juvenile life-history stages. May affect adult spawning productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduced organic matter inputs. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles;<br>Adults | Juveniles and adults: Dependence on allochthonous inputs from marine riparian vegetation is a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Potential effects resulting from this impact mechanism on remaining life-history stages are unknown. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Larvae;<br>Juveniles;<br>Adults | All life-history stages: Altered habitat complexity is likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect larval, juvenile, and adult productivity. May affect adult spawning productivity. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Eggs;<br>Larvae;<br>Adults | Eggs and larvae: Herring egg and larval development is demonstrably affected by surface water salinities beyond tolerance thresholds. Alteration of salinity characteristics may limit egg survival or cause larval abnormalities limiting to survival, growth, and fitness.<br>Adults: The influence of surface water and groundwater exchange on spawning habitat suitability is currently a data gap. However, alteration of this habitat parameter that affect submerged aquatic vegetation may decrease availability and/or suitability of spawning habitat. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect egg and larval survival and productivity. May affect adult spawning productivity. |

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## Table A-17 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pacific Herring.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs: Alteration or reduction of submerged aquatic vegetation may affect microclimate conditions in spawning substrates, decreasing egg survival.<br>All life-history stages: Altered habitat complexity is likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness.<br>Adults: Reductions in available submerged aquatic vegetation or alteration of submerged aquatic vegetation community composition may limit spawning productivity. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect productivity at larval, egg, juvenile, and adult life-history stages. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat. | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round(with stressor exposure occurring when larvae and juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All exposed life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Alteration in the aerial extent and composition of the submerged aquatic vegetation community resulting from these mechanisms may reduce available spawning habitat, leading to reduced spawning productivity. Egg incubation success may be affected by alteration in wave energy patterns. Alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Therefore, alteration of these parameters may affect foraging opportunities at the juvenile life-history stage, over time leading to decreased adult fitness, decreased survival, and decreased spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect egg and larval survival and larval fitness. Decreased larval fitness may affect survival and productivity during juvenile and adult life-history phases in offshore and open ocean environments, and may affect spawning productivity. Loss or alteration of suitable spawning habitat may affect spawning productivity. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater surface water exchange | | Year-round | Permanent | Continuous | | | | |

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Table A-17 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pacific Herring.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Larvae;<br>Juveniles;<br>Adults | Larvae and juveniles: Jetties fragment nearshore marine rearing habitat, potentially forcing planktonic herring away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion.<br>Adults: The physical footprint of jetties and their geomorphic effects on the middle and lower intertidal zone may eliminate or decrease the suitability of spawning habitat, potentially limiting the spawning productivity of affected populations. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect larval and juvenile survival, growth, and fitness. May affect adult survival, fitness, and spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs and larvae: Noise of sufficient magnitude may cause direct mortality of eggs and larvae, or permanent injury leading to decreased survival and fitness.<br>Adults and juveniles: Stressor response, dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Fatal injury or permanent auditory tissue damage limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Where possible, avoid stressor exposure during site-specific spawn timing, incubation, and larval dispersal. Require review of available data and/or site surveys to determine if spawning adults or rearing larvae are likely to be present, and time activities to avoid stressor exposure. If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | May affect survival during egg, larval, juvenile, and adult life-history stages. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: May cause avoidance behavior leading to increased stress and decreased foraging opportunity. Auditory masking or temporary hearing threshold effects may increase risk of predation due to decreased ability to sense predators. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. Limit activities to in-water work windows where practicable. | May affect growth, fitness, and survival due to avoidance behavior, decreased foraging success, and increased predation risk. |

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**Table A-17 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pacific Herring.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs: Extended dewatering may lead to egg desiccation or thermal exposure, causing mortality, or larval abnormalities limiting to survival.<br>Larvae and juveniles: Dewatering is likely to lead to mortality, as larval and juvenile herring will be difficult to capture and relocate effectively.<br>Adults: Capture, handling, and relocation are likely to cause mortality, or injury and stress, leading to mortality or decreased spawning fitness. | Limit activities to in-water work windows where practicable. | Dewatering and fish removal in marine habitats is an unlikely requirement for breakwater development. However, in the event that such activities are required, adverse effects on exposed life-history stages should be expected. Capture and removal of larvae and juveniles is impractical, meaning that these activities are likely to affect larval and juvenile survival. Capture and removal of adults is likely to affect survival and spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | Larvae and juveniles: Pump entrainment is likely to cause mortality of drifting larvae. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles.<br>Adults: Impingement is likely to cause adult mortality. | Adhere to in-water work windows; avoid use during spawning, incubation, and larval dispersal. | May cause injury and mortality of larvae, juveniles, and adults. Effects are less likely to occur if activities are conducted outside of spawning season. |
| | | Altered circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae | Larvae: Alteration of nearshore current and circulation patterns may cause larvae to be transported offshore or into habitats with increased predation risk and reduced foraging opportunity, limiting survival, growth, and fitness. | To the greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | May affect larval survival, growth, and fitness. |
| | | Bottom disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Larvae: Potential decreased larval foraging success due to turbidity exposure and substrate disturbance, leading to decreased growth and fitness.<br>Adults and juveniles: Stress caused by avoidance behavior; decreased foraging success due to increased turbidity levels.<br>Adults: Decreased availability of spawning substrate due to sedimentation effects on submerged aquatic vegetation.<br>All life-history stages: See responses to related stressors under Water Quality Modification. | Adhere to in-water work windows; avoid activity during spawning, incubation, and larval dispersal. | The likely stressor is increased suspended solids. May affect larval growth and survival. May affect juvenile and adult survival. May affect adult spawning productivity. |
| | | Localized alteration in invertebrate abundance | NA | NA | NA | NA | NA | NA | NA |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to in-water work windows. | See effects for related stressors under Water Quality Modification. |

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**Table A-17 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pacific Herring.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | When | Duration | Frequency | Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs; Larvae; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Eggs; Larvae; Juveniles; Adults | All life-history stages: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Larvae; Juveniles; Adults | All life-history stages: Entrainment of larval herring during dredging is likely to cause mortality or injury, leading to decreased survival. See responses described for related stressors under Water Quality Modification. | Require review of available data and/or site surveys to determine if spawning adults or rearing larvae are likely to be present, and time activities to avoid stressor exposure. Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Increased suspended solids and resuspension of contaminated sediments would be the likely stressors. Unlikely to affect survival of larvae and adults if activities are conducted during in-water work windows. Likely to affect survival at any life-history stage if exposure occurs. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | Eggs: Effects of suspended sediments on incubating herring eggs is currently a data gap. Larvae: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. Adults and juveniles: Same effects as above, as well as increased stress and decreased foraging opportunity due to avoidance behavior. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bluff/bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival and productivity at egg, larval, juvenile, and adult life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness. | Avoid sediment resuspension. | Decreased spawning habitat area. May affect egg, larval, juvenile, and adult survival and productivity. Reduced adult fitness may affect spawning productivity. |

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## Table A-17 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pacific Herring.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. Herring eggs are at an increased risk of exposure due to herring tendency to lay eggs directly on pilings and other vertical structures in the nearshore environment. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival and productivity of eggs, larvae, juveniles, and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. Herring eggs are at an increased risk of exposure due to herring tendency to lay eggs directly on pilings and other vertical structures in the nearshore environment. | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Eggs; Larvae; Juveniles; Adults | Eggs: Alteration or reduction of submerged aquatic vegetation may affect microclimate conditions in spawning substrates, decreasing egg survival.<br>All life-history stages: Altered habitat complexity is likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness.<br>Adults: Reductions in available submerged aquatic vegetation or alteration of submerged aquatic vegetation community composition may limit spawning productivity. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect productivity at egg, larval, juvenile, and adult life-history stages. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat. | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | | | | |

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### Table A-17 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pacific Herring.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round(with stressor exposure occurring when larvae and juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Eggs; Larvae; Juveniles; Adults | All exposed life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Alteration in the aerial extent and composition of the submerged aquatic vegetation community resulting from these mechanisms may reduce available spawning habitat, leading to reduced spawning productivity. Egg incubation success may be affected by alteration in wave energy patterns. Alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Therefore, alteration of these parameters may affect foraging opportunities at the juvenile life-history stage, over time leading to decreased adult fitness, decreased survival, and decreased spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect egg and larval survival and larval fitness. Decreased larval fitness may affect survival and productivity during juvenile and adult life-history phases in offshore and open ocean environments, and may affect spawning productivity. Loss or alteration of suitable spawning habitat may affect spawning productivity. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | Year-round | Permanent | Continuous | Larvae; Juveniles; Adults | All exposed life history stages: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators. Juvenile and adult herring may be exposed to increased predation exposure. Larvae may experience similar exposure, but increased predation rates are most likely insignificant relative to natural mortality. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect juvenile and adult survival. May affect larval survival, but effects will be insignificant relative to natural mortality. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles. | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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Table A-17 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pacific Herring.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs and larvae: Noise of sufficient magnitude may cause direct mortality of eggs and larvae, or permanent injury leading to decreased survival and fitness.<br>Adults and juveniles: Stressor response, dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Fatal injury or permanent auditory tissue damage limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Where possible, avoid stressor exposure during site-specific spawn timing, incubation, and larval dispersal. Require review of available data and/or site surveys to determine if spawning adults or rearing larvae are likely to be present, and time activities to avoid stressor exposure. If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | May affect survival during egg, larval, juvenile, and adult life-history stages. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: May cause avoidance behavior leading to increased stress and decreased foraging opportunity. Auditory masking or temporary hearing threshold effects may increase risk of predation due to decreased ability to sense predators. | Avoid/minimize propeller cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. Limit activities to in-water work windows where practicable. | May affect growth, fitness, and survival due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs: Extended dewatering may lead to egg desiccation or thermal exposure, causing mortality, or larval abnormalities limiting to survival.<br>Larvae and juveniles: Dewatering is likely to lead to mortality, as larval and juvenile herring will be difficult to capture and relocate effectively.<br>Adults: Capture, handling, and relocation are likely to cause mortality, or injury and stress, leading to mortality or decreased spawning fitness. | Limit activities to in-water work windows where practicable. | Dewatering and fish removal in marine habitats is an unlikely requirement for groin and bank barb development. However, in the event that such activities are required, adverse effects on exposed life-history stages should be expected. Capture and removal of larvae and juveniles is impractical, meaning that these activities are likely to affect larval and juvenile survival. Capture and removal of adults is likely to affect survival and spawning productivity. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae;<br>Juveniles;<br>Adults | Larvae and juveniles: Pump entrainment is likely to cause mortality of drifting larvae. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles.<br>Adults: Impingement is likely to cause adult mortality. | Adhere to in-water work windows; avoid use during spawning, incubation, and larval dispersal. | May cause injury and mortality of larvae, juveniles, and adults. Effects are less likely to occur if activities are conducted outside of spawning season. |

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## Table A-17 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pacific Herring.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Altered current and circulation conditions | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Larvae | Larvae: Alteration of nearshore current and circulation patterns may cause larvae to be transported offshore or into habitats with increased predation risk and reduced foraging opportunity, limiting survival, growth, and fitness. | To the greatest extent practicable, limit alteration of current and circulation patterns to minimal area. | May affect larval survival, growth, and fitness. |
| | | Bottom disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Larvae: Potential decreased larval foraging success due to turbidity exposure and substrate disturbance, leading to decreased growth and fitness.<br>Adults and juveniles: Stress caused by avoidance behavior; decreased foraging success due to increased turbidity levels.<br>Adults: Decreased availability of spawning substrate due to sedimentation effects on submerged aquatic vegetation.<br>All life-history stages: See responses to related stressors under Water Quality Modification. | Adhere to in-water work windows; avoid activity during spawning, incubation, and larval dispersal. | The likely stressor is increased suspended solids. May affect larval growth and survival. May affect juvenile and adult survival. May affect adult spawning productivity. |
| | | Localized alteration in invertebrate abundance | NA | NA | NA | NA | NA | NA | NA |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to in-water work windows. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Larvae;<br>Juveniles;<br>Adults | All life-history stages: Entrainment of larval herring during dredging is likely to cause mortality or injury, leading to decreased survival. See responses described for related stressors under Water Quality Modification. | Require review of available data and/or site surveys to determine if spawning adults or rearing larvae are likely to be present, and time activities to avoid stressor exposure. Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows. | Increased suspended solids and resuspension of contaminated sediments would be the likely stressors. Unlikely to affect survival of larvae and adults if activities are conducted during in-water work windows. Likely to affect survival at any life-history stage if exposure occurs. See effects for related stressors under Water Quality Modification. |

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### Table A-17 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pacific Herring.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs: Effects of suspended sediments on incubating herring eggs is currently a data gap.<br>Larvae: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness.<br>Adults and juveniles: Same effects as above, as well as increased stress and decreased foraging opportunity due to avoidance behavior. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bluff/bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival and productivity at egg, larval, juvenile, and adult life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.<br>Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness. | Avoid sediment resuspension. | Decreased spawning habitat area. May affect egg, larval, juvenile, and adult survival and productivity. Reduced adult fitness may affect spawning productivity. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing direct mortality or injury leading to reduced fitness.<br>Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness. | Avoid curing of concrete or discharge of concrete leachate to surface waters. | May affect survival of eggs and larvae, juveniles, and adults. |

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### Table A-17 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pacific Herring.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. Herring eggs are at an increased risk of exposure due to herring tendency to lay eggs directly on pilings and other vertical structures in the nearshore environment. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival and productivity of eggs, larvae, juveniles, and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. Herring eggs are at an increased risk of exposure due to herring tendency to lay eggs directly on pilings and other vertical structures in the nearshore environment. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures) | Pronounced in summer during solar radiation and ambient temperature extremes | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Eggs | Eggs: The influence of marine riparian shading on herring incubation is likely limited due to the typical elevation of herring spawn in the upper subtidal zone. However, the effects of this stressor are currently a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Potential effects resulting from this impact mechanism are unknown. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Eggs, larvae, and juveniles: See responses to increased turbidity exposure described under Water Quality Modification.<br>Adults: Potential reduction of suitable spawning habitat, leading to decreased spawning productivity. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect egg survival. May affect productivity at larval and juvenile life-history stages. May affect adult spawning productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduced organic matter inputs. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles;<br>Adults | Juveniles and adults: Dependence on allochthonous inputs from marine riparian vegetation is a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Potential effects resulting from this impact mechanism on remaining life-history stages are unknown. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Larvae;<br>Juveniles;<br>Adults | All life-history stages: Altered habitat complexity is likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect larval, juvenile, and adult productivity. May affect adult spawning productivity. |

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## Table A-17 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pacific Herring.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Eggs;<br>Larvae;<br>Adults | <u>Eggs and larvae</u>: Herring egg and larval development is demonstrably affected by surface water salinities beyond tolerance thresholds. Alteration of salinity characteristics may limit egg survival or cause larval abnormalities limiting to survival, growth, and fitness.<br><u>Adults</u>: The influence of surface water and groundwater exchange on spawning habitat suitability is currently a data gap. However, alteration of this habitat parameter that affect submerged aquatic vegetation may decrease availability and/or suitability of spawning habitat. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect egg and larval survival and productivity. May affect adult spawning productivity. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | <u>Eggs</u>: Alteration or reduction of submerged aquatic vegetation may affect microclimate conditions in spawning substrates, decreasing egg survival.<br><u>All life-history stages</u>: Altered habitat complexity is likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness.<br><u>Adults</u>: Reductions in available submerged aquatic vegetation or alteration of submerged aquatic vegetation community composition may limit spawning productivity. | <u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br><u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect productivity at egg, larval, juvenile, and adult life-history stages. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat. | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | | | | |

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## Table A-17 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Pacific Herring.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round(with stressor exposure occurring when larvae and juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Eggs; Larvae; Juveniles; Adults | All exposed life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Alteration in the aerial extent and composition of the submerged aquatic vegetation community resulting from these mechanisms may reduce available spawning habitat, leading to reduced spawning productivity. Egg incubation success may be affected by alteration in wave energy patterns. Alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Therefore, alteration of these parameters may affect foraging opportunities at the juvenile life-history stage, over time leading to decreased adult fitness, decreased survival, and decreased spawning productivity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect egg and larval survival and larval fitness. Decreased larval fitness may affect survival and productivity during juvenile and adult life-history phases in offshore and open ocean environments, and may affect spawning productivity. Loss or alteration of suitable spawning habitat may affect spawning productivity. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Larvae; Juveniles; Adults | Larvae and juveniles: Bank barbs and groins in the marine environment can fragment nearshore rearing habitat, potentially forcing planktonic herring away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion.<br>Adults: The physical footprint of groins and bank barbs and their geomorphic effects on the middle and lower intertidal zone may eliminate or decrease the suitability of spawning habitat, potentially limiting the spawning productivity of affected populations. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect larval and juvenile survival, growth, and fitness. May affect adult survival, fitness, and spawning productivity. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-18. HPA HCP Shoreline Modification Exposure and Response Matrix for Lingcod.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Juveniles and adults: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Fatal injury or permanent auditory tissue damage limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality or otherwise affect survival, growth, and fitness at all life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. Actual effects are unknown as stressor sensitivity is currently a data gap. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Juveniles;<br>Adults | Adults and juveniles: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described above under Riparian and Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Juveniles;<br>Adults | Juveniles: Post-settlement, juveniles may suffer injury or mortality as they are insufficiently mobile to avoid entrainment. Juveniles may experience temporary decrease in foraging opportunity due to short-term reduction in prey availability leading to decreased growth and fitness.<br>All exposed life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May cause direct mortality or injury to juveniles. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |

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Table A-18 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Lingcod.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and larvae;<br>Juveniles;<br>Adults | Eggs and larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased survival of eggs and larvae.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival, growth, and fitness at larval, juvenile, and adult life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and larvae;<br>Juveniles;<br>Adults | Eggs and larvae: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events. (Egg exposure may occur in rare circumstances if nests are located close to shore.)<br>Juveniles and adults: Avoidance behavior or asphyxiation during acute events. | Avoid sediment pulses. | May affect survival of incubating eggs and larvae. May affect juvenile and adult survival. May cause temporary avoidance behavior, potentially leading to decreased growth and fitness. |

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# Table A-18 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Lingcod.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and stronger currents or tidal exchange. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs:<br>Larvae;<br>Juveniles;<br>Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. Likelihood of egg exposure is limited but may occur if nesting takes place near treated wood structures. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br><br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival, growth, and fitness of all exposed life-history stages. Reduced fitness may affect adult spawning productivity. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. Likelihood of egg exposure is limited but may occur if nesting takes place near treated wood structures. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and productivity. Currently a data gap. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. Currently a data gap. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Lingcod dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, juveniles are known to use shallow vegetated habitats and pocket estuaries which contain food sources that depend on marine riparian allochthonous input. Decreased food web productivity may result in reduced foraging opportunities. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness |



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**Table A-18 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Lingcod.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival, growth, and fitness. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Juvenile lingcod are known to selectively settle and rear in areas with reduced salinities; therefore, groundwater inflow may provide increased habitat suitability. Reduction in suitable habitat area may affect survival, growth, and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of juveniles. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival. May affect adult growth and fitness. |



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**Table A-18 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Lingcod.**

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Larvae; Juveniles | Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval lingcod settlement in nearshore areas favorable for rearing, as well as the overall suitability of rearing habitat for juveniles. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at larval and juvenile life-history stages. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Larvae; Juveniles; Adults | Larvae and juveniles: Jetties fragment nearshore marine rearing habitat, potentially affecting settlement of larval lingcod. May increase nearshore habitat suitability for juvenile lingcod by providing interstitial cover; however, the resulting potential effects on lingcod populations are a data gap. Adults: Jetties create three-dimensional habitat suitable for adult lingcod in the nearshore environment, encouraging occupation. The resulting potential effects on lingcod populations are a data gap. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect larval survival. Potential effects on juvenile and adult lingcod are a data gap. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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Table A-18 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Lingcod.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Juveniles and adults: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Fatal injury or permanent auditory tissue damage limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality or otherwise affect survival, growth, and fitness at all life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. Actual effects are unknown as stressor sensitivity is currently a data gap. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Juveniles; Adults | Adults and juveniles: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described above under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Juveniles; Adults | Juveniles: Post-settlement, juveniles may suffer injury or mortality as they are insufficiently mobile to avoid entrainment. Juveniles may experience temporary decrease in foraging opportunity due to short-term reduction in prey availability leading to decreased growth and fitness.<br>All exposed life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May cause direct mortality or injury to juveniles. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |

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**Table A-18 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Lingcod.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and larvae;<br>Juveniles;<br>Adults | Eggs and larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased survival of eggs and larvae.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival, growth, and fitness at larval, juvenile, and adult life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and larvae;<br>Juveniles;<br>Adults | Eggs and larvae: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events. (Egg exposure may occur in rare circumstances if nests are located close to shore.)<br>Juveniles and adults: Avoidance behavior or asphyxiation during acute events. | Avoid sediment pulses. | May affect survival of incubating eggs and larvae. May affect juvenile and adult survival. May cause temporary avoidance behavior, potentially leading to decreased growth and fitness. |

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## Table A-18 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Lingcod.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and stronger currents or tidal exchange. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs: Larvae; Juveniles; Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. Likelihood of egg exposure is limited but may occur if nesting takes place near treated wood structures. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival, growth, and fitness of all exposed life-history stages. Reduced fitness may affect adult spawning productivity. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs; Larvae; Juveniles; Adults | | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival. May affect adult growth and fitness. |

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## Table A-18 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Lingcod.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Larvae; Juveniles | Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval lingcod settlement in nearshore areas favorable for rearing, as well as the overall suitability of rearing habitat for juveniles. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at larval and juvenile life-history stages. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased availability of foraging and resting habitat | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles: The increased hard surface area created by breakwaters may result in increased suitable habitat for juvenile lingcod.<br>Adults: Lingcod are lie-in-wait predators which favor the types of habitats created by breakwaters. Altered predator/prey dynamics associated with these structures may result in increased foraging opportunities for this species. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May (beneficially) affect survival, growth, and fitness of juveniles and adults. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Aquatic Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |



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Table A-18 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Lingcod.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Juveniles and adults: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality or otherwise affect survival, growth, and fitness at all life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. Actual effects are unknown as stressor sensitivity is currently a data gap. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Juveniles; Adults | Adults and juveniles: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described above under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Juveniles; Adults | Juveniles: Post-settlement, juveniles may suffer injury or mortality as they are insufficiently mobile to avoid entrainment. Juveniles may experience temporary decrease in foraging opportunity due to short-term reduction in prey availability leading to decreased growth and fitness. All exposed life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May cause direct mortality or injury to juveniles. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs and larvae;<br>Juveniles;<br>Adults | Eggs and larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased survival of eggs and larvae.<br>Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior.<br>Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success. | Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival, growth, and fitness at larval, juvenile, and adult life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs and larvae;<br>Juveniles;<br>Adults | Eggs and larvae: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events. (Egg exposure may occur in rare circumstances if nests are located close to shore.)<br>Juveniles and adults: Avoidance behavior or asphyxiation during acute events. | Avoid sediment pulses. | May affect survival of incubating eggs and larvae. May affect juvenile and adult survival. May cause temporary avoidance behavior, potentially leading to decreased growth and fitness. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | All life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. Adult and juvenile avoidance behavior at subacute exposure levels. | Prevent in-water curing of concrete and discharge of concrete leachate to surface waters. | Acute exposure may cause mortality at all exposed life-history stages. Juveniles and adults avoidance behavior at subacute exposure levels. |

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## Table A-18 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Lingcod.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and stronger currents or tidal exchange. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs:<br>Larvae;<br>Juveniles;<br>Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. Likelihood of egg exposure is limited but may occur if nesting takes place near treated wood structures. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival, growth, and fitness of all exposed life-history stages. Reduced fitness may affect adult spawning productivity. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | | | |
| | **Riparian and Shoreline Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and productivity. Currently a data gap. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. Currently a data gap. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Lingcod dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, juveniles are known to use shallow vegetated habitats and pocket estuaries which contain food sources that depend on marine riparian allochthonous input. Decreased food web productivity may result in reduced foraging opportunities. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness |

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| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival, growth, and fitness. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Juvenile lingcod are known to selectively settle and rear in areas with reduced salinities; therefore, groundwater inflow may provide increased habitat suitability. Reduction in suitable habitat area may affect survival, growth, and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of juveniles. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.<br>Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival. May affect adult growth and fitness. |

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**Table A-18 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Lingcod.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life-history Form** | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Larvae; Juveniles | Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval lingcod settlement in nearshore areas favorable for rearing, as well as the overall suitability of rearing habitat for juveniles. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at larval and juvenile life-history stages. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Larvae; Juveniles; Adults | Larvae and juveniles: Bank barbs and groins in the marine environment can fragment nearshore rearing habitat, potentially affecting settlement of larval lingcod. May increase nearshore habitat suitability for juvenile lingcod by providing interstitial cover; however, the resulting potential effects on lingcod populations are a data gap.<br>Adults: Groins and bank barbs in the marine environment may create three-dimensional habitat suitable for adult lingcod in the nearshore environment, encouraging occupation. The resulting potential effects on lingcod populations are a data gap. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect larval survival. Potential effects on juvenile and adult lingcod are a data gap. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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Table A-19. HPA HCP Shoreline Modifications Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Larvae;<br>Juveniles;<br>Adults | All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Barotraumas causing fatal injury or permanent auditory tissue damage in larvae, juveniles, and adults limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality or otherwise affect survival, growth, and fitness and at all life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; | Juveniles: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Larvae;<br>Juveniles | Juveniles: Post-settlement juveniles may suffer injury or mortality as they are insufficiently mobile to avoid entrainment. Juveniles may experience temporary decrease in foraging opportunity due to short-term reduction in prey availability leading to decreased growth and fitness.<br>All exposed life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May cause direct mortality of juveniles. May affect juvenile survival, growth, and fitness. See effects for related stressors under Water Quality Modification. |

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Table A-19 (continued). HPA HCP Shoreline Modifications Exposure and Response Matrix for Pacific cod, hake, and Walleye Pollock.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Larvae;<br>Juveniles | Larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased larval survival.<br>Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior. | Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival, growth, and fitness at larval and juvenile life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Larvae;<br>Juveniles | Larvae and juveniles: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events.<br>Juveniles: Avoidance behavior or asphyxiation during acute events. | Avoid sediment pulses. | May cause direct mortality of larvae and juveniles. May affect juvenile survival, growth, and fitness. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and stronger currents or tidal exchange. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Larvae;<br>Juveniles;<br>Adults | All life-history stages: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. Lingering physiological effects may limit adult fitness. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival, growth, and fitness and of larvae and juveniles. Reduced fitness may affect adult spawning productivity. |
| | Use of ACZA- and CCA type C-treated Wood | Leaching of metals (Cu, As, Cr, Zn), | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Larvae;<br>Juveniles;<br>Adults | All life-history stages: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. Lingering physiological effects may limit adult fitness. | | |

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### Table A-19 (continued). HPA HCP Shoreline Modifications Exposure and Response Matrix for Pacific cod, hake, and Walleye Pollock.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and productivity. Currently a data gap. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Pacific cod, hake and walleye pollock dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, juvenile Pacific cod, hake, and walleye pollock are known to use shallow vegetated habitats that could have marine riparian allochthonous input. Decreased food web productivity may result in reduced foraging opportunities. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile, growth, and fitness. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival, growth, and fitness. |
| | Altered freshwater input | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Pacific cod, hake, and walleye pollock dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Effects of action are unknown as receptor sensitivity to this stressor is currently a data gap. |

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## Table A-19 (continued). HPA HCP Shoreline Modifications Exposure and Response Matrix for Pacific cod, hake, and Walleye Pollock.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. | | May affect juvenile growth and fitness. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occuring when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Larvae; Juveniles | Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval settlement in nearshore areas favorable for rearing, as well as the overall suitability of juvenile rearing habitat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at larval and juvenile life-history stages. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |

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Table A-19 (continued). HPA HCP Shoreline Modifications Exposure and Response Matrix for Pacific cod, hake, and Walleye Pollock.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Larvae;<br>Juveniles | Larvae and juveniles: Jetties fragment nearshore rearing habitat, potentially affecting settlement of larval cod, pollock, and hake. Physical footprint of structures may eliminate suitable rearing habitat or decrease habitat suitability, potentially affecting larval survival, growth, and fitness | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect larval survival, growth, and fitness. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Larvae;<br>Juveniles;<br>Adults | All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Barotraumas causing fatal injury or permanent auditory tissue damage in larvae, juveniles, and adults limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality or otherwise affect survival, growth, and fitness and at all life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Larvae;<br>Juveniles;<br>Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; | Juveniles: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |

Table A-19 (continued). HPA HCP Shoreline Modifications Exposure and Response Matrix for Pacific cod, hake, and Walleye Pollock.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Larvae;<br>Juveniles | Juveniles: Post-settlement juveniles may suffer injury or mortality as they are insufficiently mobile to avoid entrainment. Juveniles may experience temporary decrease in foraging opportunity due to short-term reduction in prey availability leading to decreased growth and fitness.<br>All exposed life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May cause direct mortality of juveniles. May affect juvenile survival, growth, and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Larvae;<br>Juveniles | Larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased larval survival.<br>Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior. | Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival, growth, and fitness at larval and juvenile life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Larvae;<br>Juveniles | Larvae and juveniles: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events.<br>Juveniles: Avoidance behavior or asphyxiation during acute events. | Avoid sediment pulses. | May cause direct mortality of larvae and juveniles. May affect juvenile survival, growth, and fitness. |

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**Table A-19 (continued). HPA HCP Shoreline Modifications Exposure and Response Matrix for Pacific cod, hake, and Walleye Pollock.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and stronger currents or tidal exchange. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Larvae; Juveniles; Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. Lingering physiological effects may limit adult fitness. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br><u>Removal</u>: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival, growth, and fitness and of larvae and juveniles. |
| | Use of ACZA- and CCA type C-treated Wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Larvae; Juveniles: Adults | <u>All life-history stages</u>: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. Lingering physiological effects may limit adult fitness. | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | <u>Juveniles</u>: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | <u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br><u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.<br><u>Operation</u>: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | <u>Juveniles</u>: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. | | May affect juvenile growth and fitness. |

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**Table A-19 (continued). HPA HCP Shoreline Modifications Exposure and Response Matrix for Pacific cod, hake, and Walleye Pollock.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Larvae; Juveniles | Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval settlement in nearshore areas favorable for rearing, as well as the overall suitability of juvenile rearing habitat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at larval and juvenile life-history stages. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased availability of foraging and resting habitat | Year-round | Permanent | Continuous | Larvae; Juveniles; | All exposed life history stages: Breakwaters provide three dimensional structure potentially attractive to lie-in-wait predators. Juvenile cod, pollock, and hake may be exposed to increased predation exposure. Larvae may experience similar exposure, but increased predation rates are most likely insignificant relative to natural mortality. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival, growth, and fitness of juveniles. Affects on larvae likely insignificant relative to natural mortality. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-19 (continued). HPA HCP Shoreline Modifications Exposure and Response Matrix for Pacific cod, hake, and Walleye Pollock.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Larvae; Juveniles; Adults | All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Barotraumas causing fatal injury or permanent auditory tissue damage in larvae, juveniles, and adults limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality or otherwise affect survival, growth, and fitness and at all life-history stages, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Larvae; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; | Juveniles: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Larvae; Juveniles | Juveniles: Post-settlement juveniles may suffer injury or mortality as they are insufficiently mobile to avoid entrainment. Juveniles may experience temporary decrease in foraging opportunity due to short-term reduction in prey availability leading to decreased growth and fitness. All exposed life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May cause direct mortality of juveniles. May affect juvenile survival, growth, and fitness. See effects for related stressors under Water Quality Modification. |

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### Table A-19 (continued). HPA HCP Shoreline Modifications Exposure and Response Matrix for Pacific cod, hake, and Walleye Pollock.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Larvae;<br>Juveniles | Larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased larval survival.<br>Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior. | Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival, growth, and fitness at larval and juvenile life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Larvae;<br>Juveniles | Larvae and juveniles: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events.<br>Juveniles: Avoidance behavior or asphyxiation during acute events. | Avoid sediment pulses. | May cause direct mortality of larvae and juveniles. May affect juvenile survival, growth, and fitness. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Larvae;<br>Juveniles | Larvae and juveniles: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Prevent in-water curing of concrete and discharge of concrete leachate to surface waters. | Acute exposure may cause mortality at all exposed life-history stages. Juvenile and adult avoidance behavior at subacute exposure levels. |

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## Table A-19 (continued). HPA HCP Shoreline Modifications Exposure and Response Matrix for Pacific cod, hake, and Walleye Pollock.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and stronger currents or tidal exchange. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Larvae; Juveniles; Adults | Larvae and juveniles: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. Lingering physiological effects may limit adult fitness. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates. Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival, growth, and fitness and of larvae and juveniles. Reduced fitness may affect adult spawning productivity. |
| | Use of ACZA- and CCA type C-treated Wood | Leaching of metals (Cu, As, Cr, Zn), | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Larvae; Juveniles; Adults | Larvae and juveniles: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. Lingering physiological effects may limit adult fitness. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and productivity. Currently a data gap. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival and productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Pacific cod, hake and walleye pollock dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, juvenile Pacific cod, hake, and walleye pollock are known to use shallow vegetated habitats that could have marine riparian allochthonous input. Decreased food web productivity may result in reduced foraging opportunities. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile, growth, and fitness. |

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**Table A-19 (continued). HPA HCP Shoreline Modifications Exposure and Response Matrix for Pacific cod, hake, and Walleye Pollock.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival, growth, and fitness. |
| | Altered groundwater-surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Pacific cod, hake, and walleye pollock dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Effects of action are unknown as receptor sensitivity to this stressor is currently a data gap. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. | Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect juvenile growth and fitness. |

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**Table A-19 (continued). HPA HCP Shoreline Modifications Exposure and Response Matrix for Pacific cod, hake, and Walleye Pollock.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Larvae; Juveniles | Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval settlement in nearshore areas favorable for rearing, as well as the overall suitability of juvenile rearing habitat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at larval and juvenile life-history stages. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Larvae; Juveniles | Larvae and juveniles: Bank barbs and groins in the marine environment can fragment nearshore rearing habitat, potentially affecting settlement of larval cod, pollock, and hake. Physical footprint of structures may eliminate suitable rearing habitat or decrease habitat suitability, potentially affecting larval survival, growth, and fitness | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect larval survival, growth, and fitness. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles. | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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## Table A-20. HPA HCP Shoreline Modification Exposure and Response Matrix for Group 20—Rockfish Species.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | **Stressor** | **When** | **Duration** | **Frequency** | **Life History Form** | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Juveniles and adults: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Fatal injury or permanent auditory tissue damage limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality or injury affecting juvenile and adult survival, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Juveniles and adults: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. However, rockfish sensitivity to this stressor is currently a data gap. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect juvenile and adult survival due to avoidance behavior, decreased foraging success, and increased predation risk. Actual effects are unknown as stressor sensitivity is a data gap. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Riparian and Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Juveniles;<br>Adults | Juveniles: Direct mortality or injury from entrainment. Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness.<br>Adults : See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects background levels. | May cause direct mortality or injury to juveniles. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |

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## Table A-20 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Group 20 Rockfish Species.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Larvae;<br>Juveniles | Larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased survival of larvae.<br>Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior. | Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival, growth, and fitness at larval and juvenile life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) | Intermittent to permanent (dependent on contributing mechanism of impact) | Larvae;<br>Juveniles | Larvae and juveniles: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events.<br>Juveniles: Avoidance behavior or asphyxiation during acute events. | Avoid sediment pulses. | May affect larval survival. May affect juvenile survival. May cause temporary avoidance behavior. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Larvae;<br>Juveniles;<br>Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect growth, fitness, and survival of larvae, juveniles, and adults. |
| | Use of ACZA- and CCA type C-treated Wood | Leaching of metals (Cu, As, Cr, Zn), | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Larvae;<br>Juveniles;<br>Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |

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### Table A-20 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Group 20 Rockfish Species.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. Currently a data gap. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. Currently a data gap. |
| | Altered allochthonous inputs | Reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period) | Permanent | Continuous | Juveniles | Juveniles: Rockfish dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, juvenile rockfish are known to use shallow vegetated habitats and pocket estuaries which contain food sources that depend on marine riparian allochthonous input. Decreased food web productivity may result in reduced foraging opportunities. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival, growth, and fitness. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Rockfish dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Effects of the action resulting from this impact mechanism are unknown. |

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**Table A-20 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Group 20 Rockfish Species.**

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness.<br>Adults: Decreased refuge habitat availability. Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival. May affect adult growth and fitness. |

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### Table A-20 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Group 20 Rockfish Species.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Marine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Larvae; Juveniles | Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval rockfish settlement in nearshore areas favorable for rearing, as well as the overall suitability of rearing habitat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at larval and juvenile life-history stages. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Larvae; Juveniles; Adults | Larvae and juveniles: Jetties fragment nearshore rearing habitat, potentially affecting settlement of larval rockfish. May increase nearshore habitat suitability for juvenile rockfish, however the resulting potential effects on rockfish populations are a data gap.<br>Adults: Jetties are three dimensional habitat potentially suitable for adult rockfish in the nearshore environment, encouraging occupation. The resulting potential effects on rockfish populations are a data gap. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect larval survival. Potential effects on juvenile and adult rockfish are a data gap. |

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**Table A-20 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Group 20 Rockfish Species.**

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Juveniles and adults: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality or injury affecting juvenile and adult survival, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Juveniles and adults: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. However, rockfish sensitivity to this stressor is currently a data gap. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect juvenile and adult survival due to avoidance behavior, decreased foraging success, and increased predation risk. Actual effects are unknown as stressor sensitivity is a data gap. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |

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**Table A-20 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Group 20 Rockfish Species.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Juveniles;<br>Adults | <u>Juveniles</u>: Direct mortality or injury from entrainment. Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness.<br><u>Adults</u>: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects background levels. | May cause direct mortality or injury to juveniles. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Larvae;<br>Juveniles | <u>Larvae</u>: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased survival of larvae.<br><u>Juveniles</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior. | Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival, growth, and fitness at larval and juvenile life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) | Intermittent to permanent (dependent on contributing mechanism of impact) | Larvae;<br>Juveniles | <u>Larvae and juveniles</u>: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events.<br><u>Juveniles</u>: Avoidance behavior or asphyxiation during acute events. | Avoid sediment pulses. | May affect larval survival. May affect juvenile survival. May cause temporary avoidance behavior. |

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**Table A-20 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Group 20 Rockfish Species.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Larvae;<br>Juveniles;<br>Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect growth, fitness, and survival of larvae, juveniles, and adults. |
| | Use of ACZA- and CCA type C-treated Wood | Leaching of metals (Cu, As, Cr, Zn), | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Larvae;<br>Juveniles;<br>Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness.<br>Adults: Decreased refuge habitat availability. Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival. May affect adult growth and fitness. |

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### Table A-20 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Group 20 Rockfish Species.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Larvae; Juveniles | Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval rockfish settlement in nearshore areas favorable for rearing, as well as the overall suitability of rearing habitat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at larval and juvenile life-history stages. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased availability of foraging and resting habitat | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles: The increased hard surface area created by breakwaters may result in increased suitable habitat for juvenile rockfish.<br>Adults: Rockfish are lie-in-wait predators which favor the types of habitats created by breakwaters. Altered predator/prey dynamics associated with these structures may result in increased foraging opportunities for this species. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May (beneficially) affect survival, growth, and fitness of juveniles and adults. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Aquatic Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. |

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**Table A-20 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Group 20 Rockfish Species.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Juveniles and adults: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:<br>▪ Fatal injury or permanent auditory tissue damage limiting to survival.<br>▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.<br>▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness. | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | Activity may cause direct mortality or injury affecting juvenile and adult survival, depending on project-specific noise intensity and receptor exposure. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles;<br>Adults | Juveniles and adults: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. However, rockfish sensitivity to this stressor is currently a data gap. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | May affect juvenile and adult survival due to avoidance behavior, decreased foraging success, and increased predation risk. Actual effects are unknown as stressor sensitivity is a data gap. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles;<br>Adults | Juveniles and adults: See responses described under Riparian and Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Juveniles;<br>Adults | Juveniles: Direct mortality or injury from entrainment. Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness.<br>Adults: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects background levels. | May cause direct mortality or injury to juveniles. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |

**Table A-20 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Group 20 Rockfish Species.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Larvae;<br>Juveniles | Larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased survival of larvae.<br>Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior. | Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival, growth, and fitness at larval and juvenile life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) | Intermittent to permanent (dependent on contributing mechanism of impact) | Larvae;<br>Juveniles | Larvae and juveniles: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events.<br>Juveniles: Avoidance behavior or asphyxiation during acute events. | Avoid sediment pulses. | May affect larval survival. May affect juvenile survival. May cause temporary avoidance behavior. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Larvae;<br>Juveniles;<br>Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect growth, fitness, and survival of larvae, juveniles, and adults. |
| | Use of ACZA- and CCA type C-treated Wood | Leaching of metals (Cu, As, Cr, Zn), | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Larvae;<br>Juveniles;<br>Adults | All exposed life-history stages: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |



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## Table A-20 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Group 20 Rockfish Species.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles | Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. Currently a data gap. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile survival. Currently a data gap. |
| | Altered allochthonous inputs | Reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period) | Permanent | Continuous | Juveniles | Juveniles: Rockfish dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, juvenile rockfish are known to use shallow vegetated habitats and pocket estuaries which contain food sources that depend on marine riparian allochthonous input. Decreased food web productivity may result in reduced foraging opportunities. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival, growth, and fitness. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | Juveniles | Juveniles: Rockfish dependence on groundwater inflow to nearshore marine habitats is currently a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Effects of the action resulting from this impact mechanism are unknown. |

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### Table A-20 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Group 20 Rockfish Species.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile growth and fitness. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased refuge habitat availability. Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival. May affect adult growth and fitness. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with stressor exposure occurring when juveniles occupy nearshore habitats for rearing) | Permanent | Continuous | Larvae; Juveniles | Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval rockfish settlement in nearshore areas favorable for rearing, as well as the overall suitability of rearing habitat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at larval and juvenile life-history stages. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |

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**Table A-20 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Group 20 Rockfish Species.**

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Larvae;<br>Juveniles;<br>Adults | Larvae and juveniles: Bank barbs and groins in the marine environment can fragment nearshore rearing habitat, potentially affecting settlement of larval rockfish. May increase nearshore habitat suitability for juvenile rockfish, however the resulting potential effects on rockfish populations are a data gap.<br>Adults: Groins and bank barbs in the marine environment may create three dimensional habitat suitable for adult rockfish in the nearshore environment, encouraging occupation. The resulting potential effects on rockfish populations are a data gap. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect larval survival. Potential effects on juvenile and adult rockfish are a data gap. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival, growth, and fitness. |

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### Table A-21. HPA HCP Shoreline Modification Exposure and Response Matrix for Olympia Oyster.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary | Interannual–decadal | Veliger larvae; Juveniles; Adults | All life-history stages: Effect of piling driving sound is a data gap. | Effect of increased underwater noise level on Olympic oyster is a data gap. | Effect of increased underwater noise level on Olympic oyster is a data gap. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary | Interannual–decadal | Veliger larvae; Juveniles, Adults | All life-history stages: Effect of anthropogenic sound is a data gap. | Effect of increased ambient noise level on Olympic oyster is a data gap. | Effect of increased ambient noise level on Olympic oyster is a data gap. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Veliger larvae Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Veliger larvae; Juveniles; Adults | All life-history stages: See responses described under Riparian and Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Veliger larvae; Juveniles; Adults; | All life-history stages: Mortality from entrainment. Decreased growth and fitness. See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May affect veliger larvae productivity and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Veliger larvae; Juveniles; Adults | All life-history stages: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause mortality. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating larvae and juveniles. May affect juvenile and adult productivity. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Veliger larvae; Juveniles; Adults | All life-history stages: Olympia oyster dissolved oxygen effect thresholds are currently a data gap. Sensitivity to dissolved oxygen levels appears to be low, however. | Avoid sediment pulses. | May affect survival of incubating larvae, juveniles, and adults. May affect juvenile and adult survival, growth, and fitness, including adult spawning success. Actual effects are unknown, as sensitivity to this stressor and effects thresholds are currently data gaps. |

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## Table A-21 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympia Oyster.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Veliger larvae; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival, growth, and fitness of larvae, juveniles, and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Veliger larvae; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures) | Year-round (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles; Adults | Juveniles and adults: Although, riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors, Olympia oysters along the intertidal zone can gain benefits from extreme cold or heat that are known to cause mortality in other species. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of juvenile and adult oysters (effects may be beneficial). |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles; Adults | Juveniles and adults: Burial can smother Olympia oysters. Siltation is a known limiting factor causing injury or mortality. See turbidity effects described in Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile and adult survival. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Olympia oyster dependence on allochthonous inputs from marine riparian vegetation is a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Effects of this impact mechanism and related stressors are currently a data gap. |
| | Altered habitat complexity | Reduced food web productivity, reduced feeding opportunity | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles and adults: Decreased food resources, leading to adverse effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival, adult spawning success, and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round | Permanent | Continuous | Veliger larvae; Juveniles: Adults | All life history stages: Olympia oyster are known to prefer areas where freshwater seepage into the intertidal zone likely limits extremes in temperature. | Avoid disturbance of riparian vegetation. | Effects from this impact mechanism may also include protection from predators unable to tolerate low salinity habitats. |

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**Table A-21 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympia Oyster.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles; Adults | <u>Juveniles and adults</u>: Reduced feeding opportunities due to decreased food web productivity; decreased growth and fitness. | <u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction. <u>Operation</u>: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect juvenile and adult growth, fitness, and survival. |
| | Altered habitat complexity | Reduced food web productivity, reduced feeding opportunity | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | <u>Juveniles:</u> Decreased habitat availability and feeding opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. <u>Adults</u>: Decreased feeding opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival. May affect adult growth and spawning productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round | Permanent | Continuous | Veliger larvae; Juveniles; Adults | <u>All life-history stages</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of settling and rearing habitat for Olympia oyster. This may occur through a number of specific stressors, including food web alterations and decreased prey resources, introduced non-native species, and increased competition for suitable habitats. Alteration of circulation patterns may also affect spawn timing and the transport and settlement of veliger larvae. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine movement, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at all life-history stages. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Velliger larvae; Juveniles; Adults | <u>All exposed life-history stages</u>: The structural footprint of jetties may limit the area suitable for larval settlement, decreasing overall juvenile and adult abundance. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect larval survival, in turn affecting juvenile and adult population abundance. |

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Table A-21 (continued).  HPA HCP Shoreline Modification Exposure and Response Matrix for Olympia Oyster.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival. May affect adult growth and spawning productivity. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary | Interannual–decadal | Veliger larvae; Juveniles; Adults | All life-history stages: Effect of piling driving sound is a data gap. | Effect of increased underwater noise level on Olympic oyster is a data gap. | Effect of increased underwater noise level on Olympic oyster is a data gap. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary | Interannual–decadal | Veliger larvae; Juveniles, Adults | All life-history stages: Effect of anthropogenic sound is a data gap. | Effect of increased ambient noise level on Olympic oyster is a data gap. | Effect of increased ambient noise level on Olympic oyster is a data gap. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Veliger larvae Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Veliger larvae; Juveniles; Adults | All life-history stages: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Veliger larvae; Juveniles; Adults; | All life-history stages: Mortality from entrainment. Decreased growth and fitness. See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May affect veliger larvae productivity and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Veliger larvae; Juveniles; Adults | All life-history stages: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause mortality. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating larvae and juveniles. May affect juvenile and adult productivity. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Veliger larvae; Juveniles; Adults | All life-history stages: Olympia oyster dissolved oxygen effect thresholds are currently a data gap. Sensitivity to dissolved oxygen levels appears to be low, however. | Avoid sediment pulses. | May affect survival of incubating larvae, juveniles, and adults. May affect juvenile and adult survival, growth, and fitness, including adult spawning success. Actual effects are unknown, as sensitivity to this stressor and effects thresholds are currently data gaps. |

## Table A-21 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympia Oyster.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Veliger larvae;<br>Juveniles;<br>Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival, growth, and fitness of larvae, juveniles, and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Veliger larvae;<br>Juveniles;<br>Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles;<br>Adults | Juveniles and adults: Reduced feeding opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | May affect juvenile and adult growth, fitness, and survival. |
| | Altered habitat complexity | Reduced food web productivity, reduced feeding opportunity | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Decreased habitat availability and feeding opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.<br>Adults: Decreased feeding opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival. May affect adult growth and spawning productivity. |

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**Table A-21 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympia Oyster.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round | Permanent | Continuous | Veliger larvae; Juveniles; Adults | All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of settling and rearing habitat for Olympia oyster. This may occur through a number of specific stressors, including food web alterations and decreased prey resources, introduced non-native species, and increased competition for suitable habitats. Alteration of circulation patterns may also affect spawn timing and the transport and settlement of veliger larvae. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine movement, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at all life-history stages. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | NA | NA | NA | NA | Alteration of predator/prey dynamics will not significantly affect Olympia oyster, which are not subject to predation by lie in wait predators. Indirect effects on species which feed on veliger larvae (e.g., through increased predation on forage fish) are possible, but these effects will be insignificant relative to natural mortality rates. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | The effects of this stressor on Olympia oyster are considered insignificant. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Decreased food resources, leading to adverse effects on growth and fitness. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival, adult spawning success, and overall population productivity. |

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Table A-21 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympia Oyster.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary | Interannual–decadal | Veliger larvae; Juveniles; Adults | All life-history stages: Effect of piling driving sound is a data gap. | Effect of increased underwater noise level on Olympic oyster is a data gap. | Effect of increased underwater noise level on Olympic oyster is a data gap. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary | Interannual–decadal | Veliger larvae; Juveniles, Adults | All life-history stages: Effect of anthropogenic sound is a data gap. | Effect of increased ambient noise level on Olympic oyster is a data gap. | Effect of increased ambient noise level on Olympic oyster is a data gap. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Veliger larvae Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Veliger larvae; Juveniles; Adults | All life-history stages: See responses described under Riparian and Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Veliger larvae; Juveniles; Adults; | All life-history stages: Mortality from entrainment. Decreased growth and fitness. See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May affect veliger larvae productivity and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Veliger larvae; Juveniles; Adults | All life-history stages: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause mortality. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival of incubating larvae and juveniles. May affect juvenile and adult productivity. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Veliger larvae; Juveniles; Adults | All life-history stages: Olympia oyster dissolved oxygen effect thresholds are currently a data gap. Sensitivity to dissolved oxygen levels appears to be low, however. | Avoid sediment pulses. | May affect survival of incubating larvae, juveniles, and adults. May affect juvenile and adult survival, growth, and fitness, including adult spawning success. Actual effects are unknown, as sensitivity to this stressor and effects thresholds are currently data gaps. |



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**Table A-21 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympia Oyster.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Veliger larvae; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival, growth, and fitness of larvae, juveniles, and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Veliger larvae; Juveniles; Adults | All life-history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures) | Year-round (pronounced in summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Juveniles; Adults | Juveniles and adults: Although, riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors, Olympia oysters along the intertidal zone can gain benefits from extreme cold or heat that are known to cause mortality in other species. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival, growth, and fitness of juvenile and adult oysters (effects may be beneficial). |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles; Adults | Juveniles and adults: Burial can smother Olympia oysters. Siltation is a known limiting factor causing injury or mortality. See turbidity effects described in Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile and adult survival. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Olympia oyster dependence on allochthonous inputs from marine riparian vegetation is a data gap. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Effects of this impact mechanism and related stressors are currently a data gap. |
| | Altered habitat complexity | Reduced food web productivity, reduced feeding opportunity | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles and adults: Decreased food resources, leading to adverse effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival, adult spawning success, and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round | Permanent | Continuous | Veliger larvae; Juveniles: Adults | All life history stages: Olympia oyster are known to prefer areas where freshwater seepage into the intertidal zone likely limits extremes in temperature. | Avoid disturbance of riparian vegetation. | Effects from this impact mechanism may also include protection from predators unable to tolerate low salinity habitats. |

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### Table A-21 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Olympia Oyster.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles;<br>Adults | Juveniles and adults: Reduced feeding opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect juvenile and adult growth, fitness, and survival. |
| | Altered habitat complexity | Reduced food web productivity, reduced feeding opportunity | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles;<br>Adults | Juveniles: Decreased habitat availability and feeding opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.<br>Adults: Decreased feeding opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile survival. May affect adult growth and spawning productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round | Permanent | Continuous | Veliger larvae;<br>Juveniles;<br>Adults | All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of settling and rearing habitat for Olympia oyster. This may occur through a number of specific stressors, including food web alterations and decreased prey resources, introduced non-native species, and increased competition for suitable habitats. Alteration of circulation patterns may also affect spawn timing and the transport and settlement of veliger larvae. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine movement, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at all life-history stages. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Velliger larvae;<br>Juveniles;<br>Adults | All exposed life-history stages: The structural footprint of bank barbs and groins may limit the area suitable for larval settlement, decreasing overall juvenile and adult abundance. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect larval survival, in turn affecting juvenile and adult population abundance. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | PermVnent | Continuous | Juveniles;<br>Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival, adult spawning success, and overall population productivity. |

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**Table A-22. HPA HCP Shoreline Modification Exposure and Response Matrix for Northern Abalone.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary | Interannual to decadal (during project construction and maintenance) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Effect of piling driving sound on northern abalone is a data gap. | Effect of pile driving sound pressure on northern abalone is a data gap. Therefore appropriate minimization measures are unclear. | Effect of pile driving sound pressure on northern abalone is a data gap. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Juveniles and adults: Effect of anthropogenic sound on northern abalone is a data gap. | Effect of anthropogenic sound pressure on northern abalone is a data gap. Therefore appropriate minimization measures are unclear. | Effect of anthropogenic sound on northern abalone is a data gap. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs; Larvae; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Eggs; Larvae; Juveniles; Adults | All life-history stages: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs; Larvae; Juveniles; Adults | All life-history stages: Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. Mortality due to entrainment. See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May affect juvenile productivity and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause mortality or hinder feeding. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival and productivity of all life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Increased stress, leading to reduced growth and fitness. | Avoid sediment pulses. | May affect survival of all life-history stages. |

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Table A-22 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Northern Abalone.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs; Larvae; Juveniles | All exposed life history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival and productivity of eggs, larvae, and juveniles. |
| | Use of ACZA- and CCA type C-treated Wood | Leaching of metals (Cu, As, Cr, Zn), | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs; Larvae; Juveniles; Adults | Juveniles and Adults: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | NA | NA | NA | NA | NA | NA | NA |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles; Adults | Juveniles and adults: Burial can smother northern abalones if large pulses of landslide debris were to enter Puget Sound waters. Siltation is a known limiting factor causing injury or mortality. See turbidity effects described under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile and adult survival. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduced organic matter inputs. | NA | NA | NA | NA | NA | NA | NA |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | NA | NA | NA | NA | NA | NA | NA |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | NA | NA | NA | NA | NA | NA | NA |

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**Table A-22 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Northern Abalone.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Northern abalone dependence on allochthonous and autochthonous inputs from marine aquatic vegetation is a data gap. Northern abalone are known to use intertidal and subtidal vegetation and phytoplankton that could be a product of aquatic vegetation autochthonous input. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | Effect from this impact mechanism is currently a data gap. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge and rearing habitat availability and food resource availability, leading to increased competition and predation exposure and resulting in decreased survival, growth, and fitness.<br>Adults: Decreased feeding opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile growth, fitness, and survival. May affect adult growth and spawning productivity. |

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## Table A-22 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Northern Abalone.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round | Permanent | Continuous | Eggs; Larvae; Juveniles; Adults | All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of settling and rearing habitat for northern abalone. This may occur through a number of specific stressors, including food web alterations and decreased prey resources, introduced non-native species, and increased competition for suitable habitats. Loss of marine macroalgae may increase the visibility of the northern abalone to predators. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine movement, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival at all life-history stages. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | Altered current velocities | | Year-round | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Larvae; Juveniles; Adults | All exposed life-history stages: The structural footprint of jetties may eliminate suitable habitat for larval settlement and juvenile and adult foraging. Over time, increased hard surface area associated with structures may increase the amount of surface area available for abalone foraging, but these beneficial effects may be offset by stressors related to hydraulic and geomorphic modification. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival, growth, and fitness at all life-history stages. |

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Table A-22 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Northern Abalone.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | NA | NA | NA | NA | NA | NA | NA |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary | Interannual to decadal (during project construction and maintenance) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Effect of piling driving sound on northern abalone is a data gap. | Effect of pile driving sound pressure on northern abalone is a data gap. Therefore appropriate minimization measures are unclear. | Effect of pile driving sound pressure on northern abalone is a data gap. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Juveniles and adults: Effect of anthropogenic sound on northern abalone is a data gap. | Effect of anthropogenic sound pressure on northern abalone is a data gap. Therefore appropriate minimization measures are unclear. | Effect of anthropogenic sound on northern abalone is a data gap. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs; Larvae; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Eggs; Larvae; Juveniles; Adults | All life-history stages: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs; Larvae; Juveniles; Adults | All life-history stages: Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. Mortality due to entrainment. See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May affect juvenile productivity and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause mortality or hinder feeding. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival and productivity of all life-history stages. |

## Table A-22 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Northern Abalone.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Increased stress, leading to reduced growth and fitness. | Avoid sediment pulses. | May affect survival of all life-history stages. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs; Larvae; Juveniles; Adults | All exposed life history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates. Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival and productivity of eggs, larvae, juveniles, and adults. |
| | Use of ACZA- and CCA type C-treated Wood | Leaching of metals (Cu, As, Cr, Zn), | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs; Larvae; Juveniles; Adults | Juveniles and adults: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Northern abalone dependence on allochthonous and autochthonous inputs from marine aquatic vegetation is a data gap. Northern abalone are known to use intertidal and subtidal vegetation and phytoplankton that could be a product of aquatic vegetation autochthonous input. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring, as well as reduced ambient light from fine bubble profusion. | Effect from this impact mechanism is currently a data gap. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge and rearing habitat availability and food resource availability, leading to increased competition and predation exposure and resulting in decreased survival, growth, and fitness. Adults: Decreased feeding opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | | May affect juvenile growth, fitness, and survival. May affect adult growth and spawning productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |

### Table A-22 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Northern Abalone.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round | Permanent | Continuous | Eggs; Larvae; Juveniles; Adults | All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of settling and rearing habitat for northern abalone. This may occur through a number of specific stressors, including food web alterations and decreased prey resources, introduced non-native species, and increased competition for suitable habitats. Loss of marine macroalgae may increase the visibility of the northern abalone to predators. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine movement, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival at all life-history stages. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | NA | NA | NA | NA | Alteration of predator/prey dynamics will not significantly affect northern abalone, which are not subject to predation by lie in wait predators. Indirect effects on species which feed on larvae (e.g., through increased predation on forage fish) are possible, but these effects will be insignificant relative to natural mortality rates. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | The effects of this stressor on northern abalone are considered insignificant. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | NA | NA | NA | NA | NA | NA | NA |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary | Interannual to decadal (during project construction and maintenance) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Effect of piling driving sound on northern abalone is a data gap. | Effect of pile driving sound pressure on northern abalone is a data gap. Therefore appropriate minimization measures are unclear. | Effect of pile driving sound pressure on northern abalone is a data gap. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | Juveniles and adults: Effect of anthropogenic sound on northern abalone is a data gap. | Effect of anthropogenic sound pressure on northern abalone is a data gap. Therefore appropriate minimization measures are unclear. | Effect of anthropogenic sound on northern abalone is a data gap. |


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## Table A-22 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Northern Abalone.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Eggs; Larvae; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Eggs; Larvae; Juveniles; Adults | All life-history stages: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Eggs; Larvae; Juveniles; Adults | All life-history stages: Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. Mortality due to entrainment. See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May affect juvenile productivity and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause mortality or hinder feeding. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect survival and productivity of all life-history stages. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Eggs; Larvae; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Increased stress, leading to reduced growth and fitness. | Avoid sediment pulses. | May affect survival of all life-history stages. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Eggs; Larvae; Juveniles; Adults | All exposed life history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of | May affect survival and productivity of eggs, larvae, juveniles, and adults. |

Table A-22 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Northern Abalone.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Use of ACZA- and CCA type C-treated Wood | Leaching of metals (Cu, As, Cr, Zn), | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Eggs;<br>Larvae;<br>Juveniles;<br>Adults | Juveniles and adults: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | NA | NA | NA | NA | NA | NA | NA |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles;<br>Adults | Juveniles and adults: Burial can smother northern abalones if large pulses of landslide debris were to enter Puget Sound waters. Siltation is a known limiting factor causing injury or mortality. See turbidity effects described under Water Quality Modification. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile and adult survival. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduced organic matter inputs. | NA | NA | NA | NA | NA | NA | NA |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | NA | NA | NA | NA | NA | NA | NA |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | NA | NA | NA | NA | NA | NA | NA |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles;<br>Adults | Juveniles and adults: Northern abalone dependence on allochthonous and autochthonous inputs from marine aquatic vegetation is a data gap. Northern abalone are known to use intertidal and subtidal vegetation and phytoplankton that could be a product of aquatic vegetation autochthonous input. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation | Effect from this impact mechanism is currently a data gap. |

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| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles: Decreased refuge and rearing habitat availability and food resource availability, leading to increased competition and predation exposure and resulting in decreased survival, growth, and fitness. Adults: Decreased feeding opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. | during project construction. | May affect juvenile growth, fitness, and survival. May affect adult growth and spawning productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round | Permanent | Continuous | Eggs; Larvae; Juveniles; Adults | All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of settling and rearing habitat for northern abalone. This may occur through a number of specific stressors, including food web alterations and decreased prey resources, introduced non-native species, and increased competition for suitable habitats. Loss of marine macroalgae may increase the visibility of the northern abalone to predators. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine movement, and direct mortality. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival at all life-history stages. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell-hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching]) | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Larvae; Juveniles; Adults | All exposed life-history stages: The structural footprint of groins and bank barbs may eliminate suitable habitat for larval settlement and juvenile and adult foraging. Over time, increased hard surface area associated with structures may increase the amount of surface area available for abalone foraging, but these beneficial effects may be offset by stressors related to hydraulic and geomorphic modification. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival, growth, and fitness at all life-history stages. |

Draft

Table A-22 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Northern Abalone.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | NA | NA | NA | NA | NA | NA | NA |

NA Not applicable. Species is not exposed to stressors caused by this impact mechanism.

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**Table A-23. HPA HCP Shoreline Modification Exposure and Response Matrix for Newcomb's Littorine Snail.**

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | NA | Habitats used by this species are restricted to a narrow band of littorine and riparian terrestrial vegetation; therefore, it is not exposed to aquatic impacts from jetty construction. | NA | NA |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | NA | | NA | NA |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | NA | | NA | NA |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | NA | | NA | NA |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | NA | | NA | NA |

Draft

**Table A-23. HPA HCP Shoreline Modification Exposure and Response Matrix for Newcomb's Littorine Snail.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | NA | Habitats used by this species are restricted to a narrow band littorine and riparian terrestrial vegetation and is therefore not exposed to aquatic impacts from jetties. | NA | NA |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | NA | | NA | NA |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | NA | | NA | NA |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | NA | | | |

Draft

## Table A-23. HPA HCP Shoreline Modification Exposure and Response Matrix for Newcomb's Littorine Snail.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles;<br>Adults | Newcomb's littorine snail it is an intertidal mollusk species that lives under and on the stems of glasswort (*Salicornia virginica*), which occurs in narrow bands on the fringes of salt marshes. Little is known of the life-history of this species, although its limited distribution and dependence on specific vegetation types increases sensitivity to specific types of riparian impacts. *Salicorna* fringe habitats are typically less influenced by riparian shade, but the actual shade requirements and life-history specific temperature requirements of this species are unknown. While tolerant of both salt and fresh water, it avoids immersion for long periods and will drown if trapped. Actual dependence on freshwater inflow is a data gap. However, salt marsh habitats in general are shaped by combined surface and ground water flows; therefore, alteration of freshwater inflow may lead to reduction in suitable habitat area. | Avoid/minimize disturbance of salt marsh vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Riparian vegetation modification leading to the alteration of *Salicorna* habitat in salt marsh environments where this species occurs is likely to lead to reduced survival, growth, and fitness at one or more life-history stages. Effects resulting from exposure to specific impact mechanisms are unknown, however, as sensitivity to stressor exposure and life-history requirements are a data gap. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | | | Avoid/minimize disturbance of salt marsh riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | | | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | | | Encourage project designs that limit permanent alteration of high-quality habitat features. Avoid disturbance of salt marsh vegetation, particularly the *Salicorna* fringe. | |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | | | Avoid alteration of nearshore vegetation in and around freshwater seeps. | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | NA | NA | NA | NA |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (fresh water) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | | | | |

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## Table A-23. HPA HCP Shoreline Modification Exposure and Response Matrix for Newcomb's Littorine Snail.

| Sub-activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Wave energy, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially altering the extent and composition of *Salicorna* habitat for Newcomb's littorine snail. In particular, alteration of littoral wave energy and sediment characteristics could lead to reductions in the amount of *Salicorna* habitat, or more frequent inundation leading to reduced habitat suitability. These alterations could lead to reduced survival, growth, and fitness; however, life-history specific sensitivity to these stressors is currently a data gap. As Newcomb's littorine snail is not a truly aquatic species and spends little time below the water surface, it is not affected by changes in current and circulation patterns. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at all life-history stages. However, actual effects are uncertain as life-history specific sensitivity to these impact mechanisms and related stressors is currently a data gap. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | NA | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | NA | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | Juveniles; Adults | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time as caused by altered longshore drift patterns ) | Permanent | Continuous | Juveniles; Adults | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | Juveniles; Adults | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | All exposed life-history stages: The onshore component of the structural footprint of jetties may eliminate suitable habitat for this species, affecting survival and overall population abundance. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and overall population abundance. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under *Riparian Vegetation Modification* | Year-round | Permanent | Continuous | Juveniles; Adults | The importance of LWD recruitment to Newcomb's littorine snail is currently a data gap, therefore the effects of stressor exposure are unknown. However, except for the potential effects of this impact mechanism on the quantity and quality of available *Salicorna* habitat, the effects of this stressor are likely limited. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | The effects of exposure to this stressor are unknown, but are likely to be insignificant. |

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**Table A-23. HPA HCP Shoreline Modification Exposure and Response Matrix for Newcomb's Littorine Snail.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | NA | Habitats used by this species are restricted to a narrow band of littorine and riparian terrestrial vegetation; therefore, it is not exposed to aquatic impacts from breakwater construction. | NA | NA |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | NA | | NA | NA |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | NA | | NA | NA |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | NA | | NA | NA |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | NA | | NA | NA |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | NA | Habitats used by this species are restricted to a narrow band littorine and riparian terrestrial vegetation and is therefore not exposed to aquatic impacts from breakwater construction. | NA | NA |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | NA | | NA | NA |

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## Table A-23. HPA HCP Shoreline Modification Exposure and Response Matrix for Newcomb's Littorine Snail.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | NA | | NA | NA |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | NA | | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | NA | NA | NA | NA |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (fresh water) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | | | | |

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## Table A-23. HPA HCP Shoreline Modification Exposure and Response Matrix for Newcomb's Littorine Snail.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | <u>Juveniles and adults</u>: Wave energy, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially altering the extent and composition of *Salicorna* habitat for Newcomb's littorine snail. In particular, alteration of littoral wave energy and sediment characteristics could lead to reductions in the amount of *Salicorna* habitat, or more frequent inundation leading to reduced habitat suitability. These alterations could lead to reduced survival, growth, and fitness; however, life-history specific sensitivity to these stressors is currently a data gap. As Newcomb's littorine snail is not a truly aquatic species and spends little time below the water surface, it is not affected by changes in current and circulation patterns. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at all life-history stages. However, actual effects are uncertain as life-history specific sensitivity to these impact mechanisms and related stressors is currently a data gap. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | NA | | | |
| | Altered nearshore circulation patterns | | Year-round (with seasonally variable effects depending on site-specific geography and bathymetry, and project configuration) | Permanent | Seasonal | NA | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | Juveniles; Adults | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time as caused by altered longshore drift patterns ) | Permanent | Continuous | Juveniles; Adults | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | Juveniles; Adults | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased predation exposure | NA | NA | NA | NA | NA | NA | NA |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under *Riparian Vegetation Modification* | Year-round | Permanent | Continuous | Juveniles; Adults | The importance of LWD recruitment to Newcomb's littorine snail is currently a data gap, therefore the effects of stressor exposure are unknown. However, except for the potential effects of this impact mechanism on the quantity and quality of available *Salicorna* habitat, the effects of this stressor are likely limited. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | The effects of exposure to this stressor are unknown, but are likely to be insignificant. |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | NA | Habitats used by this species are restricted to a narrow band of littorine and riparian terrestrial vegetation; therefore, it is not exposed to aquatic impacts from groin and bank barb construction. | NA | NA |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | NA | | NA | NA |

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**Table A-23. HPA HCP Shoreline Modification Exposure and Response Matrix for Newcomb's Littorine Snail.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | NA | | NA | NA |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | NA | | NA | NA |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | NA | | NA | NA |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | NA | Habitats used by this species are restricted to a narrow band littorine and riparian terrestrial vegetation and is therefore not exposed to aquatic impacts from groins and bank barbs. | NA | NA |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | NA | | NA | NA |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration will occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | NA | | NA | NA |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | NA | | | |

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**Table A-23. HPA HCP Shoreline Modification Exposure and Response Matrix for Newcomb's Littorine Snail.**

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles; Adults | Newcomb's littorine snail it is an intertidal mollusk species that lives under and on the stems of glasswort (*Salicornia virginica*), which occurs in narrow bands on the fringes of salt marshes. Little is known of the life-history of this species, although its limited distribution and dependence on specific vegetation types increases sensitivity to specific types of riparian impacts. *Salicorna* fringe habitats are typically less influenced by riparian shade, but the actual shade requirements and life-history specific temperature requirements of this species are unknown. While tolerant of both salt and fresh water, it avoids immersion for long periods and will drown if trapped. Actual dependence on freshwater inflow is a data gap. However, salt marsh habitats in general are shaped by combined surface and ground water flows; therefore, alteration of freshwater inflow may lead to reduction in suitable habitat area. | Avoid/minimize disturbance of salt marsh vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | Riparian vegetation modification leading to the alteration of *Salicorna* habitat in salt marsh environments where this species occurs is likely to lead to reduced survival, growth, and fitness at one or more life-history stages. Effects resulting from exposure to specific impact mechanisms are unknown, however, as sensitivity to stressor exposure and life-history requirements are a data gap. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round (with primary stressor prominent during high wave energy conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | | | Avoid/minimize disturbance of salt marsh riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | | | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Short-term to permanent (dependent on nature of activity) | Continuous | | | Encourage project designs that limit permanent alteration of high-quality habitat features. Avoid disturbance of salt marsh vegetation, particularly the *Salicorna* fringe. | |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round (stressor exposure occurs during nearshore rearing period in spring and summer) | Permanent | Continuous | | | Avoid alteration of nearshore vegetation in and around freshwater seeps. | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | NA | NA | NA | NA |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (fresh water) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | | | | |

## Table A-23. HPA HCP Shoreline Modification Exposure and Response Matrix for Newcomb's Littorine Snail.

| Sub-activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life-history Form | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Wave energy, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially altering the extent and composition of *Salicorna* habitat for Newcomb's littorine snail. In particular, alteration of littoral wave energy and sediment characteristics could lead to reductions in the amount of *Salicorna* habitat, or more frequent inundation leading to reduced habitat suitability. These alterations could lead to reduced survival, growth, and fitness; however, life-history specific sensitivity to these stressors is currently a data gap. As Newcomb's littorine snail is not a truly aquatic species and spends little time below the water surface, it is not affected by changes in current and circulation patterns. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival, growth, and fitness at all life-history stages. However, actual effects are uncertain as life-history specific sensitivity to these impact mechanisms and related stressors is currently a data gap. |
| | Altered current velocities | | Year-round (with variable effects depending on site-specific current dynamics and project configuration) | Permanent | Intermittent | NA | | | |
| | Altered sediment supply | | Year-round (beginning with project installation and becoming more pronounced over time) | Permanent | Continuous | Juveniles; Adults | | | |
| | Altered substrate composition | | Year-round (beginning with project installation and becoming more pronounced over time as caused by altered longshore drift patterns ) | Permanent | Continuous | Juveniles; Adults | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | Juveniles; Adults | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | All exposed life-history stages: The onshore component of the structural footprint of groins and bank barbs may eliminate suitable habitat for this species, affecting survival and overall population abundance. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival and overall population abundance. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under *Riparian Vegetation Modification* | Year-round | Permanent | Continuous | Juveniles; Adults | The importance of LWD recruitment to Newcomb's littorine snail is currently a data gap, therefore the effects of stressor exposure are unknown. However, except for the potential effects of this impact mechanism on the quantity and quality of available *Salicorna* habitat, the effects of this stressor are likely limited. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | The effects of exposure to this stressor are unknown, but are likely to be insignificant. |

? Unknown. Life-history characteristics and habitat requirements of this species are poorly understood, therefore the exposed life history stages are unknown.

**Table A-24. HPA HCP Shoreline Modification Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.**

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| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| **Groins and Bank Barbs*** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles; Adults | <u>All life-history stages</u>: The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap. | Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Juveniles, Adults | <u>All life-history stages</u>: The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap. | Avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/antivibration technology where practicable. | The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap. |
| | Channel/work area dewatering | Species removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | <u>All life-history stages</u>: Mortality from dewatering. | Perform channel work on areas where these species do not occur (these species are rarely found in sandy substrate). | Mortality and reduced survival and productivity at affected life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | These species' potential for entrainment in pumps or impingement on pump screens is a data gap. | These species' potential for entrainment in pumps or impingement on pump screens is a data gap. | These species' potential for entrainment in pumps or impingement on pump screens is a data gap. | Juveniles; Adults | These species' potential for entrainment in pumps or impingement on pump screens is a data gap. | Perform channel work on areas where these species do not occur (these species are rarely found in sandy substrate). | These species' potential for entrainment in pumps or impingement on pump screens is a data gap. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | <u>All life-history stages:</u> Potential downstream sedimentation resulting in decreased downstream habitat suitability; decreased dissolved oxygen levels, reduced prey resource availability, and reduced suitable settling habitat; decreased fitness, growth, and productivity. | Limit alteration of flow conditions to minimal area. | May affect survival and productivity during all affected life-history stages. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | <u>All life-history stages:</u> Decreased prey resource availability, decreased dissolved oxygen, decreased suitable settling habitat; resulting in decreased fitness, growth, and survival. | Adhere to system-specific in-water work windows. | May affect growth and productivity at all life-history stages. |
| | | Localized decrease in periphyton coverage | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | <u>All life-history stages:</u> Decreased growth and fitness due to a loss of food resources (scouring of periphyton caused by bed disturbance). | Limit area of dewatering to the greatest extent practicable. | May affect growth and productivity at juvenile and adult life-history stages. |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | <u>All life-history stages</u>: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Juveniles; Adults | <u>All life-history stages</u>: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. | See effects for related stressors under Hydraulic and Geomorphic Modification |

Table A-24 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: Decreased prey resource availability; decreased fitness, growth, and productivity of adults and juveniles. See responses described above under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Juveniles; Adults | All life-history stages: Mortality from entrainment and decreased prey availability resulting in decreased growth and fitness. See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May affect all life-history stages; decreased fitness, growth and survival of affected stages. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | All life-history stages: Turbidity sufficient to cause fine sediment embededdness may lead to direct mortality and burial. Responses vary depending on stressor magnitude. Reduction in suitable settling habitat (due to substrate embededdness) and reduced dissolved oxygen could limit growth and survival. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May decrease survival and productivity. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Juveniles; Adults | All life-history stages: Requires high dissolved oxygen content. Mortality, decreased fitness, growth, and survival. | Avoid sediment pulses. | May affect productivity and survival of all life-history stages. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | All life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect survival and productivity of all life stages. |



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Table A-24 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Juveniles; Adults | Juveniles and adults: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates.<br>Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | May affect survival and productivity of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation with highest levels occurring within 7 months of initial immersion. | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Juveniles; Adults | Juveniles and adults: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at sub-acute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. | | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Juveniles; Adults | All life-history stages: Prefers cool water and temperature regulation form shading. Altered growth and productivity caused by temperatures outside optimal growth range and alteration of food web patterns. Wide tolerance range but prefers cooler waters. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival and productivity. |
| | Altered stream bank and shoreline stability | Increased suspended solids; decreased dissolved oxygen; reduced habitat complexity (e.g., filling of pools) | Year-round (with specific stressors prominent during high flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles; Adults | All life-history stages: Decreased prey resource availability, decreased dissolved oxygen, decreased suitable settling habitat; resulting in decreased fitness, growth, and survival. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival and productivity. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Reduced prey resource availability due to decreased food web productivity; decreased growth and fitness. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile and adult life-history stages. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles and adults: Decreased prey resource availability, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile and adult survival and productivity. |
| | Altered groundwater–surface water exchange | Reduced available suitable spawning habitat; reduced gravel dissolved oxygen | NA | NA | NA | NA | NA | NA | NA. |

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**Table A-24 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Submechanism |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life-history Form | | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles; Adults | Juvenile and adults: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. | Design: Site majority of facility offshore to limit grounding and prop wash effects. Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Design overwater structures and mooring buoys in accordance with USACE guidance to limit shading and anchor scour effects.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect juvenile and adult productivity and survival. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: See related stressor responses under Water Quality Alteration. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Juveniles; Adults | Juveniles and adults: Decreased prey resource availability leading to increased competition, and resulting effects on growth and fitness. | | May affect juvenile and adult survival and productivity. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced habitat availability and suitability | Year-round | Permanent | Continuous | Juveniles; Adults | All life-history stages: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased survival.<br>Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit prey resource availability and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.<br>Adults: Changes in channel morphology may lead to habitat alteration, leading to increased stress and predation rate. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect all life-history stages; decreased growth, survival, and productivity. |
| | Altered flow velocity | | Year-round (with stressor exposure occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

* The Giant Columbia River Limpet and Great Columbia River Spire Snail are only found in flowing freshwater. As such, they will not be impacted by breakwaters and jetties, since these subactivities only occur in still-water environments.

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**Table A-25. HPA HCP Shoreline Modification Exposure and Response Matrix for California Floater and Western Ridged Mussel.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| **Jetties** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Glochidia larvae; Juveniles; Adults | All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels at any life-history stage is a data gap. Any potential impact would likely occur on the host fish species for the glochidia larvae (California floater = native minnows; western ridge = coldwater stream fish such as trout and salmon). | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | This is a data gap for these species. However, effects on host fish species for glochidia larvae will affect population productivity of this species. This indirect effect applies to all stressors. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Glochidia larvae; Juveniles, Adults | All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels is a data gap. | Although little is known on the effects of anthropogenic sounds on California floater and western ridged mussels, it is prudent to avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | Very little is known of the effects of pile-driving sounds on California floater and western ridged mussels at any life-history stage. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles and adults: Mortality from dewatering. | River beds containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels. | May affect survival at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Glochidia larvae | Glochidia larvae: Any potential impact would only occur if the glochidia fish host is entrained or impinged. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when glochidia fish host are present. | Any potential impact would only occur if the glochidia fish host is entrained or impinged. |
| | | Localized alteration in periphyton abundance | NA | NA | NA | NA | NA | NA | NA |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Glochidia larvae; Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Glochidia larvae; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. Substrates containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |

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## Table A-25 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for California Floater and Western Ridged Mussel.

| Sub-Activity Type | Mechanism of Impact | Exposure: Stressor | Exposure: When | Exposure: Duration | Exposure: Frequency | Exposure: Life History Form | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Glochidia larvae; Juveniles; Adults; | All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May affect growth and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Juveniles and adults: Effects depend on the magnitude of increased suspended solids. Turbidity sufficient to cause fine sediment embeddedness may bury these mussels and lead to direct mortality and decreased population survival. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect juvenile and adult survival. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Glochidia larvae; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects to host-fish could be stressor to these mussels. | Avoid sediment pulses. | May affect survival of larvae. May affect juvenile survival and adult survival, productivity, and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury and leading to reduced fitness of host fish. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect survival of juveniles and adults. |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Juveniles; Adults | Juveniles and adults: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates. | May affect survival of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Juveniles; Adults | Juveniles and adults: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Lacustrine** | | | | | | | | |

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Table A-25 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for California Floater and Western Ridged Mussel.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | Altered riparian shading, solar input and ambient air temperature | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Glochidia larvae; Juveniles; Adults | Glochidia larvae: Host-fish of the California floater and Western ridged mussel may be affected by increased temperatures, which may lead to mortality or increased thermal stress and decreased fitness of host fish.<br>Juveniles and adults: Mortality due to increased temperatures. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival of all life-history stages. |
| | Altered shoreline and bluff stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Juveniles; Adults | Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness for mussel host-fish. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile and adult survival. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs. | Year-round | Permanent | Continuous | Glochidia larvae; Juveniles; Adults | All life-history stages: Mussel dependence on allochthonous inputs from shoreline riparian vegetation is a data gap. This could be a stressor to host fish. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile and adult growth, fitness, and productivity. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Glochidia larvae; Juveniles; Adult | All life-history stages: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival and productivity, as well as spawning success and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Mussel dependence on groundwater inflow is currently a data gap. | Avoid disturbance of vegetation along shoreline. | Effects of the action resulting from this impact mechanism are unknown. |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Glochidia larvae;<br>Juveniles; Adults | All life-history stages: Reduced prey availability due to decreased food web productivity, decreased growth and fitness of host fish. Although effects specific to altered autochthonous inputs for the California floater and Western ridged mussels are a data gap, alterations could be expected to affect prey resource availability. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect all life-history stages. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis. | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Glochidia larvae;<br>Juveniles; Adults | All life-history stages: Require high levels of dissolved oxygen. See related stressor responses under Water Quality Alteration. Effects include effects to host fish. | | See effects for related stressors under Water Quality Modification. |



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**Table A-25 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for California Floater and Western Ridged Mussel.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Glochidia larvae; Juveniles; Adults | <u>All life-history stages</u>: Reduced prey resources due to decreased food web productivity, decreased growth and fitness of the California floater and Western ridged mussel prey and host fish. Altered autochthonous production could be expected to affect foraging success for this filter feeding species. | | May affect all life stages. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring, when wind driven waves are most pronounced) | Permanent | Continuous | Glochidia larvae; Juveniles; Adults | <u>All life-history stages</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and adult mussels. This may occur through increased predation exposure, food web alterations and decreased foraging opportunity. Effects to host fish affect these mussels. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival at all life-history stages. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Glochiddia larvae; Juveniles; Adults | <u>Glochidia larvae</u>: Changes in habitat availability may indirectly affect survival through effects on host fish. <u>Juveniles and adults</u>: The structural footprint of jetties may permanently modify habitat suitable for juveniles and adults, affecting survival and overall population abundance. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at all life-history stages and affect life-history stages and productivity of host-fish. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Glochiddia larvae; Juveniles; Adults | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | See effects for related stressors under altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. |
| **Breakwaters** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |

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## Table A-25 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for California Floater and Western Ridged Mussel.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Glochidia larvae; Juveniles; Adults | All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels at any life-history stage is a data gap. Any potential impact would likely occur on the host fish species for the glochidia larvae (California floater = native minnows; western ridge = coldwater stream fish such as trout and salmon). | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | This is a data gap for these species. However, effects on host fish species for glochidia larvae will affect population productivity of this species. This indirect effect applies to all stressors. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Glochidia larvae; Juveniles, Adults | All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels is a data gap. | Although little is known on the effects of anthropogenic sounds on California floater and western ridged mussels, it is prudent to avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | Very little is known of the effects of pile-driving sounds on California floater and western ridged mussels at any life-history stage. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles and adults: Mortality from dewatering. | River beds containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels. | May affect survival at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Glochidia larvae | Glochidia larvae: Any potential impact would only occur if the glochidia fish host is entrained or impinged. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when glochidia fish host are present. | Any potential impact would only occur if the glochidia fish host is entrained or impinged. |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Glochidia larvae; Juveniles; Adults | All life-history stages: Potential downstream sedimentation, resulting in decreased downstream habitat suitability, decreased dissolved oxygen levels, reduced food resource availability, and reduced suitable habitat; decreased fitness, growth, and productivity. | Limit alteration of flow conditions to minimal area. | May affect survival in all life stages. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles and adults: Mortality from increased sedimentation. | Adhere to system-specific in-water work windows. | May affect survival at juvenile and adult life-history stages. |
| | | Localized alteration in periphyton abundance | NA | NA | NA | NA | NA | NA | NA |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Glochidia larvae; Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Glochidia larvae; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. Substrates containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels. | See effects for related stressors under Hydraulic and Geomorphic Modification. |



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Table A-25 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for California Floater and Western Ridged Mussel.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Glochidia larvae; Juveniles; Adults; | All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Juveniles and adults: Effects depend on the magnitude of increased suspended solids. Turbidity sufficient to cause fine sediment embeddedness may bury these mussels and lead to direct mortality and decreased population survival. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect juvenile and adult survival. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Glochidia larvae; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects to host-fish could be stressor to these mussels. | Avoid sediment pulses. | May affect survival of larvae. May affect juvenile survival and adult survival, productivity, and spawning success. |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury and leading to reduced fitness of host fish. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect survival of juveniles and adults |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Juveniles; Adults | Juveniles and adults: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates. | May affect survival of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Juveniles; Adults | Juveniles and adults: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | |

## Table A-25 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for California Floater and Western Ridged Mussel.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Glochidia larvae; Juveniles; Adult | All life-history stages: Reduced prey availability due to decreased food web productivity, decreased growth and fitness of host fish. Although effects specific to altered autochthonous inputs for the California floater and Western ridged mussels are a data gap, alterations could be expected to affect prey resource availability. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.<br>Operation: Enforce vessel operation rules to limit submerged aquatic vegetation damage from prop wash, grounding, and anchoring. | May affect all life-history stages. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis. | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Juveniles; Adults | Juveniles and adults: Require high levels of dissolved oxygen. See related stressor responses under Water Quality Alteration. Effects include effects to shot fish. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Glochidia larvae; Juveniles; Adults | All life-history stages: Reduced prey resources due to decreased food web productivity, decreased growth and fitness of the California floater and Western ridged mussel prey and host fish. Altered autochthonous production could be expected to affect foraging success for this filter feeding species. | | May affect all life stages. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced habitat availability and suitability | Year-round | Permanent | Continuous | Glochidia larvae; Juveniles; Adults | Glochidia larvae: Changes in channel morphology, flow velocity, and substrate composition can affect host fish.<br>Juveniles and adults: As filter feeders, constant water flow is required. Altered channel geometry, flow velocity, and substrate composition can result in decrease habitat suitability and changes in food web complexity. This may limit prey resource availability and foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival at all life-history stages and affect life-history stages and productivity of host-fish. |
| | Altered flow velocity | | Year-round (with stressor exposures occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater inputs | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |

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Table A-25 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for California Floater and Western Ridged Mussel.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | Addition of impervious surface | Alteration in the magnitude, volume, and timing of peak flows | During storm events (predominantly from fall through spring) | Permanent | Common | Glochidia larvae; Juveniles Adults | All life-history stages: Because the amount of impervious surface associated with marinas is a relatively inconsequential component of the overall drainage area of the larger river systems that would support this type of development, the magnitude of the hydrologic modification stressor is expected to be negligible. As such, this stressor is not expected to significantly affect the riverine environment, and there will be no response to the stressor. | Encourage facilities to employ modern low-impact development and stormwater treatment technology. | Impervious surface at anticipated scale is not likely to produce stressors of sufficient magnitude to adversely affect mussels at any life-history stage. |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy (short-period waves) | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring, when wind driven waves are most pronounced) | Permanent | Continuous | Glochidia larvae; Juveniles; Adults | All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and adult mussels. This may occur through increased predation exposure, food web alterations and decreased foraging opportunity. Effects to host fish affect these mussels. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival at all life-history stages. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered nearshore circulation patterns | | Year-round (with variable effects by season [e.g., circulation patterns]) | Permanent | Seasonal | | | | |
| | Altered groundwater inputs | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased availability of foraging and resting habitat | Year-round | Permanent | Continuous | Glochiddia larva; | Larvae: Floater mussels are not directly sensitive to changes in predator prey dynamics, however the effects of this stressor on host fish in all environment types may indirectly affect the survival and dispersal of larvae, affecting overall population abundance and distribution. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | No direct effects. Indirect effects on host fish may affect larval survival and dispersal, potentially limiting population abundance and distribution. |
| | Loss of LWD recruitment | Sequestration of LWD preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Glochiddia larva; Juveniles; Adults | All life-history stages: Decreased habitat availability and food availability, leading to increased competition and resulting effects on growth and fitness, including health of host fish. | No specific recommendations. | May affect juvenile survival and productivity, as well as spawning success and overall population productivity. |



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**Table A-25 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for California Floater and Western Ridged Mussel.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | **Lacustrine** | | | | | | | | |
| | Alteration of predator/prey dynamics | Increased availability of foraging and resting habitat | Year-round | Permanent | Continuous | Glochiddia larva; | Larvae: Floater mussels are not directly sensitive to changes in predator prey dynamics, however the effects of this stressor on host fish in all environment types may indirectly affect the survival and dispersal of larvae, affecting overall population abundance and distribution. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | No direct effects. Indirect effects on host fish may affect larval survival and dispersal, potentially limiting population abundance and distribution. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Glochidia larvae; Juveniles; Adult | All life-history stages: Decreased habitat availability and food availability, leading to increased competition and resulting effects on growth and fitness, including health of host fish. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | May affect juvenile survival and productivity, as well as spawning success and overall population productivity. |
| **Groins and Bank Barbs** | | | | | | | | | |
| | **Construction and Maintenance Activities** | | | | | | | | |
| | Pile driving | Increased underwater noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Glochidia larvae; Juveniles; Adults | All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels at any life-history stage is a data gap. Any potential impact would likely occur on the host fish species for the glochidia larvae (California floater= native minnows; western ridge = coldwater stream fish such as trout and salmon). | Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable. | This is a data gap for these species. However, effects on host fish species for glochidia larvae will affect population productivity of this species. This indirect effect applies to all stressors. |
| | Construction vessel operation | Increased or altered ambient noise levels | During project construction and maintenance activities | Temporary (auditory masking) to short-term (hearing threshold effects) | Interannual to decadal (during project construction and maintenance) | Glochidia larvae; Juveniles, Adults | All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels is a data gap. | Although little is known on the effects of anthropogenic sounds on California floater and western ridged mussels, it is prudent to avoid/minimize cavitation to limit noise intensity. Promote use of vessels equipped with antinoise/ antivibration technology where practicable. | Very little is known of the effects of pile-driving sounds on California floater and western ridged mussels at any life-history stage. |
| | Channel/work area dewatering | Fish removal, relocation, and exclusion | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles and adults: Mortality from dewatering. | River beds containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels. | May affect survival at juvenile and adult life-history stages. |
| | | Entrainment in pumps or impingement on pump screens | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Glochidia larvae | Glochidia larvae: Any potential impact would only occur if the glochidia fish host is entrained or impinged. | Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when glochidia fish host are present. | Any potential impact would only occur if the glochidia fish host is entrained or impinged. |

Table A-25 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for California Floater and Western Ridged Mussel.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | | Altered flow conditions (riverine) | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Glochidia larvae; Juveniles; Adults | All life-history stages: Potential downstream sedimentation, resulting in decreased downstream habitat suitability, decreased dissolved oxygen levels, reduced food resource availability, and reduced suitable habitat; decreased fitness, growth, and productivity. | Limit alteration of flow conditions to minimal area. | May affect survival in all life stages. |
| | | Stream bed disturbance, increased turbidity (associated with site rewatering) | During project construction and maintenance activities | Temporary | Interannual to decadal (depending on activity frequency) | Juveniles; Adults | Juveniles and adults: Mortality from increased sedimentation. | Adhere to system-specific in-water work windows. | May affect survival at juvenile and adult life-history stages. |
| | | Localized alteration in periphyton abundance | NA | NA | NA | NA | NA | NA | NA |
| | | Increased suspended solids | During project construction and maintenance activities | Short-term | Interannual to decadal (depending on activity frequency) | Glochidia larvae; Juveniles; Adults | All life-history stages: See responses to related stressors under Water Quality Modification. | Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. | See effects for related stressors under Water Quality Modification. |
| | Construction/maintenance dredging | Alteration of bathymetry and substrate characteristics | During project construction and maintenance activities | Permanent | Interannual–decadal | Glochidia larvae; Juveniles; Adults | All life-history stages: See responses described under Hydraulic and Geomorphic Modification. | Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. Substrates containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels. | See effects for related stressors under Hydraulic and Geomorphic Modification. |
| | | Aquatic vegetation removal and delayed recovery | During project construction and maintenance activities | Intermediate-term | Interannual–decadal | Juveniles; Adults | Juveniles and adults: See responses described under Aquatic Vegetation Modification. | Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting. | See effects for related stressors under Riparian and Aquatic Vegetation Modification. |
| | | Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments | During project construction and maintenance activities | Temporary to short-term | Interannual–decadal | Glochidia larvae; Juveniles; Adults; | All life-history stages: See responses described for related stressors under Water Quality Modification. | Avoid turbidity effects above background levels. | May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification. |
| | **Water Quality Modification** | | | | | | | | |
| | | Increased suspended solids | Dependent on contributing mechanism of impact | Temporary to short-term (dependent on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Juveniles and adults: Effects depend on the magnitude of increased suspended solids. Turbidity sufficient to cause fine sediment embeddedness may bury these mussels and lead to direct mortality and decreased population survival. | Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity. | May affect juvenile and adult survival. |
| | | Altered dissolved oxygen levels | Dependent on contributing mechanism of impact | Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact | Intermittent to permanent (dependent on contributing mechanism of impact) | Glochidia larvae; Juveniles; Adults | All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects to host-fish could be stressor to these mussels. | Avoid sediment pulses. | May affect survival of larvae. May affect juvenile survival and adult survival, productivity, and spawning success. |

## Table A-25 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for California Floater and Western Ridged Mussel.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | | Altered pH levels | Dependent on contributing mechanism of impact | Temporary to short-term (depending on contributing mechanism of impact) | Intermittent to interannual–decadal (dependent on contributing mechanism of impact) | Juveniles; Adults | Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury and leading to reduced fitness of host fish. | Avoid in-water curing of concrete or discharge of concrete leachate to surface waters. | May affect survival of juveniles and adults |
| | Use of creosote-treated wood | Leaching of polycyclic aromatic hydrocarbons (PAHs) | Leaching begins upon installation, with highest levels after initial immersion, followed by peaks during periods of increased temperatures and higher flows. Leaching more pronounced when used in fresh water. Spikes in concentration occur during removal due to leaching from freshly cut surfaces and dispersal of sawdust fragments with high surface area. | Long-term (with decreasing concentration intensity over time) | Continuous with seasonal pulses (associated with high water temperature and current velocity) | Juveniles; Adults | Juveniles and adults: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Promote removal of creosote-treated wood and prevent new uses in accordance with pertinent regulations. Avoid use of other treated wood products where practicable. Use alternative materials such as concrete, galvanized steel, plastic lumber, recycled plastics, and plastic coatings where practicable. Where treated wood is necessary, use dense-grained material to limit leaching. Use plastic or metal cuffs at abrasion points to avoid fragmentation and release of treated wood particulates. | May affect survival of juveniles and adults. |
| | Use of ACZA- and CCA type C-treated wood | Leaching of metals (Cu, As, Cr, Zn) | Leaching begins upon installation, with highest levels occurring within 7 months of initial immersion | Intermediate-term | Continuous with seasonal pulses (dependent on current velocity) | Juveniles; Adults | Juveniles and adults: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality. | Removal: Completely remove treated wood where practicable, consistent with WDNR Standard Practice Memorandum. When piles are left in place, cut off at least 2 ft below surface and cap with clean sediment. Contain and capture sawdust for disposal at approved facility. | |
| | **Riparian Vegetation Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round | Long-term to permanent (dependent on nature of riparian impacts). | Seasonal | Glochidia larvae; Juveniles; Adults | All life-history stages: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns (including food web supporting host fish).<br>Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival and productivity during incubation, rearing, and spawning. |
| | Altered shoreline stability | Increased suspended solids and burial of benthic organisms attached to coarse substrate | Year-round (with specific stressors prominent during high flow conditions) | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Glochidia larvae; Juveniles; Adults | All life-history stages: Decreased food resource availability, leading to increased competition and resulting effects on growth and fitness for mussels and host fish. Decreased suitable habitat, injury, or mortality caused by excessive turbidity or resulting smothering by burial. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile and adult fitness and survival of mussels and host fish. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs | Year-round | Permanent | Continuous | Glochidia larvae | Mussel dependence upon allochthonous input is a data gap. However, could affect host fish. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect productivity. |

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## Table A-25 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for California Floater and Western Ridged Mussel.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced feeding opportunity, reduction in available cover, reduction in available habitat. | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Glochidia larvae; Juveniles; Adults | All life-history stages: Decreased habitat availability and food availability, leading to increased competition and resulting effects on growth and fitness, including health of host fish. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect survival, spawning success, and overall population productivity. |
| | Altered groundwater–surface water exchange | The effect of groundwater exchange to California floater and Western ridged mussels is a data gap | Year-round | Permanent | Continuous | Glochidia larvae; Juveniles; Adults | Mussel responses to groundwater exchange are a data gap. | Avoid disturbance of vegetation along stream. | Effect of groundwater exchange to mussel health and fitness is a data gap. |
| | **Lacustrine** | | | | | | | | |
| | Altered shading, solar input and ambient air temperature regime | Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures) | Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes) | Long-term to permanent (dependent on nature of riparian impacts) | Seasonal | Glochidia larvae; Juveniles; Adults | Glochidia larvae: Host-fish of the California floater and Western ridged mussel may be affected by increased temperatures, which may lead to mortality or increased thermal stress and decreased fitness of host fish.<br>Juveniles and adults: Mortality due to increased temperatures. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival of all life-history stages. |
| | Altered shoreline stability | Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation) | Year-round | Intermediate-term to long-term (dependent on time required for riparian recovery) | Continuous to seasonal (dependent on specific stressor) | Glochidia larvae; Juveniles; Adults | All life-history stages: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness for mussel host-fish. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect survival of all life-history stages. |
| | Altered allochthonous inputs | Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs. | Year-round | Permanent | Continuous | Glochidia larvae; Juveniles; Adults | All life-history stages: Mussel dependence on allochthonous inputs from shoreline riparian vegetation is a data gap. This could be a stressor to host fish. | Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. | May affect juvenile and adult growth, fitness, and productivity. |
| | Altered habitat complexity | Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover. | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Glochidia larvae; Juveniles; Adult | All life-history stages: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. | Encourage project designs that limit permanent alteration of high-quality habitat features. | May affect juvenile survival and productivity, as well as spawning success and overall population productivity. |
| | Altered groundwater–surface water exchange | Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation) | Year-round | Permanent | Continuous | Juveniles; Adults | Juveniles and adults: Mussel dependence on groundwater inflow is currently a data gap. | Avoid disturbance of vegetation along shoreline | Effects of the action resulting from this impact mechanism are unknown. |

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**Table A-25 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for California Floater and Western Ridged Mussel.**

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | **Aquatic Vegetation Modification** | | | | | | | | |
| | Altered autochthonous production | Reduced food web productivity | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Continuous | Juveniles | Juveniles: Reduced prey availability due to decreased food web productivity, decreased growth and fitness of host fish. Although effects specific to altered autochthonous inputs for the California floater and Western ridged mussels are a data gap, alterations could be expected to affect prey resource availability. | Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.<br>Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. | May affect all life-history stages. |
| | | Altered dissolved oxygen levels due to reduced photosynthesis. | Year-round (most pronounced in spring and summer when vegetation growth is most extensive) | Permanent | Seasonal | Glochidia larvae; Juveniles; Adult | All life-history stages: Require high levels of dissolved oxygen. See related stressor responses under Water Quality Alteration. Effects include effects to host fish. | | See effects for related stressors under Water Quality Modification. |
| | Altered habitat complexity | Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater) | Year-round | Short-term to permanent (dependent on nature of activity) | Continuous | Glochidia larvae; Juveniles; Adult | All life-history stages: Reduced prey resources due to decreased food web productivity, decreased growth and fitness of the California floater and Western ridged mussel prey and host fish. Altered autochthonous production could be expected to affect foraging success in this filter feeding species. | | May affect all life stages. |
| | **Hydraulic and Geomorphic Modification** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Altered channel geometry | Change in habitat structure and habitat suitability, reduced food web complexity, reduced habitat availability and suitability | Year-round | Permanent | Continuous | Glochidia larvae; Juveniles; Adults | Glochidia larvae: Changes in channel morphology, flow velocity, and substrate composition can affect host fish.<br>Juveniles and adults: As filter feeders, constant water flow is required. Altered channel geometry, flow velocity, and substrate composition can result in decrease habitat suitability and changes in food web complexity. This may limit prey resource availability and foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable. | May affect survival at all life-history stages and affect life-history stages and productivity of host-fish. |
| | Altered flow velocity | | Year-round (with stressor exposures occurring during high-flow events, fall through spring) | Permanent | Seasonal | | | | |
| | Altered substrate composition (including placement of non-erodable substrate) | | Year-round | Permanent | Continuous | | | | |
| | Altered groundwater-surface water exchange | | Year-round (with stressor exposure occurring during egg incubation and juvenile rearing) | Permanent | Continuous | | | | |
| | Addition of impervious surface | | Year-round | Permanent | Continuous | | | | |

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Table A-25 (continued). HPA HCP Shoreline Modification Exposure and Response Matrix for California Floater and Western Ridged Mussel.

| Sub-Activity Type | Mechanism of Impact | Exposure | | | | | Response to Stressor | Minimization Measures | Resulting Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | | | |
| | **Lacustrine** | | | | | | | | |
| | Altered wave energy | Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability | Year-round (with predominant effects from fall through spring, when wind driven waves are most pronounced) | Permanent | Continuous | Glochidia larvae; Juveniles; Adults | All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and adult mussels. This may occur through increased predation exposure, food web alterations and decreased foraging opportunity. Effects to host fish affect these mussels. | Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. | May affect survival at all life-history stages. Decreased fitness may lead to reduced spawning productivity. |
| | Altered current velocities | | Year-round (with effects more predominant in reservoirs versus natural lakes) | Permanent | Common | | | | |
| | Altered groundwater-surface water exchange | | Year-round | Permanent | Continuous | | | | |
| | Altered sediment supply | | Year-round | Permanent | Continuous | | | | |
| | Altered substrate composition | | Year-round | Permanent | Continuous | | | | |
| | **Ecosystem Fragmentation** | | | | | | | | |
| | **Riverine** | | | | | | | | |
| | Habitat loss and fragmentation | Fragmentation of side channel and floodplain habitat, change in habitat structure, availability, and suitability, reduced food web complexity | Year-round | Permanent | Continuous | Glochiddia larvae; Juveniles; Adults | Glochidia larvae: Changes in habitat availability may indirectly affect survival through effects on host fish. Juveniles and adults: The structural footprint of groins and bank barbs may permanently modify habitat suitable for juveniles and adults, affecting survival and overall population abundance. | Require assessment of the hydraulic effects of the project before permitting and avoid permitting designs that lead to disconnection of floodplain habitat. | May affect survival at all life-history stages and affect life-history stages and productivity of host-fish. |
| | Loss of LWD recruitment | Sequestration of LWD preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Glochiddia larvae; Juveniles; Adults | See responses to altered habitat complexity under Riparian Vegetation Modification. | No specific recommendations. | May affect growth and survival, as well as spawning success and overall population productivity. |
| | **Lacustrine** | | | | | | | | |
| | Habitat loss and fragmentation | Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability | Year-round | Permanent | Continuous | Glochiddia larvae; Juveniles; Adults | Glochidia larvae: Changes in habitat availability may indirectly affect survival through effects on host fish. Juveniles and adults: The structural footprint of groins and bank barbs may permanently modify habitat suitable for juveniles and adults, affecting survival and overall population abundance. | Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. | May affect survival at all life-history stages and affect life-history stages and productivity of host-fish. |
| | Loss of LWD recruitment | Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification | Year-round | Permanent | Continuous | Glochiddia larvae; Juveniles; Adults | See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. | Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance. | See effects for related stressors under altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification. |

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