



United States Department of the Interior



FISH AND WILDLIFE SERVICE

Washington Fish and Wildlife Office
510 Desmond Dr. SE, Suite 102
Lacey, Washington 98503

SEP 05 2019

In Reply Refer To:

0IEWFW00-2016-F-1231-R001
X-Ref: 0IEWFW00-2014-1-0452

Allyson Purcell, Branch Chief
Sustainable Fisheries Division
National Marine Fisheries Service
1201 NE Lloyd Boulevard, Suite 1100
Portland, Oregon 97232-1274

Dear Ms. Purcell:

Subject: Reinitiation of Formal Consultation for the NMFS 4(d) Rule Determinations for Green River Salmon and Steelhead Hatchery Operations

This letter is in response to your July 2, 2019 letter requesting reinitiation of the consultation on the National Marine Fisheries Service's (NMFS) 4(d) Rule determination for hatchery operations in the Green River watershed. On December 22, 2017, the U.S. Fish and Wildlife Service (USFWS) concluded formal consultation and provided a Biological Opinion (Opinion) (USFWS # 0IEWFW00-2016-F-1231), to the NMFS addressing the proposed Endangered Species Act 4(d) Rule determinations for the Washington Department of Fish and Wildlife, Muckleshoot Indian Tribe, and Suquamish Tribe's operation of the salmon¹ and steelhead programs in the Green River, and their effects on bull trout (*Salvelinus confluentus*) and designated critical habitat for the bull trout. The trigger for reinitiation is based on changes in the proposed action that will result in additional adverse effects to bull trout that were not covered in the 2017 Opinion.

This letter addresses the following two issues identified by NMFS:

1. Changes in the proposed action: Specifically, alternative broodstock collection methods in the form of angling, gill netting, and beach seining for two fall Chinook salmon (*Oncorhynchus tshawytscha*) and two steelhead trout (*O. mykiss*) programs have been added. In addition, the Tacoma Power headworks fish trap will be used for broodstock collection in perpetuity instead of only temporarily.

¹ Collectively, the Washington Department of Fish and Wildlife, Muckleshoot Indian Tribe, and Suquamish Tribe are referred to as the fisheries co-managers for purposes of this consultation.

2. Reconsideration of incidental take associated with hook-and-line collection of steelhead broodstock for the Green River native winter steelhead program at the Soos Creek fish hatchery. NMFS indicates that the amount of incidental take associated with this activity was underestimated in the 2017 Opinion and is requesting that the USFWS reevaluate the effects of this element of the proposed action.

This letter amends the Opinion to address changes to the extent of effects to bull trout as a result of these new activities. This formal reinitiation of the consultation was completed in accordance with section 7(a)(2) of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*).

Our 2017 Opinion described effects to bull trout and critical habitat associated with the following broodstock collection activities:

- Hook-and-line (angling). Hook-and-line collection of winter steelhead is conducted for the native winter steelhead program (Soos Creek hatchery) in the Green River. Up to 60 adult winter steelhead are collected from February 1 through April 30 (one to two times per week weather and flows permitting) between river mile (RM) 29.3 and RM 44 in the Green River. The 60-adult broodstock target is based on an 80,000 egg take goal.
- Hatchery weirs and traps. Collection of multiple species of adult salmon and steelhead at hatchery weirs and traps, including the Soos Creek, Keta/Crisp Creek, and Icy Creek Fish Hatcheries, and the Fish Restoration Facility (FRF).
- Tacoma Power fish trap. Collection of multiple species of adult salmon and steelhead using the Tacoma Power fish trap at RM 61 on the Green River on a temporary basis until enough fish start returning to the FRF facility to meet broodstock needs.

Changes to the proposed action

The NMFS and fisheries co-managers have proposed the following two changes to broodstock collection methods and activities in the Green River:

- Revisions in the use of the Tacoma Power fish trap. Broodstock will be collected at this trap on an indefinite, on-going basis, rather than only temporarily as initially proposed.
- New/additional broodstock collection methods. As described in the 2017 Opinion, the primary means of broodstock collection were: 1) traps and weirs at hatchery facilities and the FRF and, 2) by angling to collect adults for the native winter steelhead program at the Soos Creek hatchery. The proposed action in the 2017 Opinion did not include use of alternative broodstock collection methods, such as nets (beach seines or gill nets). The NMFS and co-managers have determined that other capture methods may be needed during years when angling (Soos Creek native winter steelhead) and trapping at the facilities (Chinook programs and FRF steelhead) are not adequate to meet broodstock collection needs. Table 1 provides details regarding time, location, and methods of proposed alternative broodstock collection.

Table 1. Alternative broodstock collection time, location, and methods for fall Chinook and winter steelhead hatchery programs in the Green River watershed.

Program	Time	Location	Alternative broodstock methods	Gill net mesh size (stretch)
Soos Creek fall Chinook	August through October	RM 33–49	gill net, beach seine	5”
FRF fall Chinook		RM 33–34		
Green River native winter steelhead (for the Soos Creek Hatchery)	December through April	RM 29–44	angling, gill net, beach seine	4” to 4-1/2”
FRF steelhead		RM 34–61		

Broodstock collection methods are intended to minimize stress and injury to fish during capture and handling because the adult fish must be transported and held for days or weeks at the hatchery until they are ripe and ready for spawning. The following practices will be employed during broodstock collection involving the use of nets or angling:

- Only artificial baits and lures will be used during angling.
- Fish caught by hook-and-line will be landed as quickly as possible.
- Gill nets will be attended at all times and will be hauled in at the first sign that a fish is entangled.
- Beach seines will be set for short periods of time, typically less than 10 minutes.

In addition, the following best management practices will be employed to minimize risk to bull trout:

- Individuals engaged in broodstock collection activities will be trained and knowledgeable in the identification of bull trout and safe fish handling procedures.
- Incidentally captured bull trout will be liberated from the capture gear and released as soon as possible and as close as possible to the point of capture.
- All captured bull trout shall be released with the minimum handling necessary to liberate the fish from the capture gear and safely return it to the river.
- Handling to liberate incidentally captured bull trout will occur in the water to the greatest extent practicable. Handling of bull trout on land or out of the water will occur only to the extent absolutely necessary.

Reevaluation of exposure, adverse effects, and incidental take caused by hook-and-line collection method

Our 2017 Opinion determined that hook-and-line collection of adult steelhead would result in the incidental capture of three bull trout over the 20-year duration of the Opinion, and that delayed mortality would occur to one of the three individuals captured. This estimate was based largely

on the number of bull trout historically captured during hook-and-line broodstock collection for this ongoing program. The information used was from the time that the steelhead program was started in 2002² to the time the Opinion was completed in 2017. During this time period, a total of three bull trout were incidentally captured by angling for steelhead broodstock. The Opinion did not anticipate that bull trout abundance, steelhead abundance, or angling effort would change during the 20-year term of the consultation and only relied on the data from 2002 to 2017.

NMFS and the fisheries co-managers have identified the following two concerns with this take estimate:

1. The projected incidental capture of three bull trout during the 20-year consultation period likely underestimates the future capture rate (number of bull trout captured per year) because the historical record upon which the take estimate was based covers a shorter time period (16 years versus 20).
2. The 2017 Opinion also did not consider increased angling effort for steelhead. For most of the history of the steelhead program (2002 to 2014), the adult collection target and corresponding angling effort (time spent angling) was based on an egg take goal of 50,000 eggs. However, in 2015, this goal was increased to 80,000 eggs, which represents an increase of 60 percent. To meet the increased egg target goal, angling effort (time spent angling) would need to correspondingly increase in order to capture the additional adults needed to meet the hatchery production goals. This elevated egg take and corresponding adult capture goals was included in the proposed action. However, the bull trout capture estimate was based on historic numbers and was not adjusted to account for both the increased angling effort and longer time period of the 20-year consultation.

Effects to Bull Trout

Reevaluation of Incidental Take Caused by Hook-and-Line Collection of Steelhead

The USFWS agrees with the concerns expressed by NMFS and the fisheries co-managers. Therefore, we have recalculated the projected incidental capture of bull trout associated with the use of angling for steelhead broodstock collection. In doing so, we applied the same methods of analysis and assumptions used previously, but also accounted for the longer time period of the consultation and increased angling efforts. Specifically, we performed a more detailed calculation of historical angling effort and bull trout encounter rate, and applied this to the proposed action in order to provide a more robust projection of future bull trout encounters.

From 2002 through 2017, a total of 552 adult steelhead were collected using hook-and-line angling methods and 3 bull trout were incidentally captured. During the 20-year consultation term, up to 1,200 adult steelhead will be captured using hook-and-line/angling methods. Bull trout incidental capture rate (number of bull trout caught per steelhead caught) is dependent in part on bull trout abundance and angling efficiency (catch per unit effort), which may vary with

² For the purposes of this document, the term “return year” is defined as the year when adult natural-origin (“wild”) winter steelhead enter freshwater to spawn. In the Green River, this typically begins in February and March.

steelhead abundance. Because information on bull trout abundance in the Green River is extremely limited, we assume that during the 20-year consultation term the number would be similar to the historical abundance from 2002 to 2017. The abundance of wild winter steelhead has fluctuated since 2002. Mean abundance from 2002 to 2007 was 1,658 fish. This dropped to a mean abundance of 608 fish from 2008 to 2013. It was during these low abundance years that the three bull trout were incidentally caught. Subsequently from 2014 to 2017, the mean abundance of steelhead has increased to 1,470 fish. There are no data to suggest that steelhead abundance and fluctuations in abundance will be different during the 20-year consultation term than was observed from 2002 to 2017. Therefore, we assume that angling efficiency and bull trout encounter rate (bull trout caught per steelhead caught) during the 20-year consultation term will be similar to those from 2002 through 2017. Applying the historical incidental catch rate (3 bull trout caught per 552 steelhead caught) to the proposed action (capture target of up to 1,200 steelhead during the 20-year consultation), we estimate up to 7 bull trout will be incidentally caught during the 20-year consultation term.

Broodstock angling methods are intended to minimize stress and injury because the captured fish must be transported and kept in good condition for days or weeks at the hatchery until they are ripe and ready for spawning. For example, artificial baits and lures are used because they result in less mortality in salmonids than natural baits. In a meta-analysis of 182 studies on hooking mortality studies in salmonids, Hühn and Arlinghaus (2011, p. 156) found that mortality associated with the use of artificial baits and lures averaged 11.6 percent (immediate and delayed combined) in salmonids, compared to 27.0 percent for natural baits. This 11.6 percent figure for artificial baits and lures aligns well with the mean 15.0 percent mortality to captured steelhead broodstock reported in the Hatchery and Genetic Management Plan, although captured steelhead experience the additional stressors associated with transportation and captivity. In our 2017 Opinion, the USFWS noted that there are very few studies that evaluate hooking mortality on bull trout, and those that do exist did not evaluate delayed (post-release) mortality. Therefore, the mortality figures reported for salmonids by Hühn and Arlinghaus (2011) are a reasonable surrogate to use for bull trout. Applying the 11.6 percent salmonid mortality rate associated with the use of artificial bait to the seven bull trout expected to be captured during angling for steelhead broodstock collection, yields an expected mortality (immediate and delayed combined) of up to one bull trout during the 20-year consultation term.

Use of the Tacoma Power Fish Trap

Our 2017 Opinion concluded that the likelihood of a bull trout entering the Tacoma Power Fish Trap during the period of temporary trap operation for broodstock collection was discountable. This was based on the apparent low abundance of bull trout in the Green River, particularly in areas upstream of the Soos Creek confluence, and the fact that no bull trout have ever been captured in the fish trap during limited historical operations.

The fish trap was constructed to provide upstream passage for adult anadromous fish to access inaccessible habitat upstream of the Tacoma Power Headworks Dam and Howard Hansen Dam pursuant to an agreement and 2001 Habitat Conservation Plan (HCP) entered into by Tacoma Power. Effects to bull trout associated with the operation of the Tacoma Power fish trap were

consulted on as part of the USFWS Endangered Species Act consultation on the 2001 HCP³. However, trap and haul operations to provide upstream passage for adult fish was and continues to be contingent on the U.S. Army Corps of Engineers providing downstream passage for juveniles at Howard Hansen Dam. Because the downstream juvenile fish passage facility has not been built to date (and is unlikely to be completed during the term of this consultation), the Tacoma Power fish trap has never been used for its intended purpose. The use of the facility to collect broodstock for the hatchery programs is ancillary to the facility's primary purpose and function, and imposes no additional effects to bull trout. For these reasons, use of the Tacoma Power fish trap for broodstock collection is considered part of the baseline. No further consultation on use of this facility for broodstock collection is necessary, unless the proposed action were to change in such a manner as to alter the nature, scope, or magnitude of effects to bull trout to a degree not considered in the 2001 HCP Endangered Species Act consultation.

Alternative Broodstock Collection Methods

As described in our 2017 Opinion, bull trout abundance in the Green River appears to be very low. There are no spawning populations of bull trout in the Green River watershed. Any bull trout in the Green River are presumed to be from other nearby populations (Puyallup, Snohomish/Skykomish, and/or Stillaguamish) that enter the Green River for foraging and/or overwintering. Targeted systematic surveys for bull trout in the Green River action area (i.e., below the Tacoma Power dam and fish trap) are lacking. However, incidental observations of bull trout during other activities suggest a very low abundance. For example, bull trout are known to be highly susceptible to incidental capture during angling that targets other species such as steelhead. Despite this, only three bull trout were incidentally caught during steelhead broodstock collection from 2002 to 2018. Bull trout observations from these and other fishery activities in the action area total fewer than 20 fish since 2000, suggesting a very low abundance of bull trout in the Green River. Bull trout appear to primarily use the lower and middle reaches of the river as no bull trout have ever been observed upriver from RM 44.

Bull trout may occur in the Green River at any time of the year based on historical observations. From July through February, smaller-size subadult bull trout are primarily expected because spawning-age adults are generally in their natal watersheds during this time of year. Limited data from the Green River aligns with this expectation: only two bull trout (18 percent) observed in the eight months of July through February were larger than 380 mm long (15 inches), whereas five bull trout documented between March and June were that size or larger. Adult bull trout in the Puget Sound region can reach 600 mm long and larger. To date, the largest bull trout observed in the Green River was 610 mm (24 inches) long. Gill nets used for Chinook salmon are expected to have a selectivity⁴ of less than 0.12 for the size of bull trout expected to be present in the Green River during collection activities, based on gill net selectivity of salmonids with similar body shape (Bromaghin 2005). For steelhead gill nets, selectivity for bull trout is expected to have a broader range (0.02–0.96) because of multiple mesh sizes that may be used

³ Biological Opinion for the issuance of a Section 10(a)(1)(B) Incidental Take Permit (PRT-TE044757-0) to the Tacoma Public Utilities, Tacoma Water for the Green River Water Supply Operations and Watershed Protection HCP, July 2001.

⁴ Selectivity is a measure of the degree to which fish are susceptible to capture. Selectivity ranges from 0 to 1, with 0 indicating not susceptible to capture, and 1 indicating maximum susceptibility to capture.

and because of the broader size range of bull trout sizes that may be present during steelhead collection, particularly in March and April. Peak selectivity for steelhead gill net sizes is expected to occur for bull trout that are between 392 and 441 mm long.

The Soos Creek hatchery programs (fall Chinook, native winter steelhead) have typically collected enough broodstock using primary collection methods (traps and angling) that alternative methods have not been needed. There are usually at least twice as many adult fall Chinook that enter the Soos Creek trap than are needed for broodstock. For winter steelhead, angling is the primary method of capture. Similar to Chinook, there have typically been enough adult winter steelhead returning to the river that alternative collection methods have not been used. However, in recent years, adult return numbers for both species have been low and declining marine conditions caused by climate change could increase the frequency and severity of these low return rates.

The FRF programs (fall Chinook, winter steelhead) are not in operation yet. However, the Soos Creek hatchery propagates the same species. Therefore, information on broodstock collection methods for the Soos Creek programs are useful for informing potential needs for alternative broodstock collection for the FRF programs. The FRF fall Chinook program is relatively small compared to the Soos Creek program, and will produce fewer than 10 percent of the hatchery Chinook in the watershed. In addition, because the FRF and Soos Creek programs are closely linked, excess returns of Chinook to the Soos Creek hatchery likely will be used for FRF broodstock. For steelhead, the primary method of broodstock collection for the FRF will be fish traps (e.g., FRF, Tacoma Power), minimizing the need for in-river collection methods. Angling will be used as an alternative method, and will generally be implemented in upper reaches of the river where fewer bull trout have historically been observed.

For all of the Chinook and winter steelhead programs, alternative broodstock collection methods will only be used as needed to supplement primary methods because alternative methods are more arduous and costly to employ. Based on historical broodstock collection and adult return records, and considering the anticipated effects of climate change, we expect that alternative broodstock collection methods will likely not be used during most years of the consultation term. In addition, when alternative broodstock collection methods are used, they will only be used sparingly. Considering the facts and assumptions described above, we expect the following estimated numbers of incidental capture of bull trout associated with the use of alternative broodstock collection measures:

- For both Soos Creek programs combined, we anticipate that up to 16 bull trout may be incidentally captured during the entire term of the consultation. This does not include incidental capture associated with angling for winter steelhead, which is the primary collection method and was considered in the 2017 Opinion and discussed in a separate section above.
- For both FRF programs combined, we anticipate that up to eight bull trout may be incidentally captured during any period of 10 consecutive years. We cannot calculate a total over the term of the consultation because it is uncertain when during the consultation term the FRF programs will come online.

Mortality rates from angling employing these methods were discussed in a preceding section. Small-scale gill netting and beach seining, such as that used for broodstock collection, generally are associated with low immediate and delayed mortality rates to salmonids when entanglement and handling times are short (Raby et al. 2015; Patterson et al. 2017). For example, mortality to Chinook salmon collected for broodstock using gill nets in the Skagit River averaged 2.8 percent during a recent 12-year period. Mortality rates can vary by species and life history stage, among other factors. There are no studies of gill net or beach seine mortality to bull trout. In a meta-analysis, Patterson et al. (2017, pp. 77-83) estimated mortality risk to incidentally caught salmonids based on gear type, capture time, and handling time using 34 gill net and 18 beach seine mortality studies. The authors concluded that the risk of mortality is less than 5 percent when entanglement and handling times are short (entanglement time: less than 3 min for gill nets and 10 min for beach seines; handling time: less than 10 sec in air and 3 min in water). Mortality rates increase to 15 percent for slightly longer entanglement and handling times (e.g., entanglement times: 3-10 min in gill nets; handling time: 10 to 60 sec out of water). The entanglement and handling times that the authors concluded would result in low mortality rates (less than 5 percent and no more than 15 percent) are on the order of those expected to occur with the proposed action.

We expect that mortality of bull trout (immediate and delayed combined) associated with the use of nets and angling for alternative broodstock collection will be less than 15 percent. However, the different broodstock collection methods (angling, gill netting, beach seining) may be employed in different combinations annually. In addition, capture and handling times may vary depending on crew experience and physical and environmental conditions at particular collection sites. Therefore, using the 15 percent mortality rate represents a reasonable and conservative worst case expectation for mortality caused by the proposed action. Applying this rate to the expected incidental capture yields the following bull trout mortality estimates associated with the proposed alternative broodstock collection methods:

- Up to two bull trout (of the 16 individuals incidentally captured) will suffer immediate or delayed mortality for the Soos Creek hatchery programs during the term of the consultation.
- No more than one of the eight bull trout incidentally captured during broodstock collection for the FRF programs will suffer immediate or delayed mortality during any period of 10 consecutive years.

Amendment to the Incidental Take Statement for the Opinion

Based on our analysis of the proposed revisions to the fall Chinook salmon and steelhead programs in the Green River, the USFWS is amending the Incidental Take Statement for the 2017 Opinion (USFWS, pp. 29-31) as described below.

Amount or Extent of Take

1. Incidental take of seven adult or subadult bull trout in the form of *harassment* and *harm* resulting from capture during angling for the Soos Creek native winter steelhead program during the 20-year consultation period. We anticipate that capture and handling from angling will result in immediate or delayed mortality of up to one adult or subadult bull trout during the 20-year consultation period. It is not feasible to monitor delayed mortality. Therefore, both capture and immediate mortality will serve as surrogates for monitoring and reporting immediate and delayed mortality. Exceedances of either the anticipated capture (seven bull trout) or immediate mortality to one bull trout will be considered an exceedance of take from immediate and delayed mortality.
2. Incidental take of bull trout in the form of *harassment* and *harm* resulting from capture during alternative broodstock collection for both the Chinook salmon (angling, beach seining, and/or gill netting combined) and native winter steelhead (beach seining and/or gill netting combined; angling is covered above) programs at Soos Creek. We estimate that up to 16 adult or subadult bull trout will be caught during the consultation term. We anticipate that capture and handling from alternative broodstock collection will result in immediate or delayed mortality of up to two adult or subadult bull trout during the consultation term. It is not feasible to monitor delayed mortality. Therefore, both capture and immediate mortality will serve as surrogates for monitoring and reporting immediate and delayed mortality. Exceedances of either the anticipated capture (16 bull trout during the consultation term) or immediate mortality of two bull trout during the consultation term will be considered an exceedance of take from immediate and delayed mortality.
3. Incidental take of bull trout in the form of *harassment* and *harm* resulting from capture during alternative broodstock collection (angling, beach seining, and/or gill netting combined) for the Chinook salmon and winter steelhead programs at the FRF facility. We estimate that up to 8 adult or subadult bull trout will be caught during any period of 10 consecutive years that the FRF program is operating. We anticipate that capture and handling from alternative broodstock collection will result in immediate or delayed mortality of up to one adult or subadult bull trout during any period of 10 consecutive years. It is not feasible to monitor delayed mortality. Therefore, both capture and immediate mortality will serve as surrogates for monitoring and reporting immediate and delayed mortality. Exceedances of either the anticipated capture (8 bull trout during any period of 10 consecutive years) or immediate mortality of one bull trout over the 10 year operational period will be considered an exceedance of take from immediate and delayed mortality.

Effect of the Take

Our 2017 Opinion concluded that the level of anticipated take was not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

Reasonable and Prudent Measures

1. RPM 1 remains unchanged.
2. Minimize and monitor adverse effects to bull trout associated with alternative broodstock collection activities, including incidental capture and handling, and genetic tissue removal.

Terms and Conditions

The Terms and Conditions associated with RPM 1 remain unchanged.

Terms and Conditions associated with RPM 2:

- a. Hooks that penetrate critical areas, such as the esophagus and stomach that cannot be removed easily, will be left in the fish with the line being cut as close as possible to the hook.
- b. All captured bull trout shall be reported to the USFWS. Reports shall include the following: date and location of capture, capture method, approximate size of the fish, condition of the fish at release (including any obvious injuries or descaling, and whether these were the result of incidental capture and handling associated with alternative broodstock collection), and whether the fish was released alive or died.
- c. Bull trout mortalities shall be kept whole and put on ice or frozen. Frozen specimens shall be wrapped directly in aluminum foil to preserve the specimen in a manner that allows for future analysis. Alternative arrangements regarding the preservation or use of mortalities are allowed if coordinated with the USFWS. The USFWS office listed below must approve of the request in writing prior to the permittee implementing any alternative:

Jeff Chan, Bull Trout Lead
Listing and Recovery Division
U.S. Fish and Wildlife Service
510 Desmond Dr. SE, Suite 102
Lacey, Washington 98503
360-753-9440


Conclusion

The USFWS has determined that the identified changes will increase the overall number of bull trout exposed to adverse effects of broodstock collection, including incidental capture, handling, and mortality. However, the total number of bull trout that will be injured or killed remains small (no more than four individuals over the 20-year consultation term), and this loss of a small number of individuals is not expected to measurably reduce the overall population abundance at the scale of the core areas or the Coastal Recovery Unit. The likelihood of bull trout survival and recovery will not be appreciably reduced. Therefore, we find that the rationale and conclusions stated in our 2017 Opinion remain valid and essentially unchanged.

Issuance of this letter concludes reinitiation of formal consultation. A copy of this correspondence will be placed in the record. The action should be reanalyzed if new information reveals effects of the action that may affect listed species or critical habitat in a manner, or to an extent, not considered in this consultation. The action should also be reanalyzed if subsequently modified in a manner that causes an effect to a listed species or critical habitat that was not considered in this consultation, and/or a new species is listed or critical habitat is designated that may be affected by the action.

If you have any questions regarding the Opinion, or our shared responsibilities under the Endangered Species Act, please contact Martha Jensen at 360-753-9000, martha_l_jensen@fws.gov or Curtis Tanner at 360-753-4326, Curtis_Tanner@fws.gov.

Sincerely,

for


Brad Thompson, Acting State Supervisor
Washington Fish and Wildlife Office

cc:

NMFS, Lacey, WA (M. Celedonia)
NMFS, Portland, OR (C. Hurst)
WDFW, Olympia, WA (B. Missildine)
MIT, Auburn, WA (I. Tinoco)

LITERATURE CITED

- Bromaghin, J. F., 2005. A versatile net selectivity model, with application to Pacific salmon and freshwater species of the Yukon River, Alaska. *Fisheries Research* 74(1-3):157-168.
- Hühn, D. A., and R. Arlinghaus. 2011. Determinants of Hooking Mortality in Freshwater. In *American Fisheries Society Symposium*, Vol. 75, pp. 141-170.
- Patterson, D. A., K. A. Robinson, R. J. Lennox, T. L. Nettles, L. A. Donaldson, E. J. Eliason, G. D. Raby, J. M. Chapman, K. V. Cook, M. R. Donaldson, A. L. Bass, S. M. Drenner, A. J. Reid, S. J. Cooke, and S. G. Hinch. 2017. Review and Evaluation of Fishing-Related Incidental Mortality for Pacific Salmon. DFO Canadian Science Advisory Secretariat Research Document 2017/010. ix + 155 pp.
- Raby, G. D., M. R. Donaldson, S. G. Hinch, T. D. Clark, E. J. Eliason, K. M. Jeffries, K. V. Cook, and 6 others. 2015. Fishing for effective conservation: context and biotic variation are keys to understanding the survival of Pacific salmon after catch-and-release. *Integrative and Comparative Biology* 55(4):554-576.
- USFWS (U.S. Fish and Wildlife Service). 2017. Biological Opinion on the NMFS 4(d) Rule Determination for the WDFW, Muckleshoot Indian Tribe, and Suquamish Tribe Salmon and Steelhead Hatchery Operations in the Green River Watershed, including the Elliott Bay and Des Moines Marine Net Pens, 31 pp. (plus appendices).