STATE OF WASHINGTON **April 2018**

Validation of Habitat Preferences for Select Native Freshwater Fishes in the Chehalis River, Washington State

by Marie Winkowski and Neala Kendall

Washington Department of FISH and WILDLIFE

FPT 18-02

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April 2018

Acknowledgements

This is a contribution of the Washington Department of Fish and Wildlife's Fish Science Division to ongoing research in the Chehalis River Basin. This work was funded by the Washington State Legislature in Second Engrossed House Bill 1115 (Chapter 3, Laws of 2015) designated for study, analysis, and implementation of flood control projects in the Chehalis River Basin. Projects under this funding were selected to fill key information gaps identified in the Aquatic Species Enhancement Plan Data Gaps Report published in August 2014. Project funding was administered by the Washington State Recreation Conservation Office (RCO).

This study could not have been successful without the work of a dedicated field crew including Elizabeth Lee, Garrett Moulton, and Nathan Straten. The success of this study was also dependent on support from the WDFW Water Science Team, specifically Hal Beecher, Steve Boessow, and Kiza Gates, as well as Jim Pacheco with Ecology who helped with study design, data analyses, and providing field equipment. We also thank the many WDFW staff working in this large basin, including Curt Holt, Kim Figlar-Barnes, Sara Ashcraft, John Winkowski, Eric Walther, Julie Tyson, and Keith Douville for providing essential information about fish spawning locations, as well as the Lake Aberdeen Hatchery staff, including Ken Isaksson and Keith Burns, for use of their facility for fish tagging training. Hal Beecher also provided helpful comments that improved this report. We thank Weyerhaeuser Company and Panesko Tree Farm for land access.

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Executive Summary

Understanding the riverine distribution and habitat preferences of fishes is essential to understanding how natural and anthropogenic impacts will affect them. However, basin-specific fish habitat preferences for non-salmon or steelhead, native freshwater fish are lacking for many watersheds, including the Chehalis River in southwest Washington State. Subsequently, validations of habitat preferences, in terms of habitat suitability indices/criteria (HSCs), were identified as a data gap in section 4.1.3.1 Validation Studies in the Aquatic Species Enhancement Plan Data Gaps Report (Aquatic Species Enhancement Plan Technical Committee 2014a).

In this study, we identified microhabitat preferences in terms of HSCs for water depth, water current velocity, and substrate for largescale sucker, speckled dace, Pacific lamprey, and mountain whitefish at rearing and spawning life stages. We compared these preferences among species and life stages and with studies from other basins. Each species exhibited unique, life-stage specific habitat preferences, and these preferences were generally similar to those observed in other drainages. However, some were novel, such as the spawning habitat preferences for speckled dace, which included a range of depths (1-3 ft.), 2 ft./sec. velocity, and sand and gravel substrate as the most preferred spawning habitat. In addition to flow-habitat models, our HSCs will be used to predict and compare available habitat for these fishes under different river flow scenarios. This information provides a management and decision-support tool for evaluating potential impacts from proposed flood-retention dams or restoration actions.

Introduction

Understanding fish-habitat preferences in a river system is fundamental to understanding how changes to habitat quantity or quality impact fish assemblages or alter the suitability of streams for a given species. Changes to physical habitat, such as reduced habitat complexity, have been shown to increase competition between fish species, including non-native species (Moyle 1994). For management purposes, evaluating potential natural or anthropogenic disturbances to or restoration planning for a fish species requires the fundamental understanding of fish-habitat relationships (Beecher et al. 1993, Roni 2002). Known fish-habitat associations can be used to predict available habitat based on the number and distribution of associated fish and the amount and distribution of associated habitats (Fausch et al. 1988, Beecher et al. 1993). Despite the importance of understanding fish-habitat associations, there is a general lack of knowledge of basin-specific, non-salmonid native freshwater fish habitat preferences, especially benthic species such as sculpin and larval lamprey (Young et al. 2013, Jolley et al. 2016) and non-game fishes such as largescale sucker and speckled dace (Baxter 2002). While some species have habitat preferences described specific to other basins, here we are validating and expanding them specifically for the Chehalis River in southwest Washington State.

The Chehalis River is a coastal watershed that remained a refuge for species during the last glaciation (McPhail and Lindsey 1986) and supports a diverse array of native freshwater fishes including catostomids, cottids, cyprinids, gasterosteids, petromyzontids, salmonids, and umbrids as well as a wealth of amphibian species. While it maintains a large, relatively intact floodplain, urbanization of and building infrastructure on the floodplain have reduced its habitat complexity and function. Flooding in recent years (1996, 2007, and 2009) has led to the proposal for a flood reducing and water retention structure (hereafter “dam”) towards the headwaters of the basin as well as extensive restoration planning. In order to understand the potential impacts associated with the proposed dam and restoration efforts on native freshwater fishes, we sought to understand the habitat preferences associated with select fish species present in the Chehalis River Basin. Validations of habitat preferences, in terms of habitat suitability indices/criteria (HSCs), were also identified as a data gap in section 4.1.3.1

Validation Studies in the Aquatic Species Enhancement Plan Data Gaps Report (Aquatic Species Enhancement Plan Technical Committee 2014a).

For this study, we identified microhabitat preferences in terms of HSCs for water depth, water current velocity, and substrate for select fishes in the Chehalis and Willapa River Basins. Objectives included:

A. Identify depth, velocity, and substrate preferences for largescale sucker (*Catostomus macrocheilus*), speckled dace (*Rhinichthys osculus*), Pacific lamprey (*Entosphenus tridentatus*), and mountain whitefish (*Prosopium williamsoni*) at rearing and spawning life stages.
B. Describe any evident macrohabitat or mesohabitat associations (e.g., associations of study species to pool versus riffle habitat).

Methods

Study Area

HSC validations occurred throughout the Chehalis River Basin as well as in the Willapa River Basin (Figure 1). The Chehalis River Basin is the second-largest watershed in Washington State at 6,900 km^2. This coastal, rain-dominant system is higher gradient near the headwaters and gradually broadens and flattens further downstream (Phinney and Bucknell 1975). The river's mainstem forms at the confluence of the East Fork and West Fork Chehalis rivers at RKm 190 (elevation 260 m) with headwaters in the Willapa Hills in southwestern Washington (Phinney and Bucknell 1975, Smith and Wenger 2001). Land use in the basin is predominantly forested areas (83%) followed by agricultural lands (14%) and urban areas (2%) (Ecology 2001).

The Willapa River Basin is 570 km^2 and adjacent to the southwest of the Chehalis River Basin. It was also included in the study area due to the similarity in hydrology, geomorphology, and land use to the Chehalis River Basin (Stohr 2004) and high density of observed Pacific lamprey redds (Washington Department of Fish and Wildlife, unpublished data).

Study Species

Species included in this validation study were selected from key species previously identified by the Aquatic Species Enhancement Plan (Aquatic Species Enhancement Plan

Technical Committee 2014b) and Data Gaps Report (Aquatic Species Enhancement Plan Technical Committee 2014a). Largescale sucker, speckled dace, Pacific lamprey, and mountain whitefish are present throughout the Chehalis Basin; however relatively little is known about their distribution or spawning and rearing habitat preferences in the Chehalis Basin.

Availability and Use Measurements

We determined habitat suitability for a given fish species by comparing microhabitat use to microhabitat availability. Following Bovee and Cochnauer (1977), we identified microhabitat use based on relative occupancy or density of a target fish, which assumes fish select less favorable conditions with diminishing probability. Therefore, sufficient abundance of a target species at a given life stage is required to determine microhabitat use. Sufficient diversity of available microhabitats is also required to accurately identify microhabitat selection. Furthermore, we assume that observed fish are selecting the most preferred habitat and are not being displaced by the observation method or the presence of other fish of the same or different species. Fish use measurements preceded availability measurements to ensure observed fish were not disturbed. We recorded measurements for both fish use (i.e., microhabitat conditions at the precise point in the river where fish are observed) and availability (i.e., distribution of microhabitat conditions for the defined reach).

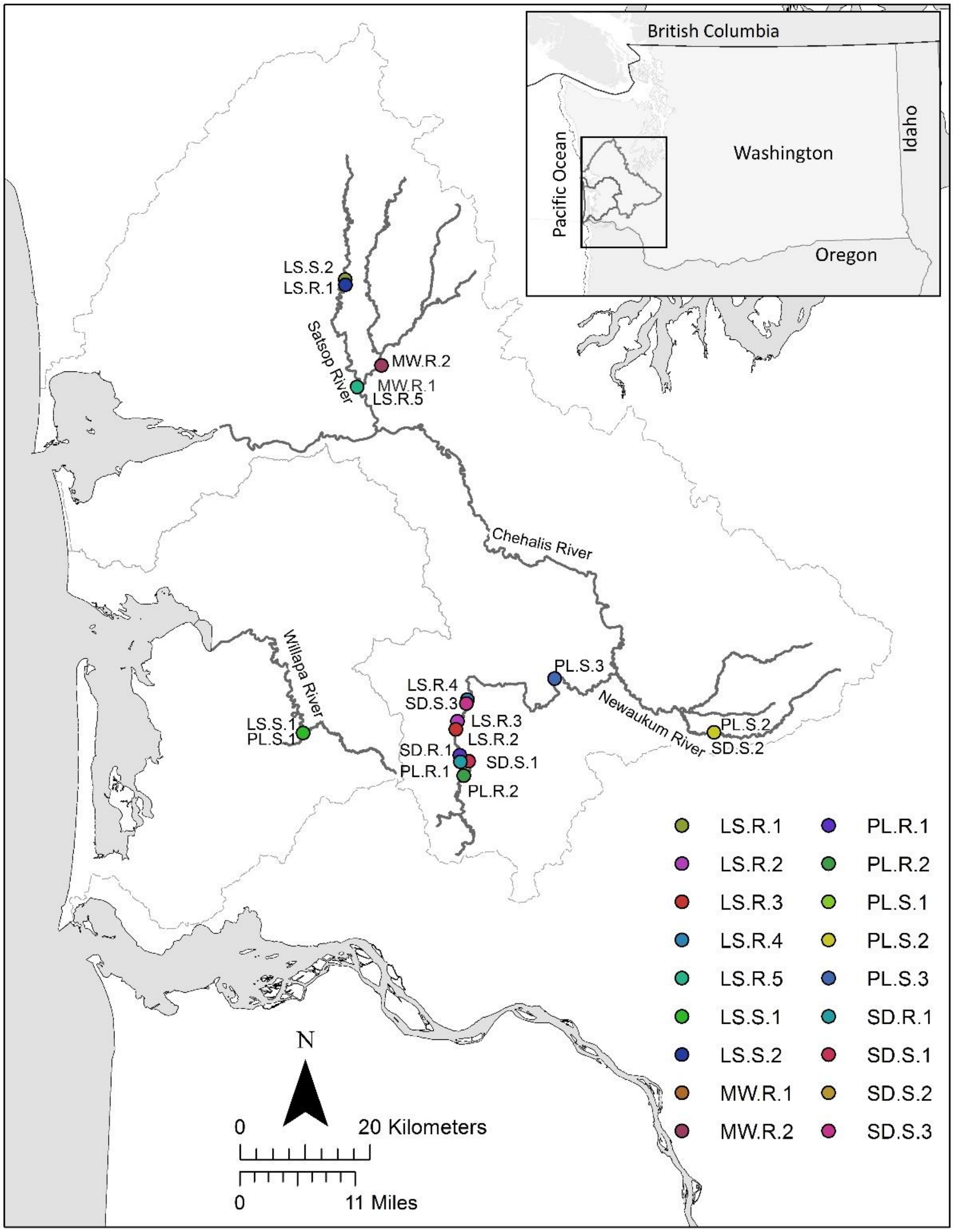

Figure 1: Chehalis and Willapa river basins with locations of HSC sampling areas. Sampling locations are labeled by species (LS is largescale sucker; MW is mountain whitefish; PL is Pacific lamprey; and SD is speckled dace), spawning or rearing (S or R), and study reach number. Inset shows locations of the basins within Washington State.

We located target fish, as single individuals or in schools, as precisely as possible within or near to the sampling grid and observed the fish to verify that the habitat selection by the target fish represented true habitat and their behavior appeared undisturbed (e.g., observations of feeding or territorial defense). Methods to locate fish included visual observation (e.g, locating redds for spawning Pacific lamprey), upstream and downstream snorkeling (e.g, observing largescale sucker spawning and rearing, mountain whitefish rearing, and speckled dace spawning and rearing), electrofishing (e.g., locating rearing Pacific lamprey ammocoetes), and tracking using radio telemetry (e.g., locating spawning and rearing mountain whitefish). Once fish locations were established, we measured depth and mean water column velocity at 60% of depth using a wading rod with gradations and designed to position the propeller of the flow meter accordingly. For flow measurements, we used a Swoffer Model 2100 Current Velocity Meter (Swoffer Instruments, Inc.) We also classified substrate and cover in the immediate vicinity (approximately 0.25-1 m^2 area centered grid points) according to Instream Flow Study Guidelines (Rantz 1982, Beecher et al. 2013). Substrate was classified as dominant and subdominant substrate as well as the percentage of dominant substrate. Substrate size categories were: (1) silt/organic; (2) sand; (3) pea gravel (0.2"-0.5"); (4) 0.5"-1.5"; (5) 1.5"-3"; (6) 3-6"; (7) 6-12"; (8) boulder >12"; and (9) bedrock (including consolidated clay and embedded logs). Cover was categorized based on Beecher et al. (2013): undercut bank; overhanging vegetation within 3' of water or near bankfull water's edge; root wad (including partly undercut); log jam/submerged brush pile; log(s) parallel to bank; aquatic vegetation; short (<1') terrestrial grass; dense grass (including reed canary grass); and/or vegetation beyond the bankfull water's edge. We also measured temperature at 60% of depth using a ProDSS multiparameter water quality meter with a ProDSS Conductivity and Temperature Sensor (YSI Inc./Xylem Inc.). For schooling fish (e.g., largescale sucker, mountain whitefish, and speckled dace), in order to get a representative measurement, multiple depth, velocity, and substrate use measurements were taken within the boundary of an observed school and averaged to give one each of a depth, velocity, and substrate measurement. In this way, individual use measurements may represent an individual fish or a school of fish.

After identifying the locations of target fish species, we established a study reach near to or overlapping the fish use areas. We used a standard grid approach for availability measurements (Bovee and Cochnauer 1977). We established transect lines equidistant from each other perpendicular to current within each reach and took measurements at predetermined, regular distances along each transect line. We measured points at fixed distances along each transect line to improve randomization of sampling and began each transect line on the opposite bank as the preceding transect to ensure we measured near to both edges of the river. In order to ensure a full range of combinations of available microhabitats were covered, additional random sampling of the range of available microhabitat conditions was also conducted when transect measurements did not incorporate all available habitats (Bovee and Cochnauer 1977, Bovee 1986, Beecher et al. 2002). At each grid point, using the same methods and categorizations as with fish use, we measured water depth, mean water column velocity, and temperature at 60% of depth, and we classified substrate and cover in the immediate vicinity. If multiple days were necessary for completing use and availability measurements within a given study reach, changes in streamflow were ensured to be less than 10% (Rantz 1982).

Species-Specific Techniques

Species- and life stage-specific techniques were established to identify fish habitat use. For largescale sucker, spawning was identified while snorkeling when two or more fish were observed aggregating at the top of a riffle or at a pool tailout. Observations were made during the day as well as at night using dive lights. For speckled dace, spawning was identified by snorkeling and observing aggregations of speckled dace at the top or bottom of riffles or in glides. Fish in aggregations identified to be spawning had brightly-colored mouth and fin regions, nuptial tubercles on their anterior dorsal region, and were associated with patches of debris-cleaned substrate. Rearing dace were identified in pools and glides, and did not have spawning-associated pigmentation changes. For Pacific lamprey, spawning was determined by observations of a lamprey actively digging a redd or when a recently-constructed (i.e., within 1-2 days based on visual identification of redd degradation) Pacific lamprey redd was identified. For rearing, Pacific lamprey use was determined by visually observing collected lamprey ammocoetes that had emerged from the substrate. In order to draw ammocoetes from the substrate, we used a backpack electrofisher (Smith-Root LR 20-B, voltage range 250 – 400V, frequency 15 Hz, duty cycle 20%) and sampled using a single-pass grid pattern within an established study reach. Using this method, there is a potential for bias towards shallower depths given the challenges backpack electrofishing at higher depths; however, every effort was made to electrofish all available habitats within a study reach. Ammocoetes were identified to species using caudal ridge and fin pigmentation according to Goodman et al. (2009).

For mountain whitefish, spawning was identified when fish were observed aggregating at the top of riffles and pool tailouts. Given the spawning time of mountain whitefish (Wydoski and Whitney 2003) and the difficulty observing fish during the fall and winter, a radio tagging effort was completed in August and September 2016 to track individual fish into the fall and winter months. Fifteen radio tags (MST 930-M Lotek Wireless) were implanted in August 2016 – three in the Upper Chehalis and twelve in the East Fork Satsop River. Radio tracking was conducted primarily on foot using a radio telemetry receiver (SRX 800 Lotek Wireless) and handheld three-element yagi antenna from the end of October 2016 through January 2017. Additional tracking was conducted from a raft during this time period. Status of each relocated fish (alive, dead, or unknown) was determined based on movement. Locations selected to conduct snorkeling observations were determined based on radio tracking results. Mountain whitefish rearing was identified by upstream and downstream snorkeling observations during timeframes outside of the spawning timeframe and/or while whitefish were displaying non-spawning behaviors (e.g., feeding or schooling in pools).

Habitat Suitability Preference Curves

We developed depth, velocity, and dominant substrate type preference curves following Beecher et al. (1993). For depth and velocity, we established intervals of 0.09 between 0 and 3.99 ft. and 0 and 3.99 ft./sec., respectively, as well as two additional bins of 0.49 between 4.0 and 4.99 ft. and 4.0 and 4.99 ft./sec., respectively. Measurements equal or greater to 5.0 ft. or 5.0 ft./sec. were also binned. We then tabulated observed numbers (O) of spawning and/or rearing largescale sucker, mountain whitefish, Pacific lamprey, and speckled dace into each interval. For each category of substrate (1-9), observed occurrences of the dominant substrate were tabulated. We then calculated the percentage of total depth, velocity, or substrate availability that occurred within each interval or category. In order to calculate an expected number (E) of each of these fish species to occur within each interval or category within their respective study reaches, we multiplied the total number of observed individuals by the percentage of depth, velocity, or substrate availability in each interval. This expected value represents the number of fish that would have occupied a given interval of depth or velocity or substrate category if they were distributed proportionally to the available habitat. For the development of the preference curves, we divided the observed number of each fish species spawning or rearing by the expected number of each fish species (O/E). When multiple study reaches were completed, they were combined by adding the corresponding intervals from each study reach weighted by the total number of observed individuals within a given study reach. We then normalized each O/E ratio by dividing by the maximum O/E ratio.

We used generalized additive models (GAMs) (Wood 2006) to examine the relationship between individual habitat metrics (depth and velocity) and O/E preference and produce a smoothed function of depth and velocity habitat preference. We conducted the GAM analyses using the mcgv package in R (Wood 2011, R Core Team 2016). For substrate, we used bar graphs to display the O/E preference.

Results

We took 141 habitat-use measurements at 18 study reaches (Table 1) between May and September along with one study reach for mountain whitefish in January 2017. The number of use measurements varied by study reach and species. In addition, the number of study reaches for each species and life stage ranged from one to five. When we had < three individual-use measurements for a given reach, these data were excluded from the development of the HSC and preference curves because preference cannot be determined from two points alone. This was the case for rearing largescale sucker at study reaches #1 and #4 and spawning largescale sucker at study reach #2 (Figure 1 and Table 1). Notably, excluded use measurements were similar to other study reaches.

Table 1: Habitat suitability use and availability measurements taken as part of this research by species, life stage, and study reach.

Study reach	Avail. or Use	Pacific lamprey		Speckled dace		Largescale sucker		Mountain whitefish
		Spawn	Rear	Spawn	Rear	Spawn	Rear	Rear
#1	Avail.	83	130	153	107	82	68	110
	Use	27	30	5	9	4	2	7
#2	Avail.	90	178	90		93	110	81
	Use	6	12	5		2	9	5
#3	Avail.	79		92			100	
	Use	3		5			5	
#4	Avail.						90	
	Use						2	
#5	Avail.						110	
	Use						3	

For largescale sucker spawning and rearing, depth, velocity, and substrate preferences varied by life stage (Figure 2 and Figure 3). Based on the smoothed preference functions, the most preferred spawning depth occurred at approximately 2 ft. (Figure 2a) and the most preferred velocity occurred at 0 ft./sec. and decreased with increased velocity (Figure 2b). For rearing largescale sucker, depth preferences increased with increasing depth and was highest at the deepest interval (5.0 ft.; Figure 2c) and velocity preference peaked at approximately 0.5 ft./sec. and generally decreased with increased velocity (Figure 2d). A secondary peak occurred near 2 ft./sec. which is likely an artifact of sample size (i.e., increased sample size should result in a smoothed curve). For substrate, spawning largescale suckers had the greatest preference for gravel 1.5 to 3-in. in diameter with less preference for gravel sizes 0.2-1.5 in., and no preference was observed for other substrate sizes (Figure 3a). Rearing largescale sucker had the greatest preference for sand, followed by pea gravel (0.2-0.5 in.) and bedrock (Figure 3b). Very few preferences were observed for other substrate categories.

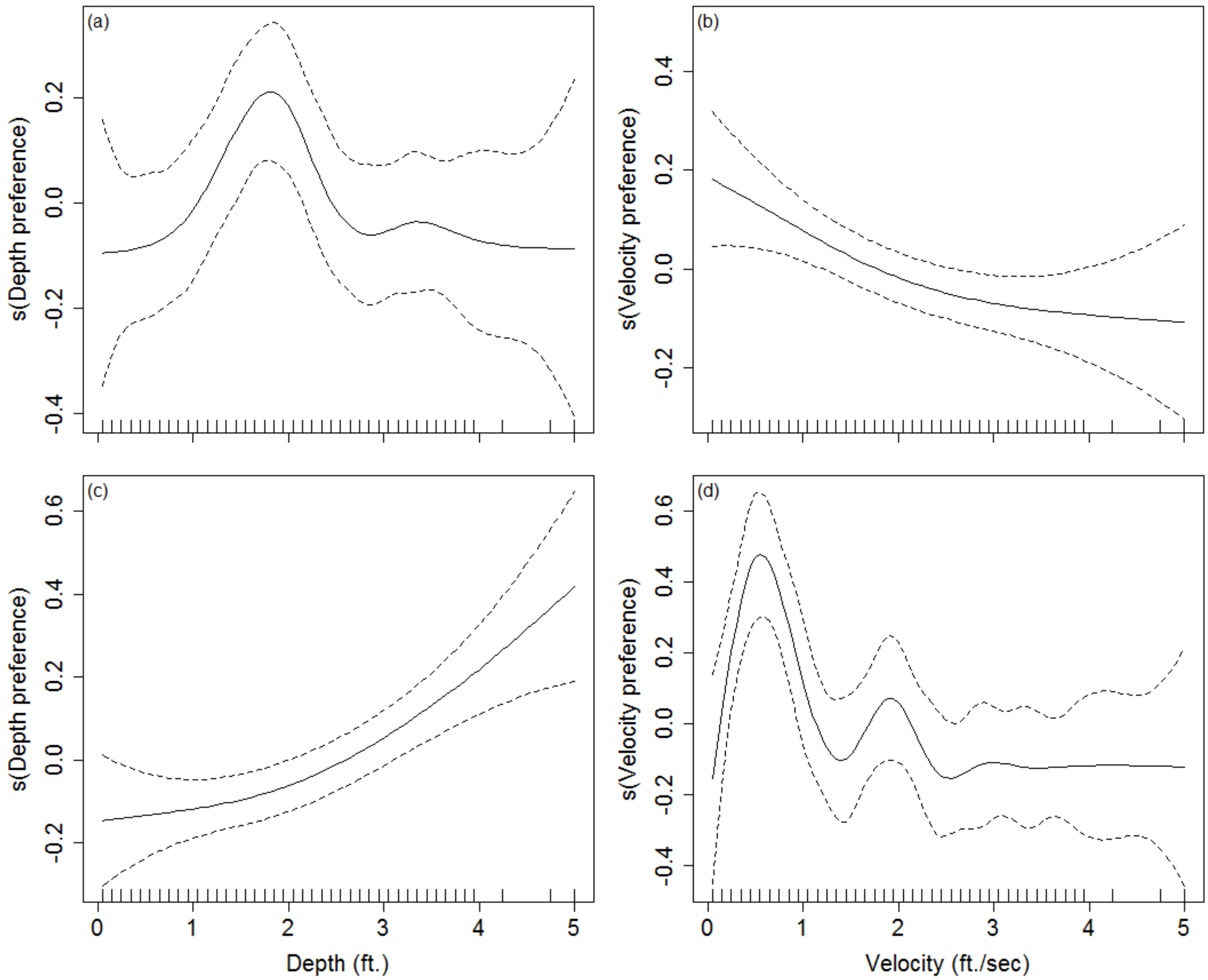

Figure 2: Nonparametric relationship of largescale sucker HSCs for spawning depth (a) and rearing depth (c) preferences as well as spawning velocity (b) and rearing velocity (d) preferences. Solid lines show the predicted preference based on the smoothed function(s) from the GAM. Dashed lines are the ±2 standard errors of the smoothed parameter.

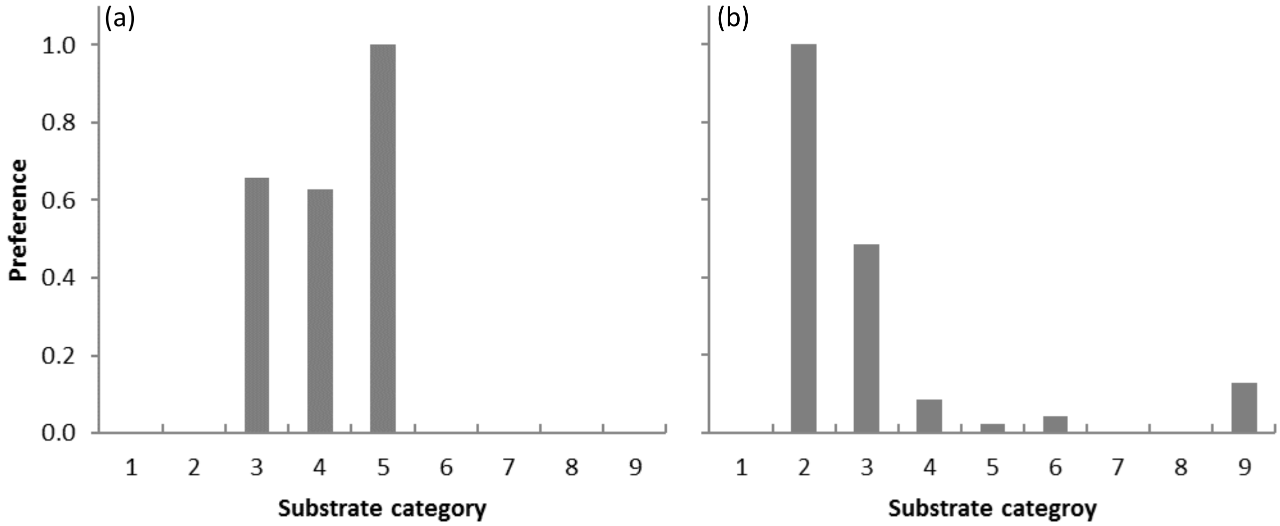

Figure 3: Largescale sucker substrate preferences for spawning (a) and rearing (b). Substrate categories are (1) silt/organic; (2) sand; (3) pea gravel (0.2"-0.5" in diameter); (4) 0.5"-1.5"; (5) 1.5"-3"; (6) 3-6"; (7) 6-12"; (8) boulder >12"; and (9) bedrock (including consolidated clay and embedded logs).

For spawning and rearing speckled dace, depth, velocity, and substrate preferences were similar, with some variation between life stage (Figure 4 and Figure 5). From the smoothed preference functions, the most preferred spawning depth occurred at approximately 2 ft., but no distinctive peak was apparent (Figure 4a). The most preferred spawning velocity occurred at approximately 2 ft./sec. (Figure 4b). For rearing speckled dace, the most preferred depth occurred between 2.5 and 3 ft., but preference remained relatively high with increased depth (Figure 4c). On the other hand, the most preferred velocity for rearing occurred at 1 ft./sec. and preference decreased sharply with increased velocity (Figure 4d).

The most preferred substrates for spawning speckled dace were gravel between 1.5 and 3 in. in diameter and, to a lesser extent, sand (Figure 5a). Additional, lower preference was observed for gravel between 0.2 and 1.5 in. as well as 3-6 in. For rearing speckled dace, the most preferred substrate was boulder between 6 and 12 in. (Figure 5b).

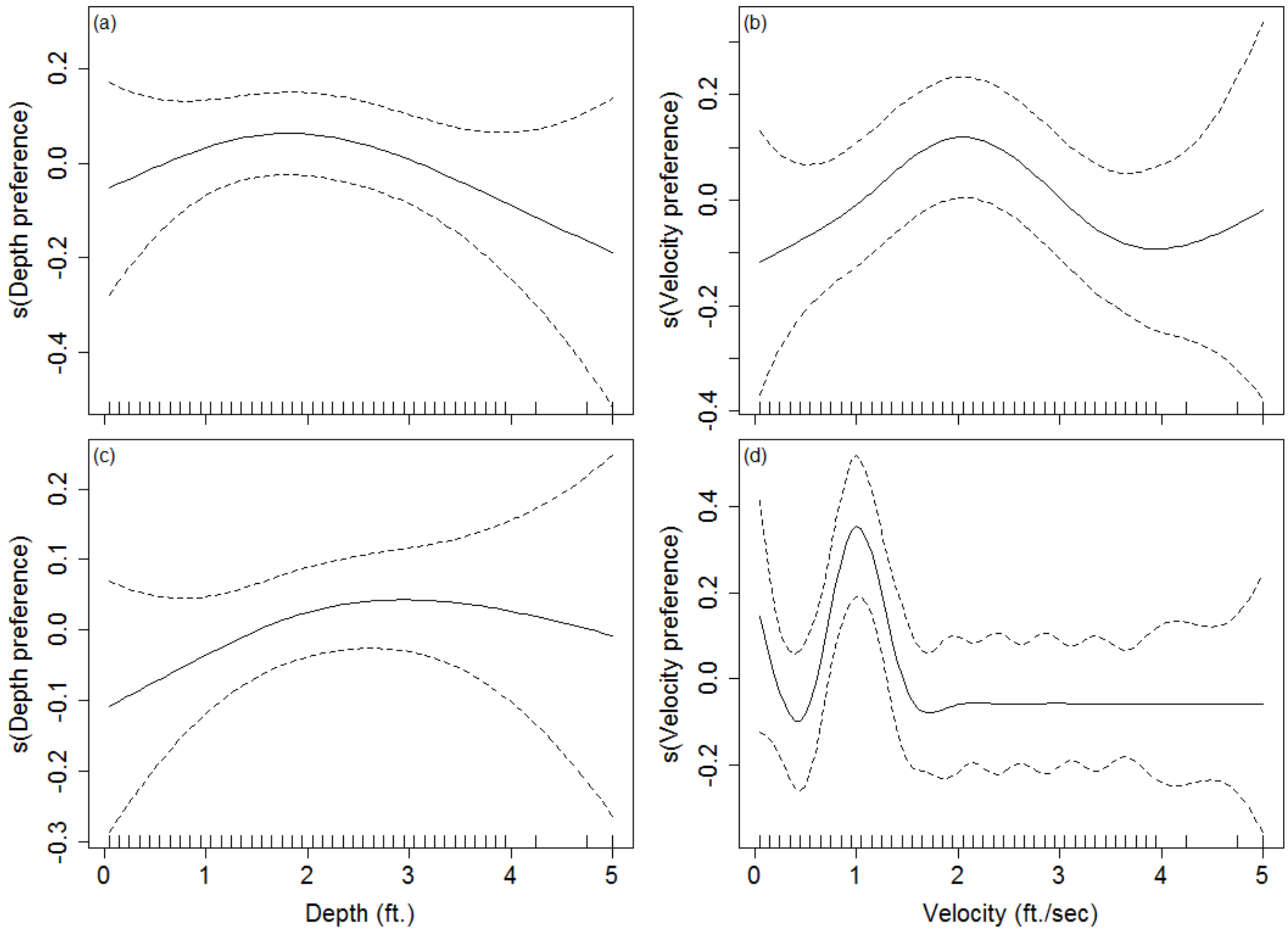

Figure 4: Nonparametric relationship of speckled dace HSCs for spawning depth (a) and rearing depth (c) preferences as well as spawning velocity (b) and rearing velocity (d) preferences. Solid lines show the predicted preference based on the smoothed function (s) from the GAM. Dashed lines are the ±2 standard errors of the smoothed parameter.

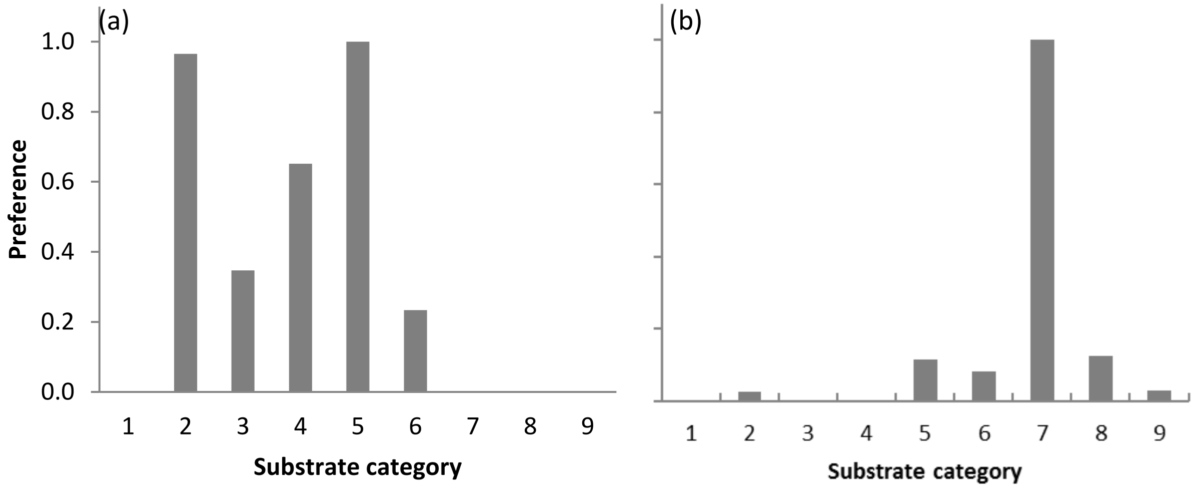

Figure 5: Speckled dace substrate preferences for spawning (a) and rearing (b). Substrate categories are (1) silt/organic; (2) sand; (3) pea gravel (0.2"-0.5"); (4) 0.5"-1.5"; (5) 1.5"-3"; (6) 3-6"; (7) 6-12"; (8) boulder >12"; and (9) bedrock (including consolidated clay and embedded logs).

For spawning and rearing Pacific lamprey, depth and velocity preferences varied by life stage (Figure 6 and Figure 7). For spawners, the most preferred depth occurred at 1 ft. and decreased with increased depth (Figure 6a), and the most preferred velocity occurred at approximately 1.8 ft./sec and decreased with increased velocity (Figure 6b). Conversely, for rearing Pacific lamprey, the most preferred depth was approximately 2.2 ft., decreasing with increased depth (Figure 6c), and the most preferred velocity occurred at 0 ft./sec and dropped off sharply with increased velocity (Figure 6d). Substrate preference for spawning Pacific lamprey were highest for pea gravel followed by gravel 1.5-3 in. in diameter (Figure 7a), whereas for rearing Pacific lamprey, preferences were highest for silt/organic followed closely by sand substrate (Figure 7b).

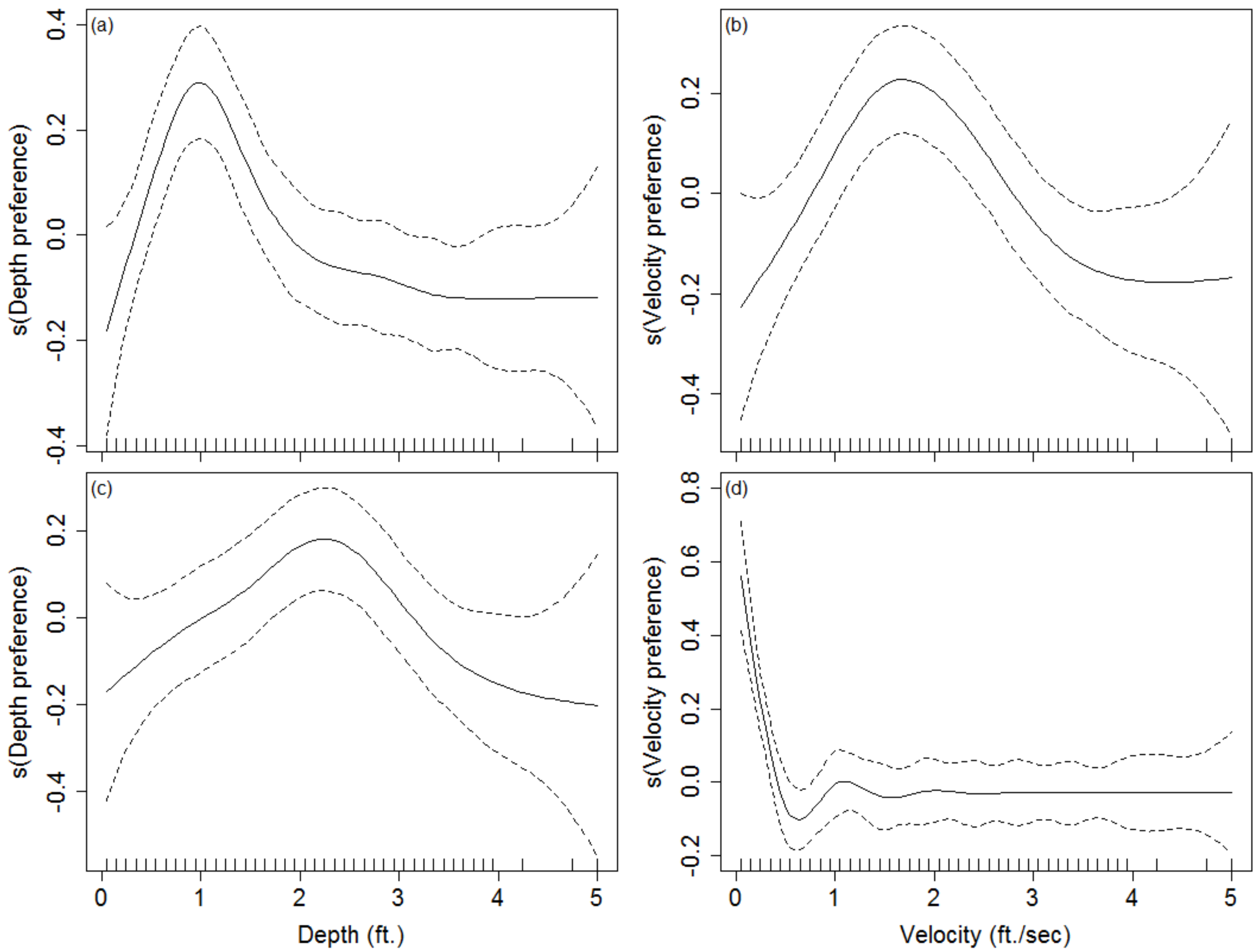

Figure 6: Nonparametric relationship of Pacific lamprey HSCs for spawning depth (a) and rearing depth (c) preferences as well as spawning velocity (b) and rearing velocity (d) preferences. Solid lines show the predicted preference based on the smoothed function (s) from the GAM. Dashed lines are the ±2 standard errors of the smoothed parameter.

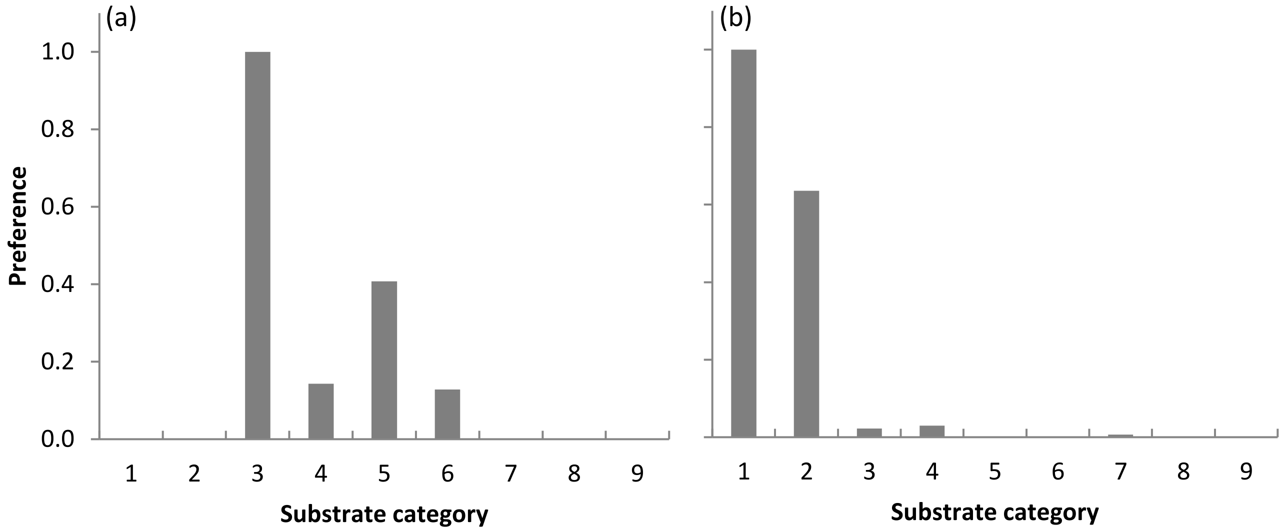

Figure 7: Pacific lamprey substrate preferences for spawning (a) and rearing (b). Substrate categories are (1) silt/organic; (2) sand; (3) pea gravel (0.2"-0.5"); (4) 0.5"-1.5"; (5) 1.5"-3"; (6) 3-6"; (7) 6-12"; (8) boulder >12"; and (9) bedrock (including consolidated clay and embedded logs).

For mountain whitefish, only rearing measurements were taken because no spawning fish were observed despite significant efforts to locate them. Rearing depth preference increased as depth increased (highest depth preference occurred at 5 ft.; Figure 8a), while velocity preference decreased with increased velocity so the highest velocity preference occurred at 0 ft./sec. flow (Figure 8b). The most preferred substrate for rearing mountain whitefish was gravel 3-6 in. in diameter with minimal preference observed for other substrates (Figure 9).

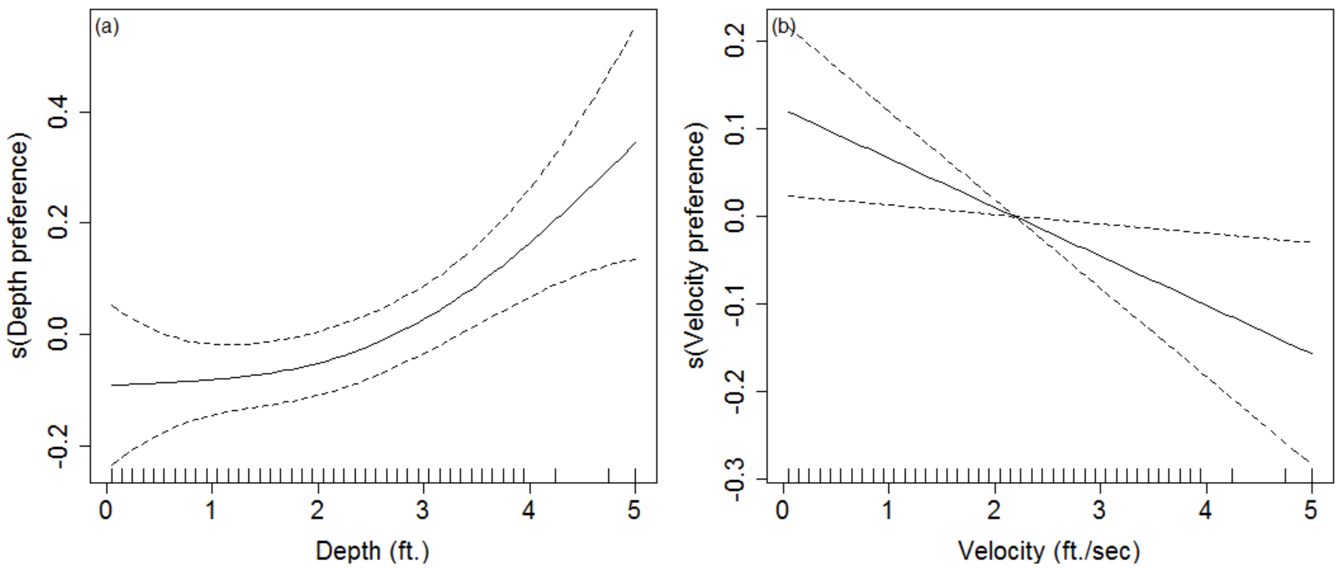

Figure 8: Nonparametric relationship of mountain whitefish HSCs for rearing depth (a) and rearing velocity (b) preferences. Solid lines show the predicted preference based on the smoothed function (s) from the GAM. Dashed lines are the ±2 standard errors of the smoothed parameter.

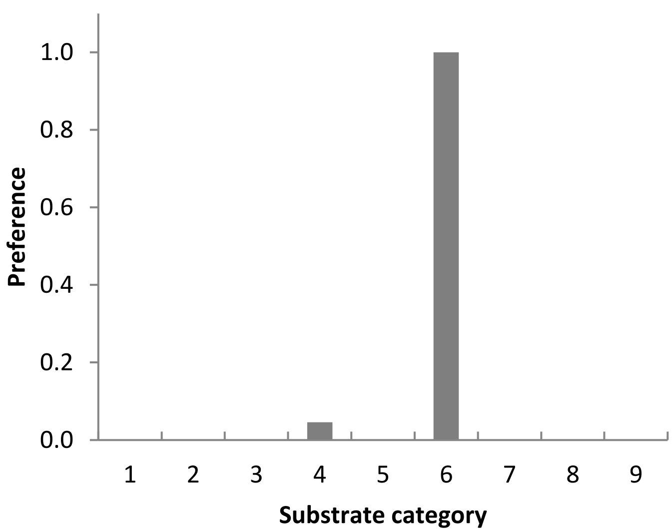

Figure 9: Mountain whitefish substrate preferences for rearing. Substrate categories are (1) silt/organic; (2) sand; (3) pea gravel (0.2"-0.5"); (4) 0.5"-1.5"; (5) 1.5"-3"; (6) 3-6"; (7) 6-12"; (8) boulder >12"; and (9) bedrock (including consolidated clay and embedded logs).

Discussion

We observed depth, velocity, and substrate preferences for largescale sucker, speckled dace, and Pacific lamprey spawning and rearing as well as mountain whitefish rearing for two coastal drainages, the Chehalis and Willapa river basins, in Washington State. We found each species to exhibit unique, life-stage specific habitat preferences. These habitat preferences reflect each fish species' behavior and were generally similar to habitat use observed in other drainages, with some exceptions. Preference for some species displayed multiple peaks across the range of habitat types measured, which likely reflects the small sample sizes resulting from sampling in one study season. Increased sample size could smooth the preference curves and decrease the uncertainty of the spawning and rearing depth and velocity preferences for each species (Ayllón et al. 2011).

Largescale sucker have been found to undergo large seasonal migrations linked to spawning and feeding (Dauble 1986, Baxter 2002), reflecting their potentially complex habitat needs; however, habitat preferences specific to largescale sucker are not abundant in the literature. Baxter (2002) found that a portion of the spawning population of largescale sucker in the Wenaha River, Oregon, migrated to higher gradient streams with faster-moving water. Baxter (2002) also found that adult suckers used riffle and glides in summer and deeper pools and glides in winter. Although these results are not specific depth, velocity, and substrate preferences, when we compared them to the results in our study, it was apparent that the spawning largescale sucker we observed did not prefer faster velocities and instead preferred shallower habitat with little to no flow. In addition, our observations occurred throughout the spring and summer months and found that deeper, slower water was most preferred by rearing largescale sucker, with additional preference for velocities up to 2 ft./sec. Thus, results from Baxter (2002) do not agree entirely with the observations from our study, which could reflect their complex habitat needs or basin-specific habitat preferences, or it could indicate a finer-scale seasonal habitat use. Additional year-round observation is required to more clearly understand the habitat preferences for largescale sucker in the Chehalis basin.

Speckled dace spawning and rearing depth preferences were relatively broad, compared to the other species examined in this study, with speckled dace preferring shallower depths for spawning than for rearing. Speckled dace spawning in the Kettle River, British Columbia, Canada, also occurred at shallow depths (0.08-0.33 ft.; Batty 2010), though even shallower than what we observed for depth spawning preferences in this study. For rearing juveniles and adults, Baltz et al. (1982) found speckled dace to occupy depths ranging from 0.8-2.1 ft. in Deer Creek, California and Batty (2010) found dace occupying depths ranging from 0.32-5.09 ft. the Kettle River, British Columbia. These wide ranges are similar to the preferred depths observed for rearing speckled dace in our study. For velocity, we found a narrower preferred range and speckled dace preferring relatively faster velocities for spawning than rearing. We did not identify speckled dace spawning velocities in the literature for comparison. However, Baltz et al. (1982) located rearing dace in velocities (0.3-1.4 ft./sec) similar to what we measured. Furthermore, although Batty (2010), reported an average velocity of 0.92 ft./sec. for rearing dace, similar to this study, the range over which they observed dace (0.32-3.54 ft./sec.) was wider than the range observed in our study. Although we took use measurements for multiple schools of speckled dace, rearing observations occurred within a single study reach, so additional sampling efforts may reveal a wider range or confirm differences in rearing dace habitat selections between the two drainages.

Spawning and rearing Pacific lamprey are known to occupy different habitats. For spawning, Pacific lamprey construct redds in riffles and pool tail-outs (Lampman 2011, Starcevich et al. 2014, Clemens et al. 2017), whereas for rearing, juvenile lamprey burrow into the substrate in slack-water areas (Stone et al. 2001, Clemens et al. 2017). Spawning and rearing preferences in this study reflected those habitats. Spawning lamprey preferred shallower depth and faster water than rearing lamprey. In addition, the depth, velocity, and substrate preferences we observed in the Chehalis Basin were similar to Pacific lamprey rearing preferences found in Cedar Creek, a tributary to the North Fork Lewis River within the Columbia River basin in Washington (Stone and Barndt 2005). Substrate preferences for spawning and rearing Pacific lamprey in this study were also similar to the substrate used in other drainages

(Stone and Barndt 2005), with spawning lamprey making use of various sizes of gravel and rearing lamprey heavily preferring silt and sand for borrowing.

Similar to largescale sucker, mountain whitefish have been found to undergo complex movement patterns relating to spawning and feeding (Baxter 2002, Pierce et al. 2012, Boyer 2016). During the summer, Baxter (2002) found mountain whitefish used shallow riffle and glide-like habitats, and during the winter they shifted to deeper pools and glides. For our study, even though habitat measurements were taken both in summer and winter, mountain whitefish were found to prefer deeper, slower water and cobble substrate for rearing, which is similar to the winter habitat use observed by Baxter (2002) . Given the complexity of their movement patters and habitat use, it is possible that additional sampling could reveal additional habitat preferences for shallower, faster water.

Known habitat-fish associations can be used to predict available habitat or fish density based on the amount and distribution of associated habitats (Fausch et al. 1988, Beecher et al. 1993). However, consideration of both micro-and mesohabitat is likely required to accurately identify habitat needs and recent studies indicate large-scale habitat variables may be better predictors of fish densities among streams and pools (e.g., Roni 2002, McMillan et al. 2013). Nevertheless, basin-specific, fish-habitat preference curves can be used in flow-habitat models, such as Physical Habitat Simulation (PHABSIM), which has been previously developed for the Chehalis River (Normandeau Associates 2012). Using our validated habitat preferences along with PHABSIM, and taking into account temperature, season, and mesohabitat, we can evaluate the changes in available habitat in terms of weighted usable area (WUA) for a variety of species in the Chehalis River. This provides a management and decision-support tool that can be used to evaluate potential impacts to relatively data-poor species from proposed flood-retention dams or restoration actions.

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