State of California
Natural Resources Agency
California Department of Fish and Wildlife

HABITAT SUITABILITY CRITERIA FOR JUVENILE SALMONIDS IN THE SOUTH FORK EEL RIVER WATERSHED, MENDOCINO AND HUMBOLDT COUNTIES

STREAM EVALUATION REPORT 2020-01

September 2020

Cover photos (clockwise from upper left): Snorkel survey in Hollow Tree Creek, unit 488, 08/21/2017; snorkel survey in Hollow Tree Creek, unit 473, 08/21/2017; fry steelhead in Hollow Tree Creek.

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Stream Evaluation Report
Report No. 2020-01

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Report No. 2020-01

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PREFACE

The California Water Action Plan[3] (CWAP) outlines ten actions and associated sub-actions to address water management challenges and promote reliability, restoration, and resilience in the management of California's water (CNRA et al. 2014). Included in Action Four of the CWAP, the California Department of Fish and Wildlife (CDFW) and the State Water Resources Control Board (State Water Board) were directed to implement a suite of actions to enhance instream flows within at least five priority watersheds. The South Fork Eel River is among these five priority watersheds. Accordingly, CDFW developed habitat suitability criteria (HSC) for anadromous salmonids in Hollow Tree Creek, tributary to the South Fork Eel River in Humboldt and Mendocino counties. Hollow Tree Creek is a relatively unimpaired stream and is valuable for informing protective flows needed to supply suitable habitat for rearing juvenile salmonids in the South Fork Eel River watershed.

Under Fish and Game Code §711.7 and §1802, CDFW is trustee for the State's fish and wildlife resources and has jurisdiction over the conservation, protection, and management of fish, wildlife, native plants, and the habitat necessary for biologically sustainable populations of those species. CDFW seeks to maintain native fish, wildlife, plant species and natural communities for their intrinsic and ecological value and for their benefits to all citizens in the State. This includes habitat protection and maintenance of habitat in sufficient amounts and quality to ensure the conservation of all native species and natural communities. CDFW is also responsible for oversight and assurance of the diverse uses of fish and wildlife including recreational, commercial, scientific and educational. As trustee agency for the aquatic resources in this State, CDFW has a material interest in assuring that water flows within streams are maintained at levels that are adequate for long-term protection, maintenance, and proper stewardship of these resources.

CDFW's Instream Flow Program develops scientific information to determine flows needed to maintain healthy conditions for fish, wildlife, and the habitats on which they depend. CDFW recommends using the Instream Flow Incremental Methodology (IFIM) to evaluate and develop instream flow criteria for actions that may affect California's aquatic resources. The IFIM process, and instream flow evaluations in general, should include broad consideration of the structure and function of riverine systems, while also evaluating five core components (i.e., hydrology, biology, geomorphology, water quality, and connectivity) of the riverine system.

The Public Resources Code §10002 (California Legislature 1982) outlines CDFW's responsibilities for developing and transmitting flow recommendations to the State

[3] More information about Proposition 1 and the California Water Action Plan can be found at http://resources.ca.gov/california_water_action_plan/.

Water Board for consideration as set forth in §1257.5 of the Water Code. The results from this study along with any other supporting information are intended to be used to identify streamflows intended to protect rearing habitat for juvenile anadromous Rainbow Trout (*Oncorhynchus mykiss*), commonly known as steelhead, and Coho Salmon (*O. kisutch*) in the South Fork Eel River watershed.

This report describes data collection efforts and resulting HSC for rearing juvenile salmonids developed in Hollow Tree Creek for the South Fork Eel River watershed. The HSC from this study were used to develop instream flow criteria for Redwood Creek, a major tributary to the South Fork Eel River. Details on the Redwood Creek instream flow study are presented in *Instream Flow Evaluation: Juvenile Steelhead and Coho Salmon Rearing in Redwood Creek, Humboldt County* (Maher et al. in prep).

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ABBREVIATIONS AND ACRONYMS

°F	degrees Fahrenheit
%	percent
CC	California Coastal
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
CWAP	California Water Action Plan
cm	centimeter(s)
dbh	diameter breast height
ESA	Endangered Species Act
ft	foot (feet)
ft/s	feet per second
HSC	habitat suitability criteria
IFIM	Instream Flow Incremental Methodology
in	inch(es)
IW	in-water
NC	Northern California
OW	out-of-water
SEFA	System for Environmental Flow Analysis
sq ft	square foot (feet)
SMET	stream margin edge type
SONCC	Southern Oregon Northern California Coast
State Water Board	State Water Resources Control Board

CONVERSIONS

1 cubic foot per second ≈ 2.83×10^{-2} cubic meters per second
1 inch = 2.54 centimeters
1 foot ≈ 0.31 meters
1 mile ≈ 1.61 kilometers
1 square mile ≈ 2.59 square kilometers
°C = (°F - 32) ÷ 1.8

1.0 INTRODUCTION

Habitat suitability criteria (HSC) are an integral biological component of an instream flow regime assessment (Annear et al. 2004). HSC incorporate the behavioral response of a species to variability in microhabitat, such as depth, velocity, cover, and substrate. Those microhabitat features influence the use of local stream mesohabitats by different aquatic species and life stages. Typically developed within the framework of the Instream Flow Incremental Methodology (IFIM; Bovee et al. 1998), HSC are input into hydraulic habitat models (Bovee 1982; Milhous et al. 1989; Jowett et al. 2017) to predict how the quantity and quality of habitat changes under different flows (Parsons and Hubert 1988; Hayes and Jowett 1994; Beecher et al. 2002).

Three types of HSC categories have been described (Bovee et al. 1998). Category I HSC are developed through professional opinion, personal experience, and discussions with interested stakeholders to negotiate the target species' habitat use with no field data collection. Category II HSC are developed from field observations of the target species habitat use without specifically accounting for habitat availability. These "utilization" curves may be biased by limited habitat or subjective sampling. An intermediate Category II½ HSC, referred to as "selectivity" curves, is developed from the target species' habitat use data and accounts for habitat availability through an equal area sampling approach. Category III HSC curves, referred to as "preference" curves (Bovee 1982; Moyle and Baltz 1985) adjust for limited habitat availability using a mathematical index. The forage ratio, devised to curtail any bias associated with habitat availability, is commonly used to develop Category III HSC (Bovee 1986). Other forms of HSC that account for habitat availability but do not use the forage ratio adjustment include density sampling (Rubin et al. 1991) and presence-absence sampling (Gard 2010).

Existing HSC are not available for the South Fork Eel River watershed. CDFW staff developed site-specific HSC in Hollow Tree Creek, a tributary to the South Fork Eel River that is relatively unimpaired with no major dams, diversions, or reservoirs. Site-specific HSC developed under natural conditions are expected to provide protective estimates of habitat needs and inform flow studies in impaired streams in the watershed (Bovee 1986). Hollow Tree Creek is valuable for developing flows needed to supply suitable habitat for rearing juvenile salmonids within the South Fork Eel River watershed. Ecological impacts arising from recurring drought conditions and cannabis cultivation underscore the need for accurate and reliable tools to inform streamflow management decisions. The results from this HSC report will be incorporated into the hydraulic habitat model for Redwood Creek, another major tributary to the South Fork Eel River. Hydraulic habitat model results, presented in the *Instream Flow Evaluation: Juvenile Steelhead and Coho Salmon Rearing in Redwood Creek, Humboldt County*

(Maher et al. in prep), will be used to enhance streamflow and protect habitat for juvenile salmonids in the South Fork Eel River watershed.

1.1 Study Goal and Objectives

The goal of the study was to develop HSC for juvenile anadromous Rainbow Trout (*Oncorhynchus mykiss*), commonly known as steelhead, and Coho Salmon (*O. kisutch*) for use in hydraulic habitat models in the South Fork Eel River watershed. The objectives include the following:

- Evaluation of juvenile steelhead and Coho Salmon habitat use, habitat availability, and preference for key microhabitat features.
- Development of regionally specific HSC curves for juvenile steelhead and Coho Salmon in Hollow Tree Creek.

2.0 DESCRIPTION OF STUDY AREA

Hollow Tree Creek, tributary to the South Fork Eel River, is nestled in Mendocino and Humboldt Counties (Figure 1). The entire Hollow Tree Creek watershed is owned and managed by two timber harvest companies, the Usal Redwood Forest Company[4] and the Mendocino Redwood Company[5]. Hollow Tree Creek has 24 miles of free-flowing stream with a drainage area of about 42 sq mi. The minimum and maximum basin elevations are 742 ft and 2,971 ft, respectively. Forested areas cover 65% of the watershed, while only 5.5% is developed land (USGS 2019). The forested areas contain a combination of coast redwood (*Sequoia sempervirens*), Douglas fir (*Pseudotsuga menziesii*), and a mix of conifer and hardwood species (Mendocino Redwood Co. 2004). The dry season is typically May through September while the rainy season usually extends from October through April (Anderson et al. 2014). Mean annual precipitation is about 75 in (USGS 2019). Coastal mean monthly air temperatures range from 36°F to 83°F (U.S. Climate Data 2019). The watershed lies within the coastal marine layer and is characterized as having foggy mornings with overcast conditions (Anderson et al. 2014).

[4] http://brandhubonline.com/usalredwoodforestcompany/

[5] https://www.hrcllc.com/

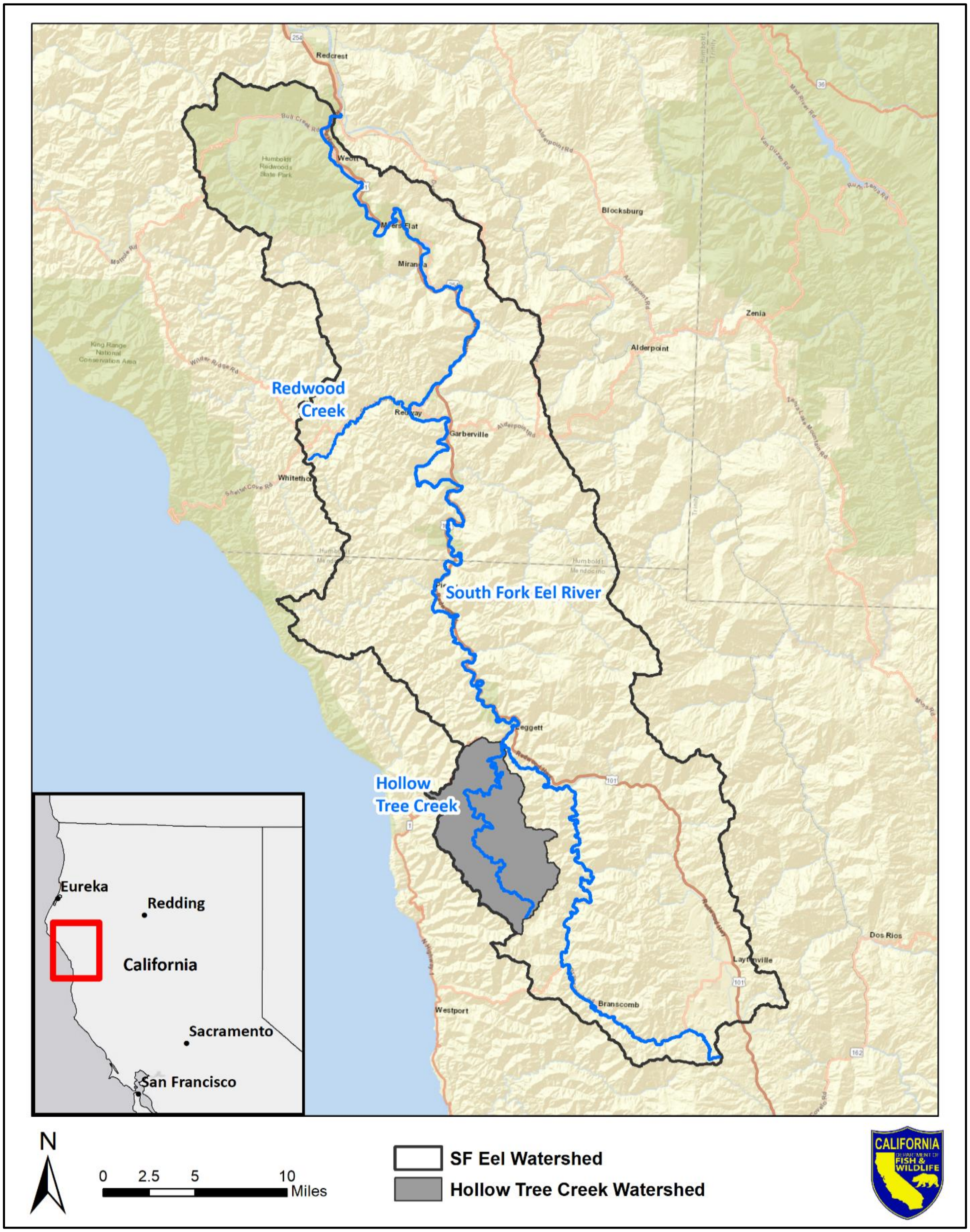

Figure 1. Map of the South Fork Eel River watershed encompassing Mendocino and Humboldt counties. The Hollow Tree Creek watershed is highlighted.

2.1 Fish Species and Periodicity

The South Fork Eel River watershed supports both spawning and rearing life stages of Northern California (NC) steelhead, Southern Oregon Northern California Coast (SONCC) Coho Salmon, and fall-run California Coastal (CC) Chinook Salmon (*Oncorhynchus tshawytscha*). Both NC steelhead (65 Federal Register 36074) and fall-run CC Chinook Salmon (64 Federal Register 72960) are currently listed as federally threatened according to the Endangered Species Act (ESA). The federal listing for NC steelhead was reaffirmed in 2006 (NMFS 2011). SONCC Coho Salmon are listed as threatened pursuant to both the federal ESA (62 Federal Register 33038) and the California ESA. The federal listing for SONCC Coho Salmon was reaffirmed in 2005 (NMFS 2014).

All life stages of NC steelhead, SONCC Coho Salmon, and fall-run CC Chinook Salmon are known to inhabit the South Fork Eel River watershed during the months shown in Figure 2 (A. Renger personal communication 05/2019). Resident Rainbow Trout are also known to occupy the South Fork Eel River watershed (Yoshiyama and Moyle 2010). Although adult Chinook Salmon are known to spawn in tributaries to the South Fork Eel River, including Hollow Tree Creek, juveniles are not residents in the watershed and only sometimes exhibit holding during drought years (A. Renger personal communication 05/2019). For this reason, juvenile Chinook Salmon were not evaluated in this study.

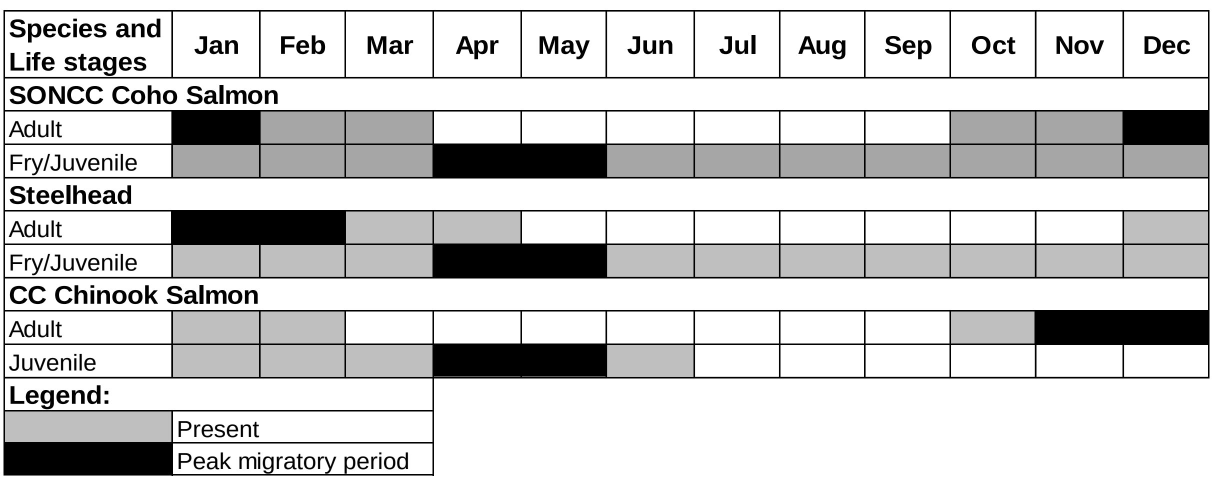

Figure 2. Species and life stage periodicity in the Redwood Creek watershed[6].

[6] Adult migration data from personal communication with Allan Renger, May 6, 2019; Sproul Creek and Hollow Tree spawning ground surveys 1988 to 2016 and South Fork Eel River basin spawning ground surveys, 2010 to 2016. Juvenile migration is based on South Fork Eel River downstream migrant trapping, 2015.

Shapovalov and Taft (1954) provide information on the life history traits and ecology of both steelhead and Coho Salmon in California. Steelhead are anadromous and represent the sea-run form of *O. mykiss*, while resident rainbow trout represent the non-migratory form. Steelhead are iteroparous, being able to breed multiple times throughout their life cycle. Due to their anadromy, steelhead can grow much larger than resident rainbow trout and gain most of their size during their time in the ocean. In California, most steelhead rear in their natal stream for one year, with some individuals remaining in freshwater for up to three years. Once they emigrate to the ocean as smolts, steelhead remain in the ocean from one to four years prior to returning to freshwater to spawn.

Coho Salmon are anadromous and semelparous, dying after a single spawning event. Most Coho Salmon spend one to two years rearing in freshwater (Shapovalov and Taft 1954; CDFG 2004) prior to emigrating to the ocean, where they spend two to three years feeding and growing before returning to their natal stream to spawn.

Upon emerging from the gravel, yolk-sac fry of both steelhead and Coho Salmon seek out shallow areas where they feed on drift material and grow rapidly prior to seeking deeper pool habitat as they grow larger. Coho Salmon generally spawn and emerge from gravel earlier than steelhead. Therefore, juvenile Coho Salmon have a size advantage over juvenile steelhead during their stream residency. Coho Salmon can exclude steelhead from preferred pool habitats, displacing them to shallower riffles (Young 2004).

Other native species found in the South Fork Eel River watershed include Pacific lamprey (*Lampetra tridentata*), Prickly sculpin (*Cottus asper*), Sacramento sucker (*Catostomus occidentalis*), and Threespine stickleback (*Gasterosteus aculeatus*; Brown and Moyle 1997).

2.2 Hydrology

Hollow Tree Creek hydrology is typical of most western tributaries in the South Fork Eel River watershed. Precipitation falls as rain, and Hollow Tree Creek experiences low flows in the summer and peak storm events in the winter (Anderson et al. 2014). With no major diversions, dams, or reservoirs, Hollow Tree Creek has relatively unimpaired flows. Flow is variable from year to year depending on the frequency and magnitude of winter storms (Lane et al. 2018).

A record of watershed hydrology is preferably obtained from stream gages with a long continuous record, where flows have not been significantly impaired by diversions (CDFW 2018). Hollow Tree Creek does not contain any gages and therefore a historical record of the hydrology is unavailable. To describe natural flow patterns, median monthly natural flows were calculated using the California Natural Flows Database

(Zimmerman et al. 2018). This database presents estimated natural flows for all streams and rivers in the state of California from 1950-2015. Natural flows were estimated for a stream segment of Hollow Tree Creek at the confluence with the South Fork Eel River (COMID 8287274; Zimmerman et al. 2018).

To illustrate interannual flow variability, estimated natural flow data were used to calculate median monthly flow for three water month types: wet, average, and dry. Water month types were defined using exceedance percentage ranges based on CDFG (2008): 0-30%, >30-70%, and >70-100% for each type, respectively. The median monthly values for each water month type are presented in Figure 3. These median monthly values provide an estimate of unimpaired water availability and variation by month.

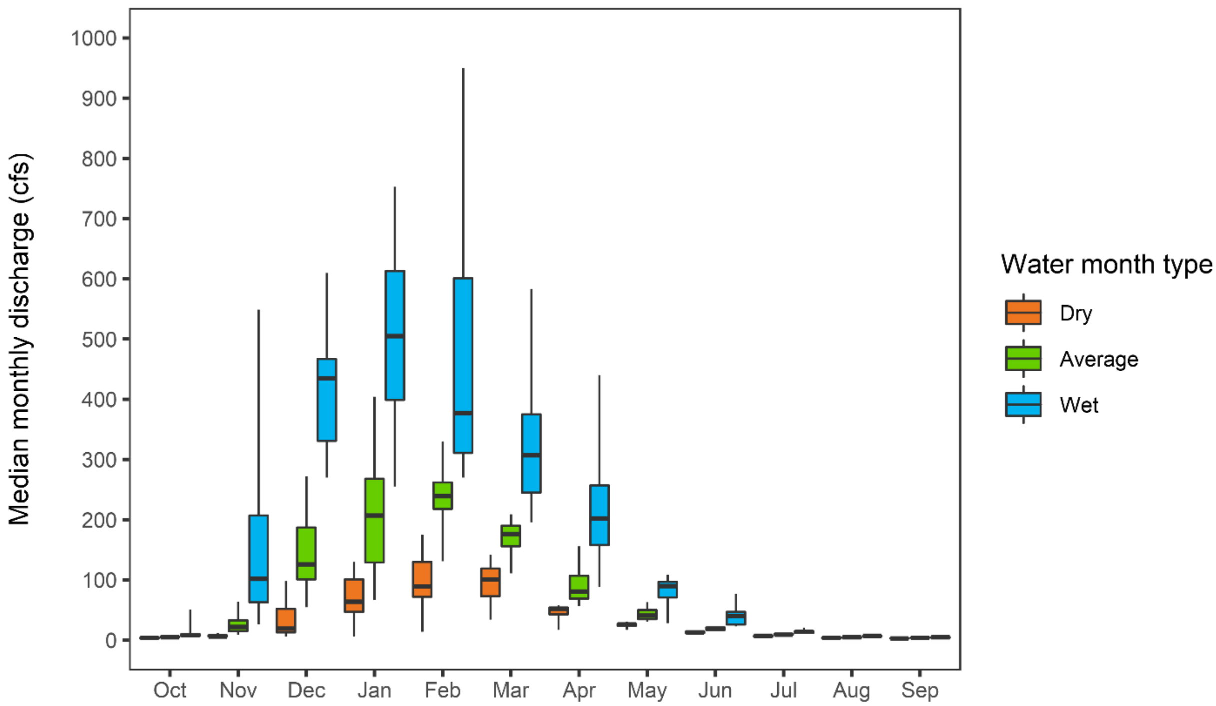

Figure 3. Boxplots of estimated median monthly natural flow in Hollow Tree Creek by water month type from water years 1951 through 2015. Colored bars represent 25th to 75th percentile values, whiskers are minimum and maximum values, and horizontal lines are median values. Data from (Zimmerman et al. 2018).

3.0 METHODS

3.1 Identification of Sampling Sites and Sampling Strategy

Project sampling occurred in Hollow Tree Creek from the confluence with the South Fork Eel River to approximately 20 miles upstream with the confluence of Huckleberry Creek. Hollow Tree Creek was partitioned into three approximately equal reaches based on river miles (Table 1; Figure 4). Habitat mapping was conducted prior to snorkel survey sampling.

Table 1. Distances and lengths of surveyed reaches in Hollow Tree Creek.

Reach	Distance (mi)	Total Length (mi)	Description
1	0 - 6.1	6.1	Lower reach: Begins at the confluence with the SF Eel River.
2	6.1 - 12.2	6.1	Middle reach: Continues upstream from the top of Reach 1.
3	13.9 - 20.1	6.2	Upper reach: Continues upstream and ends at the confluence with Huckleberry Creek.

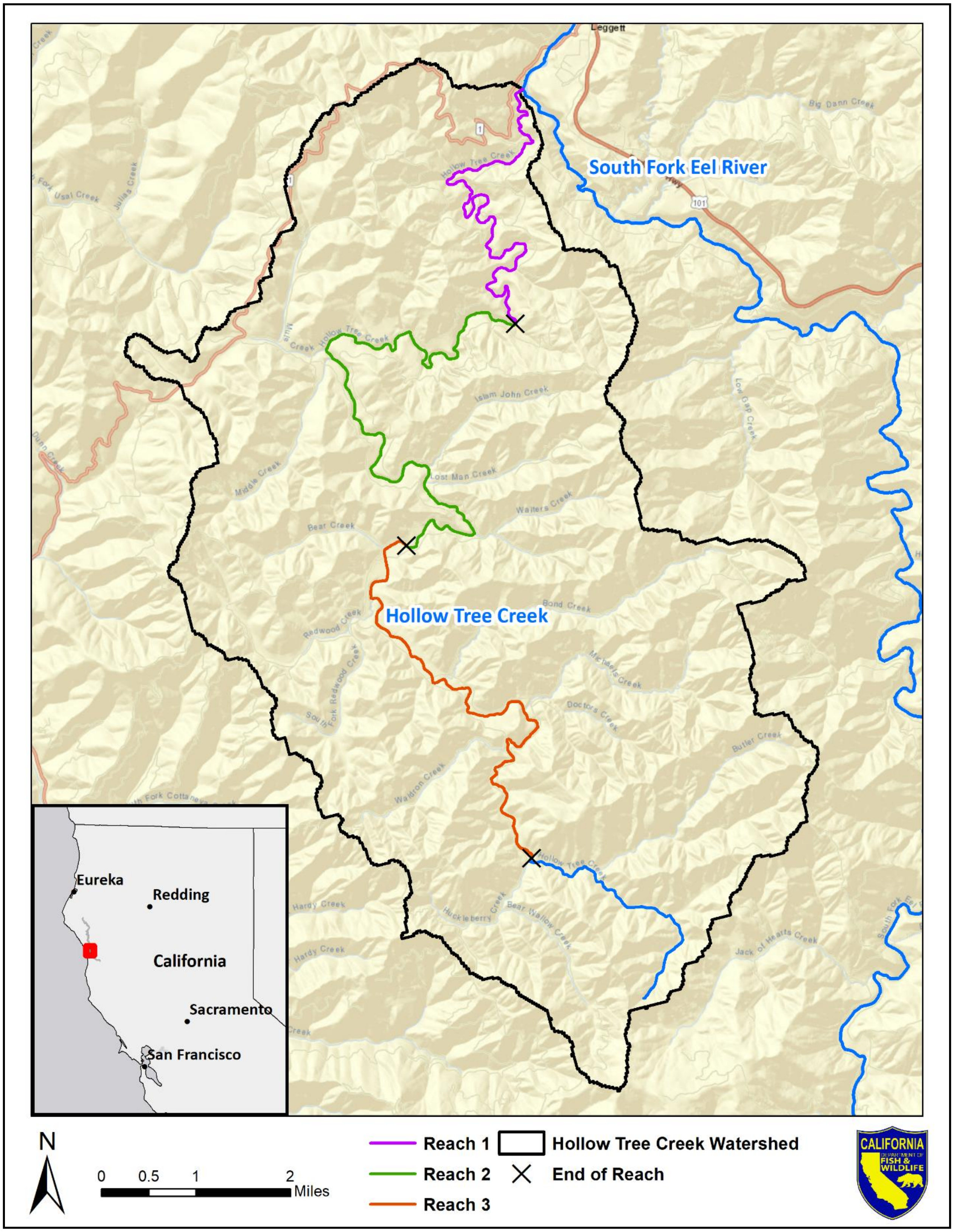

Figure 4. Map of Hollow Tree Creek. Reaches 1, 2, and 3 are highlighted.

Habitat mapping was conducted in the summer of 2016. CDFW staff hiked Hollow Tree Creek beginning at the first mesohabitat unit at the confluence with the South Fork Eel River and worked upstream. Two sections within reaches 2 and 3 were not mapped because the watershed's geomorphology and dominant bedrock substrate made it difficult to navigate (Figure 5).

Mesohabitat types were classified using channel habitat typing methods consistent with Flosi et al. (2010). Level IV mesohabitat units were aggregated into broader mesohabitat categories of riffles, pools, glides, and runs as described in Table 2, and numbered sequentially. Riffles were related with shallow/fast habitat, pools with deep/slow habitat, glides with shallow/slow habitat, and runs with deep/fast habitat (Allen 2000). Tables 3, 4 and 5 summarize the mesohabitat units mapped in each reach during the summer of 2016.

Table 2. Mesohabitat type definitions adapted from Snider et al. (1992).

Mesohabitat Type	Definition
Riffle	Below average depth, above average velocity, thalweg has relatively uniform slope going downstream, substrate of uniform size and composed of large gravel and/or cobble, change in gradient noticeable. Primary determinants are relatively high gradient and turbulence.
Pool	Fine and uniform substrate, below average water velocity, above average depth, tranquil water surface. Primary determinant is downstream control - thalweg gets deeper moving upstream from tail of pool. Depth is not used to determine whether a habitat unit is a pool.
Glide	Low gradient, uniform substrate across channel width with channel composed of small gravel and/or sand/silt, depth below average and similar across channel width, below average water velocities, generally associated with tails of pools or heads of riffles, width of channel tends to spread out, thalweg has relatively uniform slope going downstream. Primary determinants are no turbulence (surface smooth, slow and laminar) and no downstream control.
Run	Moderate gradient, mixed substrate particles sizes composed of small cobble and gravel, with some large cobble and boulders, above average water velocities, usually slight gradient change from top to bottom, generally associated with downstream extent of riffles, thalweg has relatively uniform slope going downstream. Primary determinants are moderate turbulence and average depth.

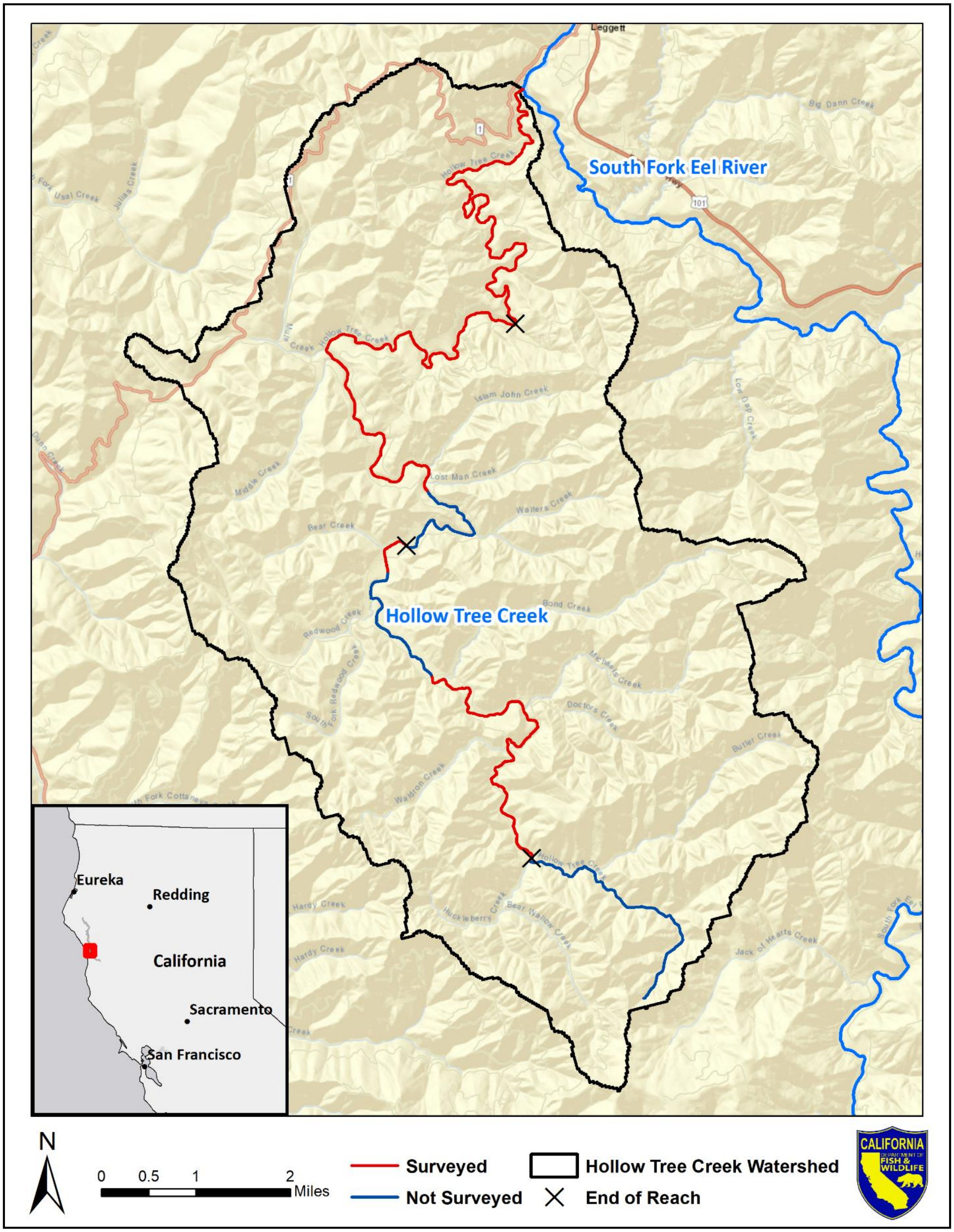

Figure 5. Map of surveyed and non-surveyed locations in Hollow Tree Creek.

Table 3. Summary of reach 1 mesohabitat unit types.

Mesohabitat type	Number of Units	Total Length (ft)	Average Length (ft)
Riffle	84	5,211	63
Pool	162	20,226	126
Glide	14	1,470	105
Run	61	5,148	87

Table 4. Summary of reach 2 mesohabitat unit types.

Mesohabitat type	Number of Units	Total Length (ft)	Average Length (ft)
Riffle	91	4,257	45
Pool	144	20,220	141
Glide	13	1,572	120
Run	75	6,690	87

Table 5. Summary of reach 3 mesohabitat unit types.

Mesohabitat type	Number of Units	Total Length (ft)	Average Length (ft)
Riffle	101	5,226	51
Pool	168	13,743	81
Glide	17	1,728	102
Run	46	3,621	78

Sampling effort was carried out by reach (i.e., reach 1, reach 2, and reach 3), and mesohabitat type (i.e., riffle, pool, glide, and run). To achieve an equal area sampling design, 5,000 sq ft (± 150 sq ft) of each mesohabitat type were sampled in each reach. An equal area sampling design was used to ensure all combinations of depth and velocity were equally represented when collecting HSC data (Allen 2000), and to determine feasibility of using Category II½ for HSC development. Sampling consisted of snorkel surveys (i.e., direct underwater observation) to examine fish habitat use for juvenile life stages of steelhead and Coho Salmon.

Mesohabitat units within each reach were selected for HSC sampling using a stratified random sampling design. Mesohabitat units were randomly selected in each reach until at least one of each mesohabitat type was included (Tables 6, 7, and 8; Figures 6, 7, and 8). Additional mesohabitat units beyond the initial random draw were also selected in each reach to meet the equal area sampling design (i.e., 5,000 sq ft) if needed. In the event a randomly selected mesohabitat unit had restricted access, an accessible mesohabitat unit of similar length and width was selected as a replacement.

Table 6. Reach 1 sampling sites.

Unit	Mesohabitat Type	Mean Length (ft)	Mean Width (ft)
8	Riffle	83	14
51	Pool	128	40
84	Glide	118	41
86	Run	70	24
88	Glide	51	30
150	Riffle	62	24
161	Riffle	86	21
202	Riffle	71	21
211	Run	129	17
310	Run	116	26

Table 7. Reach 2 sampling sites.

Unit	Mesohabitat Type	Mean Length (ft)	Mean Width (ft)
473	Pool	142	36
488	Run	77	23
496	Riffle	98	22
525	Run	114	25
554	Glide	106	48
566	Riffle	98	18
610	Riffle	103	19
627	Run	80	17

Table 8. Reach 3 sampling sites.

Unit	Mesohabitat Type	Mean Length (ft)	Mean Width (ft)
652	Pool	124	29
670	Glide	134	33
693	Run	101	19
758	Riffle	156	19
789	Run	133	20
925	Run	80	14
942	Riffle	63	22
971	Riffle	93	14
974	Pool	90	16
978	Glide	31	22

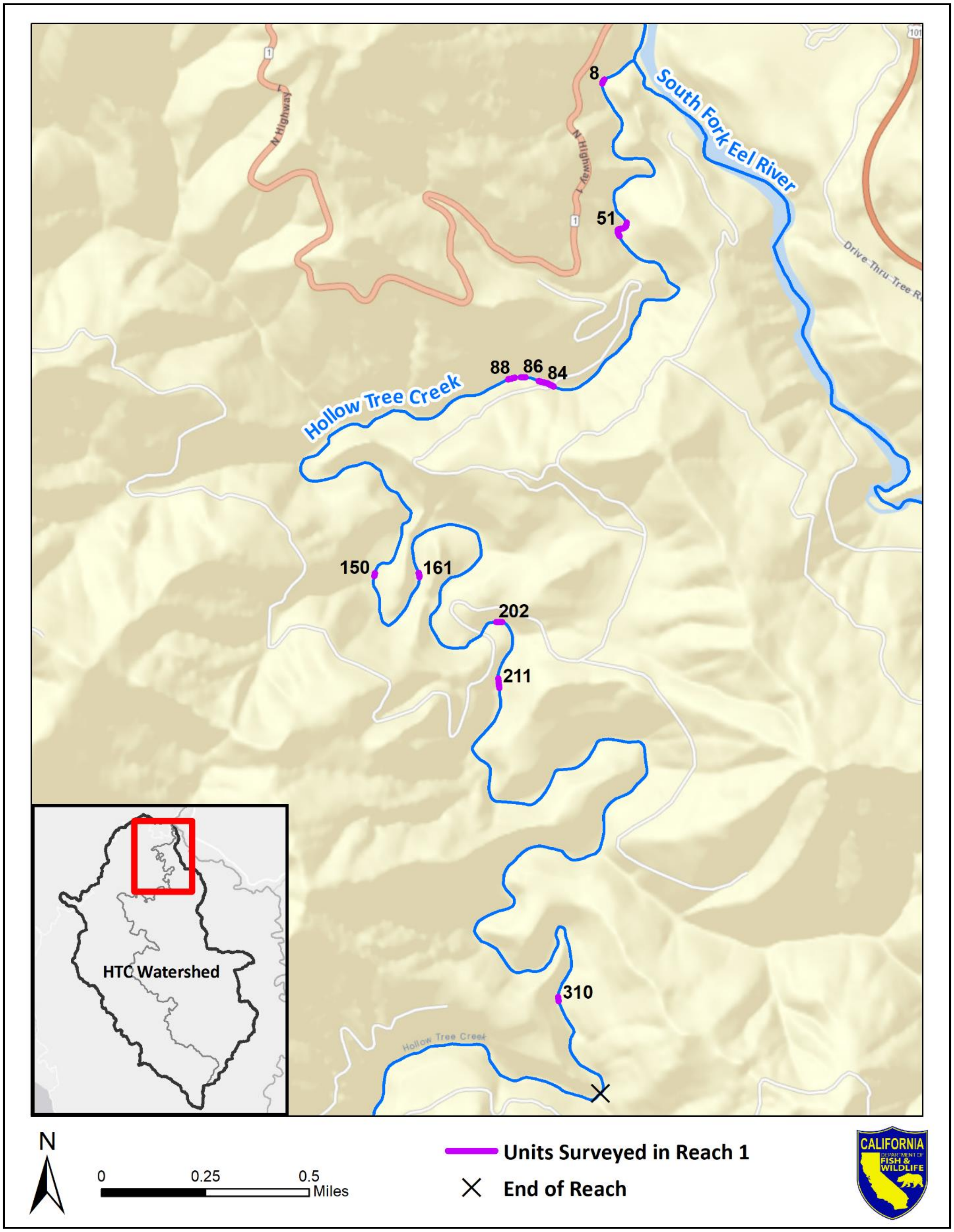

Figure 6. Map of reach 1 snorkel survey locations.

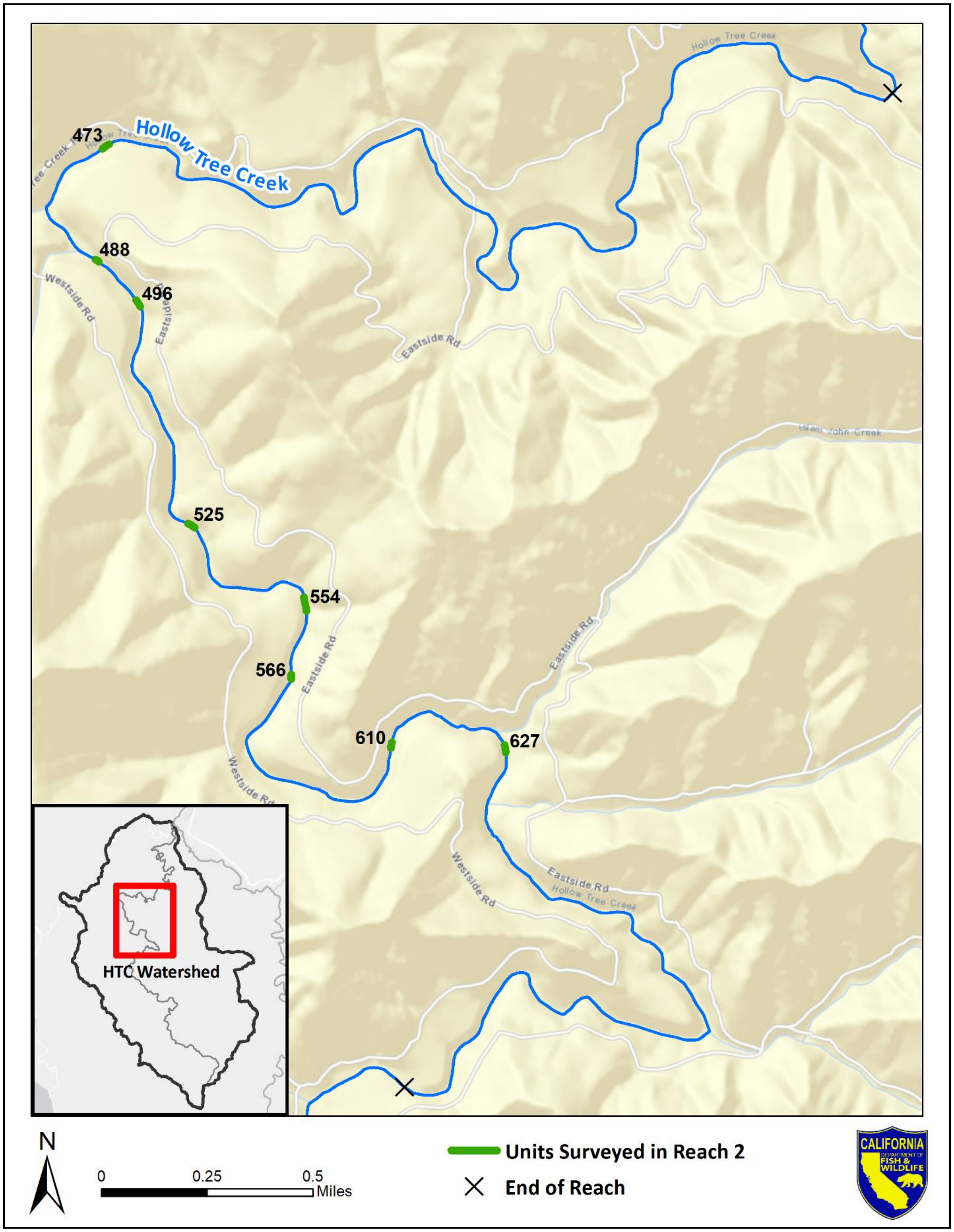

Figure 7. Map of reach 2 snorkel survey locations.

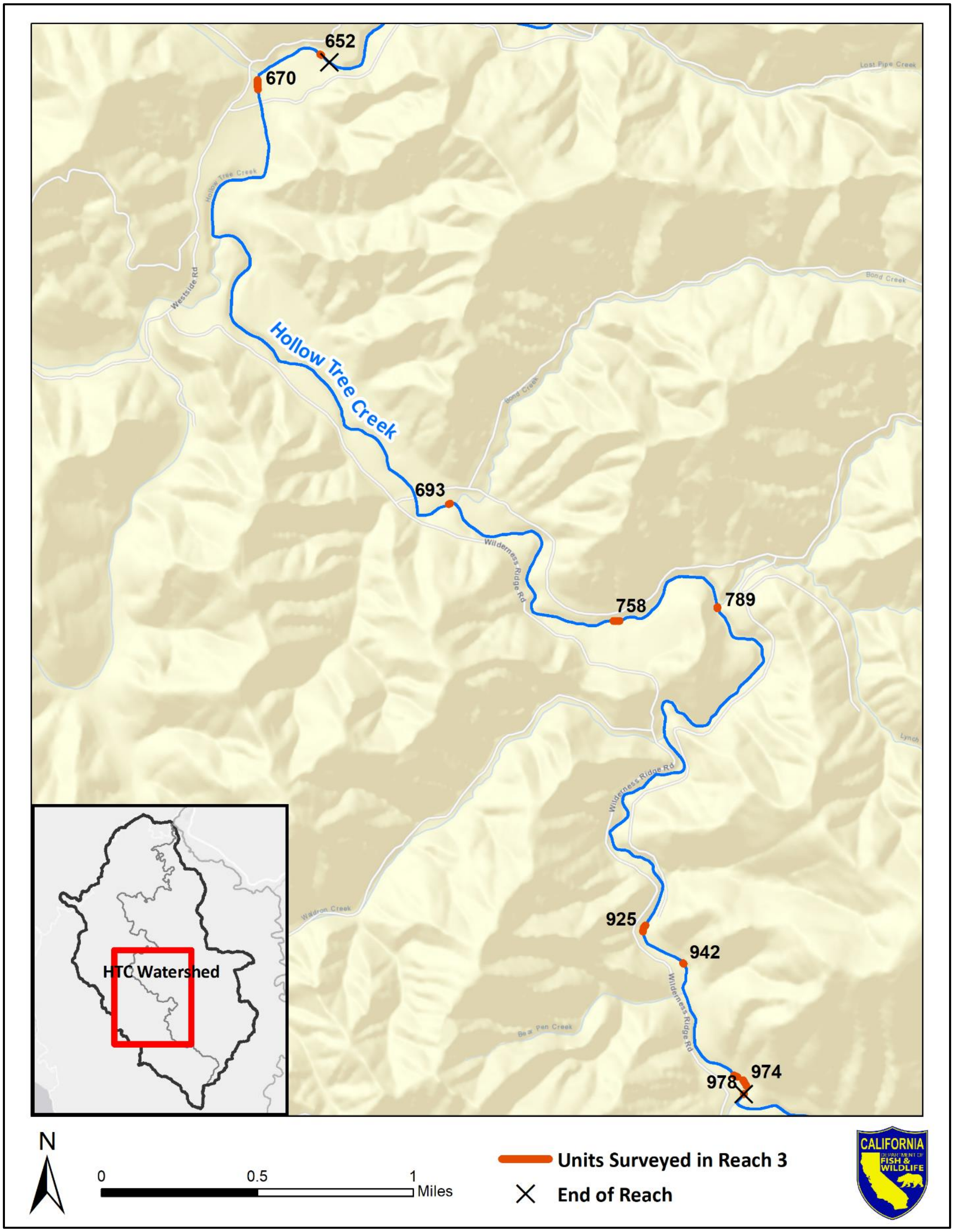

Figure 8. Map of reach 3 snorkel survey locations.

Stream margin edge type (SMET) classifications (Table 9) were used to describe the microhabitat features at the banks or edges of the stream. Cover and substrate codes (Tables 10 and 11) were used to describe microhabitat features within the stream at each fish observation marker and habitat availability marker (see Section 3.2 Fish Observation Techniques).

Table 9. SMET codes.

Code	SMET
0	Open
1	Gravel
2	Cobble/boulder
3	Sparse shrubs/herbs/vines/poison oak IW[7]
4	Dense shrubs/herbs/vines/poison oak OW[8]
5	Sparse branches <4 in, IW
6	Sparse branches <4 in, OW
7	Sparse branches >4 in, IW
8	Sparse branches >4 in, OW
9	Dense branches <4 in, IW
10	Dense branches <4 in, OW
11	Dense branches >4 in, IW
12	Dense branches >4 in, OW
13	Trees <4 in, dbh[9]
14	Trees >4 in, dbh
15	Small woody debris <4 in, dead
16	Large woody debris >4 in, dead
17	Roots
18	Grass
19	Sparse shrubs/herbs/vines/poison oak OW
20	Dense shrubs/herbs/vines/poison oak IW
21	Undercut bank
22	Bedrock
23	Rip-rap

[7] IW = in-water
[8] OW = out-of-water
[9] dbh = diameter breast height

Table 10. Cover codes.

Code	Vegetation Type
0	None
1	Filamentous algae
2	Non-emergent rooted aquatic vegetation
3	Emergent rooted aquatic vegetation
4	Grass
5	Sedges/rushes
6	Vines/poison oak
7	Branches/small vegetation <4 in, IW
8	Branches/small vegetation <4 in, OW
9	Branches >4 in, IW

Code	Vegetation Type
10	Branches >4 in, OW
11	Tree trunks <4 in, dbh IW
12	Tree trunks <4 in, dbh OW
13	Tree trunks >4 in, dbh IW
14	Tree trunks >4 in, dbh OW
15	Roots and root-wads
16	Shrubs <4 in
17	Duff, leaf litter, organic debris
18	Small woody debris <4 in, dead
19	Large woody debris >4 in, dead

Table 11. Substrate codes.

Code	Substrate Type
0	None
21	Clay
22	Sand or silt/sand (<0.1 in)
23	Coarse sand/DG (0.1-0.2 in)
24	Small gravel (0.2-1 in)
25	Medium gravel (1-2 in)
26	Large gravel (2-3 in)
27	Gravel/cobble (3-4 in)
28	Small cobble (4-6 in)

Code	Substrate Type
29	Medium cobble (6-9 in)
30	Large cobble (9-12 in)
31	Small boulder (12-24 in)
32	Medium boulder (24-48 in)
33	Large boulder (>48 in)
34	Bedrock
35	Undercut bank
36	Rip-rap bank

Discharge measurements were collected for each snorkel survey event. Discharge surveys were consistent with the CDFW's *Standard Operating Procedure for Discharge Measurements in Wadeable Streams in California* (CDFW 2020). Hach FH 950 velocity flow meters were calibrated according to the manufacturer's instructions each day before use in the field (CDFW 2020). A single discharge measurement was used to represent the flow for multiple habitat units when units were in close proximity to one another and where there were no flow inputs or diversions between transects. If necessary, multiple discharge measurements were taken within a given reach to account for additional flow inputs or diversions.

3.2 Fish Observation Techniques

Habitat use data (i.e., habitat choice by the fish) were collected for all undisturbed juvenile steelhead and Coho Salmon observed by snorkelers. CDFW staff used flexible claw pickup tools called “grabbers” (Figure 9) to place fish markers where undisturbed fish were observed (Figure 10). The grabber was also used for estimating salmonid fork lengths while observing them underwater. Fork length (cm) was estimated from the tip of the snout to the fork in the caudal fin. Length frequency distributions were used to partition HSC data into fry (<6 cm) and juvenile (≥6 cm) size classes.

Figure 9. Grabber used for placing fish markers and estimating fish length.

Figure 10. Fish markers placed where undisturbed fish were observed. Run, unit 525, 08/22/2018.

Prior to the first snorkel survey each day, water visibility was estimated using a 10 cm juvenile trout rapala fishing lure (Figure 11). A sinker was attached to the lure with fishing line and placed in a stream location where the lure could be fully submerged. Snorkelers would enter the stream facing flow. Starting about a foot away from the lure, snorkelers would slowly back away until they could no longer discern the parr marks on the lure. Visibility was determined to be the maximum distance the snorkeler could see the parr marks on the lure underwater.

Figure 11. Juvenile trout rapala fishing lure and sinker used for water visibility estimates.

Potential snorkeling scenarios for collecting HSC data depended on 1) channel width, 2) water clarity, and 3) fry/juvenile salmonid densities. Where narrow channel widths and adequate water visibilities allowed, a single snorkeler collected HSC data with support from a stream-side data recorder. Where channel widths and water visibilities prevented a single snorkeler from fully covering the habitat being sampled, two snorkelers worked upstream together. In addition, if salmonid densities were high, two snorkelers would survey the unit and work together to avoid missing or double counting fish. One snorkeler would survey the left half of the channel while the other snorkeler surveyed the right half (Figures 12, 13, and 14). Each snorkeler relayed HSC data to a stream-side data recorder.

Fish activity was recorded as feeding or holding. Fish that were not selecting a position in the habitat unit, but rather were swimming around were not marked. Fish that were observed selecting a habitat position but were disturbed before CDFW staff could identify the species and estimate fork length were recorded as disturbed. Focal position (i.e., actual distance above the substrate or relative height in the water column) was determined using a scaling system: 1 represented the bottom of the water column and 10 represented the top. The scale of the focal position would increase or decrease as depths changed.

Figure 12. CDFW staff snorkeling the left and right halves of a glide. Unit 978, 08/16/2017.

Figure 13. CDFW staff snorkeling the left and right halves of a riffle. Unit 758, 06/28/2018.

Figure 14. CDFW staff snorkeling the left and right halves of a run. Unit 488, 08/21/2017.

Snorkelers proceeded with the following guidelines for direct underwater observations at each site:

1) Snorkelers entered the water about 20 ft downstream of the mesohabitat unit. Moving slowly upstream, snorkelers observed steelhead and/or Coho Salmon and determined their positions before disturbance by human activity. Fish markers (i.e., numbered weights with flagging attached) were placed underneath undisturbed salmonids. The following were recorded for each observation:
    a. Fish marker number
    b. Species
    c. Number of fish
    d. Estimated fork length to the nearest cm
    e. Focal position
    f. Fish activity
2) Where fry/juvenile salmonids were seen grouped together (4+) in a location that encompassed different water depths and velocities, fish were recorded and marked separately to characterize the different microhabitat features in which they were residing. If grouped together (4+) in a location that encompassed relatively the same water depths and velocities, fish were recorded as a group. Microhabitat data was measured once to represent all the fish within that location.

3) Snorkelers avoided herding fish by moving slowly around observed fish locations. Grabbers were used as a tool to maneuver the fish downstream after being observed, if needed. When two observers were present, they moved through the habitat unit side-by-side and communicated to ensure fish were not double-counted or herded from one side of the stream to the other.

4) Fish that were disturbed by snorkelers prior to identification of the species, fork length, and/or focal position were not marked, but were noted as present and were excluded from subsequent analyses.

5) Snorkelers continued upstream through the sampling unit to identify and mark all undisturbed fry/juvenile steelhead and Coho Salmon locations as described above. Snorkelers exited the site in the least disturbing way possible after underwater observations were complete.

6) Microhabitat features were then measured at each fish marker placed in the habitat unit. Cover and substrate codes (Tables 10 and 11) were used to describe microhabitat features within the stream. Data collection at each fish marker included:

    a. Water depth: measured where a fish was observed and in the thalweg to the nearest 0.05 ft with a top-setting wading rod

    b. Mean water column velocity: measured where a fish was observed and in the thalweg to the nearest 0.01 ft/s using a HACH FH 950 velocity meter

    c. Focal point velocity: measured where a fish was observed in the water column at the focal position to the nearest 0.01 ft/s using a HACH FH 950 velocity meter

    d. Dominant and subdominant substrate particle size: visually estimated within a 1.0 sq ft area around the point of observation

    e. Substrate percent embeddedness: visually estimated within a 1.0 sq ft area around the point of observation

    f. Water velocity shelter: a distinct microhabitat feature instream that creates a reduction in water velocities upstream of where a fish was observed. The object may be some distance away but has a direct influence on water velocities where the fish was observed. Water velocity shelter distance was measured to the nearest 0.5 ft.

    g. In-water cover: a microhabitat feature located instream that is directly over where a fish was observed. This type of functional cover provides concealment from predation, sunlight, or other factors that may contribute to or influence a fish's daily activities.

    h. Out-of-water cover: a microhabitat feature located out of the stream that is within 18 in from the water surface, overhead from where a fish was observed. This type of functional cover provides concealment from predation, sunlight, or other factors that may contribute to or influence a fish’s daily activities. Microhabitat features located more than 18 in away from the water surface were considered canopy.

i. Escape cover: a microhabitat feature located instream or out of stream within 18 in of the water surface over where a fish was observed. This cover type provides concealment for a fish’s response to fright or a threat. Escape cover was measured within 10 ft from where a fish was observed to the nearest 0.5 ft.

j. Closest bank distance: measured to the nearest 0.5 ft.

k. Distance (ft) to thalweg: measured to the nearest 0.5 ft.

l. Dominant and subdominant SMET: features of the closest stream bank/edge to where a fish was observed (Table 9).

3.3 Habitat Availability Techniques

Habitat availability data were collected in each sampled habitat unit after fish observations were complete and habitat use had been characterized (Figure 15). Habitat availability measurements were collected using a systematic randomized approach consisting of a) random selection of cross-sectional transects, then b) random selection of measurement points along each transect.

Figure 15. Habitat availability markers with orange flagging placed in a pool after completing fish observations, unit 652 on 06/05/2017.

The number of transects selected was dependent on the length of the habitat unit. Three transects were placed in habitat units up to 100 ft long. An additional transect was selected for each additional 50 ft of unit length (e.g., four transects were placed in units 101-150 ft long; five transects were placed in units 151-200 ft long). To assign transect placement, the habitat unit was divided by the number of transects, and a single randomly selected number was used to determine placement within each section. For example, a 90-ft unit would be divided into thirds, and a transect placed into each third using the randomly selected number. This design ensured that habitat availability points would be distributed evenly throughout the habitat unit.

Three points along each transect were selected as habitat availability points using the same systematic random sampling design. At each transect, stream width was measured to the nearest foot. To assign habitat availability points, the stream width was divided into thirds, and a single randomly selected number was used to determine placement within each third. This design ensured habitat availability points were selected along the left bank, middle, and right bank of each transect and were representative of available habitat. A minimum of nine habitat availability points were measured per sampled habitat unit.

The same microhabitat data collected for fish observations (see Section 3.2) were also collected for habitat availability points. A systematic random selection of available habitat points within each sampled habitat unit allowed for direct comparison of habitat use and habitat availability data during construction of HSC curves (Holmes et al. 2014).

3.4 Data Analyses

Frequency distributions were constructed for fish use observations with habitat availability points taken during spring and summer seasons. Figures of each microhabitat feature collected (see Section 3.2) were produced using the smallest practical bin size for each microhabitat feature within each season, for both species and size classes.

Category III HSC (Bovee et al. 1998) for depth (ft) and mean water column velocity (ft/s) were developed for rearing fry (<6 cm) and juvenile (≥6 cm) steelhead and Coho Salmon using the forage ratio (Equation 1; Jowett and Davey 2007).

Equation 1. Forage ratio.

$$w_i = \frac{\boxed{u_i / \sum_{i=1}^{n} u_i}}{\boxed{a_i / \sum_{i=1}^{n} a_i}}$$

Fish use

Habitat availability

In equation 1, w_i is the forage ratio for the ith of n microhabitat categories, u_i is the total abundance in category i, Σu_i is the total abundance for all microhabitat categories, a_i is the number of samples from category i, and Σa_i is the total number of samples (Manly et al. 1993 as cited in Jowett and Davey 2007).

The forage ratio is calculated by taking the proportion of used microhabitat units of a feature (e.g., water depths between 0.10 and 0.15) divided by the proportion of total available microhabitat units of that feature. The forage ratios were standardized by dividing each value by the maximum value within each dataset to arrange the data into a suitability index between 0.0 (unsuitable) and 1.0 (suitable). Kernel smoothing techniques (Silverman 1986) were used to generate the curves using a Gaussian distribution in the modeling program System for Environmental Flow Analysis (SEFA; Jowett et al. 2017).

4.0 RESULTS

Fish use and habitat availability data collection began in June 2017. Sampling continued in 2018 to acquire an acceptable sample size of fish (150-200 observations) as described by (Bovee 1986). Sampling effort was stratified by season (i.e., spring and summer), reach (i.e., reach 1, reach 2, and reach 3), mesohabitat type (i.e., riffle, pool, glide, and run), species (i.e., steelhead and Coho Salmon), and size class (i.e., <6 cm and ≥6 cm).

Fish use and habitat availability data were combined in spring months (June 2017 and May/June 2018) and summer months (August 2017 and July 2018) to compare microhabitat features between seasons. Summer flows were low (0.3-3.7 cfs) relative to the spring flows (5.2-22.5 cfs; Table 12). Water temperature ranged from 49 to 67°F (mean 57°F) in the spring and from 57 to 70°F (mean 63°F) in the summer. Water visibility ranged from 8 to 16 ft (mean 12.5 ft) in the spring and from 6 to 20 ft (mean 10.5 ft) in the summer.

Table 12. Summary of flows measured in all three reaches during each season and year.

Season	Month(s) Year	Flows (cfs)
Spring	June 2017	5.5-16.8
Summer	August 2017	0.3-1.5
Spring	May/June 2018	5.2-22.5
Summer	July 2018	0.8-3.7

Staff collected data in approximately 5,000 sq ft per mesohabitat type for each reach and season, maintaining the equal area sampling design (Tables 13, 14, and 15). In total, the area sampled among all reaches and seasons was 242,519 sq ft.

Table 13. Total area sampled in reach 1.

Mesohabitat Type	Spring 2017	Spring 2018	Summer 2017	Summer 2018
Riffles	5,212	4,975	5,138	5,004
Pools	4,998	5,125	5,040	4,917
Glides	5,000	5,047	5,106	4,961
Runs	4,978	5,060	5,080	5,064
Total (sq ft)	20,188	20,207	20,364	19,946

Table 14. Total area sampled in reach 2.

Mesohabitat Type	Spring 2017	Spring 2018	Summer 2017	Summer 2018
Riffles	5,004	5,068	5,250	4,934
Pools	4,920	5,040	5,056	5,100
Glides	5,200	5,145	5,029	4,876
Runs	4,990	4,940	6,080	5,034
Total (sq ft)	20,114	20,193	21,415	19,944

Table 15. Total area sampled in reach 3.

Mesohabitat Type	Spring 2017	Spring 2018	Summer 2017	Summer 2018
Riffles	4,837	5,001	4,869	4,875
Pools	5,090	5,085	5,046	4,928
Glides	5,003	5,012	5,051	5,148
Runs	5,000	5,021	5,052	5,130
Total (sq ft)	19,930	20,119	20,018	20,081

4.1 Steelhead and Coho Salmon Fish Counts

Total observations per reach for each species by season, year and mesohabitat type are shown in Tables 16 to 21. More steelhead were observed in the summer season for both sampling years combined versus the spring season (spring n=446; summer n=1,684; Table 22). Total observations of Coho Salmon for both years and seasons were similar (spring n=785; summer n=639), although summer 2018 had almost 19 times the amount of Coho Salmon observations than the summer of 2017. No steelhead were observed in reach 3 of spring 2018; no Coho Salmon were observed in reach 1 of summer 2017.

Table 16. Total steelhead observed in reach 1 by season, year, and mesohabitat type.

Mesohabitat type	Spring 2017	Spring 2018	Summer 2017	Summer 2018
Riffle	55	110	62	136
Pool	3	18	13	7
Glide	15	48	61	40
Run	44	89	34	89
Total	117	265	170	272

Table 17. Total steelhead observed in reach 2 by season, year, and mesohabitat type.

Mesohabitat type	Spring 2017	Spring 2018	Summer 2017	Summer 2018
Riffle	13	16	138	98
Pool	4	0	68	41
Glide	0	2	28	29
Run	23	0	171	115
Total	40	18	405	283

Table 18. Total steelhead observed in reach 3 by season, year, and mesohabitat type.

Mesohabitat type	Spring 2017	Spring 2018	Summer 2017	Summer 2018
Riffle	3	0	63	88
Pool	0	0	102	43
Glide	1	0	51	35
Run	2	0	117	55
Total	6	0	333	221

Table 19. Total Coho Salmon observed in reach 1 by season, year, and mesohabitat type.

Mesohabitat type	Spring 2017	Spring 2018	Summer 2017	Summer 2018
Riffle	13	0	0	1
Pool	14	2	0	0
Glide	11	0	0	0
Run	21	1	0	0
Total	59	3	0	1

Table 20. Total Coho Salmon observed in reach 2 by season, year, and mesohabitat type.

Mesohabitat type	Spring 2017	Spring 2018	Summer 2017	Summer 2018
Riffle	18	13	0	3
Pool	19	42	0	36
Glide	27	27	9	10
Run	28	73	0	5
Total	92	155	9	54

Table 21. Total Coho Salmon observed in reach 3 by season, year, and mesohabitat type.

Mesohabitat type	Spring 2017	Spring 2018	Summer 2017	Summer 2018
Riffle	57	44	0	49
Pool	57	106	16	170
Glide	38	52	4	156
Run	101	21	3	177
Total	253	223	23	552

Table 22. Total observations by species for each season and year.

Species	Spring 2017	Spring 2018	Summer 2017	Summer 2018
Steelhead	163	283	908	776
Coho Salmon	404	381	32	607

Total observations of steelhead and Coho Salmon by reach and mesohabitat type are shown in Tables 23 and 24. Collectively, there were more steelhead than Coho Salmon in riffles and runs, and more Coho Salmon than steelhead in pools. More steelhead were observed in downstream reaches, and more Coho Salmon were observed in upstream reaches.

Table 23. Total steelhead observed per reach and mesohabitat type.

Mesohabitat Type	Reach 1	Reach 2	Reach 3	Total
Riffle	363	265	154	782
Pool	41	113	145	299
Glide	164	59	87	310
Run	256	309	174	739
Total	824	746	560	2,130

Table 24. Total Coho Salmon observed per reach and mesohabitat type.

Mesohabitat Type	Reach 1	Reach 2	Reach 3	Total
Riffle	14	34	150	198
Pool	16	97	349	462
Glide	11	73	250	334
Run	22	106	302	430
Total	63	310	1,051	1,424

Total observations of steelhead and Coho Salmon by season and size class are shown in Tables 25 and 26. There were more observations of steelhead than Coho Salmon for all seasons and size classes combined. Among the <6 cm size class, more Coho Salmon were observed than steelhead. Among the ≥6 cm size class, more steelhead were observed than Coho Salmon.

Table 25. Total steelhead observed per season and size class.

Size Class	Spring	Summer	Total
<6 cm	120	455	575
≥6 cm	326	1,229	1,555
Total	446	1,684	2,130

Table 26. Total Coho Salmon observed per season and size class.

Size Class	Spring	Summer	Total
<6 cm	568	70	638
≥6 cm	217	569	786
Total	785	639	1,424

4.2 Habitat Availability

Habitat availability survey results are presented by reach, season, and year in Table 27. Collectively, 441 habitat availability points were collected during the spring, and 458 habitat availability points were collected in the summer. In total, 899 habitat availability points were collected. The number of habitat availability points collected between seasons and reaches were consistent with the data collection protocol described in Section 3.3.

Table 27. Number of habitat availability points collected in each year, season, and reach.

Reach	Spring 2017	Spring 2018	Summer 2017	Summer 2018
1	62	70	82	63
2	65	64	67	73
3	95	85	84	89
Total	222	219	233	225

Flow levels were low in the summer season (0.3-3.7 cfs) and only provided limited habitat use and habitat availability for fry/juvenile salmonid rearing habitat (Table 28). Summer datasets were therefore excluded from HSC curve development. HSC were developed using the spring dataset only, which was collected over a higher range of flows and a broader variety of available habitat. Due to homogeneous features among reaches, data were analyzed using all three reaches combined for curve development.

Table 28. Statistical comparison of water depth and water velocity habitat availability measurements taken during spring and summer.

Season and Feature	N	Minimum	Maximum	Mean	Median	Std. Dev.
Spring Water Depth (ft)	441	0.15	8.60	0.99	0.80	0.89
Spring Water Velocity (ft/s)	441	0.00	4.75	0.69	0.42	0.76
Summer Water Depth (ft)	458	0.15	7.90	0.77	0.50	0.91
Summer Water Velocity (ft/s)	458	0.00	1.75	0.19	0.08	0.28

4.3 Spring Habitat Use and Availability by Species and Size Class

For each species and size class, fish observations are presented first. Fish observation data are then compared to habitat availability data. The habitat availability data are the same for all species and size classes observed in the spring (see Table 31). Spring species observations and habitat availability data are presented here and in Appendices A to D. Summer species observations and habitat availability data can be found in Appendices E to H.

4.3.1 <6 cm Steelhead Observation Data

Spring <6 cm steelhead observation statistics are outlined in Table 29. Associated frequency distributions are in Appendix A.

Table 29. <6 cm steelhead observational statistics collected in spring 2017 and 2018.

Statistic	N	Minimum	Maximum	Mean	Median	Std. Dev.
Focal Point Position	120	1	8	3	2	1.81
Focal Point Velocity (ft/s)	120	0.00	1.71	0.27	0.18	0.32
Distance to Thalweg (ft)	120	0.0	46.5	11.7	10.0	9.54

Continuous Data:

Fork Length: The minimum fork length observed for <6 cm steelhead was 3 cm, and the maximum fork length was 5 cm, with a mean of 4 cm (Figure A-1).

Focal Point Position: The minimum focal point position observed for <6 cm steelhead was position 1, near the bottom of the water column. The maximum focal point position observed was 8, towards the top of the water column. The mean focal point position was 3, indicating most <6 steelhead were observed in the lower half of the water column (Figure A-2).

Focal Point Velocity: The focal point velocities for <6 cm steelhead were between 0.00 ft/s and 1.71 ft/s. The mean focal point velocity was 0.27 ft/s, but the majority were observed in between 0.10 ft/s and 0.19 ft/s (Figure A-3).

Distance to Thalweg: The distance to thalweg for <6 cm steelhead ranged from 0.0 ft to 46.5 ft. The mean distance to thalweg was 11.7 ft (Figure A-4).

Categorical Data:

Mesohabitat Type: <6 cm steelhead were observed in each of the four mesohabitat types. <6 cm steelhead were mostly observed in riffles and runs and were least abundant in pools (Figure A-5).

Fish Activity: Most <6 cm steelhead were observed holding (n=83) and fewer were observed feeding (n=37; Figure A-6).

4.3.2 <6 cm Steelhead Habitat Use vs. Availability Data

Spring <6 cm steelhead habitat use and habitat availability statistics are summarized in Tables 30 and 31, and described below. Associated frequency distributions are in Appendix A.

Table 30. <6 cm steelhead habitat use statistics observed in spring 2017 and 2018.

Statistic	N	Minimum	Maximum	Mean	Median	Std. Dev.
Water Depth (ft)	120	0.20	1.60	0.67	0.60	0.29
Water Velocity (ft/s)	120	0.00	1.82	0.37	0.21	0.39
Distance to Water Velocity Shelter (ft)	120	0.0	5.0	1.5	1.0	1.56
Distance to Escape Cover (ft)	120	0.0	6.0	1.5	1.0	1.37
Distance to Bank (ft)	120	0.0	25.5	5.8	4.5	4.41
Thalweg Depth (ft)	120	0.50	3.70	1.13	1.05	0.50
Thalweg Velocity (ft/s)	120	0.15	2.99	1.21	1.18	0.66

Table 31. Habitat availability statistics observed in spring 2017 and 2018.

Statistic	N	Minimum	Maximum	Mean	Median	Std. Dev.
Water Depth (ft)	441	0.15	8.60	0.99	0.80	0.89
Water Velocity (ft/s)	441	0.00	4.75	0.69	0.42	0.76
Distance to Water Velocity Shelter (ft)	441	0.0	5.0	1.1	0.5	1.29
Distance to Escape Cover (ft)	441	0.0	10.0	1.6	1.0	1.87
Distance to Bank (ft)	441	0.0	26.0	7.5	6.0	5.14
Thalweg Depth (ft)	441	0.30	10.50	1.60	1.25	1.33
Thalweg Velocity (ft/s)	441	0.00	3.92	1.02	0.80	0.82

Continuous Data:

Water Depth: <6 cm steelhead were observed in depths ranging from 0.20 ft to 1.60 ft. The mean water depth used was 0.67 ft. The distribution of water depth availability indicated deeper habitats available than <6 cm steelhead were using. The maximum depth recorded for availability was 8.60 ft (Figure A-7).

Water Velocity: <6 cm steelhead were observed in locations with water velocities ranging from 0.00 ft/s to 1.82 ft/s. Distribution of water velocities indicated <6 cm steelhead were using slower velocities than what was available. The maximum available velocity was 4.75 ft/s (Figure A-8).

Distance to Water Velocity Shelter: <6 cm steelhead were rarely observed using locations near a water velocity shelter; if they were, the water velocity shelter was mostly within one foot. Only 20% of <6 cm steelhead were observed using water velocity shelter. Distributions of water velocity shelter use and availability were similar (Figure A-9).

Distance to Escape Cover: The distance to escape cover ranged from 0.0 ft to 6.0 ft for <6 cm steelhead. The mean distance to escape cover was 1.5 ft with most fish observations within 4.0 ft of some type of escape cover. Similarly, available escape cover was primarily found within 5.0 ft (Figure A-10).

Distance to Bank: <6 cm steelhead were observed from approximately 0.0 ft to 25.5 ft from the bank. The mean distance to bank used by <6 cm steelhead was 5.8 ft, while the mean distance available was 7.5 ft (Figure A-11).

Thalweg Depth: <6 cm steelhead were observed in thalweg depths ranging from 0.50 ft to 3.70 ft. Available thalweg depths ranged from 0.30 ft to 10.50 ft. The majority of both used and available thalweg depths were between 1.00 ft and 2.00 ft (Figure A-12).

Thalweg Velocity: <6 cm steelhead were observed in thalweg velocities ranging from 0.15 ft/s to 2.99 ft/s. Available thalweg velocities ranged from 0.00 ft/s to 3.92 ft/s (Figure A-13).

Categorical Data:

Dominant/subdominant Substrate: Most <6 cm steelhead were observed using gravel and cobble substrate types; small gravel was more frequently used. Available substrate types ranged from sandy material to bedrock; small gravel and bedrock were most frequently available (Figures A-14 and A-15).

Percent Embedded: <6 cm steelhead were primarily observed using substrate that was between 10% to 20% embedded. Both used and available substrates ranged from 0% to 80% embedded (Figure A-16).

Water Velocity Shelter: Most <6 cm steelhead were observed in locations without a water velocity shelter; a few were observed in locations with cobble and bedrock water velocity shelters. Availability of water velocity shelters was similar (Figure A-17).

In-water Cover: Out of the total <6 cm steelhead observed in spring, 93% were in locations without in-water cover; small branches/vegetation and roots or root-wads were occasionally used for in-water cover. Availability of in-water cover types was similar to use (Figure A-18).

Out-of-water Cover: Out of the total <6 cm steelhead observed in spring, 88% were in locations without out-of-water cover; grass and small branches/vegetation were occasionally used for out-of-water cover. Availability of out-of-water types was similar to use (Figure A-19).

Escape Cover: <6 cm steelhead were mostly observed in locations near a hard substrate escape cover, with some observed near a vegetative escape cover. Use and availability escape cover types were similar; small to large cobbles were the most common escape cover types (Figure A-20).

4.3.3 ≥6 cm Steelhead Observation Data

Spring ≥6 cm steelhead observation statistics are summarized in Table 32 and described below. Associated frequency distributions are in Appendix B.

Table 32. ≥6 cm steelhead observational statistics collected in spring 2017 and 2018.

Statistic	N	Minimum	Maximum	Mean	Median	Std. Dev.
Focal Point Position	326	1	8	3	2	1.71
Focal Point Velocity (ft/s)	326	0.00	3.41	0.39	0.26	0.44
Distance to Thalweg (ft)	326	0.0	46.5	8.0	5.0	9.58

Continuous Data:

Fork Length: Fork length observed for ≥6 cm steelhead ranged from 6 cm to 15 cm with a mean of 7 cm (Figure B-1).

Focal Point Position: The minimum focal point position observed for ≥6 cm steelhead was at position 1, near the bottom of the water column. The maximum focal point position observed was 8, towards the top of the water column. The mean focal point position was 3, indicating most ≥6 steelhead were observed in the lower half of the water column (Figure B-2).

Focal Point Velocity: The focal point velocities for ≥6 cm steelhead were between 0.00 ft/s and 3.41 ft/s. The mean focal point velocity was 0.39 ft/s, but the majority were observed between 0.10 ft/s and 0.19 ft/s (Figure B-3).

Distance to Thalweg: The distance to thalweg for ≥6 cm steelhead ranged from 0.0 ft to 46.5 ft. The mean distance was 8.0 ft (Figure B-4).

Categorical Data:

Mesohabitat Type: ≥6 cm steelhead were observed in each of the four mesohabitat types. ≥6 cm steelhead were mostly observed in riffles and runs and were least abundant in pools (Figure B-5).

Fish Activity: Most ≥6 cm steelhead were observed holding (n=218) and fewer were observed feeding (n=108; Figure B-6).

4.3.4 ≥6 cm Steelhead Habitat Use vs. Availability Data

Spring ≥6 cm steelhead habitat use and habitat availability statistics are summarized in Tables 33 and 31, respectively, and described below. Associated frequency distributions are in Appendix B.

Table 33. ≥6 cm steelhead habitat use statistics observed in spring 2017 and 2018.

Statistic	N	Minimum	Maximum	Mean	Median	Std. Dev.
Water Depth (ft)	326	0.20	2.90	0.90	0.90	0.35
Water Velocity (ft/s)	326	0.00	3.41	0.57	0.40	0.59
Distance to Water Velocity Shelter (ft)	326	0.0	5.0	1.2	1.0	1.30
Distance to Escape Cover (ft)	326	0.0	7.0	1.3	1.0	1.32
Distance to Bank (ft)	324	0.0	19.0	6.5	6.0	3.94
Thalweg Depth (ft)	326	0.50	3.70	1.22	1.10	0.51
Thalweg Velocity (ft/s)	326	0.04	3.50	1.19	1.13	0.79

Continuous Data:

Water Depth: ≥6 cm steelhead were observed in depths ranging from 0.20 ft to 2.90 ft. The mean water depth used was 0.90 ft. The distribution of water depth availability indicated deeper habitats available than ≥6 cm steelhead were using. The maximum depth recorded for availability was 8.60 ft (Figure B-7).

Water Velocity: ≥6 cm steelhead were observed in locations with water velocities ranging from 0.00 ft/s to 3.41 ft/s. Distribution of water velocities indicated ≥6 cm steelhead were using slower velocities than what was available. The maximum available velocity was 4.75 ft/s, while the maximum recorded velocity used by ≥6 cm steelhead was 3.41 ft/s (Figure B-8).

Distance to Water Velocity Shelter: ≥6 cm steelhead were rarely observed using locations near a water velocity shelter; if they were, the water velocity shelter was mostly within one foot. Only 37% of ≥6 cm steelhead were observed using a water velocity shelter. Distributions of water velocity shelter use and availability were similar (Figure B-9).

Distance to Escape Cover: The distance to escape cover ranged from 0.0 ft to 7.0 ft for ≥6 cm steelhead. The mean distance to used escape cover was 1.3 ft with most observations within 4.0 ft of some type of escape cover. Similarly, available escape cover was primarily found within 5.0 ft (Figure B-10).

Distance to Bank: ≥6 cm steelhead were observed approximately 0.0 ft to 19.0 ft from the bank. The mean distance to bank used by ≥6 cm steelhead was 6.5 ft, while the mean distance available was 7.5 ft (Figure B-11).

Thalweg Depth: ≥6 cm steelhead were observed in thalweg depths ranging from 0.50 ft to 3.70 ft. Available thalweg depths ranged from 0.30 ft to 10.50 ft. The majority of both used and available thalweg depths were between 1.00 ft and 2.00 ft (Figure B-12).

Thalweg Velocity: ≥6 cm steelhead thalweg velocities ranged from 0.04 ft/s to 3.50 ft/s. Available thalweg velocities ranged from 0.00 ft/s to 3.92 ft/s (Figure B-13).

Categorical Data:

Dominant/subdominant Substrate: Most ≥6 cm steelhead were observed using gravel and cobble substrate types; small cobble was more frequently used. Available substrate types were similar to used substrate types and ranged from sandy material to bedrock; small gravel and bedrock were most frequently available (Figures B-14 and B-15).

Percent Embedded: ≥6 cm steelhead primarily used substrate that was between 10% to 20% embedded. Use and availability of embedded substrate ranged from 0% to 80% embedded (Figure B-16).

Water Velocity Shelter: Most ≥6 cm steelhead were observed in locations without water velocity shelter; some were observed in locations with small to large cobble, boulders, and bedrock. Availability of water velocity shelters was similar, with some cobble, boulder, and bedrock water velocity shelters available (Figure B-17).

In-water Cover: Out of the total ≥6 cm steelhead observed in spring, 90% were in locations without in-water cover; small branches/vegetation and roots or root wads were occasionally used for in-water cover. Availability of in-water cover types was similar to use (Figure B-18).

Out-of-water Cover: Out of the total ≥6 cm steelhead observed in spring, 87% were in locations without out-of-water cover; grass, small branches/vegetation, and roots or root wads were occasionally used for out-of-water cover. Availability of out-of-water cover types was similar to use (Figure B-19).

Escape Cover: ≥6 cm steelhead were mostly observed in locations near a hard substrate escape cover, with some observed near a vegetative escape cover. Use and availability escape cover types were similar; small to large cobble, boulders, and bedrock were the most common escape cover types (Figure B-20).

4.3.5 <6 cm Coho Salmon Observation Data

Spring <6 cm Coho Salmon observation statistics are outlined in Table 34 and described below. Associated frequency distributions are in Appendix C.

Table 34. <6 cm Coho Salmon observational statistics collected in spring 2017 and 2018.

Statistic	**N**	**Minimum**	**Maximum**	**Mean**	**Median**	**Std. Dev.**
Focal Point Position	568	1	9	3	2	2.05
Focal Point Velocity (ft/s)	568	0.00	1.85	0.18	0.09	0.23
Distance to Thalweg (ft)	568	0.0	46.5	10.7	8.5	8.08

Continuous Data:

Fork Length: The minimum fork length observed for <6 cm Coho Salmon was 3 cm and the maximum fork length was 5 cm with a mean of 4 cm (Figure C-1).

Focal Point Position: The minimum focal point position observed for <6 cm Coho Salmon was position 1, near the bottom of the water column. The maximum focal point position observed was 9, towards the top of the water column. The mean focal point position was 3, indicating most <6 Coho Salmon were observed in the lower half of the water column (Figure C-2).

Focal Point Velocity: The focal point velocities for Coho Salmon <6 cm were between 0.00 ft/s and 1.85 ft/s. The mean focal point velocity was 0.18 ft/s, but the majority were observed between 0.10 ft/s and 0.19 ft/s (Figure C-3).

Distance to Thalweg: The distance to thalweg for <6 cm Coho Salmon ranged from 0.0 ft to 46.5 ft. The mean distance to thalweg was 10.7 ft (Figure C-4).

Categorical Data:

Mesohabitat Type: <6 cm Coho Salmon were observed in each of the four mesohabitat types. <6 cm Coho Salmon were mostly observed in runs and pools and were less abundant in riffles and glides (Figure C-5).

Fish Activity: Most <6 cm Coho Salmon were observed holding (n=441) and fewer were observed feeding (n=127; Figure C-6).

4.3.6 <6 cm Coho Salmon Habitat Use vs. Availability Data

Spring <6 cm Coho Salmon habitat use and habitat availability statistics are summarized in Tables 35 and 31, respectively, and described below. Associated frequency distributions are in Appendix C.

Table 35. <6 cm Coho Salmon habitat use statistics observed in spring 2017 and 2018.

Statistic	N	Minimum	Maximum	Mean	Median	Std. Dev.
Water Depth (ft)	568	0.15	2.60	0.78	0.70	0.46
Water Velocity (ft/s)	568	0.00	2.75	0.24	0.30	0.13
Distance to Water Velocity Shelter (ft)	568	0.0	5.0	1.1	0.5	1.28
Distance to Escape Cover (ft)	568	0.0	10.0	1.4	1.0	1.56
Distance to Bank (ft)	568	0.0	24.0	4.6	3.0	4.12
Thalweg Depth (ft)	568	0.30	15.00	1.58	1.35	1.22
Thalweg Velocity (ft/s)	568	0.03	4.47	0.83	0.61	0.68

Continuous Data:

Water Depth: <6 cm Coho Salmon were observed in depths ranging from 0.15 ft to 2.60 ft. The mean water depth used was 0.78 ft. The distribution of water depth availability indicated deeper habitats available than <6 cm Coho Salmon were using. The maximum depth recorded for availability was 8.60 ft (Figure C-7).

Water Velocity: <6 cm Coho Salmon were observed in locations with water velocities ranging from 0.00 ft/s to 2.75 ft/s. Distribution of water velocities indicated <6 cm Coho Salmon using slower velocities than what was available. The maximum available velocity was 4.75 ft/s (Figure C-8).

Distance to Water Velocity Shelter: <6 cm Coho Salmon were rarely observed using locations near a water velocity shelter; if they were, the water velocity shelter was mostly within one foot. Only 30% of <6 cm Coho Salmon were observed using water velocity shelter. Distributions of water velocity shelter use and availability were similar (Figure C-9).

Distance to Escape Cover: The distance to escape cover ranged from 0.0 ft to 10.0 ft for <6 cm Coho Salmon. The mean distance to used escape cover was 1.4 ft with most observations within 4.0 ft of some type of escape cover. Similarly, available escape cover was primarily found within 5.0 ft (Figure C-10).

Distance to Bank: <6 cm Coho Salmon were observed from approximately 0.0 ft to 24.0 ft from the bank. The mean distance to bank used by <6 cm Coho Salmon was 4.6 ft, while the mean distance available was 7.5 ft (Figure C-11).

Thalweg Depth (ft): <6 cm Coho Salmon were observed in thalweg depths ranging from 0.30 ft to 15.00 ft. Available thalweg depths ranged from 0.30 ft to 10.50 ft. The majority of both used and available thalweg depths were between 1.00 ft and 2.00 ft (Figure C-12).

Thalweg Velocity (ft/s): <6 cm Coho salmon thalweg velocities ranged from 0.03 ft/s to 4.47 ft/s. Available thalweg velocities ranged from 0.00 ft/s to 3.92 ft/s (Figure C-13).

Categorical Data:

Dominant/subdominant Substrate: Most <6 cm Coho Salmon were observed using sandy material to medium gravel and bedrock substrate types; bedrock was most frequently used. Available substrate types were similar, ranging from sandy material to bedrock; small gravel and bedrock were most frequently available (Figures C-14 and C-15).

Percent Embedded: <6 cm Coho Salmon primarily used substrate that was between 10% to 20% embedded. Use and availability of embedded substrate were similar, ranging from 0% to 100% embedded (Figure C-16).

Water Velocity Shelter: Most <6 cm Coho Salmon were observed in locations without a water velocity shelter; some were found using cobble, boulder, and bedrock water velocity shelters. The distribution of available water velocity shelters was similar (Figure C-17).

In-water Cover: Out of the total <6 cm Coho Salmon observed in spring, 86% were in locations without in-water cover. Roots or root wads, small branches/vegetation, and small woody debris were occasionally used for in-water cover. Availability of in-water cover types were similar to use (Figure C-18).

Out-of-water Cover: Out of the total <6 cm Coho Salmon observed in spring, 81% were in locations without out-of-water cover. Small branches/vegetation, grass, roots or root wads, and large woody debris were occasionally used for out-of-water cover. Availability of out-of-water cover types were similar to use (Figure C-19).

Escape Cover: <6 cm Coho Salmon were mostly observed in locations near a hard substrate escape cover, with some observed near a vegetative escape cover. Use and availability escape cover types were similar; small to large cobbles were the most common escape cover types (Figure C-20).

4.3.7 ≥6 cm Coho Salmon Observation Data

Spring ≥6 cm Coho Salmon observation statistics are outlined in Table 36 and described below. Associated frequency distributions are in Appendix D.

Table 36. ≥6 cm Coho Salmon observational statistics collected in spring 2017 and 2018.

Statistic	N	Minimum	Maximum	Mean	Median	Std. Dev.
Focal Point Position	217	1	8	4	3	2.48
Focal Point Velocity (ft/s)	217	0.00	3.22	0.21	0.09	0.35
Distance to Thalweg (ft)	217	0.0	46.0	9.5	6.5	10.7

Continuous Data:

Fork Length: The fork length observed for ≥6 cm Coho Salmon ranged from 6 cm to 8 cm with a mean of 6 cm (Figure D-1).

Focal Point Position: The minimum focal point position observed for ≥6 cm Coho Salmon was position 1, near the bottom of the water column. The maximum focal point position observed was 8, towards the top of the water column. The mean focal point position was 4, indicating most ≥6 Coho Salmon were observed in the lower half of the water column (Figure D-2).

Focal Point Velocity: The focal point velocities for Coho Salmon ≥6 cm were between 0.00 ft/s and 3.22 ft/s. The mean focal point velocity was 0.21 ft/s, but the majority were observed between 0.10 ft/s and 0.19 ft/s (Figure D-3).

Distance to Thalweg: The distance to thalweg for ≥6 cm Coho Salmon ranged from 0.0 ft to 46.0 ft. The mean distance was 9.5 ft (Figure D-4).

Categorical Data:

Mesohabitat Type: ≥6 cm Coho Salmon were observed in each of the four mesohabitat types. ≥6 cm Coho Salmon were mostly observed in pools and runs and were less abundant in riffles and glides. (Figure D-5).

Fish Activity: Most ≥6 cm Coho Salmon were observed holding (n=153) and fewer were observed feeding (n=64; Figure D-6).

4.3.8 ≥6 cm Coho Salmon Habitat Use vs. Availability Data

Spring ≥6 cm Coho Salmon habitat use and habitat availability statistics are summarized in Tables 37 and 31, respectively, and described below. Associated frequency distributions are in Appendix D.

Table 37. ≥6 cm Coho Salmon habitat use statistics observed in spring 2017 and 2018.

Statistic	N	Minimum	Maximum	Mean	Median	Std. Dev.
Water Depth (ft)	217	0.20	2.60	1.03	1.05	0.41
Water Velocity (ft/s)	217	0.00	3.19	0.27	0.12	0.41
Distance to Water Velocity Shelter (ft)	217	0.0	5.0	1.1	0.5	1.23
Distance to Escape Cover (ft)	217	0.0	10.0	1.4	0.5	1.87
Distance to Bank (ft)	217	0.0	18.0	4.7	4.0	3.46
Thalweg Depth (ft)	217	0.50	15.00	2.28	1.65	2.93
Thalweg Velocity (ft/s)	217	0.02	4.47	0.68	0.47	0.72

Continuous Data:

Water Depth: ≥6 cm Coho Salmon were observed in depths ranging from 0.20 ft to 2.60 ft. The mean water depth used was 1.03 ft. The distribution of water depth availability indicated deeper habitats available than ≥6 cm Coho Salmon were using. The maximum depth recorded for availability was 8.60 ft (Figure D-7).

Water Velocity: ≥6 cm Coho Salmon were observed in locations with water velocities ranging from 0.00 ft/s to 3.19 ft/s. Distribution of water velocities indicated ≥6 cm Coho Salmon were using slower velocities than what was available. The maximum available velocity was 4.75 ft/s (Figure D-8).

Distance to Water Velocity Shelter: ≥6 cm Coho Salmon were rarely observed using locations near a water velocity shelter; if they were, the water velocity shelter was mostly within two feet. Only 26% of ≥6 cm Coho Salmon were observed using water velocity shelter. Distributions of water velocity shelter use and availability were similar. (Figure D-9).

Distance to Escape Cover: The distance to escape cover ranged from 0.0 ft to 10.0 ft for ≥6 cm Coho Salmon. The mean distance to used escape cover was 1.4 ft with most observations within 4.0 ft of some type of escape cover. Similarly, available escape cover was primarily found within 5.0 ft (Figure D-10).

Distance to Bank: ≥6 cm Coho Salmon were observed approximately 0.0 ft to 18.0 ft from the bank. The mean distance to bank used by ≥6 cm Coho Salmon was 4.7 ft, while the mean distance available was 7.5 ft (Figure D-11).

Thalweg Depth (ft): ≥6 cm Coho Salmon were observed in thalweg depths ranging from 0.50 ft to 15.00 ft. Available thalweg depths ranged from 0.30 ft to 10.50 ft. The majority of both used and available thalweg depths were between 1.00 ft and 2.00 ft (Figure D-12).

Thalweg Velocity (ft/s): ≥6 cm Coho Salmon thalweg velocities ranged from 0.02 ft/s to 4.47 ft/s. Available thalweg velocities ranged from 0.00 ft/s to 3.92 ft/s (Figure D-13).

Categorical Data:

Dominant/subdominant Substrate: Most ≥6 cm Coho Salmon were observed using a range of substrates from sandy material to bedrock, which was most frequently used. Available substrate types were similar; small gravel and bedrock were most frequently available (Figures D-14 and D-15).

Percent Embedded: ≥6 cm Coho Salmon primarily used substrate that was 0% embedded. Use and availability of embedded substrate were similar, ranging from 0% to 100% embedded (Figure D-16).

Water Velocity Shelter: Most ≥6 cm Coho Salmon were observed in locations without water velocity shelter; some were observed in locations with cobble, boulders, and bedrock. Availability of water velocity shelters was similar, with some large cobble and bedrock water velocity shelters available (Figure D-17).

In-water Cover: Out of the total ≥6 cm Coho Salmon observed in spring, 74% were in locations without in-water cover; small branches/vegetation and roots or root wads were occasionally used for in-water cover. Availability of in-water cover types was similar to use (Figure D-18).

Out-of-water Cover: Out of the total ≥6 cm Coho Salmon observed in spring, 71% were in locations without out-of-water cover; roots or root wads, small branches/vegetation, and large woody debris were occasionally used for out-of-water cover. Availability of out-of-water cover types also indicated no cover was typically available; small branches/vegetation and grass were occasionally available (Figure D-19).

Escape Cover: ≥6 cm Coho Salmon were mostly observed in locations near a vegetative or hard substrate escape cover. Use and availability of escape cover types were similar; roots/root wads, cobbles, boulders, and bedrock were the most common escape cover types (Figure D-20).

4.4 Habitat Suitability Criteria Curves and Data

Although equal area sampling was achieved, use of Category II½ HSC was limited by low flows and lack of habitat availability. Therefore, Category III HSC were devised using the forage ratio (see Section 3.4) to account for bias associated with habitat availability.

Category III HSC were developed for water depth and mean water column velocity for <6 cm and ≥6 cm steelhead and Coho Salmon using the spring dataset. Water depth and water velocity HSC curves by species and size class are described below (Tables 38 to 45; Figures 16 to 23). HSC were not developed for other microhabitat features (e.g., cover, substrate).

<6 cm Steelhead HSC Curves

Water Depth: Peak suitability (i.e., an index of 1.00) occurred from 0.52 ft to 0.60 ft deep. Suitability declined to 0.20 at 1.81 ft deep; depths at 3.10 ft and deeper were considered unsuitable (Table 38; Figure 16).

Water Velocity: Suitability of mean water column velocity for <6 cm steelhead peaked between 0.14 ft/s and 0.19 ft/s. Suitability drops to 0.20 at 1.14 ft/s and is considered unsuitable when velocities reach 2.28 ft/s or faster (Table 39; Figure 17).

≥6 cm Steelhead HSC Curves

Water Depth: Peak suitability occurred from 1.12 ft to 1.20 ft deep. Suitability declined to 0.20 at 2.92 ft deep; depths of 3.44 ft or deeper were considered unsuitable (Table 40; Figure 18).

Water Velocity: Suitability of mean water column velocity for ≥6 cm steelhead peaked between 1.28 ft/s and 1.43 ft/s. Suitability drops to 0.20 at 3.28 ft/s and is considered unsuitable when velocities reach 4.75 ft/s or faster (Table 41; Figure 19).

Table 38. Water depth HSC data for <6 cm steelhead.

Water Depth (ft)	Suitability
0.00	0.00
0.15	0.00
0.26	0.90
0.34	0.95
0.43	0.98
0.52	**1.00**
0.60	**1.00**
0.69	0.98
0.77	0.94
0.86	0.88
0.95	0.82
1.03	0.74
1.12	0.67
1.20	0.59
1.29	0.51
1.38	0.44
1.46	0.38
1.55	0.32
1.63	0.28
1.72	0.23
1.81	0.20
1.89	0.17
1.98	0.15
2.06	0.13
2.15	0.11
2.24	0.09
2.32	0.08
2.41	0.07
2.49	0.06
2.58	0.05
2.67	0.04
2.75	0.03
2.84	0.03
2.92	0.02
3.01	0.02
3.10	0.01
3.18	0.01
3.27	0.01
3.35	0.01
3.44	0.01
3.53	0.01
3.61	0.00
3.70	0.00
3.78	0.00

Note: Peak suitabilities are indicated with bold font.

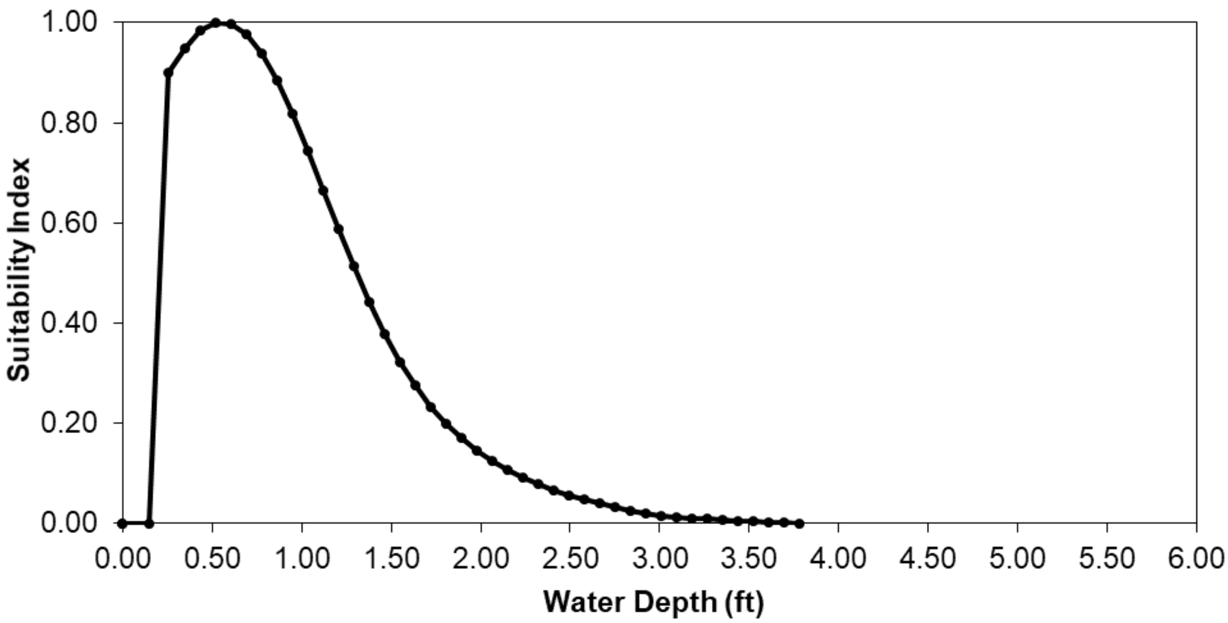

Figure 16. <6 cm steelhead water depth HSC.

Table 39. Water velocity HSC data for <6 cm steelhead.

Water Velocity (ft/s)	Suitability	Water Velocity (ft/s)	Suitability	Water Velocity (ft/s)	Suitability
0.00	0.89	0.90	0.32	1.81	0.05
0.05	0.94	0.95	0.29	1.85	0.05
0.10	0.98	1.00	0.26	1.90	0.04
0.14	**1.00**	1.05	0.23	1.95	0.04
0.19	**1.00**	1.09	0.21	2.00	0.03
0.24	0.99	1.14	0.19	2.04	0.03
0.29	0.96	1.19	0.17	2.09	0.03
0.33	0.93	1.24	0.15	2.14	0.02
0.38	0.88	1.28	0.13	2.19	0.02
0.43	0.83	1.33	0.12	2.23	0.02
0.48	0.77	1.38	0.11	2.28	0.01
0.52	0.71	1.43	0.10	2.33	0.01
0.57	0.65	1.47	0.09	2.38	0.01
0.62	0.59	1.52	0.09	2.42	0.01
0.67	0.53	1.57	0.08	2.47	0.00
0.71	0.48	1.62	0.07	2.52	0.00
0.76	0.43	1.66	0.07	2.57	0.00
0.81	0.39	1.71	0.06	2.61	0.00
0.86	0.35	1.76	0.06		

Note: Peak suitabilities are indicated with bold font.

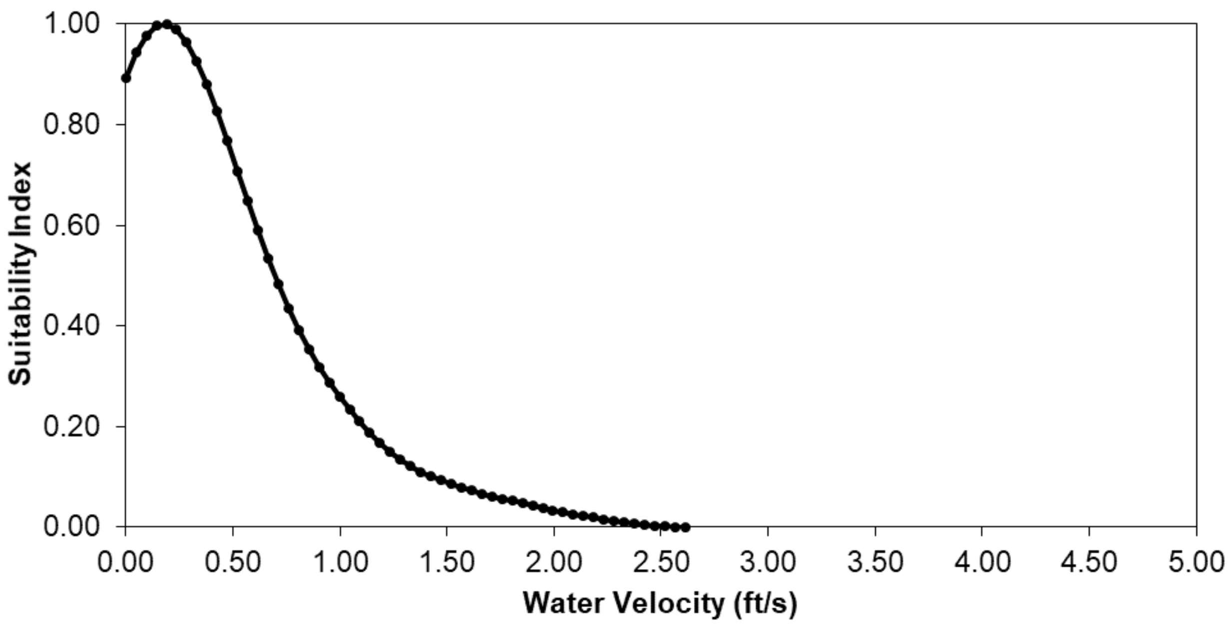

Figure 17. <6 cm steelhead water velocity HSC in Hollow Tree Creek.

Table 40. Water depth HSC data for ≥6 cm steelhead.

Water Depth (ft)	Suitability	Water Depth (ft)	Suitability	Water Depth (ft)	Suitability
0.00	0.00	1.29	0.98	2.49	0.40
0.15	0.00	1.38	0.95	2.58	0.36
0.26	0.44	1.46	0.89	2.67	0.32
0.34	0.50	1.55	0.85	2.75	0.28
0.43	0.56	1.63	0.80	2.84	0.24
0.52	0.63	1.72	0.76	2.92	0.20
0.60	0.70	1.81	0.72	3.01	0.16
0.69	0.76	1.89	0.68	3.10	0.13
0.77	0.83	1.98	0.64	3.18	0.09
0.86	0.89	2.06	0.60	3.27	0.06
0.95	0.94	2.15	0.56	3.35	0.03
1.03	0.97	2.24	0.52	3.44	0.00
1.12	**1.00**	2.32	0.48		
1.20	**1.00**	2.41	0.44		

Note: Peak suitabilities are indicated with bold font.

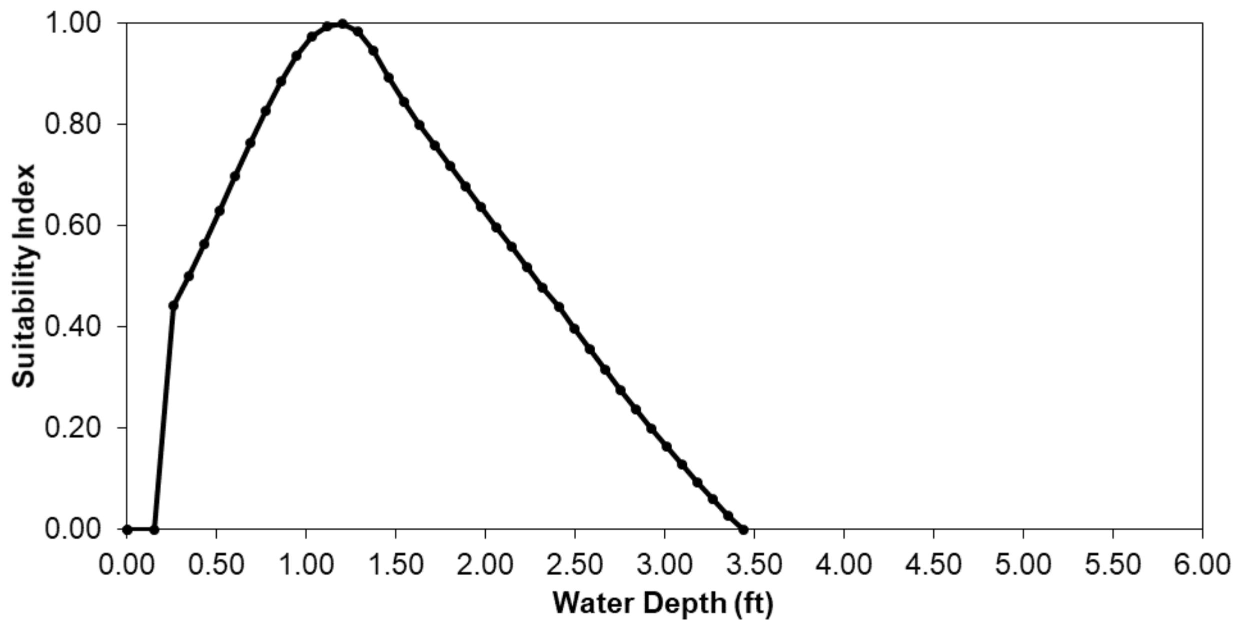

Figure 18. ≥6 cm steelhead water depth HSC in Hollow Tree Creek.

Table 41. Water velocity HSC data for ≥6 cm steelhead.

Water Velocity (ft/s)	Suitability
0.00	0.50
0.05	0.52
0.10	0.54
0.14	0.56
0.19	0.58
0.24	0.60
0.29	0.62
0.33	0.64
0.38	0.66
0.43	0.68
0.48	0.70
0.52	0.72
0.57	0.73
0.62	0.75
0.67	0.77
0.71	0.79
0.76	0.81
0.81	0.84
0.86	0.86
0.90	0.88
0.95	0.90
1.00	0.92
1.05	0.94
1.09	0.96
1.14	0.97
1.19	0.98
1.24	0.99
1.28	**1.00**
1.33	**1.00**
1.38	**1.00**
1.43	**1.00**
1.47	0.99
1.52	0.98

Water Velocity (ft/s)	Suitability
1.57	0.97
1.62	0.96
1.66	0.95
1.71	0.93
1.76	0.92
1.81	0.90
1.85	0.89
1.90	0.87
1.95	0.86
2.00	0.84
2.04	0.83
2.09	0.81
2.14	0.79
2.19	0.77
2.23	0.75
2.28	0.73
2.33	0.70
2.38	0.68
2.42	0.66
2.47	0.63
2.52	0.61
2.57	0.59
2.61	0.56
2.66	0.53
2.71	0.51
2.76	0.48
2.80	0.45
2.85	0.42
2.90	0.39
2.95	0.36
2.99	0.33
3.04	0.30
3.09	0.28
3.14	0.25

Water Velocity (ft/s)	Suitability
3.18	0.23
3.23	0.21
3.28	0.19
3.33	0.17
3.37	0.15
3.42	0.14
3.47	0.13
3.52	0.12
3.56	0.11
3.61	0.10
3.66	0.10
3.71	0.09
3.75	0.08
3.80	0.08
3.85	0.07
3.90	0.07
3.94	0.06
3.99	0.06
4.04	0.05
4.09	0.05
4.13	0.05
4.18	0.04
4.23	0.04
4.28	0.04
4.32	0.03
4.37	0.03
4.42	0.03
4.47	0.03
4.51	0.02
4.56	0.02
4.61	0.02
4.66	0.02
4.70	0.02
4.75	0.02

Note: Peak suitabilities are indicated with bold font.

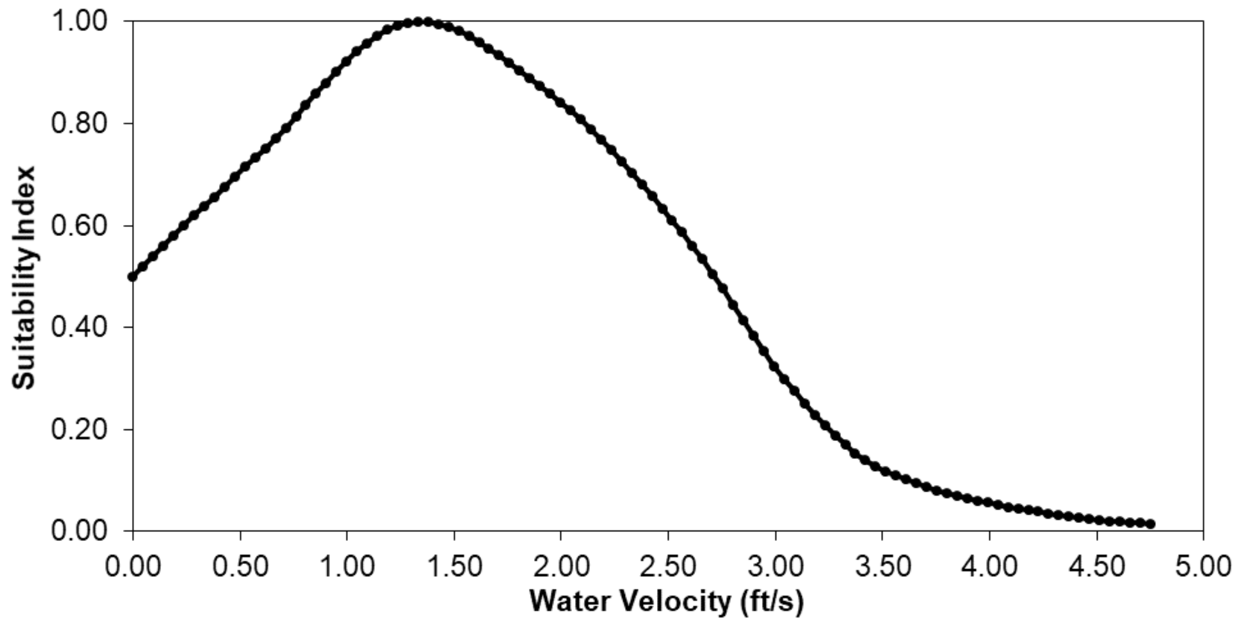

Figure 19. ≥6 cm steelhead water velocity HSC in Hollow Tree Creek.

<6 cm Coho Salmon HSC Curves

Water Depth: Peak suitability occurred from 0.43 ft to 0.52 ft deep. Suitability declined to 0.20 at 2.58 ft; depths of 3.18 ft and deeper were considered unsuitable (Table 42; Figure 20).

Water Velocity: Suitability of mean water column velocity for <6 cm Coho Salmon peaked at 0.10 ft/s. Suitability dropped to 0.20 at 0.86 ft/s and was considered unsuitable when velocities reached 1.95 ft/s or faster (Table 43; Figure 21).

≥6 cm Coho Salmon HSC Curves

Water Depth: Peak suitability occurred from 1.72 ft to 1.89 ft deep. Coho Salmon were most frequently observed in pools, therefore a suitability of 0.50 for depths deeper than 2.60 ft (i.e., the maximum depth Coho Salmon were observed) was maintained (Table 44; Figure 22).

Water Velocity: Suitability of mean water column velocity for ≥6 cm Coho Salmon peaked at 0.10 ft/s. Suitability declined to 0.20 at 0.86 ft/s and was considered unsuitable when velocities reach 2.80 ft/s or faster (Table 45; Figure 23).

Table 42. Water depth HSC data for <6 cm Coho Salmon.

Water Depth (ft)	Suitability	Water Depth (ft)	Suitability	Water Depth (ft)	Suitability
0.00	0.00	1.12	0.82	2.24	0.37
0.09	0.00	1.20	0.78	2.32	0.33
0.17	0.91	1.29	0.74	2.41	0.29
0.26	0.95	1.38	0.70	2.49	0.26
0.34	0.98	1.46	0.67	2.58	0.22
0.43	**1.00**	1.55	0.63	2.67	0.19
0.52	**1.00**	1.63	0.60	2.75	0.16
0.60	0.99	1.72	0.57	2.84	0.12
0.69	0.98	1.81	0.54	2.92	0.09
0.77	0.95	1.89	0.51	3.01	0.05
0.86	0.92	1.98	0.48	3.10	0.03
0.95	0.89	2.06	0.44	3.18	0.00
1.03	0.85	2.15	0.41		

Note: Peak suitabilities are indicated with bold font.

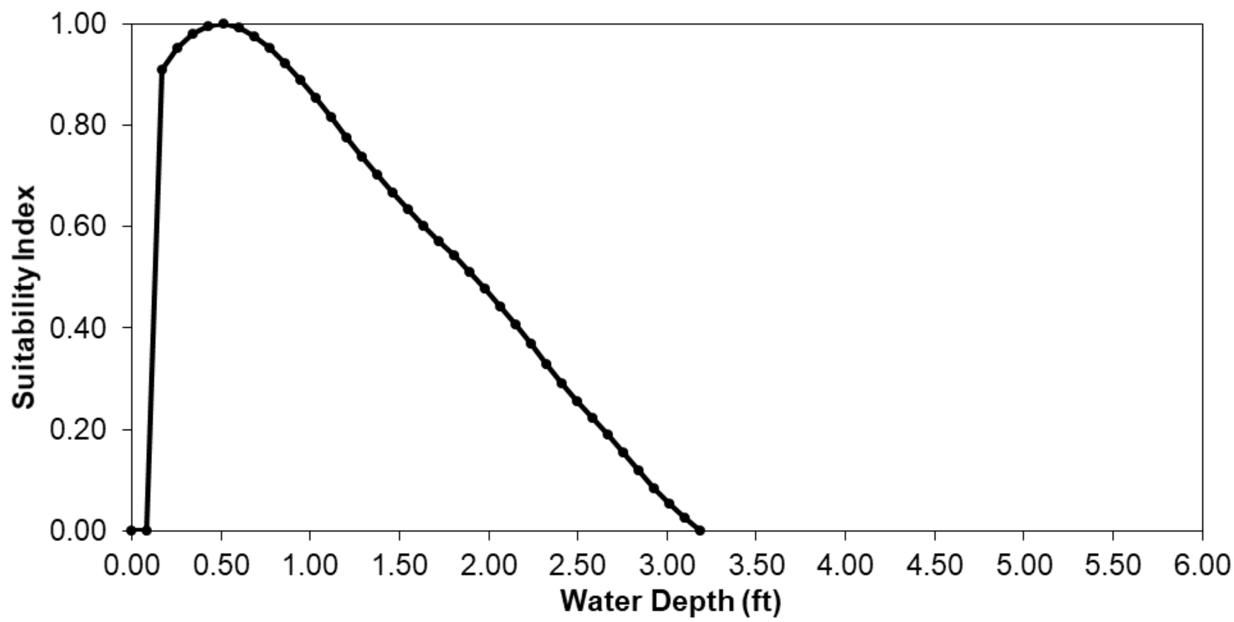

Figure 20. <6 cm Coho Salmon water depth HSC in Hollow Tree Creek.

Table 43. Water velocity HSC data for <6 cm Coho Salmon.

Water Velocity (ft/s)	Suitability
0.00	0.96
0.05	0.99
0.10	**1.00**
0.14	0.99
0.19	0.97
0.24	0.94
0.29	0.89
0.33	0.83
0.38	0.77
0.43	0.70
0.48	0.63
0.52	0.57
0.57	0.50
0.62	0.44
0.67	0.39
0.71	0.34
0.76	0.29
0.81	0.25
0.86	0.22
0.90	0.19
0.95	0.16
1.00	0.14
1.05	0.12
1.09	0.11
1.14	0.09
1.19	0.08
1.24	0.07
1.28	0.06
1.33	0.05
1.38	0.05
1.43	0.04
1.47	0.04
1.52	0.04
1.57	0.03
1.62	0.03
1.66	0.03
1.71	0.02
1.76	0.02
1.81	0.02
1.85	0.02
1.90	0.02
1.95	0.01
2.00	0.01
2.04	0.01
2.09	0.01
2.14	0.01
2.19	0.01
2.23	0.01
2.28	0.01
2.33	0.00
2.38	0.00
2.42	0.00
2.47	0.00
2.52	0.00
2.57	0.00
2.61	0.00
2.66	0.00
2.71	0.00
2.76	0.00

Note: Peak suitability is indicated with bold font.

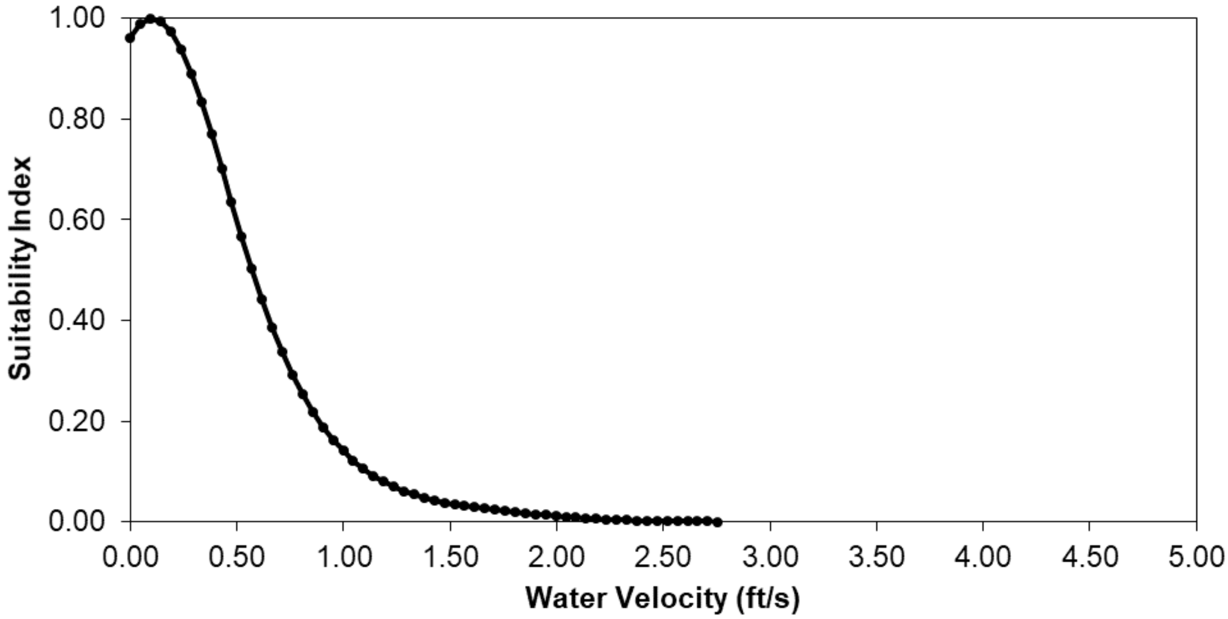

Figure 21. <6 cm Coho Salmon water velocity HSC in Hollow Tree Creek.

Table 44. Water depth HSC data for ≥6 cm Coho Salmon.

Water Depth (ft)	Suitability
0.00	0.00
0.17	0.00
0.26	0.63
0.34	0.66
0.43	0.68
0.52	0.70
0.60	0.73
0.69	0.75
0.77	0.78
0.86	0.81
0.95	0.83
1.03	0.86
1.12	0.88
1.20	0.90
1.29	0.92
1.38	0.94
1.46	0.96
1.55	0.98
1.63	0.99
1.72	**1.00**
1.81	**1.00**
1.89	**1.00**
1.98	0.99
2.06	0.98
2.15	0.97
2.24	0.95
2.32	0.92
2.41	0.89
2.49	0.85
2.58	0.81
2.67	0.76
2.75	0.71
2.84	0.66
2.92	0.61
3.01	0.56
3.10	0.50
3.18	0.50
3.27	0.50
3.35	0.50
3.44	0.50
3.53	0.50
3.61	0.50
3.70	0.50
3.78	0.50
3.87	0.50
3.96	0.50
4.04	0.50
4.13	0.50
4.21	0.50
4.30	0.50
4.39	0.50
4.47	0.50
4.56	0.50
4.64	0.50
4.73	0.50
4.82	0.50
4.90	0.50
4.99	0.50
5.07	0.50
5.16	0.50
5.25	0.50
5.33	0.50
5.42	0.50
5.50	0.50
5.59	0.50
5.68	0.50
5.76	0.50
5.85	0.50
5.93	0.50
6.02	0.50
6.11	0.50
6.19	0.50
6.28	0.50
6.36	0.50
6.45	0.50
6.54	0.50
6.62	0.50
6.71	0.50
6.79	0.50
6.88	0.50
6.97	0.50
7.05	0.50
7.14	0.50
7.22	0.50
7.31	0.50
7.40	0.50
7.48	0.50
7.57	0.50
7.65	0.50
7.74	0.50
7.83	0.50
7.91	0.50
8.00	0.50
8.08	0.50
8.17	0.50
8.26	0.50
8.34	0.50
8.43	0.50
8.51	0.50
8.60	0.50

Note: Peak suitabilities are indicated with bold font.

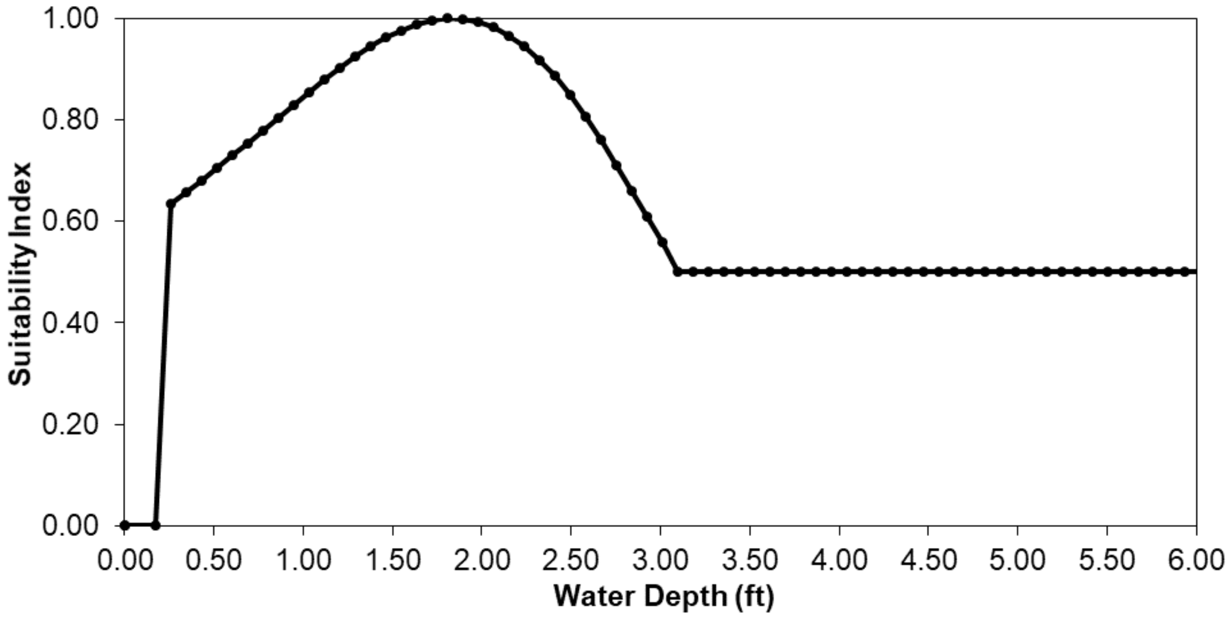

Figure 22. ≥6 cm Coho Salmon water depth HSC in Hollow Tree Creek.

Table 45. Water velocity HSC data for ≥6 cm Coho Salmon.

Water Velocity (ft/s)	Suitability
0.00	0.97
0.05	0.99
0.10	**1.00**
0.14	0.99
0.19	0.97
0.24	0.93
0.29	0.88
0.33	0.82
0.38	0.76
0.43	0.70
0.48	0.63
0.52	0.56
0.57	0.50
0.62	0.44
0.67	0.39
0.71	0.34
0.76	0.29
0.81	0.26
0.86	0.22
0.90	0.19
0.95	0.17
1.00	0.14
1.05	0.12
1.09	0.11
1.14	0.10
1.19	0.08
1.24	0.08
1.28	0.07
1.33	0.06
1.38	0.06
1.43	0.05
1.47	0.05
1.52	0.05
1.57	0.05
1.62	0.05
1.66	0.04
1.71	0.04
1.76	0.04
1.81	0.04
1.85	0.04
1.90	0.04
1.95	0.04
2.00	0.04
2.04	0.04
2.09	0.04
2.14	0.03
2.19	0.03
2.23	0.03
2.28	0.03
2.33	0.03
2.38	0.03
2.42	0.03
2.47	0.03
2.52	0.02
2.57	0.02
2.61	0.02
2.66	0.02
2.71	0.02
2.76	0.02
2.80	0.01
2.85	0.01
2.90	0.01
2.95	0.01
2.99	0.01
3.04	0.01
3.09	0.01
3.14	0.00
3.18	0.00

Note: Peak suitability is indicated with bold font.

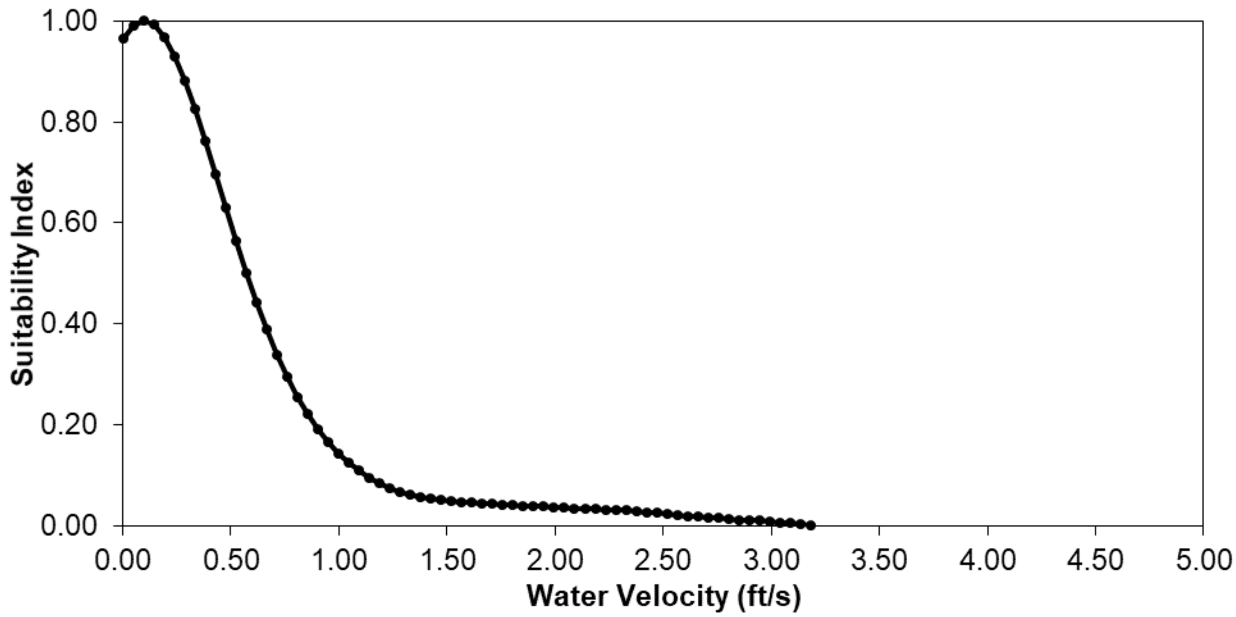

Figure 23. ≥6 cm Coho Salmon water velocity HSC in Hollow Tree Creek.

4.5 Comparison of Category II½ and Category III HSC Curves

Category II½ HSC (i.e., equal area sampling approach) and Category III HSC (i.e., forage ratio) were developed and compared to habitat availability. Category II½ HSC were compared by plotting the frequency of fish use observations with available habitat data. Use and availability curves were incongruent; observations indicated fish were generally selecting microhabitat features that were limited in availability. The spring season had variable flows with some limited habitat availability; the summer season had low flows and limited habitat availability. CDFW staff elected to develop Category III (i.e., preference) HSC using the spring dataset because low flows in the summer season resulted in decreased habitat availability due to drought conditions.

Formulation of the preference curve using the forage ratio sometimes resulted in unrealistic values at the tail ends of the curves, depending on the bin width of each microhabitat category. Kernel smoothing techniques were used to adjust the tail ends of the preference curves to be as smooth as practically possible to realistic depths and velocities based on what CDFW staff experienced in the field. When this occurred, the preference curve was replotted from the trough to exclude spurious data to reach 0.0 suitability smoothly (Jowett et al. 2017).

<6 cm Steelhead Curves

Water depth: The peak depth used was 0.60 ft; the peak available was 0.69 ft. Because use and availability peaks were marginally different, the preference curve shifted slightly to the left of the availability curve, resulting in a peak depth preference of 0.52 ft to 0.60 ft (Figure 24).

Water velocity: The peak velocity used was 0.24 ft/s; the peak available was 0.48 ft/s. Because use and availability peaks were marginally different, the preference curve shifted to the left of the use and availability curves, resulting in a peak velocity preference of 0.14 ft/s to 0.19 ft/s (Figure 25).

≥6 cm Steelhead Curves

Water depth: The peak depth used was 0.86 ft; the peak available was 0.69 ft. Because use was greater than availability, the preference curve shifted to the right of the use and availability curves, resulting in a peak depth preference of 1.12 ft to 1.20 ft (Figure 26).

Water velocity: The peak velocity used was 0.38 ft/s; the peak available was 0.33 ft/s. Because use was greater than availability, the preference curve shifted to the right of the use and availability curves resulting in a peak velocity preference of 1.28 ft/s to 1.43 ft/s (Figure 27).

<6 cm Coho Salmon Curves

Water depth: The peak depth used was 0.60 ft; the peak available was 0.77 ft. Because use was less than availability, the preference curve shifted to the left of the use and availability curves, resulting in a peak depth preference of 0.43 ft to 0.52 ft (Figure 28).

Water velocity: The peak velocity used was 0.14 ft/s; the peak available was 0.43 ft/s to 0.48 ft/s. Because use was less than availability, the preference curve shifted to the left of the use and availability curves, resulting in a peak depth preference of 0.10 ft/s (Figure 29).

≥6 cm Coho Salmon Curves

Water depth: The peak depth used was 1.03 ft; the peak available was 0.77 ft. Because use was greater than availability, the preference curve shifted to the right of the use and availability curves, resulting in a peak preference of 1.72 ft to 1.89 ft (Figure 30).

Water velocity: The peak velocity used was 0.14 ft/s; the peak available was 0.48 ft/s. Because use was less than availability, the preference curve shifted to the left of the use and availability curves, resulting in a peak velocity preference of 0.10 ft/s (Figure 31).

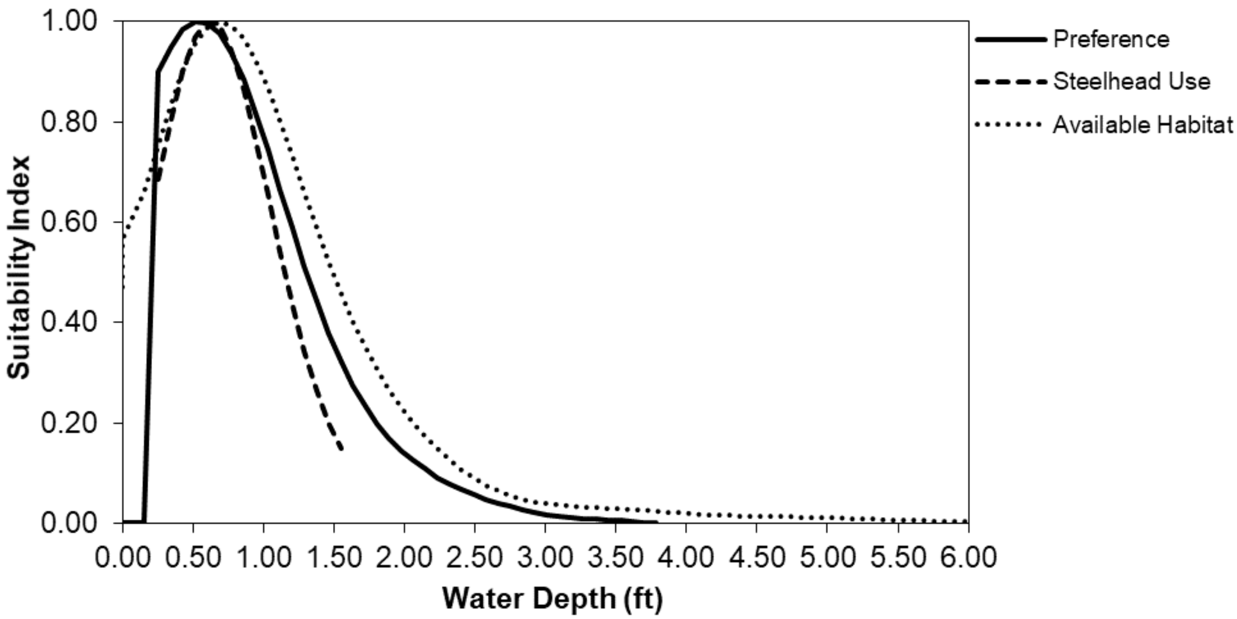

Figure 24. <6 cm steelhead comparison of water depth preference, use, and availability.

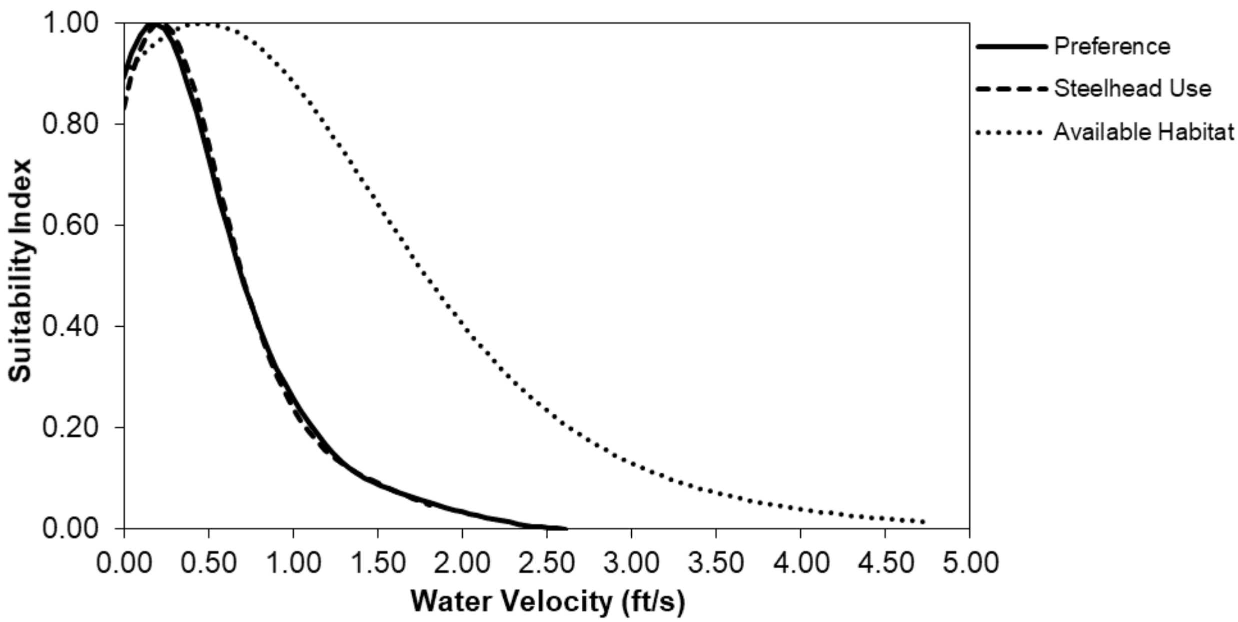

Figure 25. <6 cm steelhead comparison of water velocity preference, use, and availability.

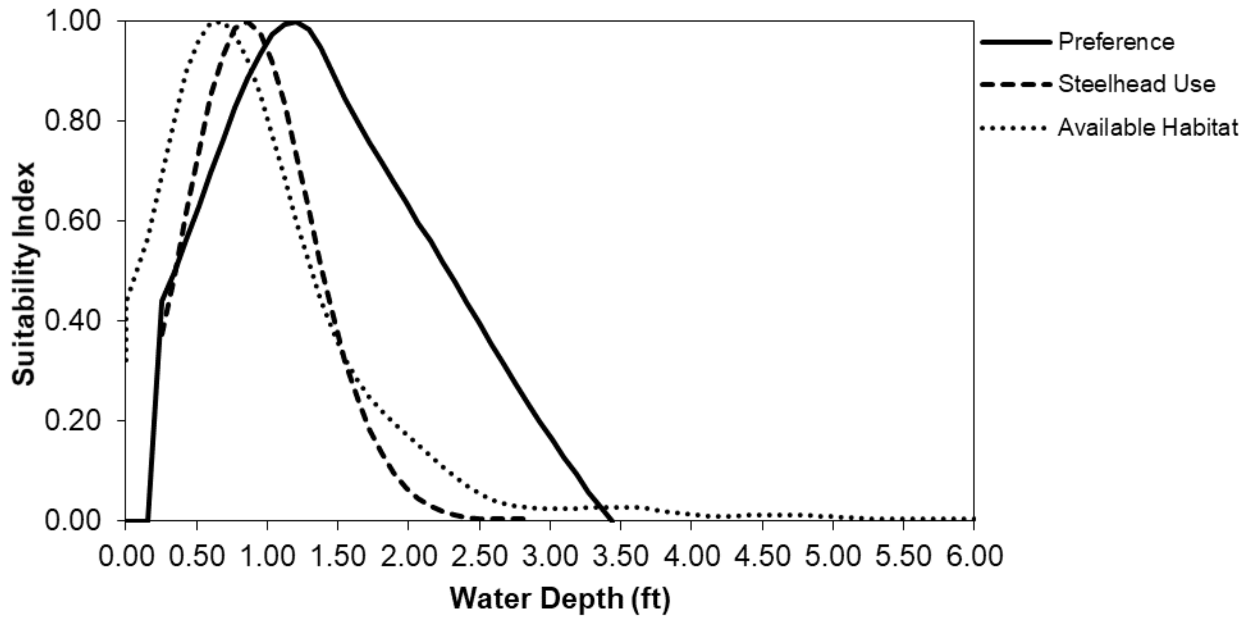

Figure 26. ≥6 cm steelhead comparison of water depth preference, use, and availability.

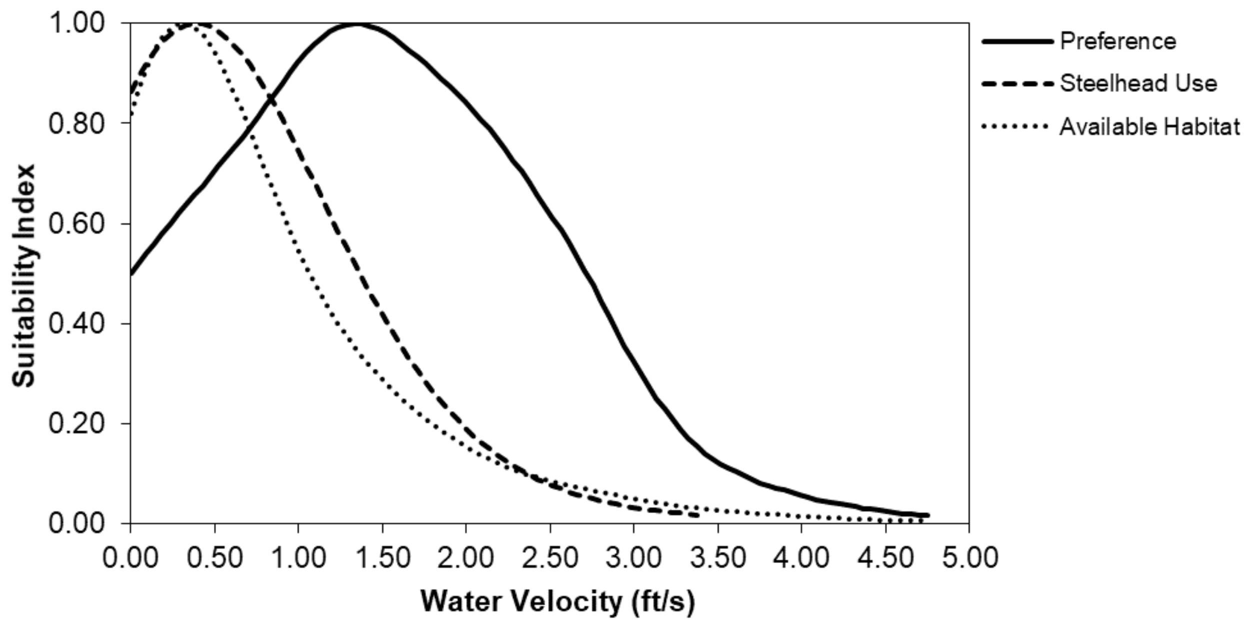

Figure 27. ≥6 cm steelhead comparison of water velocity preference, use, and availability.

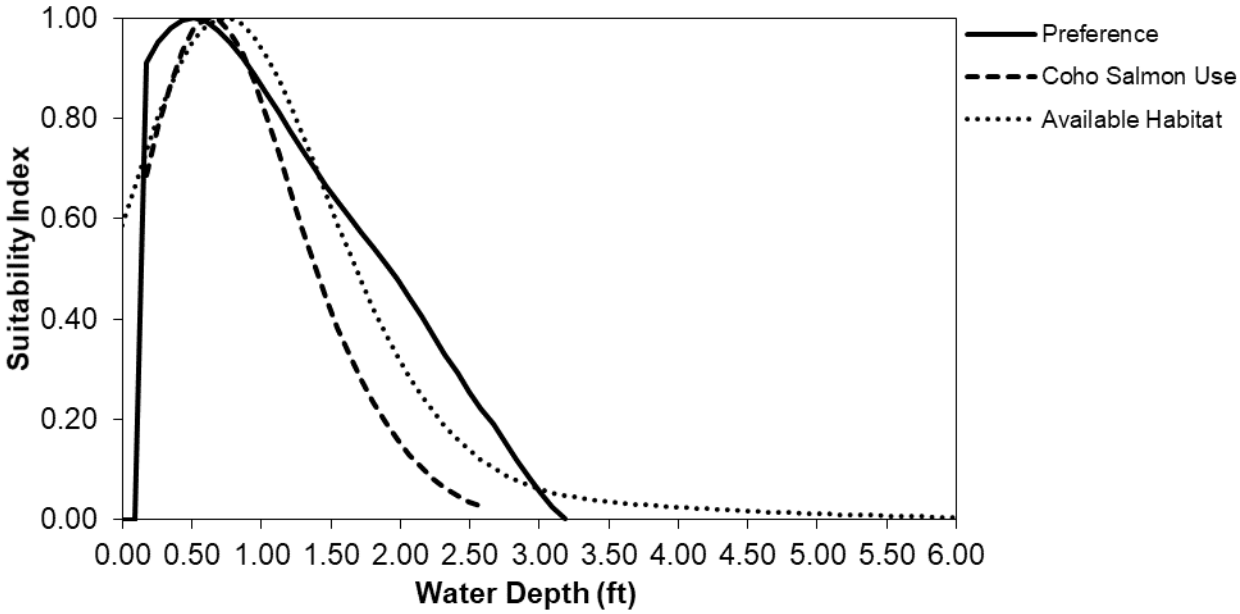

Figure 28. <6 cm Coho Salmon comparison of water depth preference, use, and availability.

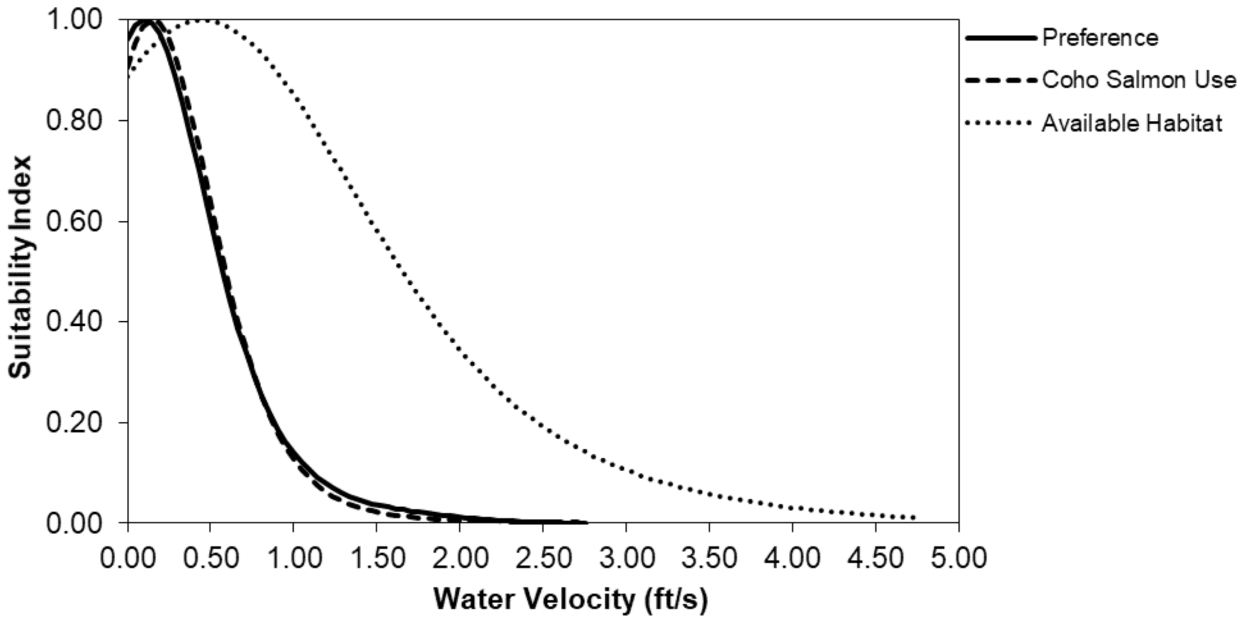

Figure 29. <6 cm Coho Salmon comparison of water velocity preference, use, and availability.

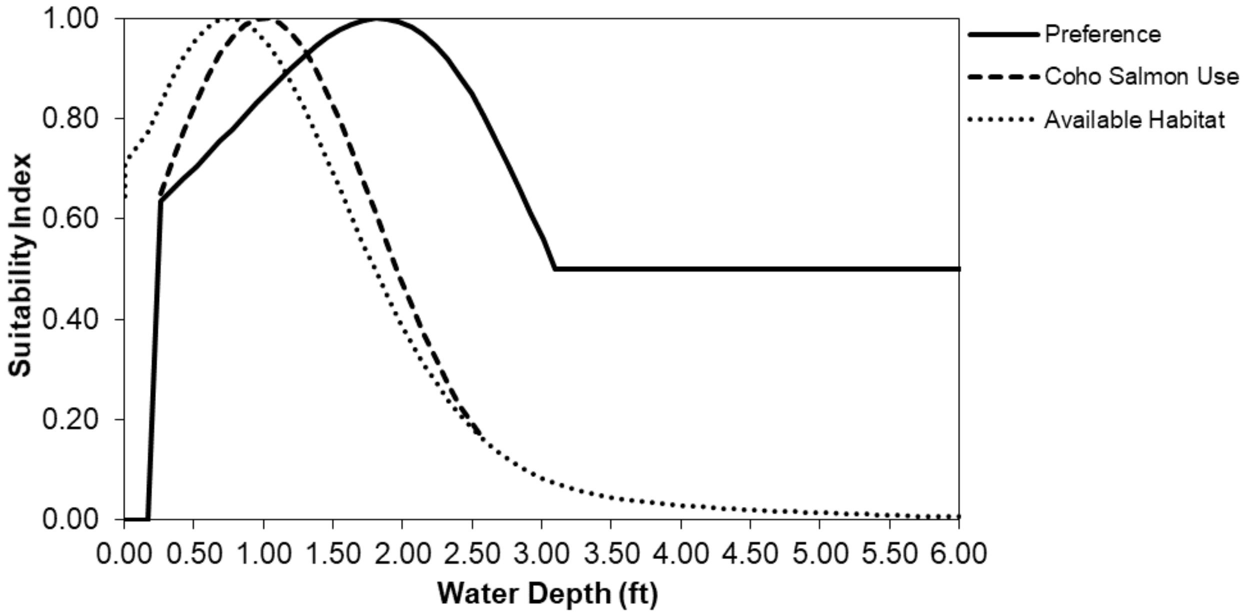

Figure 30. ≥6 cm Coho Salmon comparison of water depth preference, use, and availability.

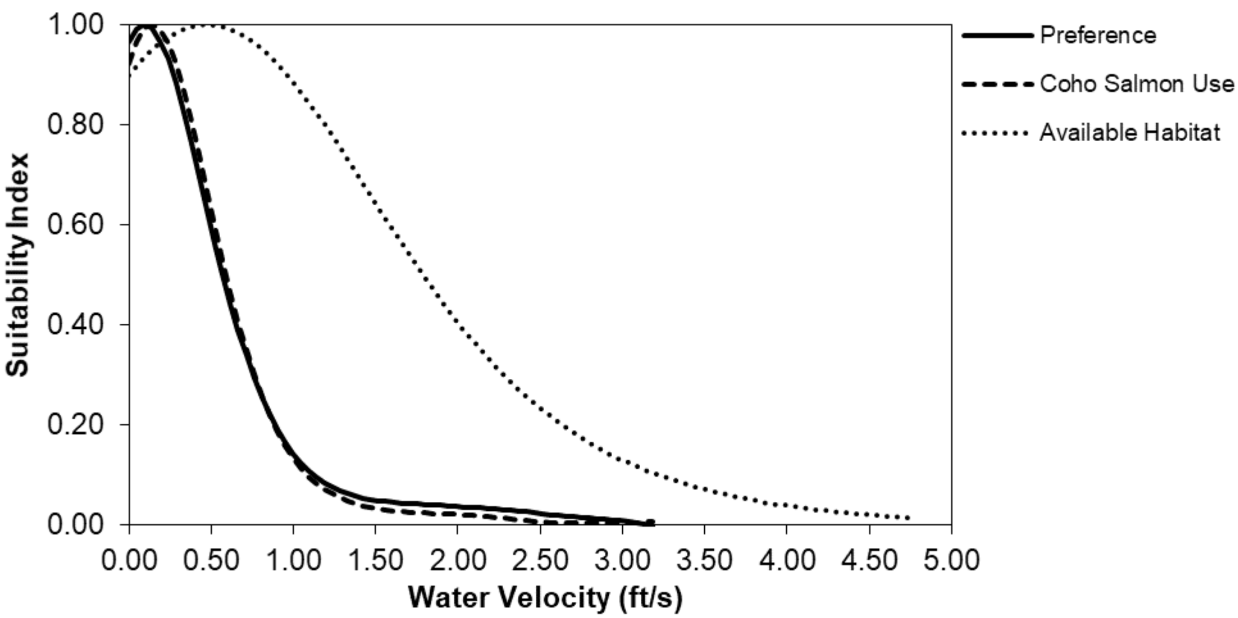

Figure 31. ≥6 cm Coho Salmon comparison of water velocity preference, use, and availability.

5.0 DISCUSSION

Fry and juvenile steelhead and Coho Salmon were observed in multiple mesohabitat types with a wide range of depths and velocities. Results and direct field observations by CDFW staff indicated that fry steelhead and Coho Salmon selected shallow depths and slow velocities. This result is reasonable as fry were frequently found occupying stream margins. Juvenile steelhead selected faster velocities and were often observed in riffle mesohabitat types, whereas juvenile Coho Salmon selected deeper depths and slower velocities and were predominantly observed in pool mesohabitat types.

Category II½ HSC curves are based on frequency distributions of fish observations and habitat availability. However, if habitat availability is limited this can result in greater suitability at lower flows (Rubin et al. 1991). Ideally, HSC data are collected from unimpaired streams over a wide range of flows that present all conceivable combinations of microhabitat features. This allows for data collection to reflect fish selectivity because fish would have access to preferred conditions (Bovee 1986). If data collection occurs during low flows, Category II½ HSC would not accurately reflect a species' selectivity because preferred conditions were unavailable (Bovee 1986).

The spring season data set was used to develop Category III HSC due to improved habitat availability. The majority of Hollow Tree Creek's precipitation usually occurs November through April. Substrate in the stream ranges from small gravel to bedrock, however, it is largely dominated by bedrock. This combination of seasonal peak flows over bedrock-dominated substrate produces a flashy stream following rainfall from which flow quickly collects and recedes. These characteristics are common for most streams in California's Mediterranean climate (Yoshiyama and Moyle 2010). Flow rapidly declines during the spring season; in the summer season flows are reduced further as groundwater is likely the only source of water supplying the stream (Salve et al. 2012). Applying the forage ratio accounted for potential biases in sampling technique and the availability of habitat within the spring season.

There are limited site-specific California-based literature on HSC for steelhead and Coho Salmon. Though results of this study provide site-specific criteria for use in the South Fork Eel River watershed, other gaps in HSC literature still exist in California, for example, inland versus coastal streams, and northern versus southern streams for different native species. As California's salmonid populations continue to decline (CDFG 2004; NMFS 2011; Moyle et al. 2017), the state requires tools to help manage our native species from further losses. HSC are a necessary tool that can be used in hydraulic modeling programs to evaluate flow and habitat relationships for salmonids when considering streamflow management decisions.

Hollow Tree Creek HSC curves were compared to several other HSC curves from various studies. Comparison of fry steelhead curves among the studies indicated the peak values for depth and velocity were very similar (Table 46; Figures 32 and 33). When comparing juvenile steelhead curves, the peak values for depth were mostly similar except for the Trinity River and the WDFW studies (Table 47; Figure 34). Juvenile size determination among studies could have affected the slight difference in peak depth values. Larger juveniles tend to occupy deeper depths, and the Trinity River study defined juvenile sizes from 50 mm to 200 mm (Hampton 1997). The WDFW study did not include a defined size range for juvenile steelhead; the curve was also created from 10 different studies within the state of Washington (WDFW 2008). Peak velocity values for juvenile steelhead among the five studies were similar (Table 47; Figure 35).

Table 46. HSC literature comparison of <6 cm steelhead peak values.

Watershed	HSC Category	Peak Depth Values	Peak Velocity Values	Reference
Multiple	I	0.60-0.70	0.50-0.60	Bovee (1978)
Trinity	II	0.70	0.40	Hampton (1997)
Klamath	I	0.25-1.00	0.10-0.80	Hardy and Addley (2001)
Big Sur	II½	0.46-0.53	0.18-0.25	Holmes et al. (2014)
Hollow Tree	III	0.52-0.60	0.14-0.19	This report

Table 47. HSC literature comparison of ≥6 cm steelhead peak values.

Watershed	HSC Category	Peak Depth Values	Peak Velocity Values	Reference
Multiple	I	1.25	0.70-1.10	Bovee (1978)
Trinity	II	2.30	1.30-1.40	Hampton (1997)
Klamath	I	1.40	0.60	Hardy and Addley (2001)
Big Sur	II½	1.19-1.67	0.91-1.47	Holmes et al. (2014)
WDFW	III	2.65-2.96	1.35-1.55	WDFW (2008)
Hollow Tree	III	1.12-1.20	1.28-1.43	This report

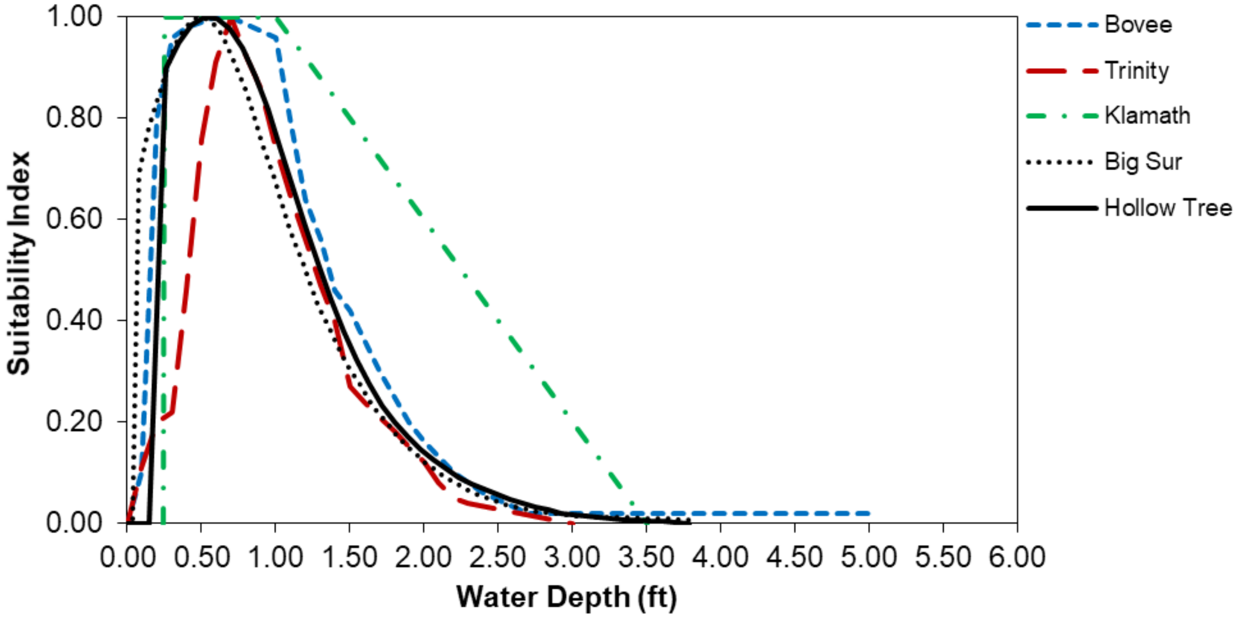

Figure 32. Comparison of <6 cm steelhead water depth HSC.

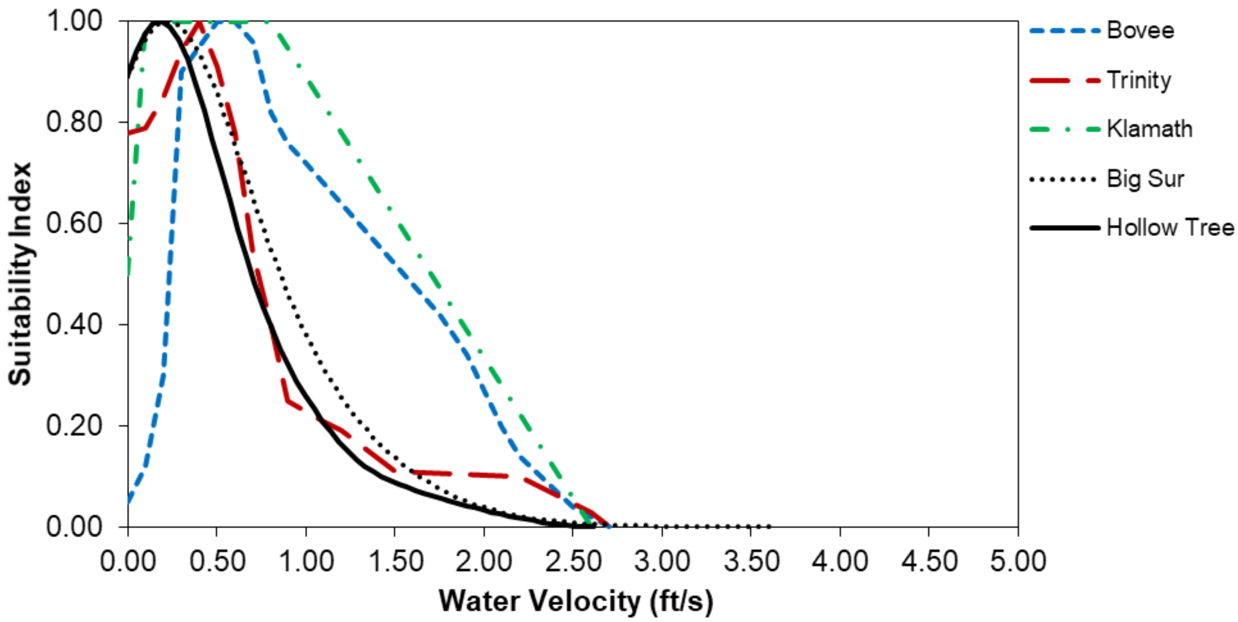

Figure 33. Comparison of <6 cm steelhead water velocity HSC.

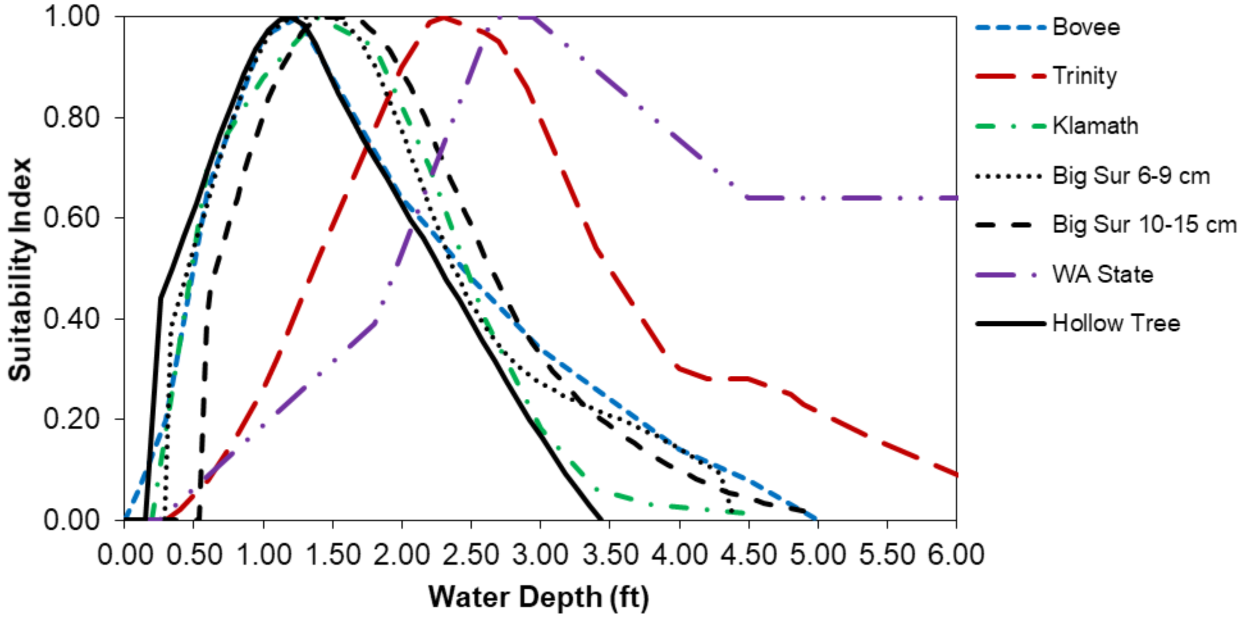

Figure 34. Comparison of ≥6 cm steelhead water depth HSC.

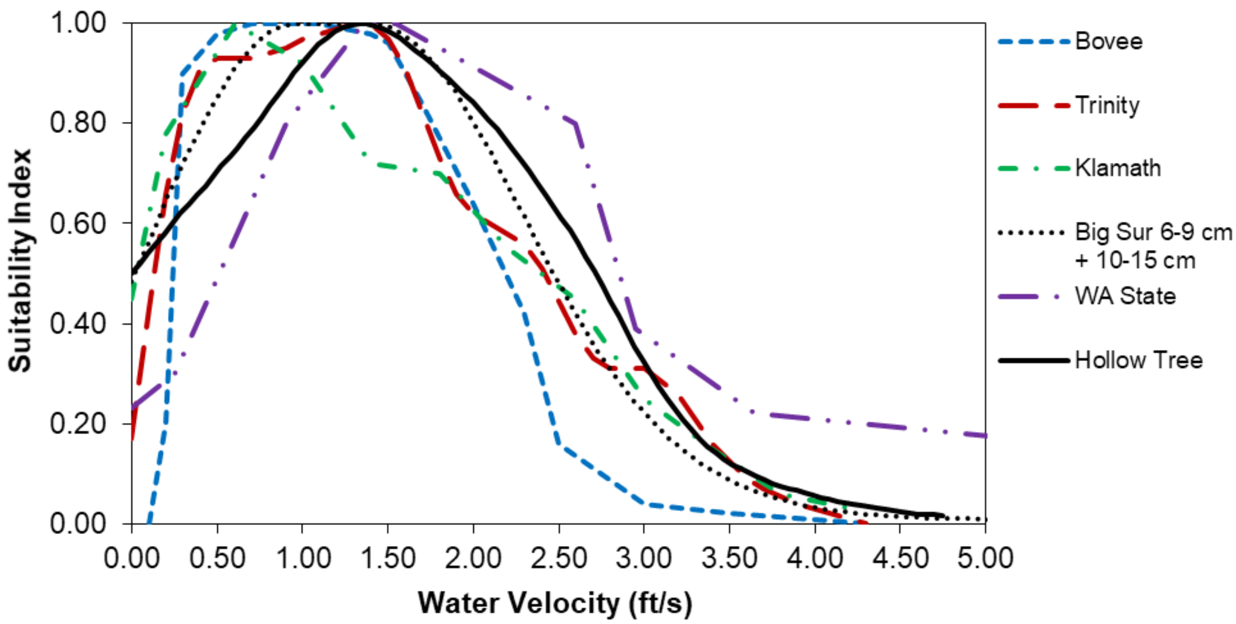

Figure 35. Comparison of ≥6 cm steelhead water velocity HSC.

The Hollow Tree Creek fry Coho Salmon peak values for depth were less than those from Bovee (1978; developed from multiple streams), Trinity River, and Klamath River curves (Table 48; Figure 36). It is a reasonable possibility that the difference in fry Coho Salmon peak depth values could be a result of a greater range of available depths in larger streams (e.g., drainage area of Trinity River = 2,970 sq mi, Klamath River = 15,689 sq mi) versus smaller streams (Hollow Tree Creek = 42 sq mi). Peak velocity values for fry Coho Salmon were similar between Hollow Tree Creek and the Trinity River study, while the Bovee and Klamath River studies were similar (Table 48; Figure 37). However, all four studies indicate that fry Coho Salmon tend to occupy habitats with slow velocities. Hollow Tree Creek juvenile Coho Salmon peak values for depth and velocity were similar to those from the other studies (Table 49; Figures 38 and 39). The Big Sur River HSC were only developed for steelhead (Holmes et al. 2014) and were therefore not used in the curve comparisons for Coho Salmon.

HSC are essential for developing biologically representative hydraulic habitat models and resulting flow and habitat relationships. The HSC constructed in this report are considered relevant and representative of juvenile salmonid habitat. These HSC are intended to be used within the South Fork Eel River watershed to identify flows needed to protect juvenile steelhead and Coho Salmon rearing habitat.

Table 48. HSC literature comparison of <6 cm Coho Salmon peak values.

Watershed	HSC Category	Peak Depth Values	Peak Velocity Values	Reference
Multiple	I	1.80-2.00	0.50-0.55	Bovee (1978)
Trinity	II	1.10	0.00	Hampton (1997)
Klamath	I	1.00-2.00	0.25-0.50	Hardy and Addley (2001)
Hollow Tree	III	0.43-0.52	0.10	This report

Table 49. HSC literature comparison of ≥6 cm Coho Salmon peak values.

Watershed	HSC Category	Peak Depth Values	Peak Velocity Values	Reference
WDFW	III	2.50-3.25	0.15	WDFW (2008)
Trinity	II	≥2.20	0.00	Hampton (1997)
Klamath	I	1.50-2.50	0.20-0.50	Hardy and Addley (2001)
Hollow Tree	III	1.72-1.89	0.10	This report

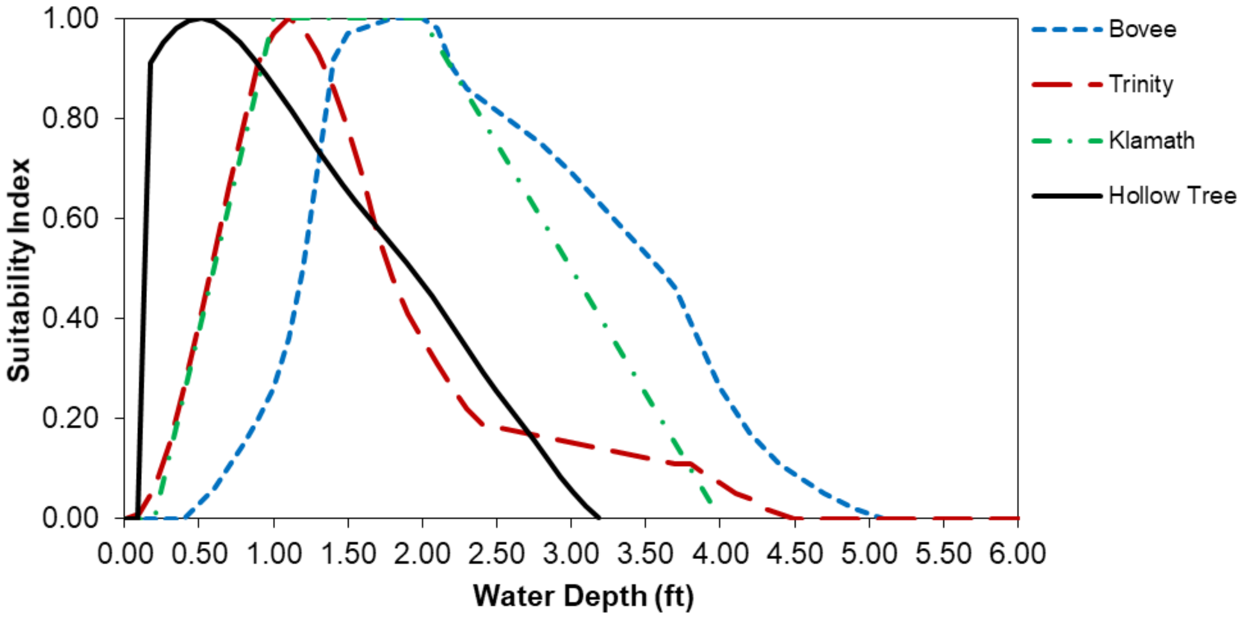

Figure 36. Comparison of <6 cm Coho Salmon water depth HSC.

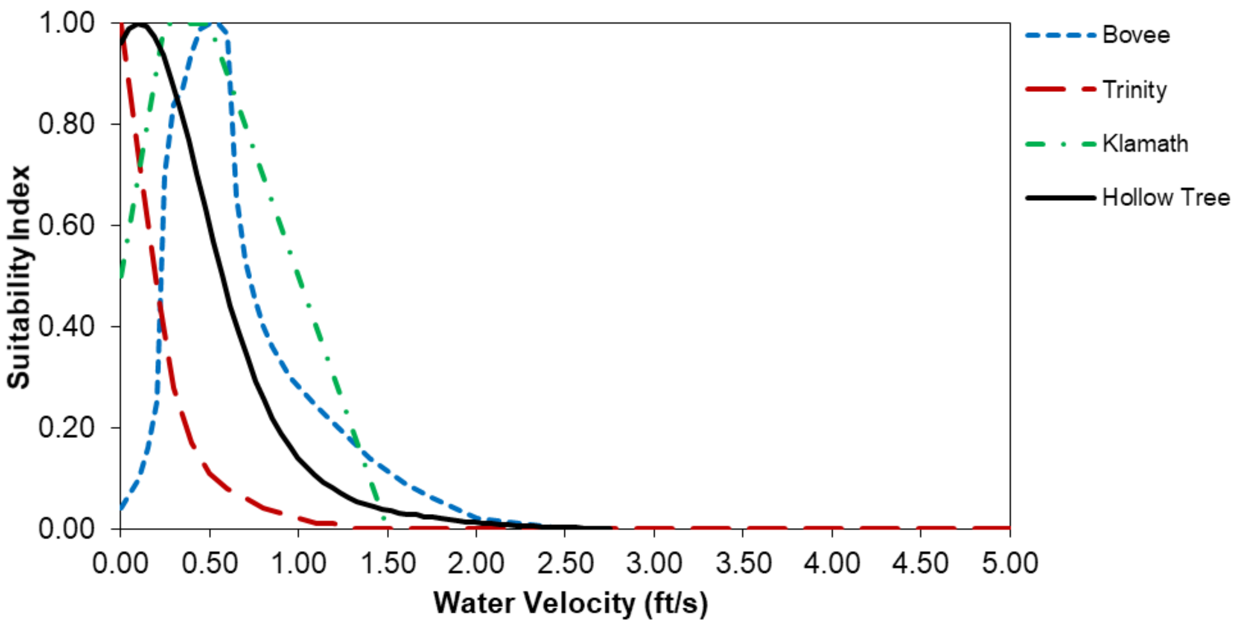

Figure 37. Comparison of <6 cm Coho Salmon water velocity HSC.

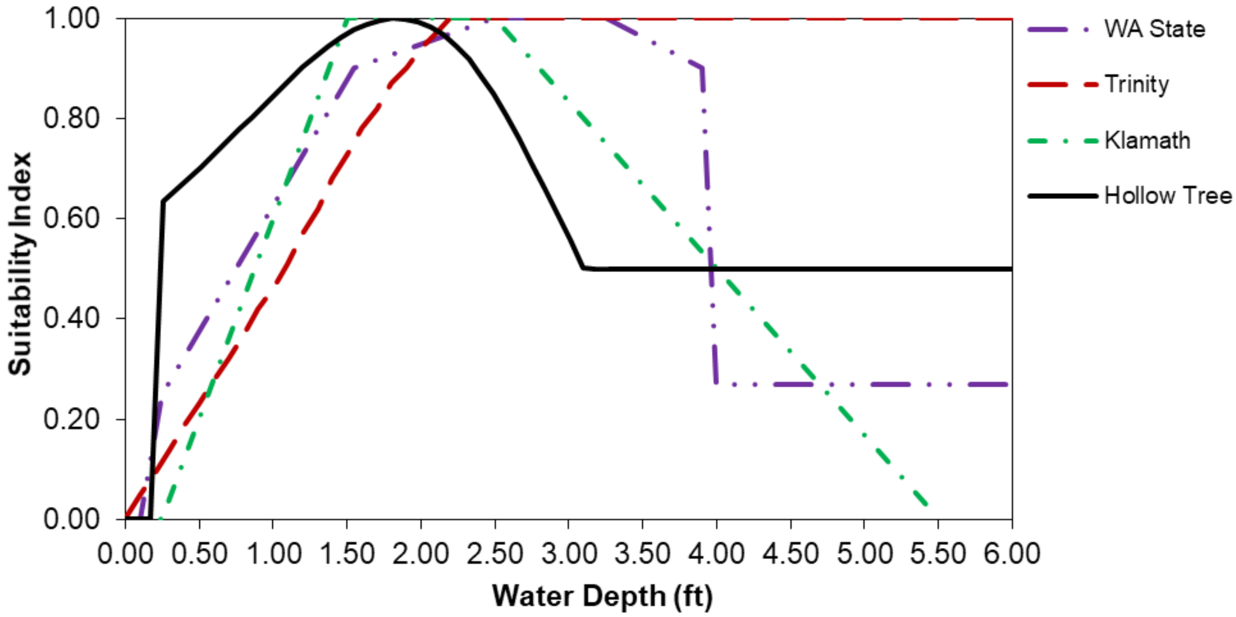

Figure 38. Comparison of ≥6 cm Coho Salmon water depth HSC.

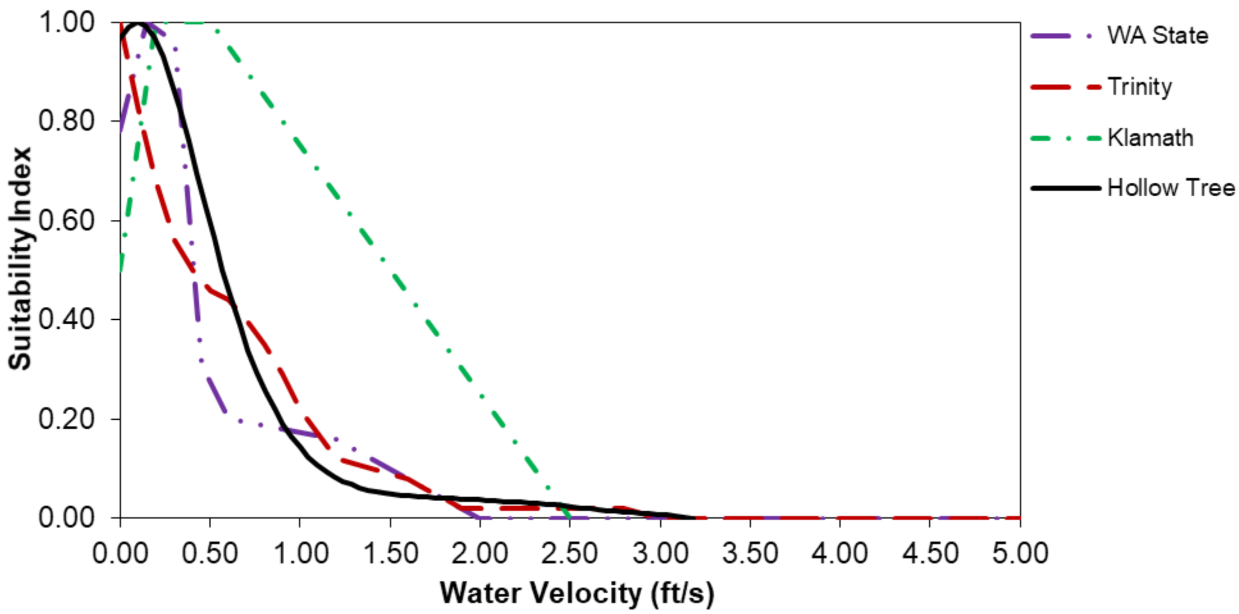

Figure 39. Comparison of ≥6 cm Coho Salmon water velocity HSC.

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