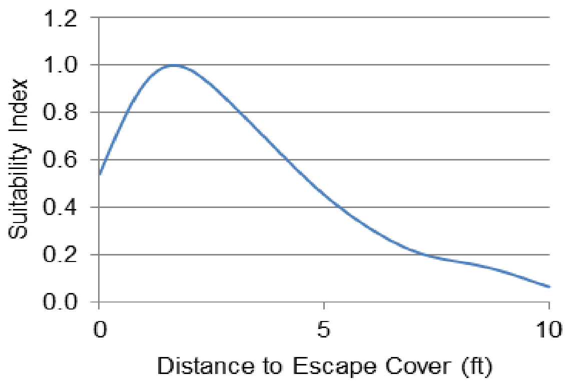
State of California
Natural Resources Agency

Department of Fish and Wildlife

Habitat Suitability Criteria
Juvenile Steelhead
BIG SUR RIVER, Monterey County



STREAM EVALUATION REPORT 14-1
July 2014

Department of Fish and Wildlife
Stream Evaluation Report
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John Laird	Edmund G. Brown Jr.	Charlton H. Bonham
Secretary for Resources	Governor	Director
Natural Resources Agency	State of California	Department of
		Fish and Wildlife

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Juvenile Steelhead
BIG SUR RIVER, Monterey County

Robert W. Holmes[1], Mark A. Allen [2], and Shannon Bros-Seeman [3]

ABSTRACT

Microhabitat data were collected at focal positions of juvenile steelhead (*Oncorhynchus mykiss*) in the Big Sur River, California during spring, summer, and fall. An equal-area sampling approach was used to guide fish surveys and allocate habitat availability sampling among seasons, river reaches, and mesohabitat types. Juvenile steelhead habitat selection changed with fish size, season, discharge, and habitat availability. Water depth and water velocity were of primary importance in habitat selection for all size groups of rearing steelhead. Habitat Suitability Criteria (HSC) were prepared for water depth, mean water velocity, focal velocity, specific escape cover types, and distance to in-water escape cover to reflect seasonal habitat selectivity for rearing steelhead. Habitat "preference" HSC (use adjusted for availability using the U/A forage ratio) were also developed and compared with the equal-area selectivity HSC and with habitat availability. The U/A results produced extreme shifts in maximum suitability for several curves, and perhaps more significantly the U/A ratios severely deflated suitabilities where the majority of the fish were observed. With proper habitat stratification and non-limiting sampling conditions (e.g., adequate flows and non-degraded habitat), use of an equal-area sampling design for site-specific selectivity HSC development was determined to be a viable option for development of biologically relevant and representative HSC, and essential for accurate environmental flow recommendations.

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ABBREVIATIONS, ACRONYMS, AND CONVERSIONS

cfs	cubic feet per second
dbh	diameter breast height
CDFW	California Department of Fish and Wildlife
cm	centimeter
DBH	diameter breast height
DG	decomposed granite
DPS	distinct population segment
^{o}F	degrees Fahrenheit; ^{o}F = ([1.8 x degrees Celsius] + 32)
FL	fork length
ft	foot (feet) (30.5 centimeters)
ft/s	feet per second
ft^3	cubic foot (feet)
GLD	glide
HSC	habitat suitability criteria
in	inch
IFIM	Instream Flow Incremental Methodology
IW	in water
km	kilometer
km^2	square kilometer
LGR	low gradient riffle
m	meter
mm	millimeter
N	sample size
NMFS	National Marine Fisheries Service
#	number
OW	out of water
%	percent
PHABSIM	Physical Habitat Simulation Model
PRC	Public Resources Code
RUN(S)	shallow run
sq ft	square foot (feet)
SMET	stream margin edge type
SI	suitability index
USGS	U.S. Geological Survey
YOY	young-of-year

FOREWORD

California's south-central coast steelhead (*Oncorhynchus mykiss*) populations have declined from about 25,000 spawning adults per year to fewer than 500 (NMFS 2007). Consequently, the south-central steelhead Distinct Population Segment (DPS) was listed as threatened in 1997 (NMFS 1997) and reaffirmed in 2006 (NMFS 2006). The National Marine Fisheries Service (NMFS) later issued the results of a five-year review and concluded that south-central steelhead should remain listed as threatened (NMFS 2011). All of the watersheds in the south-central coast DPS are impacted by a variety of anthropogenic stressors, but the most frequent source of threat stems from water management activities, such as diversions (Monterey County 1986; NMFS 2008).

The Big Sur River is identified on the California Department of Fish and Wildlife's (CDFW's) priority rivers and streams list (CDFW 2008) because it is a south-central steelhead stronghold (Wild Salmon Center 2010) and information is needed to determine stream flow requirements for protecting this resource (CDFW 2009). CDFW's policy is that the federal Instream Flow Incremental Methodology (IFIM) will be used to evaluate and develop instream flow requirements. The Public Resources Code (PRC) §10000-10005 outlines CDFW's responsibilities for developing and transmitting flow recommendations for priority streams to the State Water Resources Control Board (State Water Board) for consideration as set forth in 1257.5 of the Water Code.

INTRODUCTION

Habitat suitability criteria (HSC) are an integral biological component of an instream flow regime needs assessment (Annear et al. 2004). HSC are typically developed within the framework of the Instream Flow Incremental Methodology (IFIM) approach (Bovee et al. 1998), and are then input into hydraulic habitat models (Bovee 1982; Milhous et al. 1989; Waddle et al. 2000; Steffler and Blackburn 2002) to evaluate flow and habitat relationships. Biologically accurate and relevant HSC are required for the models to accurately predict and reflect how the quantity and quality of habitat changes under different flow regimes (Parsons and Hubert 1988; Hayes and Jowett 1994; Beecher et al. 2002; Payne and Allen 2009).

HSC incorporate the behavioral response of a species to habitat variability. Mesohabitat components (i.e., pools, riffles, runs, glides) typically guide sampling for development of riverine HSC. Microhabitat variables, such as water depth, water velocity, cover, and substrate are typical variables used in the development of HSC. These microhabitat components influence the use of local stream habitats by different aquatic species and life stages. The range of suitability for each microhabitat variable is between 0.0 (unusable) and 1.0 (optimal; Bovee and Cochnauer 1977).

Bovee (1986) provided an overview of the types or forms of HSC through the use of a category naming system. Category I HSC are based upon species life history studies and often rely upon professional judgment, with no actual field data or validation for the species, life stage, or river of interest. Category II HSC are developed from field observations of habitat use or “utilization” without specifically accounting for habitat availability, which may be biased by limited or purposive sampling effort, and hence may not reflect selection or preferred habitat use by the species. Category III HSC directly accounts for habitat availability and is intended to address potential biases from sampling efforts (Bovee 1986).

Type III HSC curves have been referred to as “preference” curves (Bovee 1982; Moyle and Baltz 1985; Beecher 1995), which typically equate to HSC curves that are mathematically adjusted, or corrected, for habitat availability and sampling biases. A common approach for mathematically correcting HSC use with availability data is to use the forage ratio formula (Johnson 1980). Other forms of HSC that account for habitat availability, but do not use the forage ratio adjustment include equal area sampling (Allen 2000), density sampling (Rubin et al. 1991), and presence-absence sampling (Thielke 1985, Gard 2010).

Use of an equal area sampling approach to directly account for habitat availability (i.e., Type II ½ HSC, Bovee et al. 1998), is more recently referred to as representing target organism “selection” (Manly et al. 2002) or “selectivity”.

Although use of the terms “preference” and “selectivity” may seem a matter of semantics, there are broader concerns for HSC development, application, and associated biological representativeness and relevance for the target species. For example, a primary limitation of developing “preference” HSC using the forage ratio is that the mathematical adjustments for limited habitat availability may result in inaccurate HSC if applied when habitat availability is not limited (Hayes and Jowett 1994). Such instances could lead to overinflating the HSC use curves and as such could result in inaccurate environmental flow recommendations.

The primary objective of this study was to develop site-specific HSC for rearing juvenile steelhead in the Big Sur River. A secondary objective was to evaluate use of an equal area sampling approach for developing Type II ½ “selectivity” HSC as a surrogate for developing “preference” HSC using the forage ratio.

DESCRIPTION OF STUDY AREA

The Big Sur River is located in southern Monterey County (Figure 1). It originates in the steep canyons of California's Ventana Wilderness within the Los Padres National Forest and flows northwesterly through federal and private lands, two state parks (Pfeiffer Big Sur and Andrew Molera), and a small lagoon before joining the Pacific Ocean about 2.8 miles (4.5 km) southeast of Point Sur. Significant tributaries include Pfeiffer-Redwood Creek, Juan Higuera Creek, Post Creek and Pheneger Creek. The Big Sur River has a watershed of approximately 60 square miles (150 km^2) with no major dams, diversions, or reservoirs. However, only the lower 7.5 miles of the river (lower Big Sur River) are accessible to anadromous steelhead for migration, spawning, and rearing. Upstream fish migration is generally thought to be prevented by a partial or complete bedrock barrier, depending on stream flow conditions (Figure 2).

The hydrology of the Big Sur River is typical of many coastal California rivers. It experiences high winter flows, low summer flows, and variable annual discharges. Most of the annual flow occurs in the winter with stream discharge reflecting local and watershed-wide rainfall patterns. Flows in winter may rise and recede rapidly in association with rainfall events, while flows in the summer tend to be more stable and predictable as they recede into the fall months. The Big Sur River is a free-flowing river, with no dams or on-stream reservoirs.

There are two U.S. Geological Survey (USGS) stream flow gages on the Big Sur River. USGS gage 11143000 is located in Pfeiffer State Park, is upstream of all known diversions, and does not reflect accretion of flow from several lower river tributaries. USGS gage 11143000 has recorded flow data for the Big Sur River from March 1950 to the present. USGS gage 11143010 is located approximately six river miles downstream of USGS gage 11143000 in Molera State Park within the current study reach, and has been in operation since October 2010. USGS gage 11143010 is located downstream of all river tributaries and most diversions.

Figure 1. Map of Big Sur River showing study reaches.

Figure 2. Photo of natural bedrock barrier and upstream end of steelhead anadromy in Big Sur River Gorge near Pfeiffer State Park.

The lower Big Sur River is characterized by a mild climate year-round, with a sunny, dry summer and fall, and a cool, wet winter. Coastal temperatures vary little during the year, ranging from the 50s Fahrenheit (^{o}F) at night to the 70s ^{o}F by day from June through October, and in the 40s ^{o}F to 60s ^{o}F from November through May. Average annual rainfall in Big Sur is 41.94 inches (1,065 mm), with measurable precipitation falling an average of 62 days each year. The wettest year on record was 1983 with 88.85 inches (2,257 mm) and the driest year was 1990 with 17.90 inches (455 mm). More than 70% of the rainfall falls from December through March. Human population density in the Big Sur area is low. Land uses in the area include residential, ranching, timber harvest, and recreation. Land owner ship is a mix of federal, state, and private lands.

The Basin Complex Fire of 2008 burned over 90% of the Big Sur watershed (Smith et al. 2008), and resulted in short term increases in woody debris and fine sediment loads to the lower river and lagoon during the first storms of 2009. While remnants of fire associated woody debris are still remaining at various locations along the river, it appeared that the fine organic sediments were flushed through the river and lagoon during the intense storms early in the 2009 winter season.

The study areas are described as the Lower Molera Reach, Molera Reach, and Campground Reach of the Big Sur River and represents generally homologous stream segments based upon gradient, geomorphology, hydrology, riparian zone type, flow accretion, diversion influence, and channel metrics (Figure 3). The reaches extend from the lower-most part of the river at the lagoon/river transition up to Pfeiffer State Park near USGS 1114300.

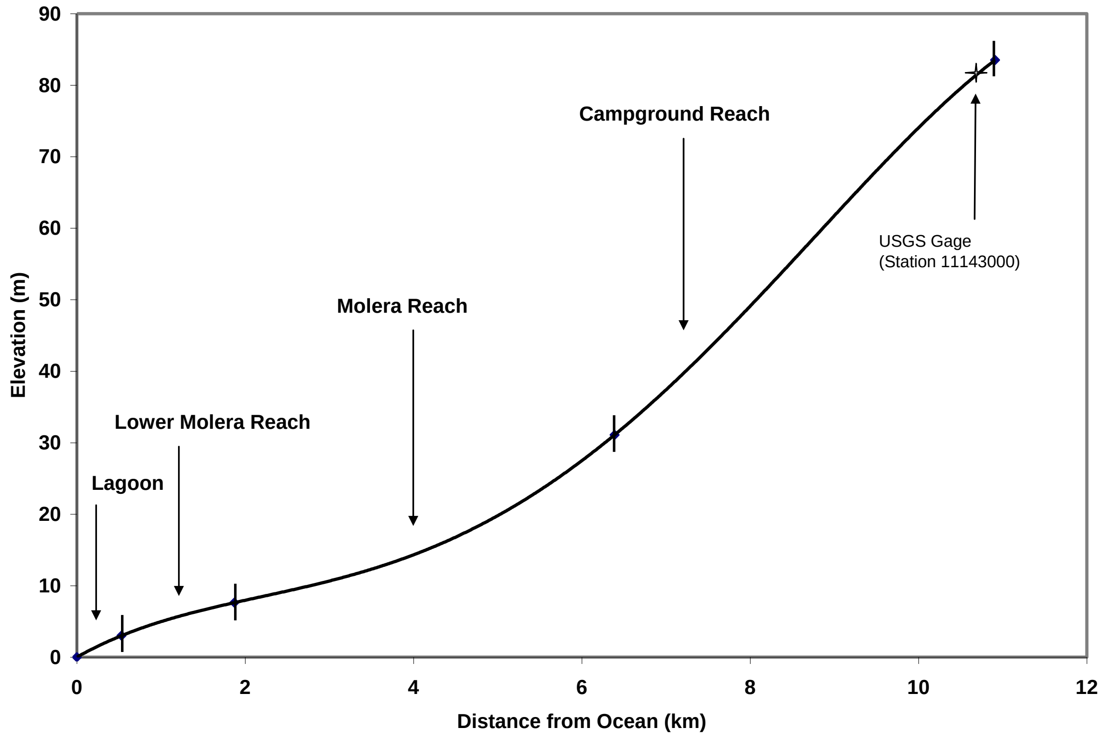

Figure 3. Gradient profile for the Big Sur River from lagoon through study area.

Fishery Resource

The Big Sur River is home to approximately 5 native species of freshwater fishes, including the anadromous steelhead (Table 1). There do not appear to be any introduced freshwater fishes in the study area. Steelhead use the study area year-round for migration, spawning, incubation, rearing, and/or emigration.

Table 1. Fish species occurring in the Big Sur River.

Scientific Name	Common Name
Lampetra tridentata	Pacific Lamprey
Oncorhynchus mykiss	Steelhead
Cottus asper	Prickly Sculpin
Cottus aleuticus	Coast Range Sculpin
Gasterosteus aculeatus	Threespine Stickleback

Steelhead are an anadromous member of the salmonid family, spending their adult life in the ocean and returning to freshwater to spawn (Shapovalov and Taft 1954; Quinn 2005). In the Big Sur River, steelhead return to the river as spawning adults between November and May (Table 2). Steelhead spawn in gravel areas throughout the river between the lagoon and the impassable bedrock barrier in the gorge area of Pfeiffer State Park. Spawning generally occurs at the tail of pools or head of riffles, where water depth, velocity, and substrate composition are favorable. Eggs are deposited in redds or nests excavated by the females, then covered with gravel. The eggs generally hatch between 80 and 120 days, depending on water temperature.

Table 2. Life stage periodicity for south-central steelhead in the Big Sur River.

<table>
<tr><th></th><th>Jan.</th><th>Feb.</th><th>March</th><th>April</th><th>May</th><th>June</th><th>July</th><th>Aug.</th><th>Sept.</th><th>Oct.</th><th>Nov.</th><th>Dec.</th></tr>
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<tr><td>Juvenile Rearing</td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td></tr>
<tr><td>Smolt Emigration</td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td><td></td><td></td><td></td><td></td><td bgcolor="#C0C0C0"></td><td bgcolor="#C0C0C0"></td></tr>
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The newly hatched steelhead fry remain in the gravel until the yolk-sac is absorbed. Upon emerging from the gravels fry (approximately 1.5-2.0 cm fork length (FL)) typically move into nearby shallow slow-water habitats to feed and grow until making the transition to YOY juvenile fish (approximately 6-15 cm FL). As they grow young steelhead typically seek deeper water and faster velocities. Young steelhead may emigrate to the ocean as YOY, however most remain in the freshwater river for a year or longer before emigrating to the ocean. Young steelhead generally reach 5.5-6 inches (14-15 cm FL) or larger before smolting, a physiological change which prepares the fish for migrating to, and life in, the ocean.

METHODS

Identification of Target Flows for Sampling

Mean daily flows and percent exceedance flows for the Big Sur River at USGS gage 11143000 are presented in Figure 4 and Figure 5, respectively. Since there are no diversions or dams upstream of USGS gage 11143000, the hydrology patterns reported at USGS gage 11143000 reflect the natural unimpaired flow regime. Target sampling flows were based upon the 20, 50, and 80 percent exceedance flows of USGS gage 11143000. Percent exceedance flows are typically used as a guideline for describing the watershed hydrology, as well as for making informed decisions about water resources planning and management. The percent exceedance flows between 20 and 80 percent reflect the most commonly observed flows in the stream, with the 50 percent exceedance flow reflecting the stream’s natural benchmark. The 20, 50, and 80 percent exceedance flows for the Big Sur River are 100, 29, and 14 cfs, respectively.

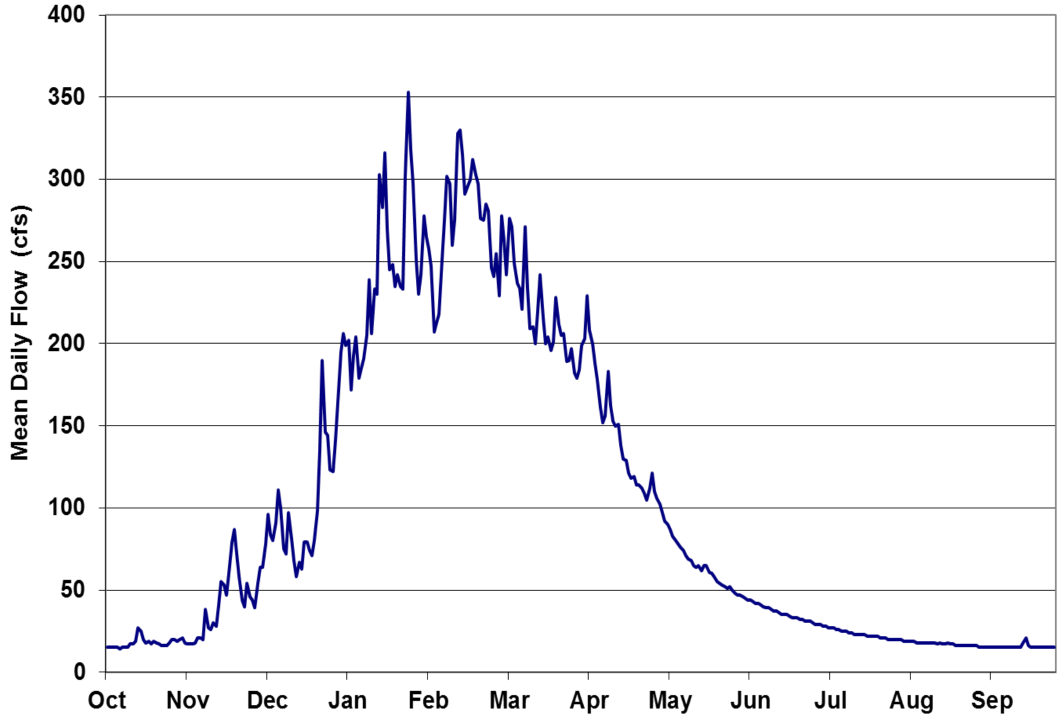


Figure 4. Mean daily unimpaired flow at USGS gage 11143000 on the Big Sur River from March 1950-2010.

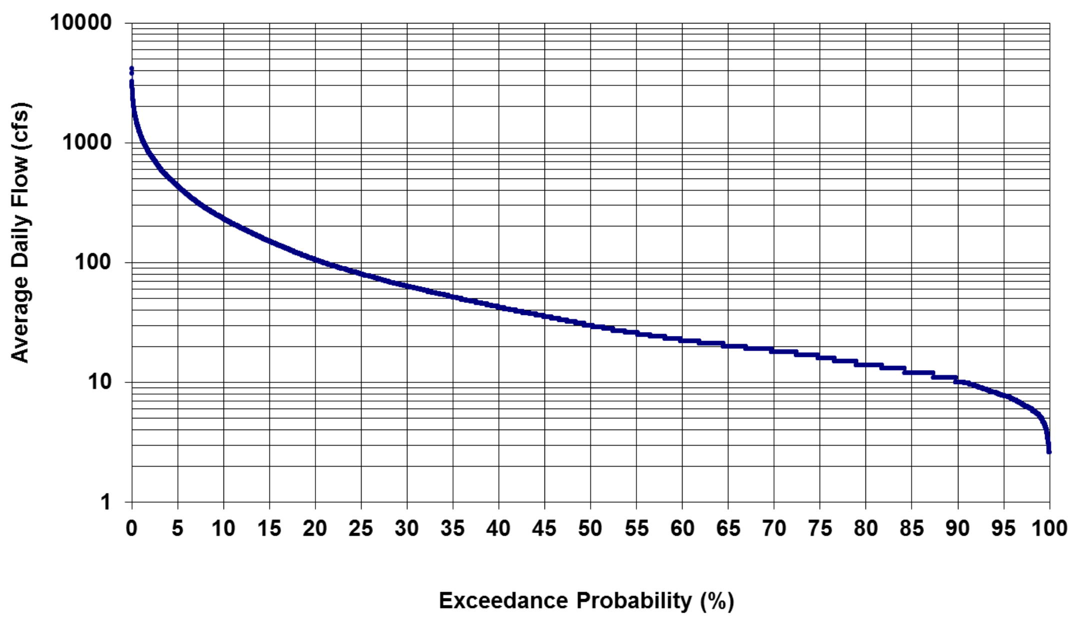


Figure 5. Percent exceedance flows using mean daily unimpaired flow at USGS gage 11143000 on the Big Sur River from 1950-2010.

Identification of Sampling Sites and Sampling Strategy

All sampling for this investigation was conducted within the stretch of the Big Sur River from the lagoon and river transition within Molera State Park upstream to within Julia Pfeiffer State Park. We sampled for steelhead fry and juvenile lifestages during three seasons: summer (June 2010 and August 2010), fall (October 2010), and spring (May 2012). Only the Lower Molera Reach was sampled during the June 2010 sample event. Only the Molera Reach and Campground Reach were sampled during August 2010 sample event. All three reaches were sampled during the October 2010 and May 2012 sample events.

Mesohabitat types were mapped and numbered sequentially, beginning at the first habitat unit at the lower end of the Molera Reach and working upstream. Mesohabitat classification consisted of partitioning the reach into low gradient riffle, pool, glide, run, and shallow run mesohabitat types. Mesohabitat type classifications were consistent with Flosi et al. (2010). Adhering to the equal-area sampling approach (Allen 2000) we related pools with deep/slow microhabitat, glides with shallow/slow habitat, runs with deep/fast habitat, shallow runs with shallow/fast generally non-turbulent habitat, and riffles with shallow/fast habitat. For the remainder of this report, mesohabitat data collected make reference to the habitat type and unit number to apportion sampling effort. A summary of the mesohabitat unit types in the study area is located in Table 3.

The partitioning of mesohabitat types was done in an effort to differentiate steelhead fry and steelhead juvenile habitat use characteristics consistent with the methodology in Hardin et al. (2005). Study sites for HSC sampling were selected using a stratified random sampling design. First, the study reach was partitioned into three approximately equal sub-reaches based upon the number of mesohabitat units. A study site was then randomly selected in the lower third, middle third, and upper third of each sub-reach. This process was repeated until each sub-reach contained one of each of mesohabitat types (Table 4, Figure 6, Figure 7, and Figure 8).

Table 3. Summary of mesohabitat types in Big Sur River study area.

	Mesohabitat Unit Type				
	Low Gradient Riffle (LGR)	POOL	Glide (GLD)	RUN	Shallow Run RUN(S)
Lower Molera					
# Units	11	11	3	8	0
Total Length (ft)	735	2362	341	974	0
Average Length (ft)	66	217	115	121	0
Molera					
# Units	43	30	17	31	4
Total Length (ft)	3615	3219	2641	3478	522
Average Length (ft)	85	108	154	112	131
Campground					
# Units	70	44	15	32	16
Total Length (ft)	8225	5102	2024	3343	2418
Average Length (ft)	118	115	135	105	151

Table 4. Sampling sites in Lower Molera, Molera, and Campground reaches.

Unit	Mesohabitat Type	Length (ft)	Mean Width (ft)
Lower Molera Reach			
10	POOL	83	41.5
15	LGR	47	38.5
16	GLD	63	36.8
17	GLD/POOL	35	24.5
18	LGR	151	39.5
19	GLD/POOL	61	44
20	POOL	288	29.3
22	LGR	69	19
24	GLD/POOL	40	28
26	LGR	213	29.2
28	GLD	99	31.7
29	RUN	59	32.5
33	LGR	40	25
34	RUN	210	36.8
36	RUN	123	36.3
37	GLD	182	35.7
38	RUN	138	25
40	POOL	230	29
Molera Reach			
Unit	**Mesohabitat Type**	**Length (ft)**	**Mean Width (ft)**
45	GLD	163	31
53	POOL	110	24.3
55	POOL	108	40.7
62	LGR	55	28
64	LGR	43	24.5
70	LGR	140	28.3
75	RUN	93	30.5
92	LGR	49	26.5
98	POOL	120	32
101	GLD	256	32.2
110	RUN	175	29.2
121	POOL	34	24.5
146	POOL	149	28.3
154	LGR	120	51
156	LGR	88	32
160	GLD	75	39.5
161	RUN	268	28.3
Campground Reach			
Unit	**Mesohabitat Type**	**Length (ft)**	**Mean Width (ft)**
196	GLD	296	47.3
197	POOL	125	34.7
202	LGR	38	32
208	RUN(S)	172	43
215	RUN	79	28.5
217	RUN	47	31.5
222	POOL	155	37.2
224	POOL	180	44.25
229	GLD	58	43
260	LGR	158	33.5
266	RUN	53	29.5
276	LGR	157	42.5
280	LGR	65	46.5
282	LGR	64	47
285	GLD	146	43.7
287	RUN	101	30.7
295	RUN(S)	303	39.4
303	RUN	244	26
308	RUN	80	36.5
312	POOL	93	25

Figure 6. Habitat suitability criteria sampling sites in Lower Molera reach of Big Sur River.

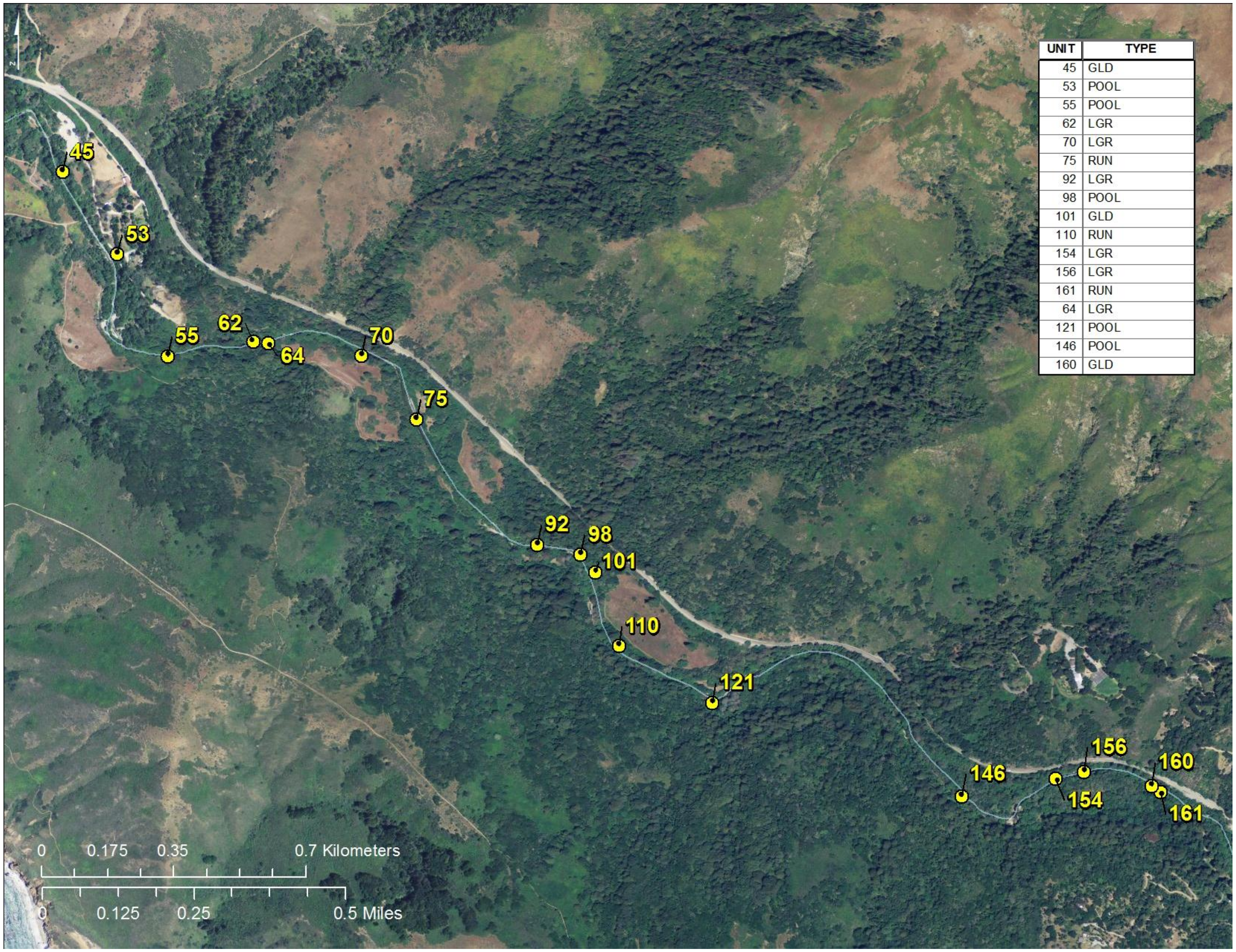
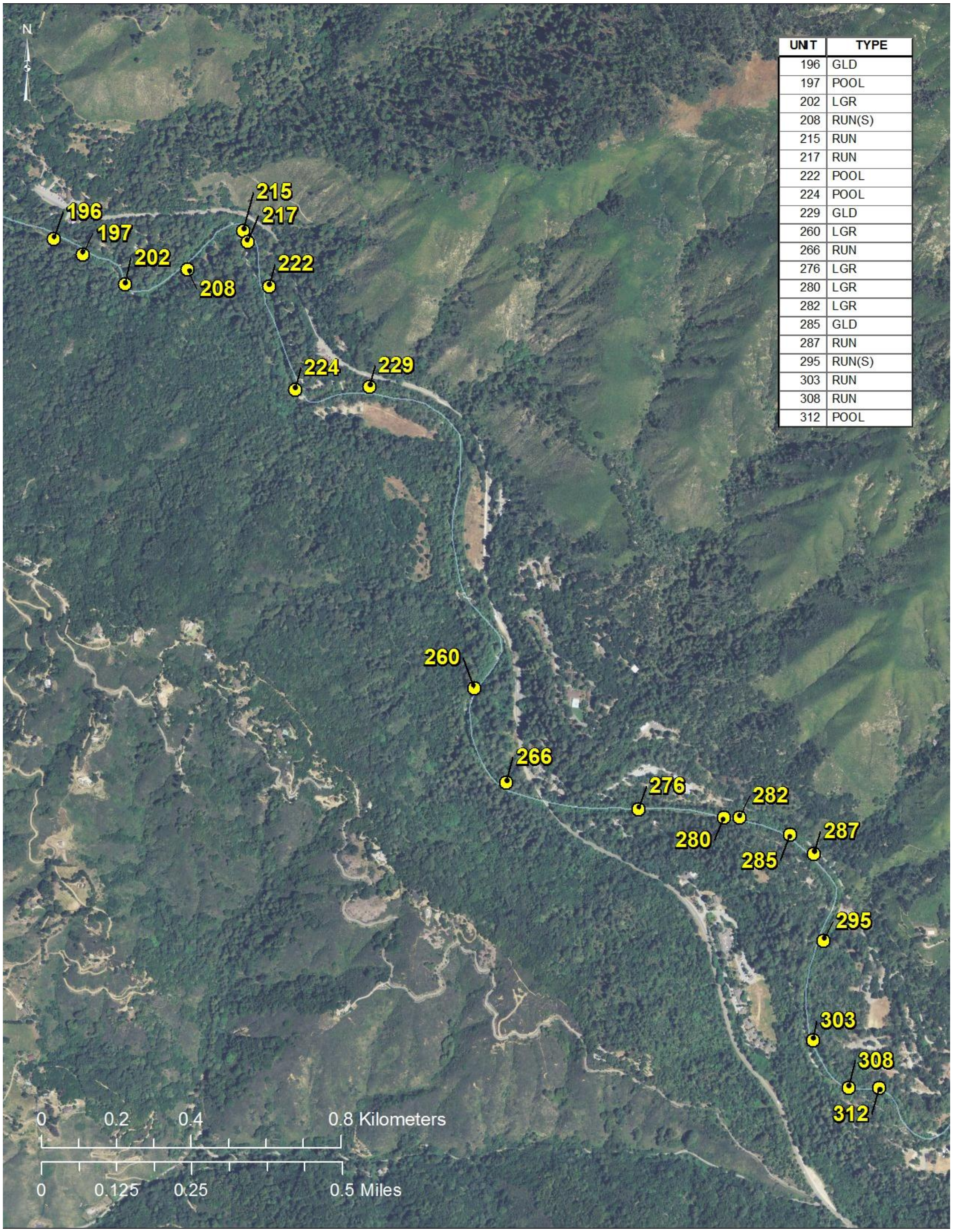


Figure 7. Habitat suitability criteria sampling sites in Molera reach of Big Sur River.



UNIT	TYPE
196	GLD
197	POOL
202	LGR
208	RUN(S)
215	RUN
217	RUN
222	POOL
224	POOL
229	GLD
260	LGR
266	RUN
276	LGR
280	LGR
282	LGR
285	GLD
287	RUN
295	RUN(S)
303	RUN
308	RUN
312	POOL

Figure 8. Habitat suitability criteria sampling sites in Campground reach of Big Sur River.

Additional mesohabitat units, beyond the initial random draw, were also randomly selected from each reach/habitat type stratum if needed to achieve equal-area sampling (i.e., square feet) and adequate sample of fish, as described by Bovee et al. (1998). Sub-mesohabitat components were identified as Stream Margin Edge Types (SMET). SMET classifications are outlined in Table 5. These edge types were further classified into specific vegetative and substrate components (Table 6).

Table 5. Stream Margin Edge Type (SMET) codes.

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

Table 6. Vegetative and substrate codes[4].

	Vegetative Codes		Substrate Codes	Size (in)
0	None	20	None	
1	Filamentous algae	21	Clay	
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand	< 0.1
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG	0.1-0.2
4	Grass	24	Small gravel	0.2-1
5	Sedges/rushes	25	Medium gravel	1-2
6	Vines/ poison oak	26	Large gravel	2-3
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble	3-4
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble	4-6
9	Branches > 4 inches, IW	29	Medium cobble	6-9
10	Branches > 4 inches, OW	30	Large cobble	9-12
11	Tree trunks < 4 inches dbh, IW	31	Small boulder	12-24
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder	24-48
13	Tree trunks > 4 inches dbh, IW	33	Large boulder	>48
14	Tree trunks > 4 inches dbh, OW	34	Bedrock	
15	Roots and root-wads	35	Undercut bank	
16	Shrubs < 4 inches			
17	Duff, leaf litter, organic debris			
18	Small woody debris (< 4 inches), dead			
19	Large woody debris (> 4 inches), dead			

Fish Observation Techniques

Habitat use data were collected for all undisturbed young steelhead observed by divers. Steelhead fork length (FL) was estimated, and length frequency distributions derived from these data were used to partition HSC data into fry (2-5 cm) and older rearing juvenile size classes (6-9 cm; 10-15 cm; and 16 cm and greater).

Steelhead juveniles were observed via direct underwater observation. Water visibility was estimated using an 8 cm juvenile trout rapala. The recorder would suspend the rapala mid-depth in the water column using a sinker and

[4] dbh = diameter breast height; IW = in=water; OW = out-of-water.

monofilament line. The snorkeler would move away from the rapala until they were as far away as possible while still being able to see color markings on the rapala. Visibility was determined to be the maximum distance the underwater observer could see the rapala and color markings.

Potential diving scenarios for collecting HSC data depend upon 1) fry/juvenile densities, 2) water clarity, and 3) channel width. Where narrow channel widths and adequate water visibilities permit, a single diver collected HSC data with support from a stream-side data recorder. Where channel widths or water visibilities prevented a single diver from fully covering the entire sampling area, two or more divers worked upstream together, where one diver surveys the left half of the channel and the other surveys the right half (Figure 9, Figure 10, Figure 11). Each diver transferred HSC data to one data recorder.

The following protocol for direct underwater observation was followed at each site for HSC collection:

1) The observers enter the water about 20 ft downstream of the site, and move slowly upstream through the site, observing steelhead and determining their positions before disturbed by human activity.

2) Location markers (weights with flagging attached) are placed where undisturbed steelhead (1 or more) are observed (Figure 12).

3) Where large groups (20+) of fry or juveniles are distributed over an area greater than a foot wide that encompassed different water depths and velocities, they are recorded and marked as at least two smaller groups to characterize the different habitats in which they resided and potentially different sizes of fish with the group.

4) Underwater observers avoid herding fish within or out of the site by moving around rather than moving through the fish positions.

5) Fish that were disturbed by the diver prior to identification of the fish's focal position were not marked, but were noted as present and not included in subsequent analyses.

6) Fish marker number, species of fish, number of fish, estimated size (fork length(s) to nearest cm, and focal depth (i.e., actual distance above the substrate or relative height in the water column) were recorded for each observation.

7) A numbered marker was placed underneath individual fish or sub-group focal position and the data were transmitted to the nearby data recorder.

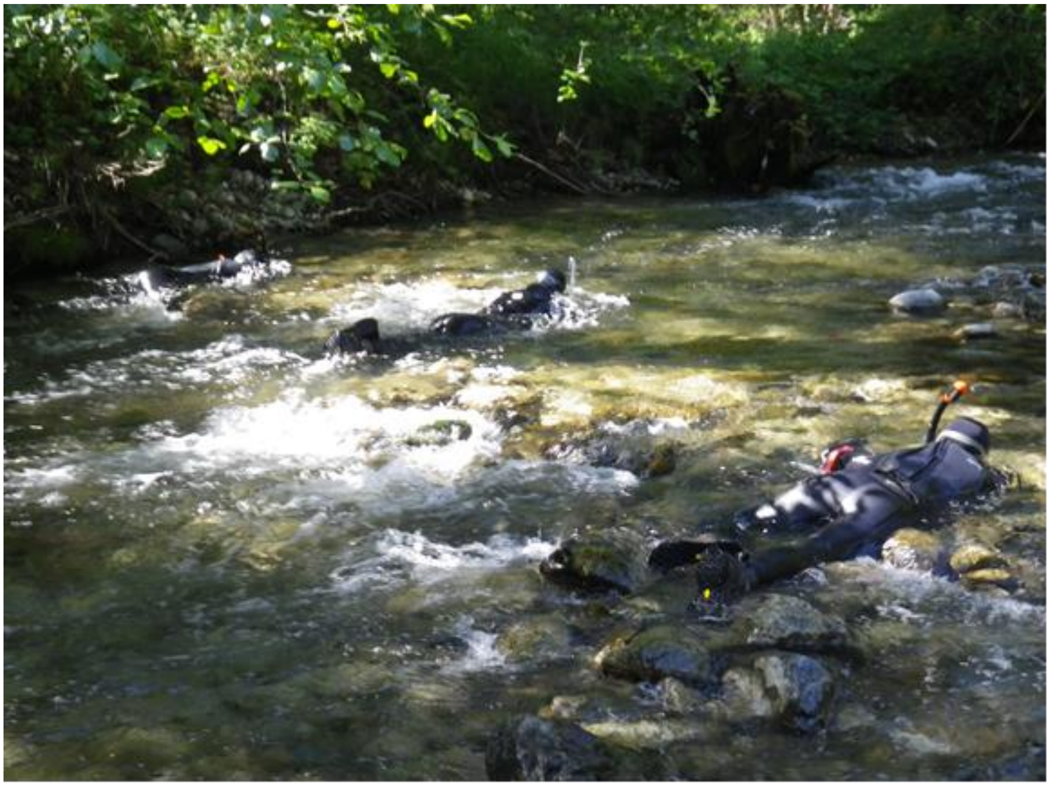


Figure 9. Biologists surveying low gradient riffle site #260 for juvenile steelhead.

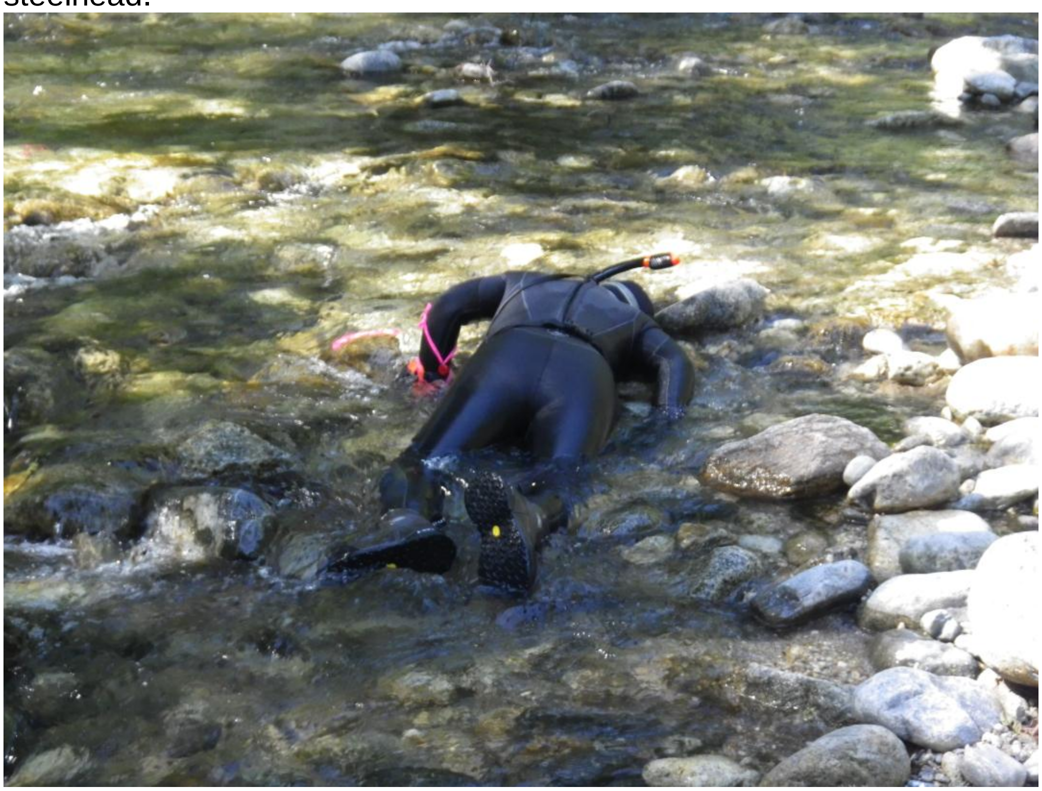


Figure 10. Biologist surveying low gradient riffle site #260 for juvenile steelhead.


Figure 11. Biologists surveying glide site #28 in Lower Molera reach for juvenile steelhead.


Figure 12. Biologist placing fish observation marker at location of juvenile steelhead.

8) The observer then proceeds upstream and similarly identifies and marks all undisturbed fish in the sampling unit.

9) After the underwater observation is completed, the observers exit the site in the least disturbing way possible.

10) Habitat characteristics were then measured at all observation markers (Figure 13, Figure 14, Figure 15 a and b, Figure 16 a and b, and Figure 17). HSC characteristics recorded for each marked fish location were:

    a. Mesohabitat number and type.

    b. Site number and SMET type.

    c. Water depth, focal velocity, and mean column velocity. Water depth is measured with a graduated top-setting rod to nearest 0.1 ft (30.5 mm). Velocity is measured with a Marsh McBirney electromagnetic water velocity meter to the nearest 0.01 ft/sec (3.0 mm/sec). Standard U.S. Geological Survey protocol will be followed for water velocity measurements (Rantz, 1982).

    d. Overhead cover (in water), overhead cover (out of water <18 inches above surface), and escape cover. Collectively, overhead cover types are referred to as functional cover to differentiate from escape cover (Hardin et al. 2005). Functional cover refers to cover components that influence a fish's daily activities (feeding, holding, etc.), and to which the fish may select or orientate. Cover components to which a fish may flee when threatened are defined as escape cover. Partitioning overhead cover into in- and out-of-water components resulted in six functional cover types being considered. These are defined as:

        i. No cover: Water velocity shelter and/or overhead cover are not directly affecting a fish's position or habitat station.

Figure 13. Low gradient riffle site #260 in Campground reach just after snorkel survey was conducted (prior to data collection) showing locations of fish observation markers.

Figure 14. Pool site #222 in Campground reach just after snorkel survey was conducted (prior to data collection) showing locations of fish observation markers.

a)

b)

Figure 15. (a and b). Juvenile steelhead (<6 cm) in Campground reach positioned above fish observation markers.

a)

b)

Figure 16. (a and b). Juvenile steelhead (<6 cm) in glide site #101 in Molera reach positioned above fish observation markers and using small branches for overhead in-water and/or escape cover.

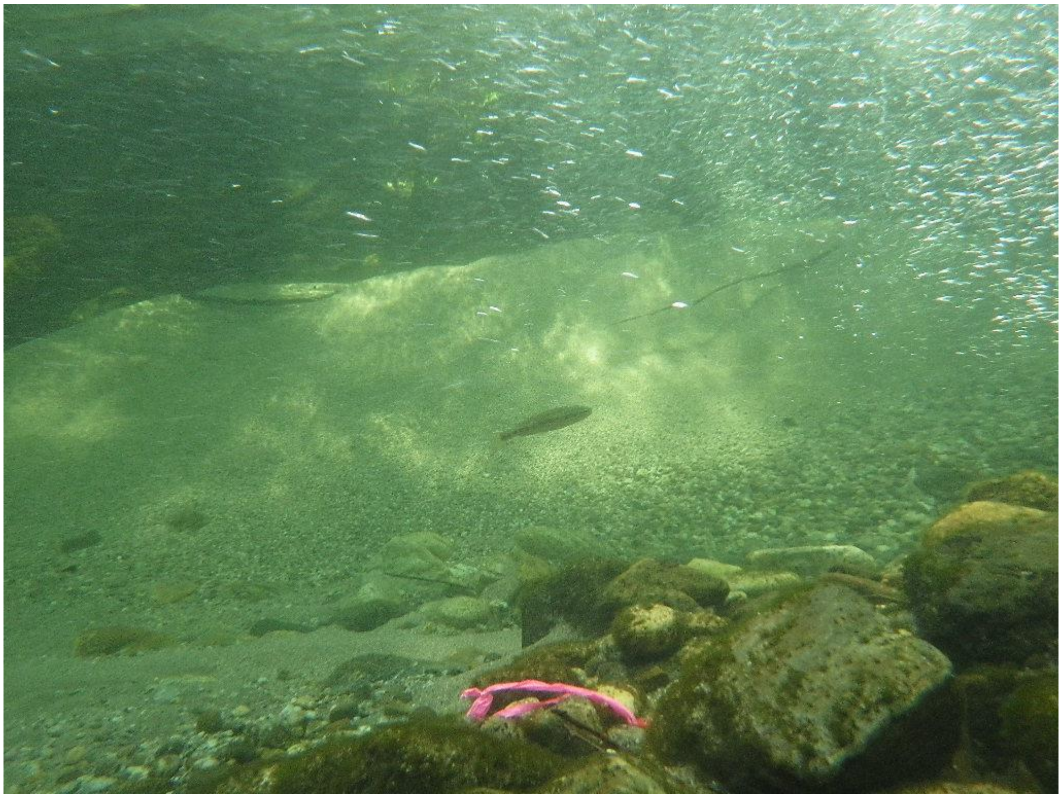


Figure 17.Juvenile steelhead (6-9 cm) in pool site #98 in Molera reach positioned above fish observation marker.

ii. Water velocity shelter: A substrate, vegetative, or structure component that creates a break (i.e., reduction) in water velocity, to which the fish being sampled occupies or orients. The substrate/overhead component or structure feature may be some distance away, but has a direct influence on the water velocity at a fish's position. Water velocity shelter components include boulders and large cobbles, tree trunks, debris jams, and patches of rooted aquatic vegetation. Channel features such as point bars or bedrock outcrops are not typically included as water velocity components as they are considered channel morphometric features rather than discrete objects.

iii. In-water overhead cover: Any substrate, structural, vegetative component, or feature located within the water that affords fish being sampled concealment or camouflage from avian or piscine predation, sunlight, or other factor that may influence a fish's daily activities (i.e., non-fright response). For in-water overhead cover to be considered present, an observed fish must be directly beneath the cover component (i.e., horizontal distance from the fish position to this cover type is 0.0 ft). In-water overhead cover components include crevices among cobbles and boulders, (ledges, aquatic vegetation, submerged overhanging branches of riparian vegetation, submerged organic debris, etc. In the event out-of-water overhead cover is also present (i.e., directly over a fish), in-water overhead cover is generally given priority consideration.

iv. Out-of-water overhead cover: Any substrate, structural, or vegetative component or feature located out of the water, but within 18 inches (46 cm) of the water surface, that affords the fish being sampled concealment or camouflage from avian or piscine predation, sunlight, or other factor that may influence a fish's daily activities (i.e., non-fright response). For overhead cover to be considered present, an observed fish must be directly beneath the cover component (i.e., horizontal distance from the fish position to this cover type is 0.0 ft [0.0 mm]). Out-of-water cover components include bent-over emergent sedges, low-hanging branches of riparian vegetation, high-flow debris clinging to overhanging riparian vegetation, riverbank features, etc. Components more than 18 inches (46 cm) from the water surface are considered canopy.

v. Water velocity shelter and in-water overhead cover (Figure 18): Combinations of water velocity shelter and in-water overhead cover (cover types 2 and 3, above, respectively).

vi. Water velocity shelter and out-of-water overhead cover: Combinations of water velocity shelter cover and out-of-water overhead cover (cover types 2 and 4 above, respectively).

d. Type and distance to object (escape cover and velocity shelter) for both, in-water, and out-of-water escape and velocity (shelter) cover types for observations where specific cover type is being used. Distances <10 ft (3.1 m) were measured to the nearest 0.5 ft. Distances over 10 ft (3.1 m) were not recorded.

e. Escape cover: Any substrate, structural, or vegetative component or feature located within or out of the water, but within 18 inches (46 cm) of the water surface, that an observed fish seeks out, or may seek, out for concealment, hiding, etc. in response to fright or threat is defined as escape cover (Figure 19; Hardin et al. 2005). Escape cover type and distance from each fish or group of fish observed is recorded up to 10 ft (3.1 m), to the nearest 0.5 ft (15.2 mm). This cover type is used for short-term fright response concealment, and is not necessarily used on a routine basis for daily activities (i.e., feeding, resting, etc.). Escape cover may, or may not, have conditions (e.g., water depth and velocity) the observed fish would select for extended use. In-water escape cover components include crevices among cobbles and boulders, ledges, aquatic vegetation, submerged overhanging branches of riparian vegetation, submerged organic debris, etc. Escape cover components also include the above SMET, substrate, and vegetative component listed above. Other components include bent-over emergent sedges, low-hanging branches of riparian vegetation, high-flow debris clinging to overhanging riparian vegetation, riverbank features, etc. Components more than 18 inches (45.0 cm) from the water surface are considered canopy. In the event in-water and out-of-water escape cover are present equal distance from an observed fish, in-water escape cover is generally given priority consideration.

f. Water velocity shear zone presence and distance from the observed fish. A shear zone is defined as a zone of rapid difference in water velocities.

g. Dominant and subdominant substrate particle sizes estimated.

h. Embeddedness of the substrate is visually estimated.

Figure 18. Juvenile steelhead (6-15 cm) in low gradient riffle site #260 in Campground reach using velocity shelter from medium to large cobble substrate as well as small branches as overhead in-water and/or escape cover.

Figure 19. Juvenile steelhead (<6 cm) in close proximity to cobble escape cover.

Habitat Availability Techniques

Habitat availability data were collected in each mesohabitat unit sampled immediately upon conclusion of fish observation and data collection procedures using a random point sampling design. Habitat availability measurements were collected in each sampled mesohabitat unit using a randomized approach consisting of a) random selection of cross-sectional transects, then b) random selection of measurement points along each transect.

In order to keep the level of effort for habitat availability data consistent with the effort for fish habitat use data (i.e., according to the equal-effort design), the number of availability measurement points in each sampled habitat unit was roughly proportional to the size of that habitat unit (e.g., larger individual mesohabitat units will have more availability points than smaller units, but overall number of availability points will be equal among the mesohabitat types). Transect locations for habitat availability were selected in each sampled mesohabitat by partitioning each unit into equal subunits (based on unit lengths) as follows: two transects sampled for mesohabitat units from 1 to 100 ft, with an additional transect sampled for each additional 50 ft of mesohabitat length.

Cross-stream transects were randomly chosen using a random multiplier multiplied by the subunit length for each of the identified subunits of the mesohabitat site. After habitat availability transects were identified, each transect was sub-divided into three equal segments based on the wetted distance of the cross-stream transect. Sampling locations for the same hydraulic and physical variable as measured for the fish observations, were identified in each third of the cross-stream transect using the same process for randomly selecting transect locations. This process resulted in a minimum of 3 measurement locations on each transect, and a minimum of 6 measurement locations per a site for habitat availability. This design insures random selection and that habitat availability data is collected in the same locations and in the same proportions as the habitat use data, which will allow a direct comparison of habitat use and habitat availability data during construction of HSC curves.

Data Analyses

Data collected during the three seasons were used to compare microhabitat use distributions, and to develop HSC during the core rearing period for juvenile steelhead. Field data were compiled into summary histograms to compare habitat utilization observations and habitat availability made during the three seasons. Histograms of key variables (e.g., water depth, average water velocity, focal depth, focal velocity, cover, distance to water’s edge, distance to in-water escape cover, and SMET) were constructed using the smallest practical bin size for each variable.

HSC were developed using the fish observation (utilization) data for those variables deemed important by the frequency of use observations and statistical analyses for juvenile <6 cm, 6-9 cm, and 10-15 cm steelhead during the spring, summer, and fall rearing period in the Big Sur River. The spring sample event was used to develop HSC for <6 cm juvenile steelhead for total water depth, average water velocity, focal water velocity distance to escape cover, and escape cover type. Summer and fall HSC curves were used to develop depth and velocity umbrella HSC for juvenile 6-9 cm and 10-15 cm steelhead sizes. The umbrella curves represent steelhead habitat utilization during the core summer and fall rearing time period in the Big Sur River for each size group.

The selectivity (Type II ½) HSC were compared to Type III HSC developed using the forage ratio. The fish selectivity HSC directly reflects habitat selection (i.e., habitat use) by the fish. The forage ratio criteria, also referred to as preference criteria (Moyle and Baltz 1985) reflect fish habitat use adjusted for habitat availability (i.e., U/A). The U/A forage ratio is the proportion of used habitat units of a particular category (e.g., water depths between 1.0 ft and 1.10 ft) divided by the proportion of habitat units of that category available (Manly et al. 2002).

Kernel-smoothing techniques (Hayes and Jowett 1994; Jowett 2002; Jowett and Davey 2007) were used to develop frequency of use, habitat availability, and preference HSC curves. All curves were standardized by dividing them by their maximum values to provide suitability indices ranging from 0 to 1. A software program, HabSel[5], was used to fit kernel smoothed curves to histograms of habitat use, availability, and suitability. For depth, some practitioners choose to subjectively maintain suitability at 0.5, 1.0, or at some intermediate value for depths beyond the last observation; we chose to maintain suitability at the value from the last observation into deeper water.

Statistical Analyses

The primary question of the statistical analyses was focused on assessing whether habitat availability differed from the habitat characteristics of where fish were observed (habitat used). The basic strategy for analysis was to test whether mean values for continuous measures differed between habitat characteristics where fish were observed versus available habitat; significant differences would indicate that fish are exhibiting selectivity for those variables. Separate analyses were conducted for each of the fish length classes (<6 cm, 6-9 cm, and 10-15 cm).

[5] HabSel © 2011 Jowett Consulting is software program for development of habitat suitability models available at: http://www.jowettconsulting.co.nz/home/habprf

Habitat selectivity for continuous measures (i.e, depth, velocity, percent embedded, escape distance, and distance to bank) used 2-Way and 3-Way ANOVAs (Analysis of Variance) to test for differences between the fish habitat use and habitat availability data. Percent embedded was transformed as the arcsine of the square root of the proportion for analysis. The factors in the analysis were data type (fish use, available), mesohabitat (runs, riffles, pools and glides) and, for the 6-9 cm and 10-15 cm fish length size classes, sample period (spring, summer, and fall for 6-9 cm fish, summer and fall only for 10-15 cm fish). Data was insufficient to test seasonal effects for fish <6 cm (i.e., a 2-Way ANOVA was conducted). Fish frequency at a marker location was not included in the analyses, so as to provide a conservative approach and not skew the results with marker locations that had higher frequencies of fish greater than one. Significant effects associated with the data type variable would indicate habitat selectivity.

RESULTS

Data were collected during three seasons (i.e., spring, summer, fall) to compare water depth, velocity, and other microhabitat use distributions, and to develop HSC during the core rearing period for juvenile steelhead. Sampling in June 2010 only included the Lower Molera Reach. Sampling for the upper two reaches was completed after habitat mapping data were collected, in August 2010. The June 2010 and August 2010 survey (fish use) data were then combined to reflect the equal area sampling design and represent juvenile steelhead microhabitat distributions during the summer time period. All three reaches were sampled in October 2010 and represent the fall time period for rearing juvenile steelhead. Sampling resumed in May 2012 on all reaches to identify fry microhabitat distributions during spring. Flows ranged from 35-51, 31-62, and 23-26 cfs for the spring, summer, and fall sample periods (Table 7). Water visibility ranged from 9 to 19.5 ft (average 15.4 ft). Water temperature ranged from 50 to 64 F (average 58.5 F).

Table 7. Sampling time periods and corresponding Big Sur River flows[6].

	Sample Dates	Flows (cfs)	Season	Reach
June 2010	6/22-6/30	54-62	Summer	Lower Molera
August 2010	8/9-8/19	31-36	Summer	Molera, Campground
October 2010	10/4-10/14	23-26	Fall	Lower Molera, Molera, Campground
May 2012	5/7-5/24	35-51	Spring	Lower Molera, Molera, Campground

Equal areas of the four primary mesohabitat types (RUN = run, LGR = low gradient riffle, POOL = pool, GLD = glide) in each of the three reaches were sampled (Table 8). The run habitat represents deep and fast habitat. The low gradient riffle habitat represents shallow fast habitat. The pool habitat represents deep slow habitat. The glide habitat represents shallow slow habitat. The Campground Reach also contained an additional mesohabitat unit, the RUN(S) or shallow run mesohabitat type.

[6] Flows determined by USGS 11143000.

Table 8. Summary of total area sampled among mesohabitat types in Lower Molera, Molera, and Campground reaches in 2010 and 2012.

Lower Molera Reach

Habitat Type	Summer 2010 Total Area (Sq. Ft)	Fall 2010 Total Area (Sq. Ft)	Spring 2012 Total Area (Sq. Ft)
RUN	17,564	17,141	21,531
LGR	16,305	14,524	16,474
POOL	18,236	18,663	19,430
GLD	16,604	15,431	15,357
Total:	68,709	65,759	72,792

Molera Reach

Habitat Type	Summer 2010 Total Area (Sq. Ft)	Fall 2010 Total Area (Sq. Ft)	Spring 2012 Total Area (Sq. Ft)
RUN	15,639	15,715	15,673
LGR	19,776	17,355	10,906
POOL	15,963	15,048	12,702
GLD	16,251	16,792	19,809
Total:	67,629	64,910	59,090

Campground Reach

Habitat Type	Summer 2010 Total Area (Sq. Ft)	Fall 2010 Total Area (Sq. Ft)	Spring 2012 Total Area (Sq. Ft)
RUN	18,409	15,841	14,554
LGR	19,212	17,775	11,395
POOL	19,808	22,899	18,083
GLD	22,880	23,270	25,520
Total w/o RUN(S):	80,309	79,784	69,551
RUN(S)	19,343	18,611	8,127
Total w/ RUN(S):	99,652	98,395	77,678

Summer 2010 Total Area (Sq. Ft): 235,990
Fall 2010 Total Area (Sq. Ft): 229,064
Spring 2012 Total Area (Sq. Ft): 209,560

Fish Observations

Sample sizes of fish frequencies for spring, summer, and fall sampling events were 4318, 1410, and 736, respectively (Table 9). The spring sample event was elected to identify rearing microhabitat selectivity for <6 cm steelhead fry which represent the steelhead size class most representative of spring young-of-year rearing conditions. The summer and fall sampling events were elected to identify rearing microhabitat selectivity for larger juvenile steelhead in the 6-9 cm and 10-15 cm size groups through the summer and fall time periods. We also observed 8, 25, 53, and 26 steelhead 16 cm and greater during June, August, October, and May, respectively. Habitat selectivity is not discussed for these 16 cm and larger steelhead due to inadequate sample sizes. Juvenile steelhead were observed in all the mesohabitat types sampled in all seasons (Table 10).

Table 9. Summary of fish observations during sample periods.

	Number of Juvenile Fish Observed			
	Summer	Fall	Spring	Total
<6 cm	53	0	3921	3974
6-9 cm	748	166	294	1208
10-15 cm	609	570	103	1282
Totals:	1410	736	4318	6464

Table 10. Summary of total number of juvenile steelhead observed in mesohabitat types in Lower Molera, Molera, and Campground reaches in 2010 and 2012.

Lower Molera Reach

Habitat Type	Summer 2010 Total Fish	Fall 2010 Total Fish	Spring 2012 Total Fish
RUN	74	113	85
LGR	98	53	300
POOL	81	130	170
GLD	14	13	110
Total:	267	309	665

Molera Reach

Habitat Type	Summer 2010 Total Fish	Fall 2010 Total Fish	Spring 2012 Total Fish
RUN	116	48	295
LGR	91	43	144
POOL	101	74	103
GLD	24	10	101
Total:	332	175	643

Campground Reach

Habitat Type	Summer 2010 Total Fish	Fall 2010 Total Fish	Spring 2012 Total Fish
RUN	306	69	758
LGR	175	37	244
POOL	202	175	1569
GLD	90	5	281
Total w/o RUN(S):	773	286	2852
RUN(S)	71	19	184
Total w/ RUN(S):	844	305	3036

Summer 2010 Total Fish: 1443
Fall 2010 Total Fish: 789
Spring 2012 Total Fish: 4344

Spring Habitat Use

Habitat use statistics for <6 cm juvenile steelhead observed in the Big Sur River in spring 2012 are outlined in Table 11. Number of <6 cm fish per a mesohabitat type in spring are in Figure 20. Steelhead <6 cm were found in all habitat types, with most occurring in pool and run mesohabitat types in spring. Over 75 percent of the <6 cm fish observations in spring were of fish 2-3 cm in length (Figure 21).

Table 11. Habitat use statistics for <6 cm juvenile steelhead observed in the Big Sur River in spring 2012.

Statistic	N	Minimum	Maximum	Average	Median	Std. Dev.
Water Depth (ft)	3,921	0.05	3.80	0.79	0.60	0.57
Water Velocity (ft/s)	3,920	0.00	3.61	0.49	0.32	0.48
Fish Focal Point Height	3,921	0	10	6.92	8.00	2.32
Fish Focal Point Water Velocity (ft/s)	3,905	0.00	2.67	0.37	0.26	0.36
Distance to Escape Cover (ft)	3,767	0.00	10.00	1.44	1.00	1.55
Distance to Bank (ft)	3,921	0.00	33.00	7.16	4.50	6.77
Thalweg Depth (ft)	3,921	0.40	7.00	2.04	1.70	1.00
Distance to Thalweg (ft)	3,921	0.00	71.50	16.86	15.50	9.86

Total Water Depth: Juvenile <6 cm steelhead were observed in locations with water depths ranging from 0.05 ft to 3.8 ft (Table 11). The average water depth for all observations was 0.79 ft. The histogram of water depth frequencies in shown in Figure 22.

Average Water Velocity: Juvenile <6 cm steelhead were observed in locations with average water column velocities ranging from 0.00 ft/s to 3.61 ft/s (Table 11). The average and median water velocity for all observations was 0.49 ft/s and 0.32 ft/s, respectively. The histogram of average water velocity frequencies is shown in Figure 23.

Fish Focal Point Position: The focal point position (from the water surface to the fish with 0 = water surface and 10 = on stream bottom) of juvenile <6 cm steelhead at which the fish were observed ranged from 0 to 10. The median fish focal point position was 8 (Table 11). The histogram of fish focal point water depth frequencies is shown in Figure 24.

Fish Focal Point Velocity: Water velocities at the fish focal point were slightly less than average water column velocities. Focal point velocities ranged from 0.00 ft/s to 2.67 ft/s, and averaged 0.37 ft/s (Table 11).The histogram of fish focal point velocity frequencies is shown in Figure 25.

Substrate: Although it was not uncommon to find <6 cm fish in areas of sand and course sand (DG), most observations were in locations dominated by small gravel to small cobble-sized particles (Figure 26).

Embeddedness: Substrate embeddedness at locations used by <6 cm fish ranged from 0-100 percent with most observations occurring at locations with embeddedness values ranging from 30-80 percent (Figure 27).

Overhead Cover: Over 95% of <6 cm fish during spring occurred at locations with no overhead cover (Figure 28). Branches and/or small vegetation (both in-water and out-of-water) were used occasionally by <6 cm fish.

Escape Cover: Most <6 cm fish were observed in locations near some type of escape cover either in form of vegetative or hard substrate types (Figure 29). Hard substrate types (large gravel to large cobble sizes) were the most common types of escape cover observed near the fish observation locations.

Distance to Escape Cover: Most <6 cm fish were observed to be within 0.5 ft – 1.0 ft proximity to escape cover (Figure 30; Table 11). Less than 5% of <6 cm fish were not near (within 10 ft) of escape cover.

Shear Zone: Most <6 cm fish were not observed to be using any discernable type of a shear zone (Figure 31).

Fish Activity: Most <6 cm fish observed were feeding, as opposed to holding (Figure 32).

Water Velocity Shelter: Most <6 cm fish were not observed to be using any type of water velocity shelter (Figure 33).

Distance to Bank: Although <6 cm fish were observed using habitats from 0.5 ft to > 30 ft from the bank, most <6 cm fish were observed within 5 ft of the bank (Figure 34; Table 11).

SMET: Most observations of <6 cm fish were in locations that were either open (sand substrate), or dominated by gravel and/or cobble substrates (Figure 35).

Distance to Thalweg: Observations of <6 cm fish ranged from 0 ft to >40 ft from the thalweg, with most observations being made at locations within 8-23 ft of the thalweg (Figure 36).

Thalweg Depth: Thalweg depths associated with <6 cm fish ranged from about 0.5 ft - > 6.0 ft, although most were in the 1-3 ft range (Figure 37).

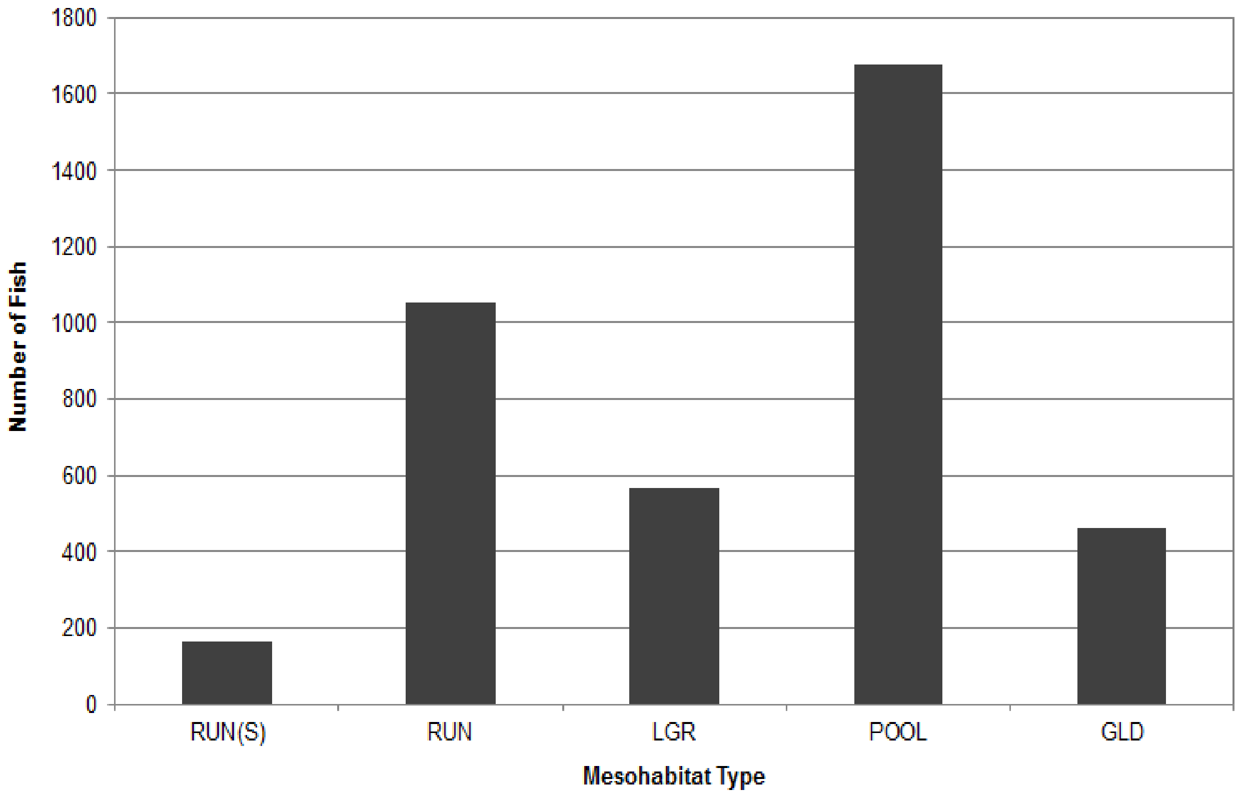


Figure 20. Frequency distribution of <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.

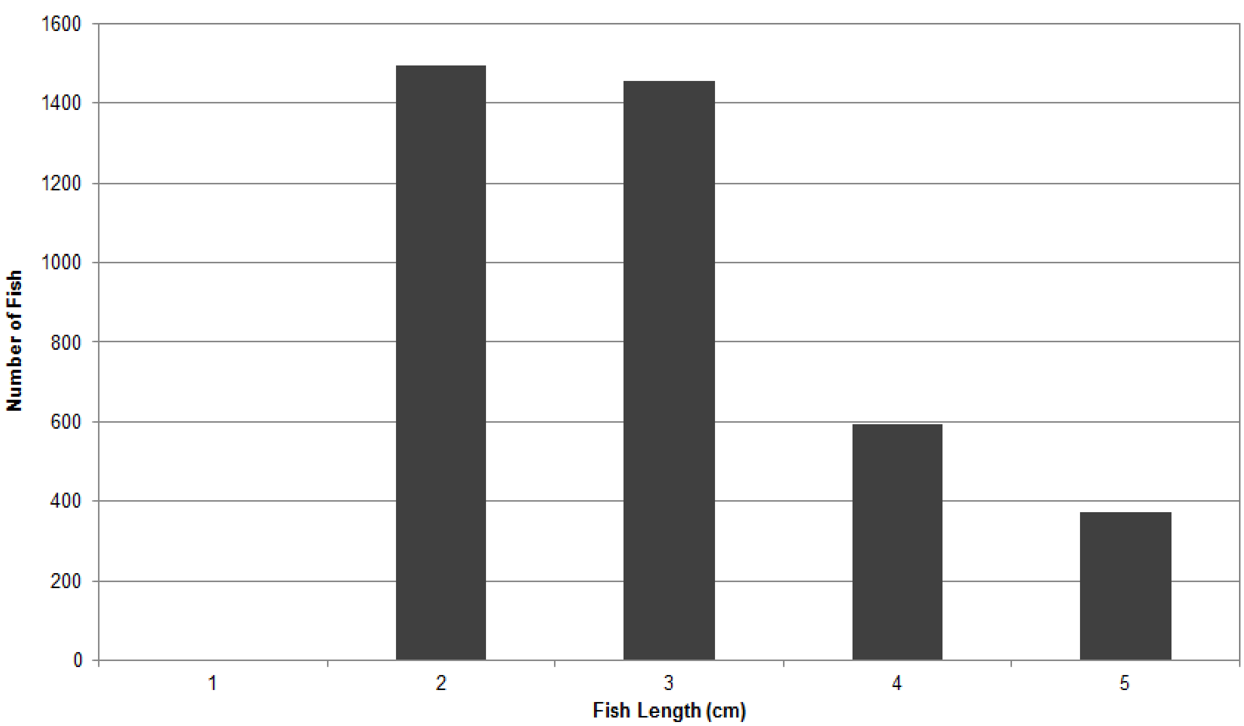


Figure 21. Frequency distribution of fish length for <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.

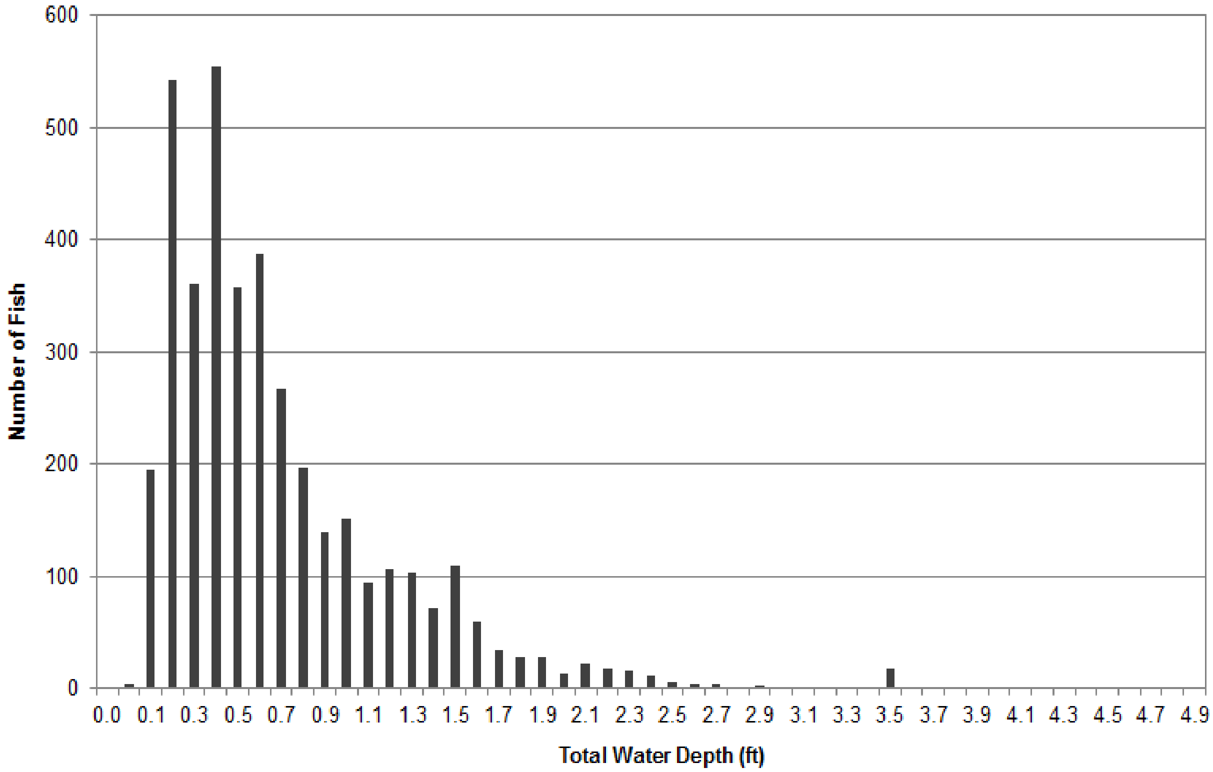


Figure 22. Total water depth frequency distribution for <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.

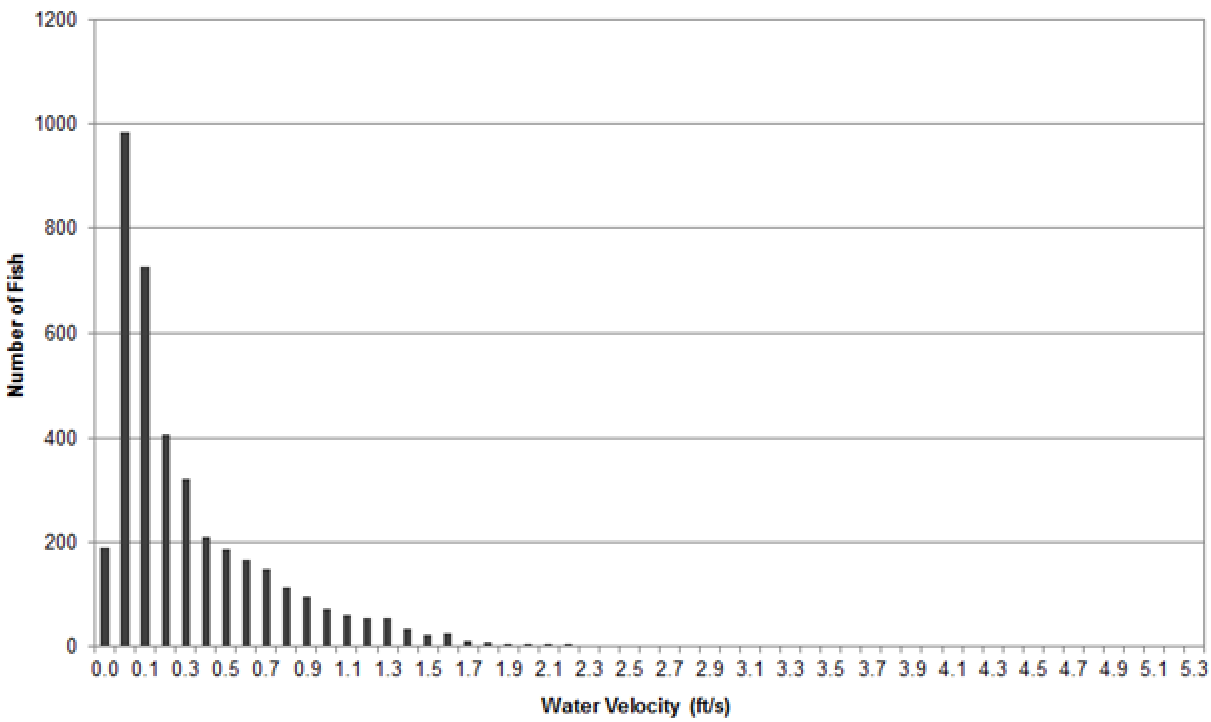


Figure 23. Frequency distribution for average water velocities used by <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.

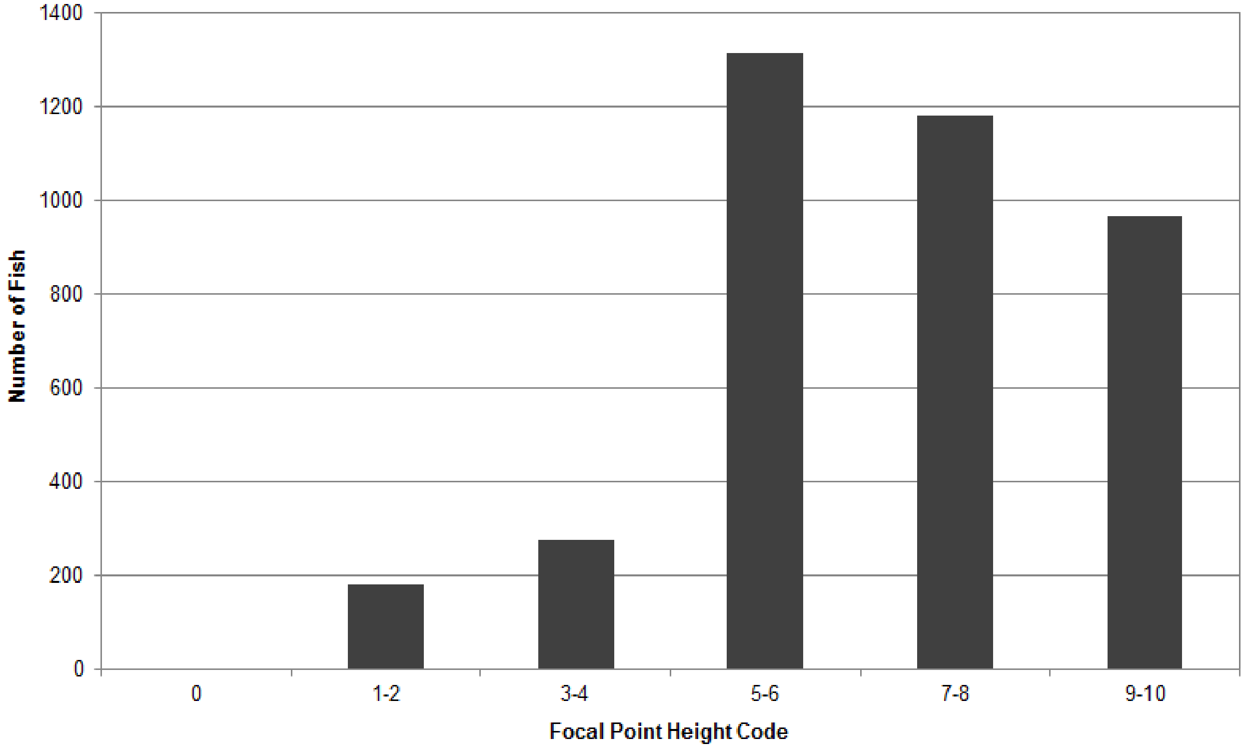


Figure 24. Frequency distribution of fish focal point height for <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.

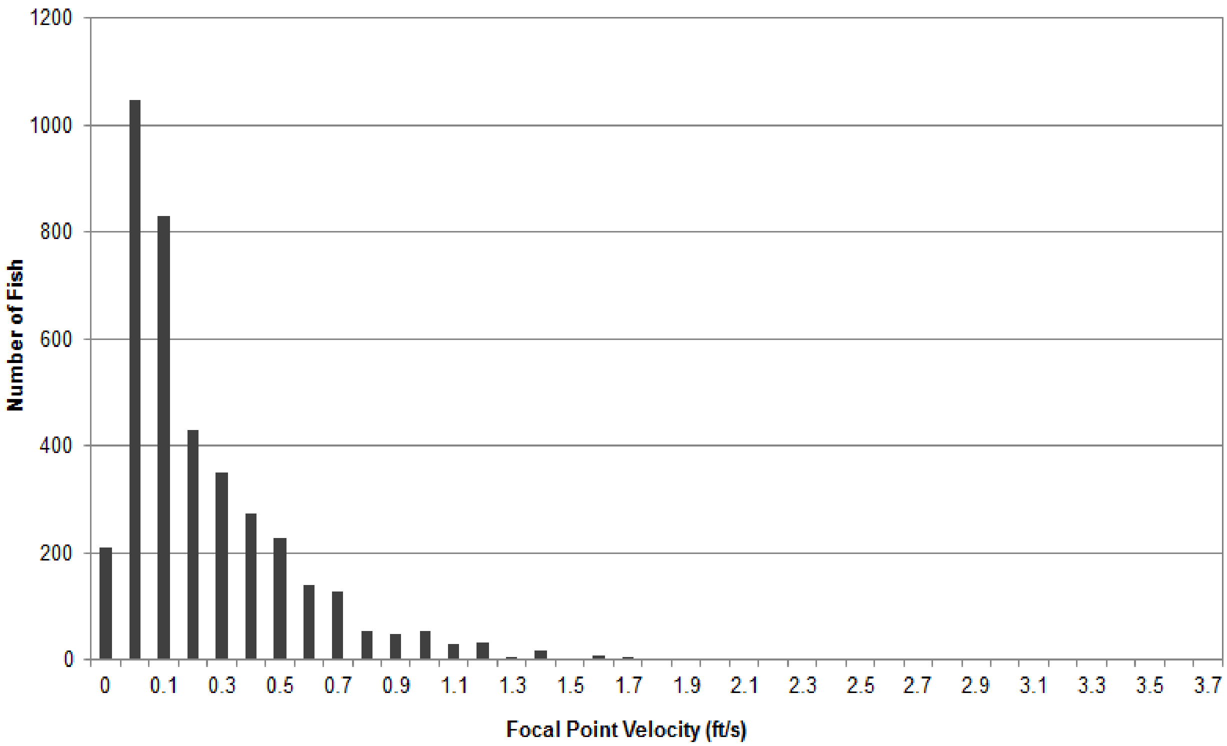
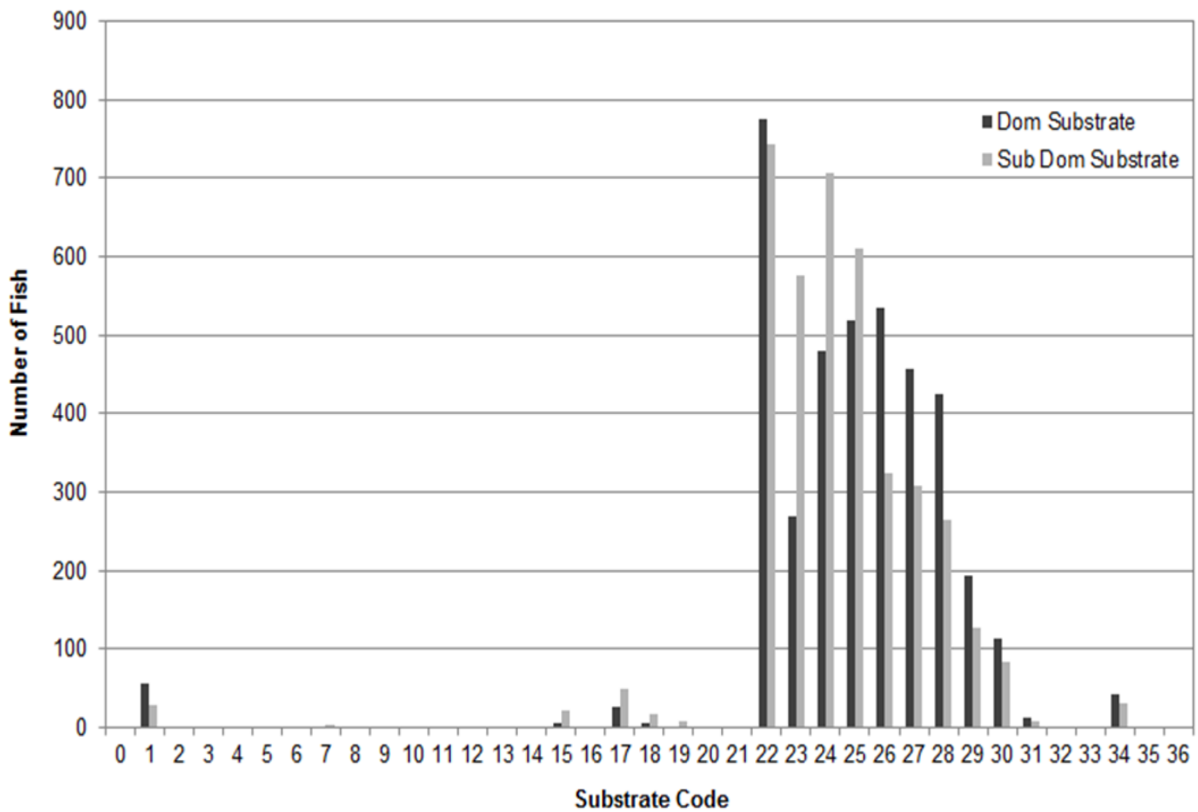


Figure 25. Frequency distribution for fish focal point water velocity used by <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 26. Frequency distribution for substrate types used by <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.

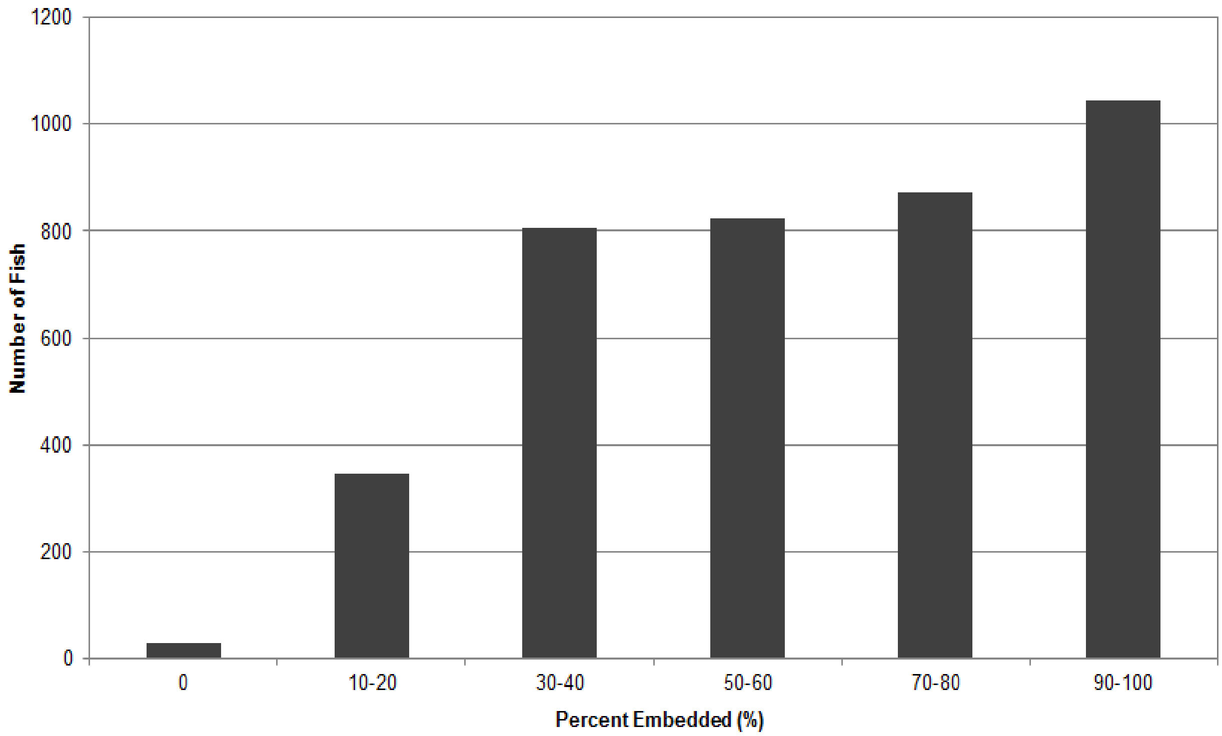
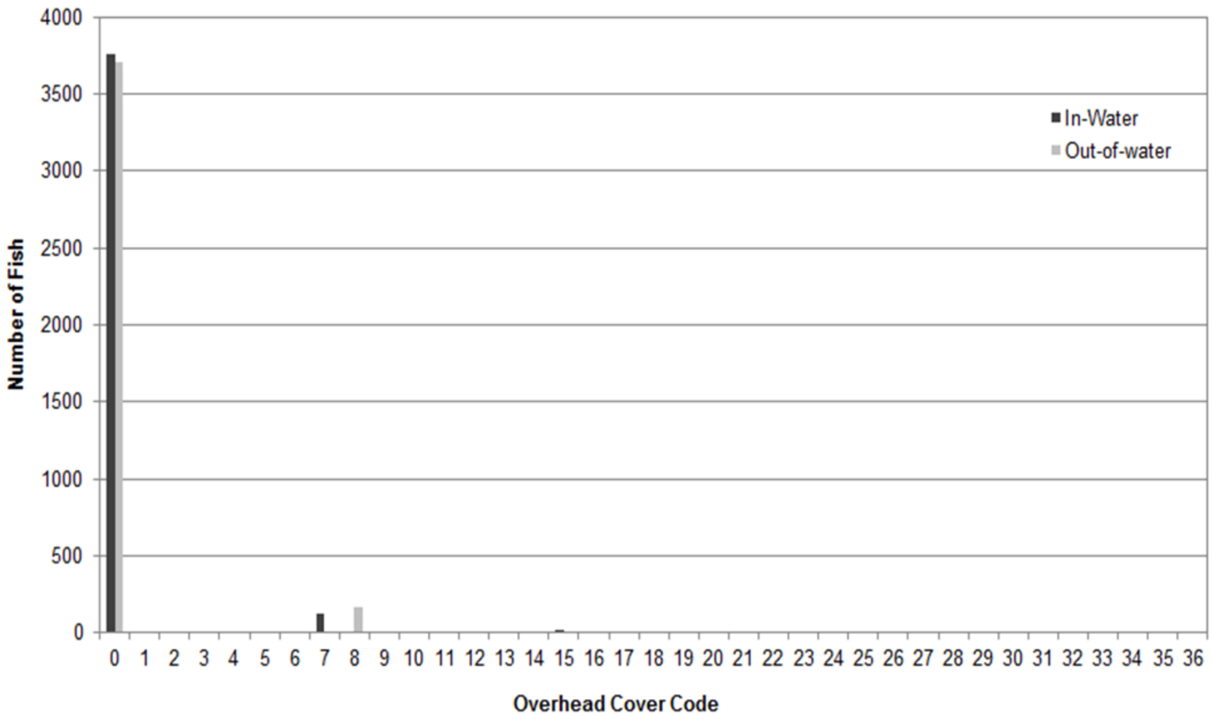


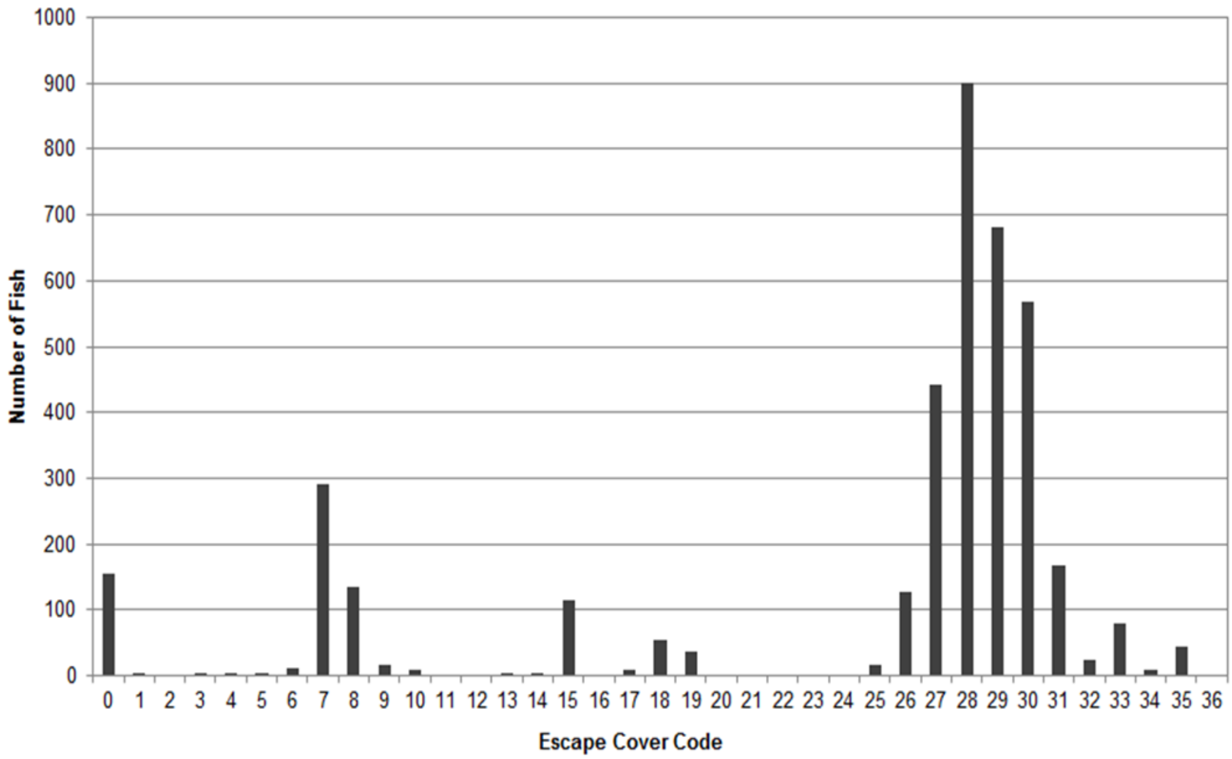
Figure 27. Frequency distribution for substrate percent embedded used by <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 28. Frequency distribution of nearest in-water and out-of-water overhead cover for <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 29. Frequency distribution for distance to escape cover for <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.

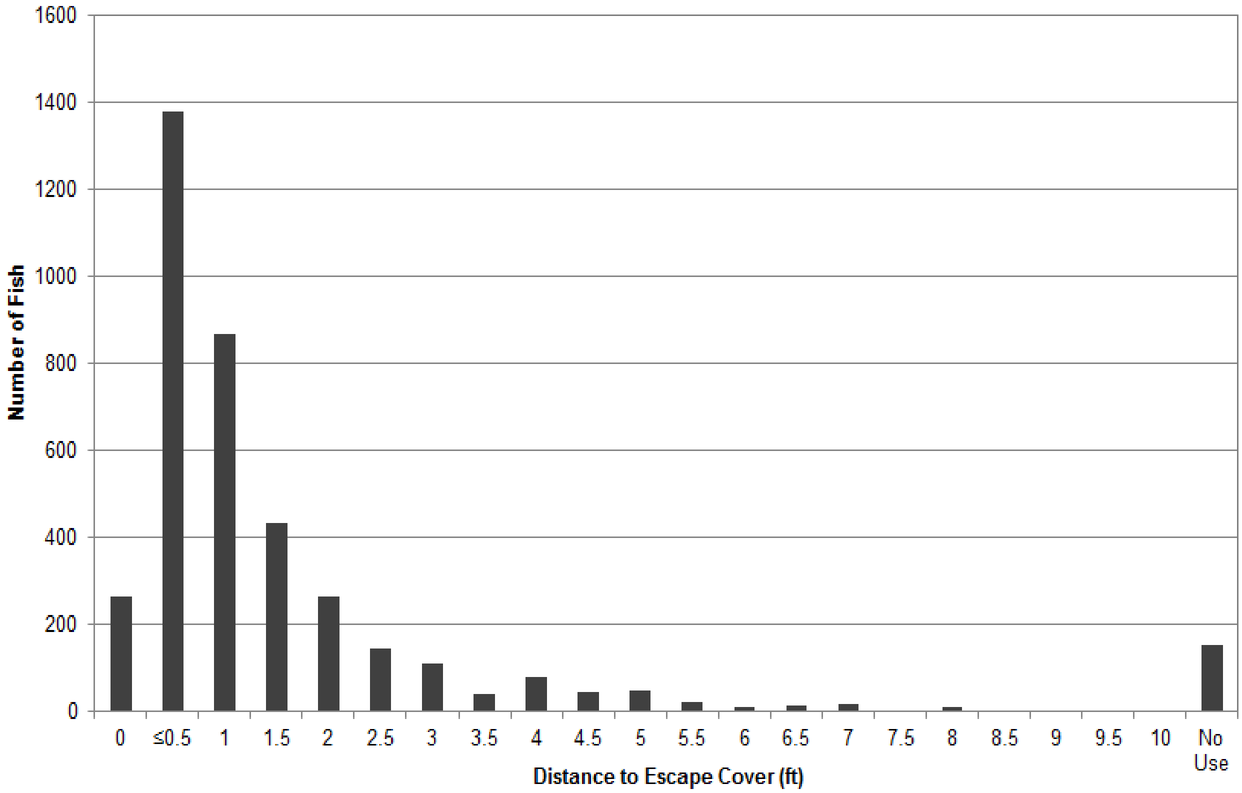


Figure 30. Frequency distribution for distance to escape cover for <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.

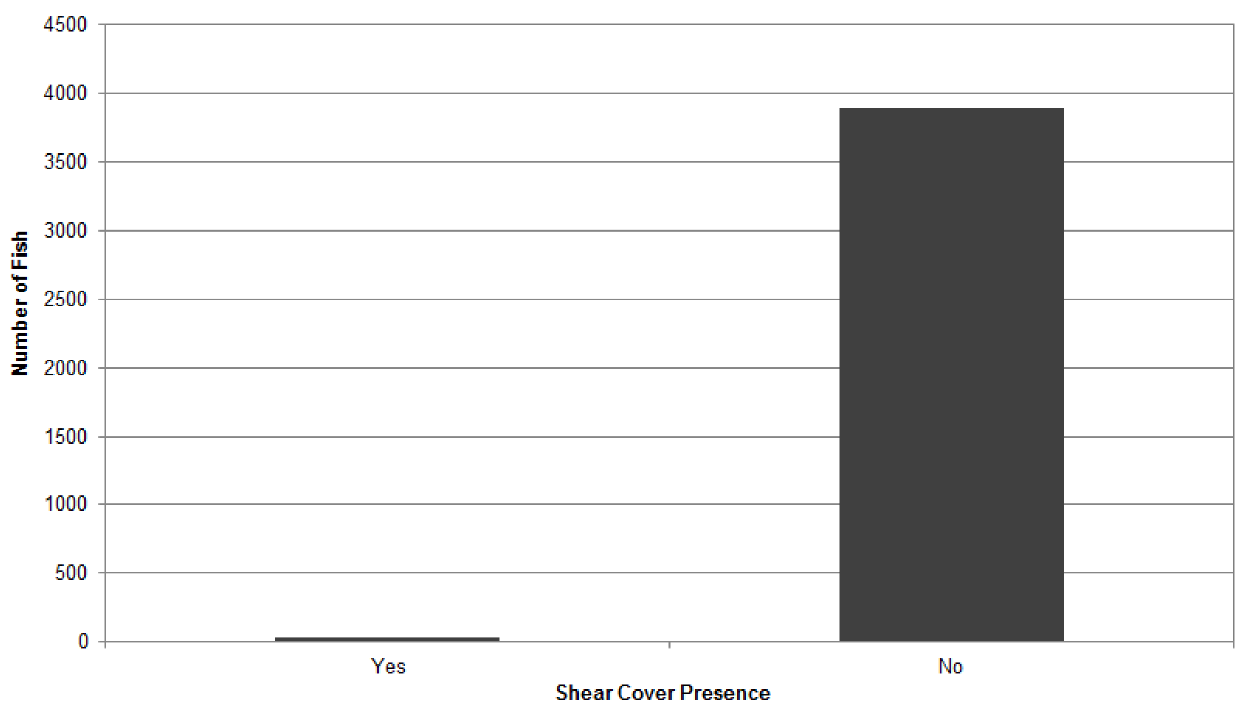


Figure 31. Frequency distribution for shear cover presence used by <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.

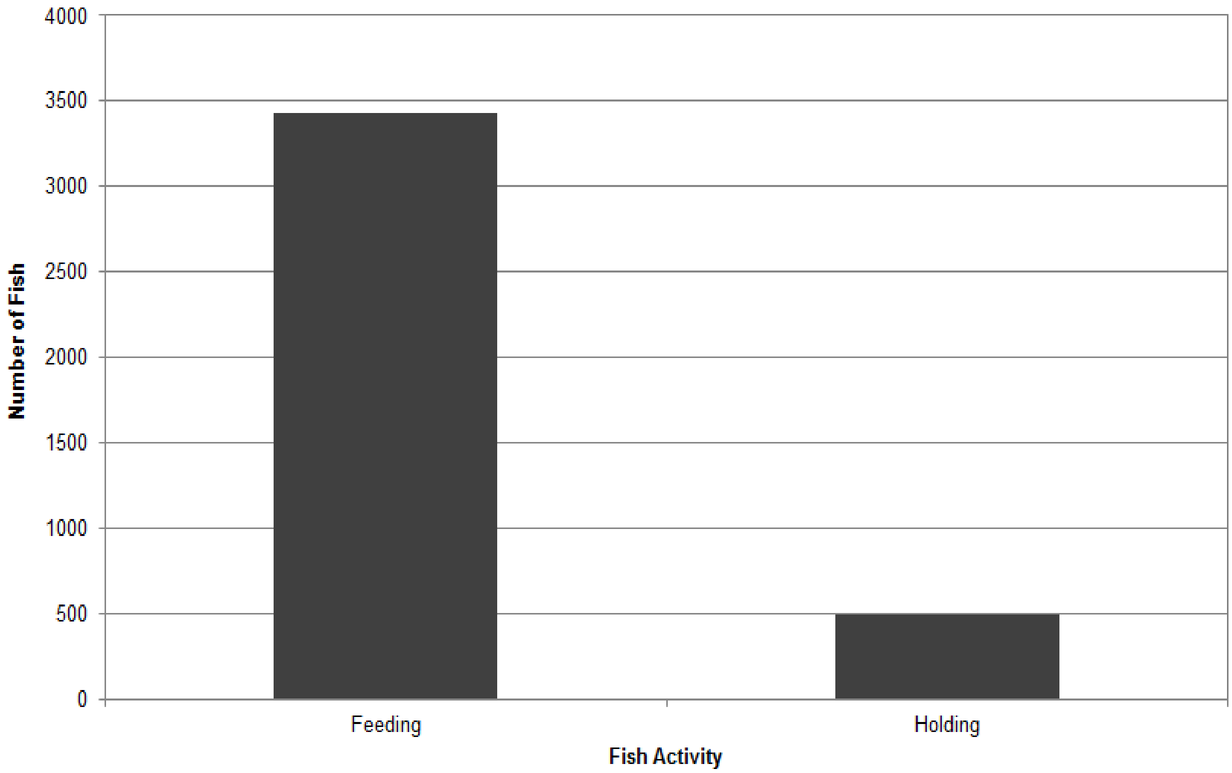
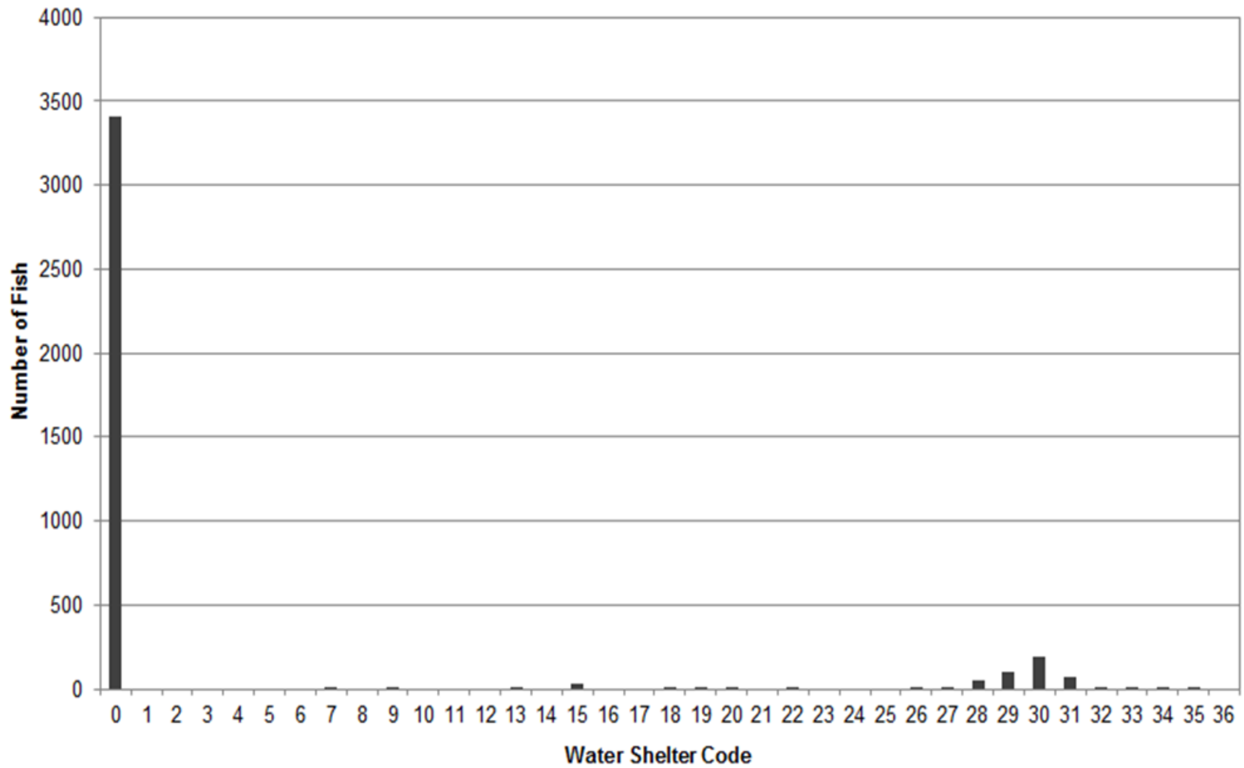


Figure 32. Frequency distribution of fish activity for <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 33. Frequency distribution for water shelter used by <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.

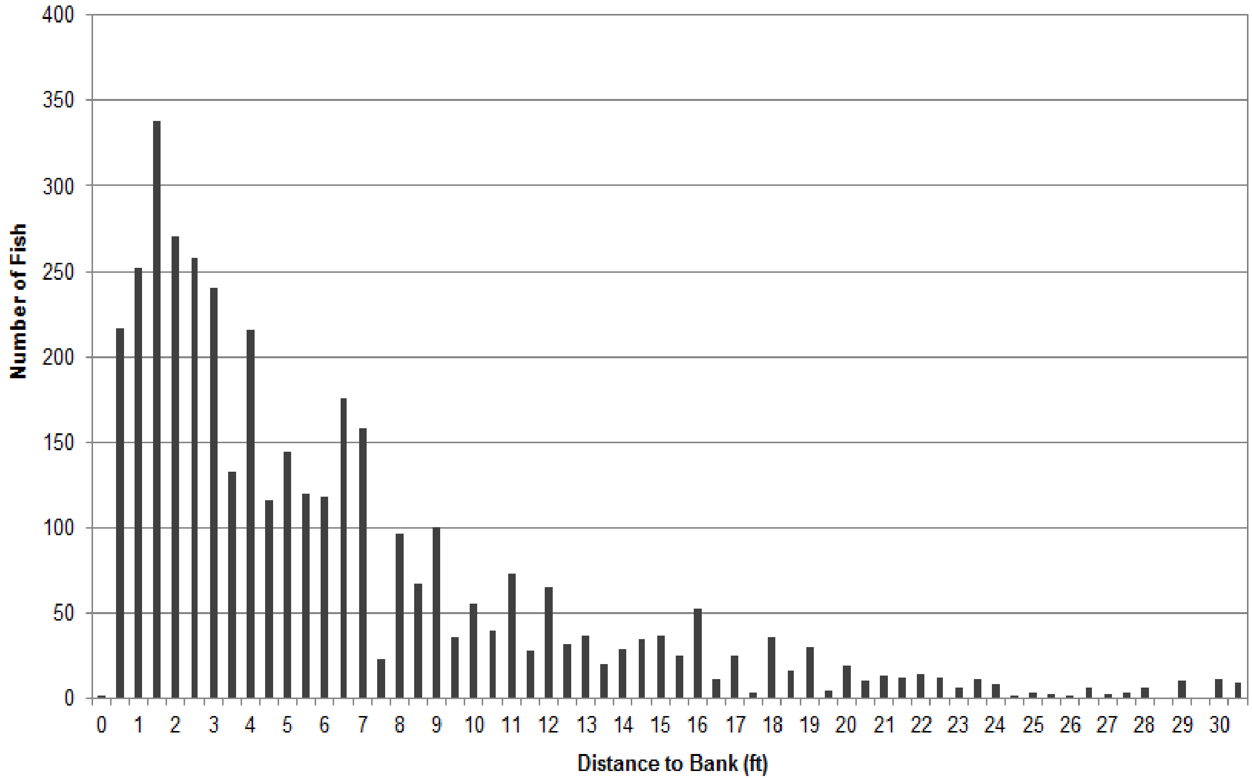
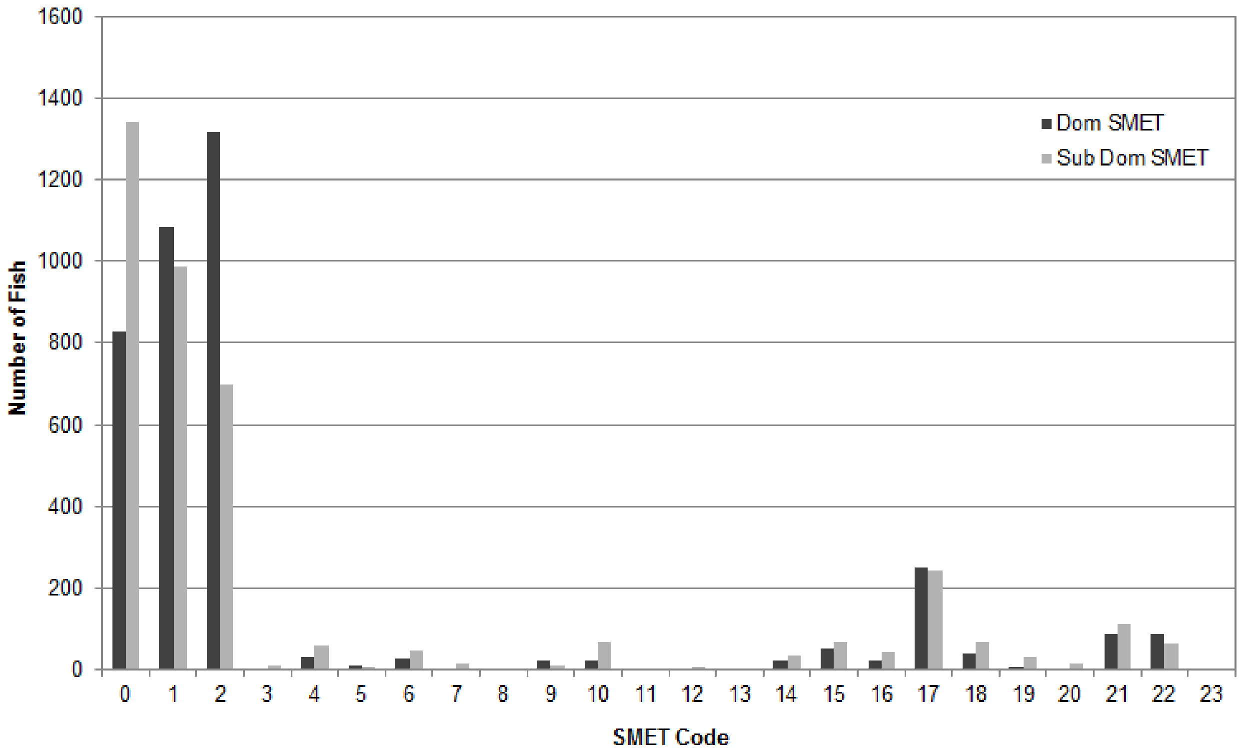


Figure 34. Frequency distribution for distance to bank for <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.



Code	SMET
0	Open
1	Gravel
2	Cobble/boulder
3	Sparse shrubs/herbs/vines/poison oak, IW
4	Sparse shrubs/herbs/vines/poison oak, OW
5	Sparse branches < 4 inches, IW
6	Sparse branches < 4 inches, OW
7	Sparse branches > 4 inches, IW
8	Sparse branches > 4 inches, OW
9	Dense branches < 4 inches, IW
10	Dense branches < 4 inches, OW
11	Dense branches > 4 inches, IW
12	Dense branches > 4 inches, OW
13	Trees < 4 inches
14	Trees > 4 inches
15	Small wood debris < 4 inches (dead)
16	Large woody debris > 4 inches (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

Figure 35. Distribution for stream margin edge type (SMET) used by <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.

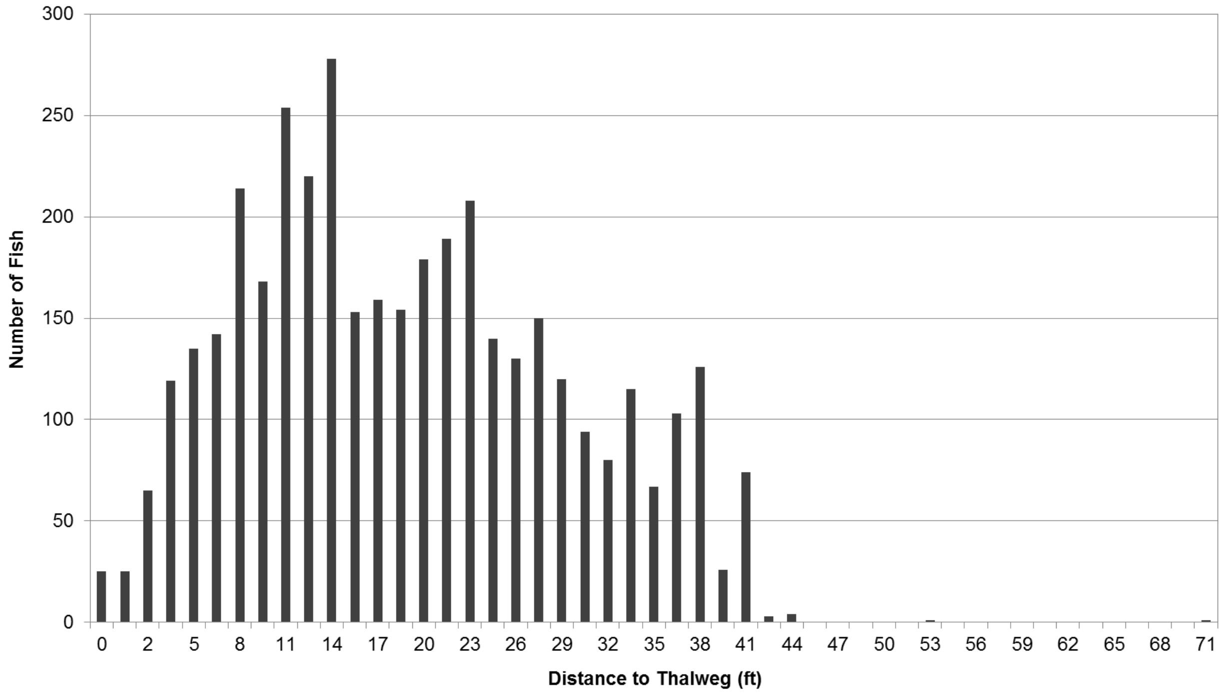


Figure 36. Frequency distribution for distance to thalweg for <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.

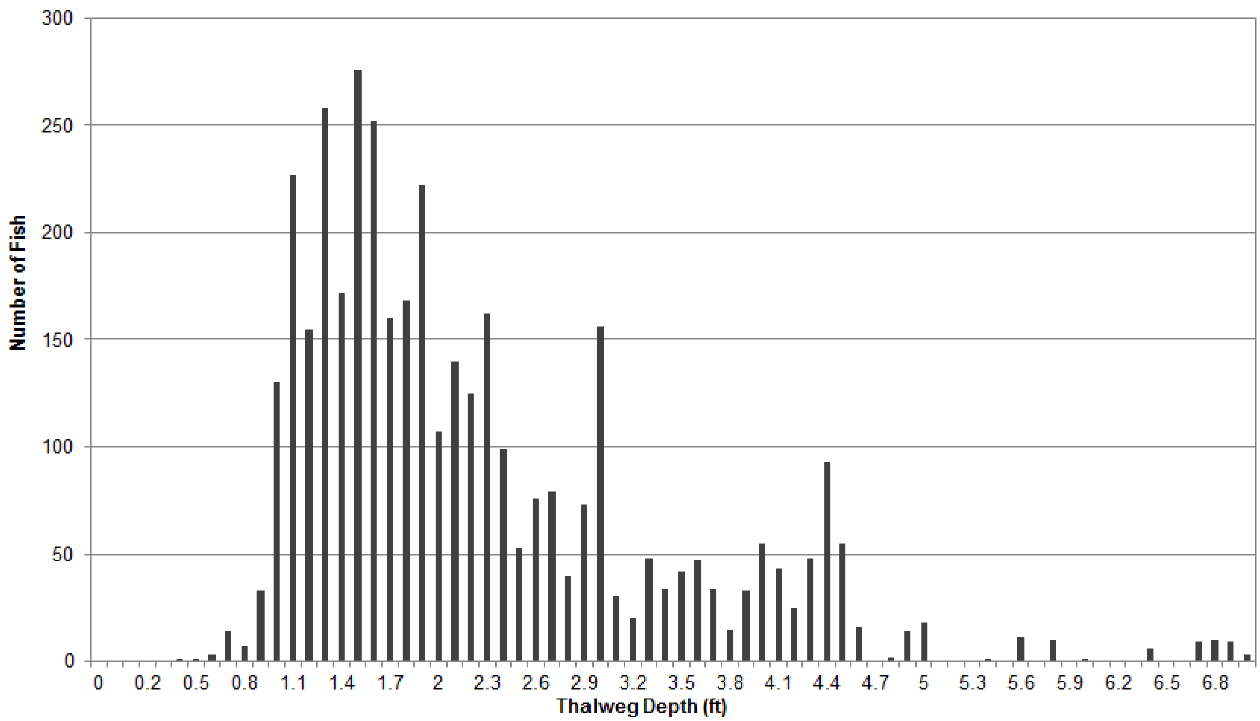


Figure 37. Frequency distribution of thalweg depth for <6 cm juvenile steelhead observed in Big Sur River, spring 2012.

Summer Habitat Use

Habitat use statistics for 6-9 cm and 10-15 cm juvenile steelhead observed in the Big Sur River in summer 2010 (June and August) are outlined in Table 12. The number of 6-9 cm and 10-15 cm fish observed per a mesohabitat type in summer are in Figure 38 and Figure 39, respectively. Steelhead 6-9 cm and 10-15 cm were found in all habitat types, with most 6-9 cm occurring in run mesohabitat type in summer. Steelhead 10-15 cm were fairly evenly distributed among run, low gradient riffle, and pool habitat. Frequencies of fish sizes observed in summer for 6-9 cm and 10-15 cm are in Figures 40 and 41, respectively.

Table 12. Habitat use statistics for 6-9 cm and 10-15 cm juvenile steelhead observed in the Big Sur River in summer 2010.

Fish Size	Statistic	N	Minimum	Maximum	Average	Median	Std. Dev.
6-9 cm	Water Depth (ft)	748	0.30	4.75	1.35	1.20	0.55
	Water Velocity (ft/s)	748	0.00	4.31	1.43	1.39	0.65
	Fish Focal Point Height	748	6	10	8.91	9.00	0.82
	Fish Focal Point Water Velocity (ft/s)	740	0.00	3.25	0.89	0.83	0.55
	Distance to Escape Cover (ft)	650	0.00	10.00	3.02	2.50	2.30
	Distance to Bank (ft)	738	1.00	29.00	10.81	10.00	4.91
10-15 cm	Water Depth (ft)	609	0.60	4.75	1.60	1.50	0.62
	Water Velocity (ft/s)	609	0.06	5.24	1.47	1.43	0.73
	Fish Focal Point Height	609	6	10	8.50	9.00	0.82
	Fish Focal Point Water Velocity (ft/s)	605	0.00	3.75	1.02	0.97	0.59
	Distance to Escape Cover (ft)	523	0.00	10.00	3.07	2.50	2.28
	Distance to Bank (ft)	608	1.00	28.00	10.30	10.00	4.41

Total Water Depth: Juvenile steelhead 6-9 cm were observed in locations with water depths ranging from 0.30 ft to 4.75 ft (Table 12). Juvenile steelhead 10-15 cm were observed in locations with water depths ranging from 0.60 ft to 4.75 ft. The average water depths where juvenile steelhead 6-9 cm and 10-15 cm were observed were 1.35 ft and 1.6 ft, respectively. The histograms of water depth frequencies for 6-9 cm steelhead and 10-15 cm steelhead are shown in Figures 42 and 43, respectively.

Average Water Velocity: Juvenile steelhead 6-9 cm were observed in locations with average water velocities ranging from 0.00 ft/s to 4.31 ft/s (Table 12). Juvenile steelhead 10-15 cm were observed in locations with average water velocities ranging from 0.06 ft/s to 5.24 ft/s. The average water velocities where juvenile steelhead 6-9 cm and 10-15 cm were observed were 1.43 ft/s and 1.47

ft/s, respectively. The histograms of average water velocity frequencies for 6-9 cm and 10-15 cm steelhead are shown in Figures 44 and 45, respectively.

Fish Focal Point Position: The focal point position (from the water surface to the fish with 0 = water surface and 10 = on stream bottom) of juvenile 6-9 cm and 10-15 cm steelhead at which the fish were observed ranged from 6 to 10. The median fish focal point position was 9 for both 6-9 cm and 10-15 cm juvenile steelhead (Table 12).The histograms of fish focal point water depth frequencies are shown in Figures 46 and 47, respectively.

Fish Focal Point Velocity: Water velocities at the fish focal point were slightly less than average water column velocities. Focal point velocities ranged from 0.00 ft/s to 3.75 ft/s for juvenile 6-9 cm and 10-15 cm steelhead (Table 12). The histograms of fish focal point velocity frequencies are shown in Figures 48 and 49, respectively.

Substrate: Juvenile 6-9 cm and 10-15cm steelhead were predominately observed occupying sites with gravel and cobble substrates (Figures 50 and 51).

Embeddedness: Juvenile 6-9 cm and 10-15cm steelhead were predominately observed at locations with embeddedness values ranging from 30-80 percent (Figures 52 and 53).

Fish Activity: Most 6-9 cm and 10-15 cm steelhead were observed feeding, as opposed to holding (Figures 54 and 55).

Overhead Cover: Over 99 percent of 6-9 cm and 10-15 cm fish during summer occurred at locations with no overhead cover (Figures 56 and 57). Branches and/or small vegetation (both in-water and out-of-water) were used occasionally by both size groups of fish.

Escape Cover: Juvenile steelhead 6-9 cm and 10-15 cm during summer were observed in proximity to a variety of escape cover types (Figures 58 and 59). The most common types of escape cover near the fish observation locations for both 6-9 am and 10-15 cm fish were cobble and boulders, followed by branches in water. Approximately 12 and 14 percent of 6-9 cm and 10-15 cm steelhead were observed selecting habitat locations without any type of escape cover, respectively.

Distance to Escape Cover: Most juvenile 6-9 cm and 10-15 cm steelhead were observed to be within approximately 2 ft of escape cover (Figures 60 and 61). The average distance to escape cover was 3 ft for both 6-9 cm and 10-15 cm juvenile steelhead (Table 12). Approximately 13 and 14 percent of 6-9 cm and 10-15 cm steelhead were observed selecting habitat locations not near (>10 ft) any type of escape cover, respectively.

Shear Zone: Over 95 percent of 6-9 cm and 10-15 cm steelhead were observed to not be selecting locations with a discernable shear zone present (Figures 62 and 63).

Water Velocity Shelter: Most juvenile 6-9 cm steelhead were selecting sites that did not contain a water velocity shelter (Figure 64). About half of juvenile 10-15 cm steelhead were selecting sites that contained a water velocity shelter (Figure 65). When a velocity shelter was being used by juvenile 6-9 and 10-15 cm steelhead it was predominately consisted of cobble and/or boulders.

Distance to Bank: Juvenile steelhead 6-9 cm and 10-15 cm were observed from 1-29 feet from the bank (Figures 66 and 67).

SMET: Juvenile 6-9 cm and 10-15 cm steelhead were observed selecting locations adjacent to a variety of SMET types (Figures 68 and 69). The most common types of SMET fish were observed adjacent to were cobble, roots, and open types.

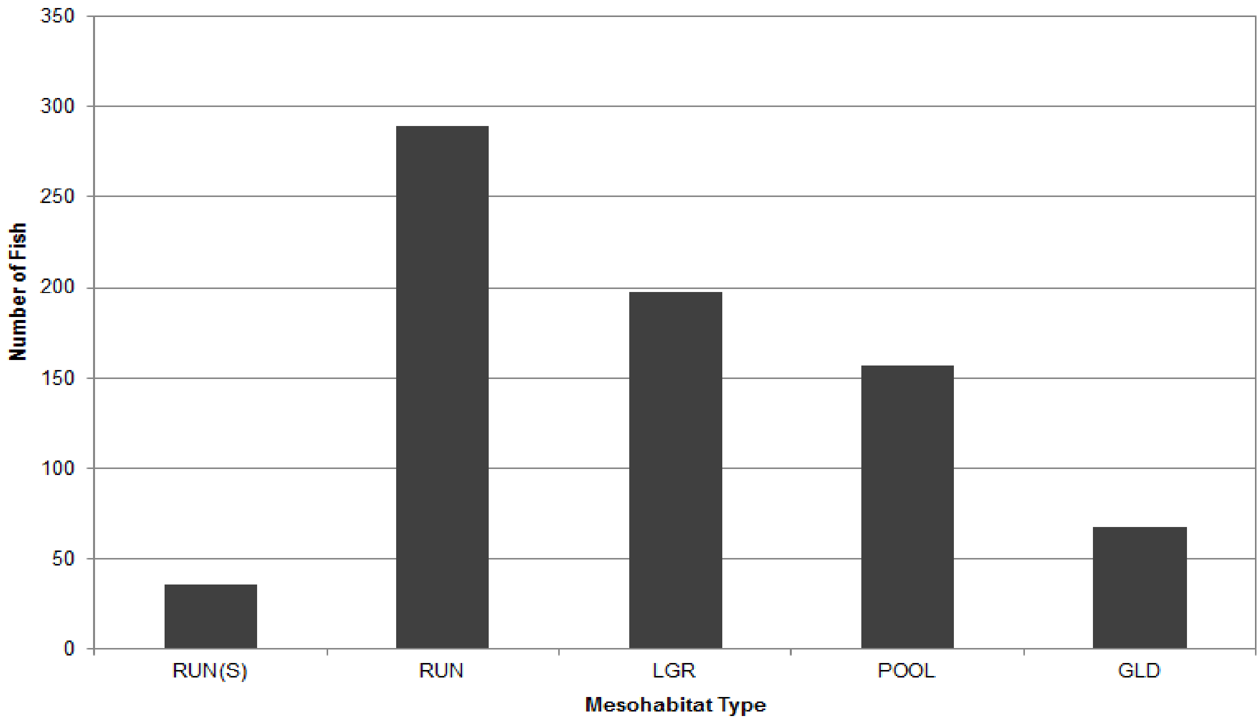


Figure 38. Frequency distribution of 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.

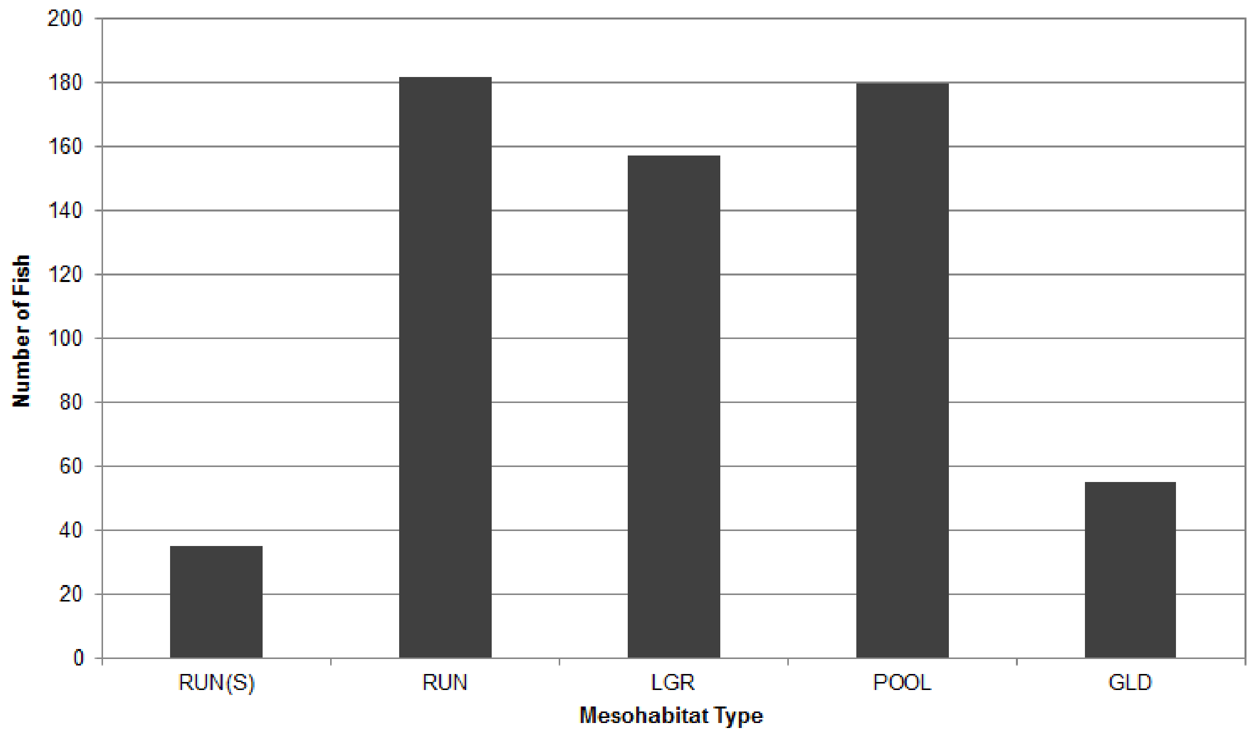


Figure 39. Frequency distribution of 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.

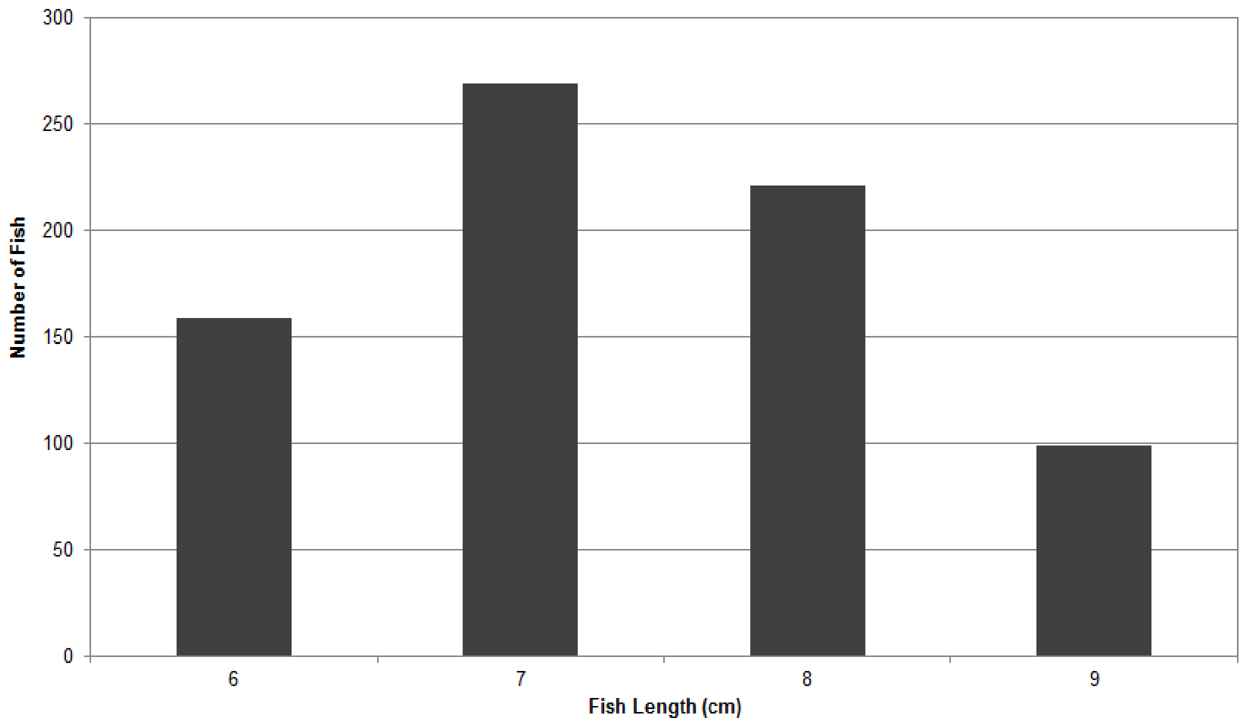


Figure 40. Frequency distribution of fish length for 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.

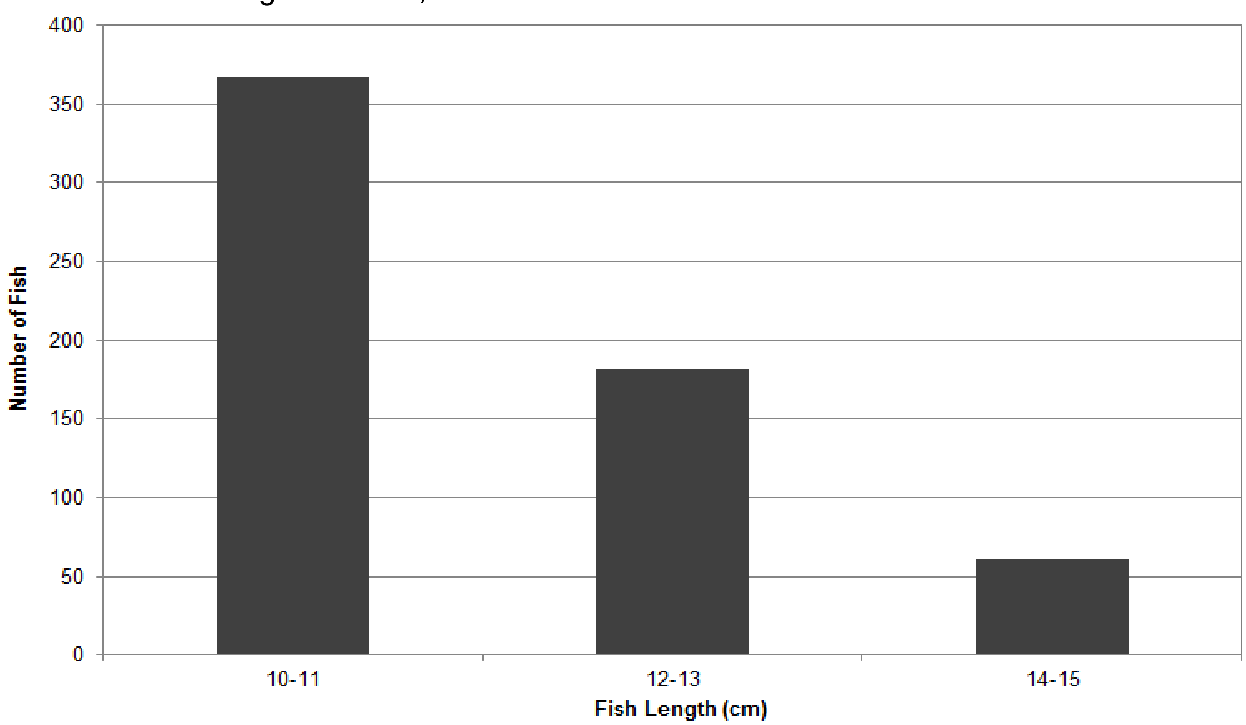


Figure 41. Frequency distribution of fish length for 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.

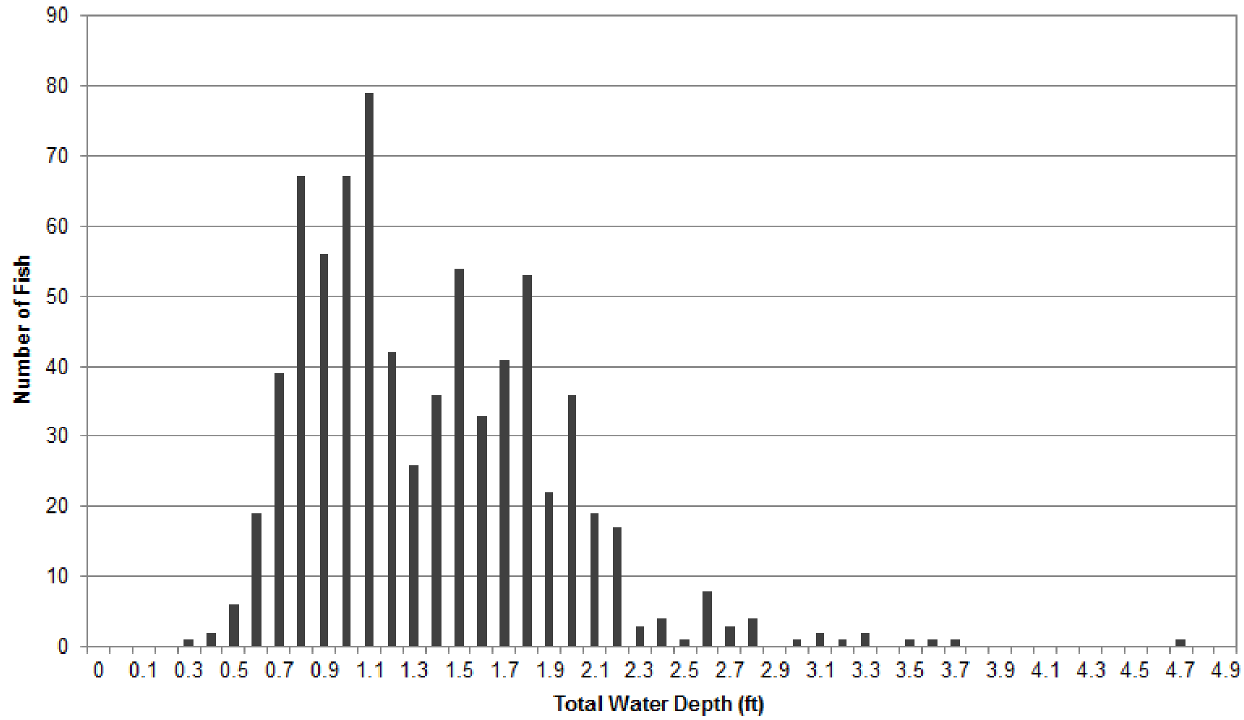


Figure 42. Total water depth frequency distribution for 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.

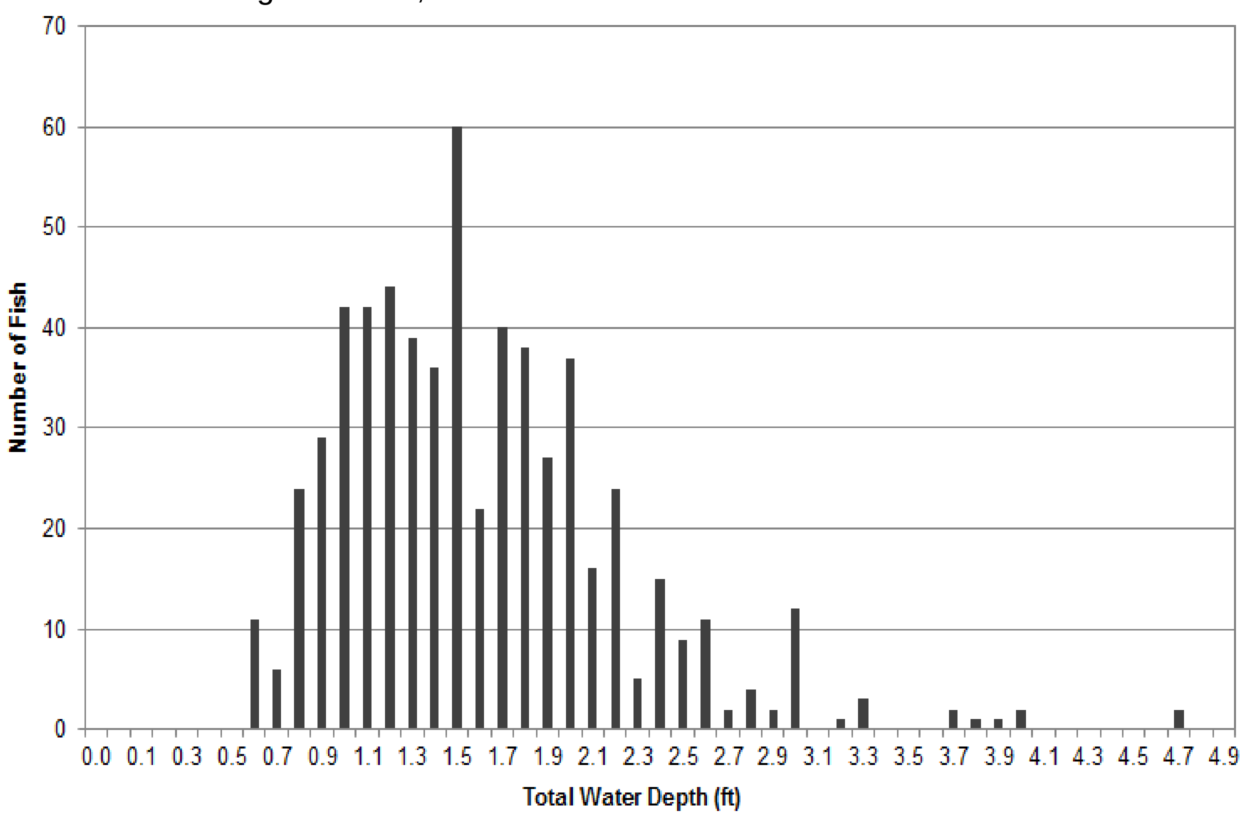


Figure 43. Total water depth frequency distribution 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.

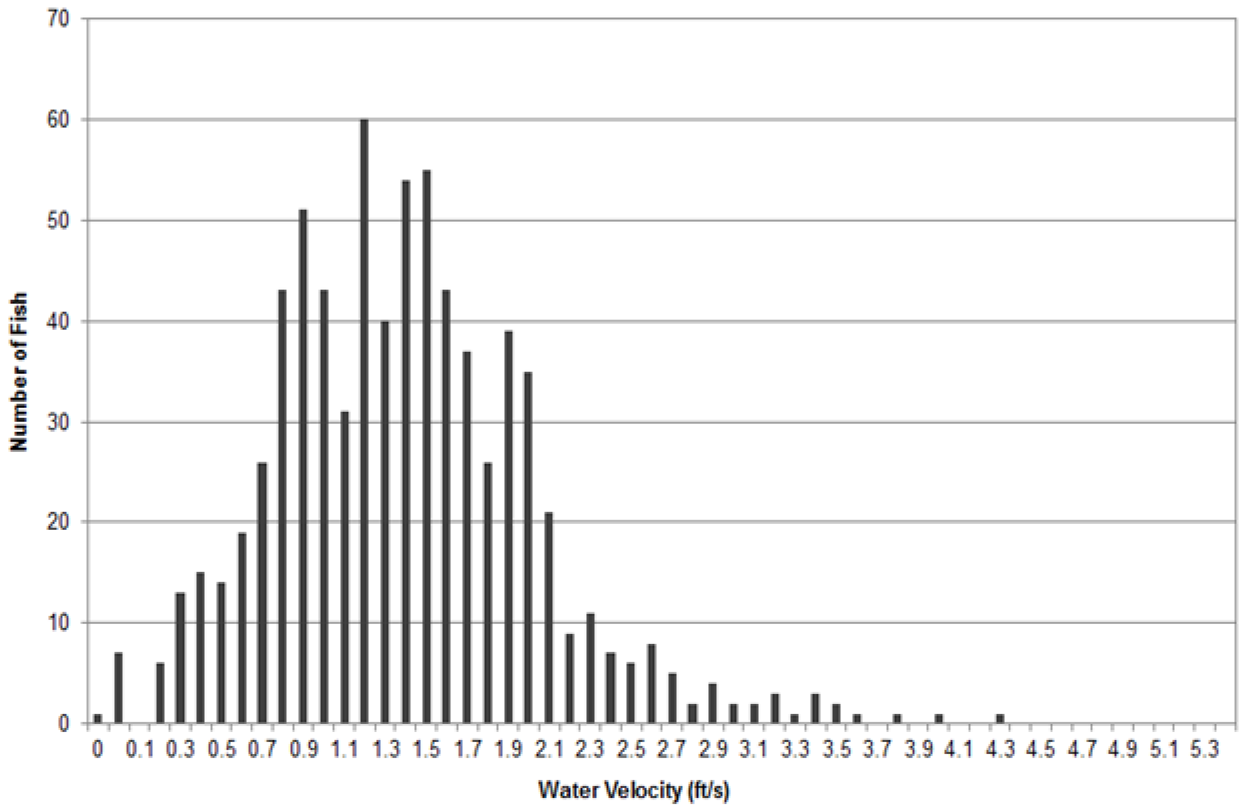


Figure 44. Frequency distribution for average water velocities used by 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.

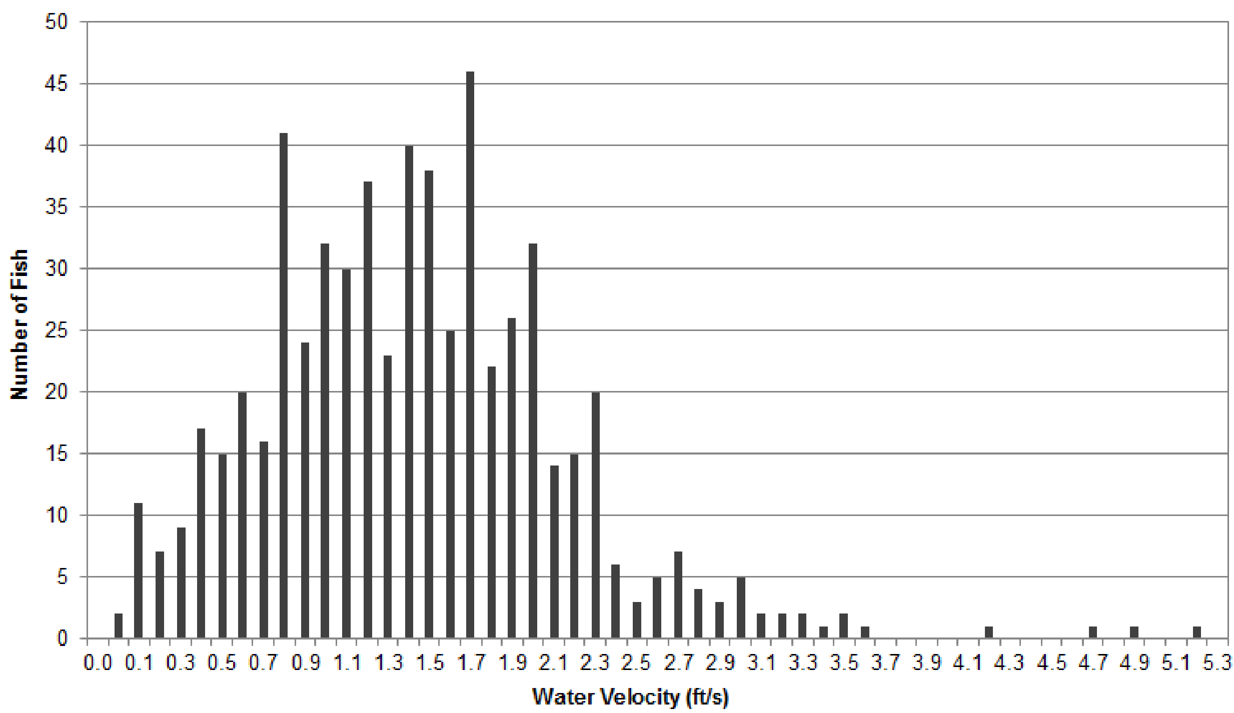


Figure 45. Frequency distribution for average water velocities used by 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.

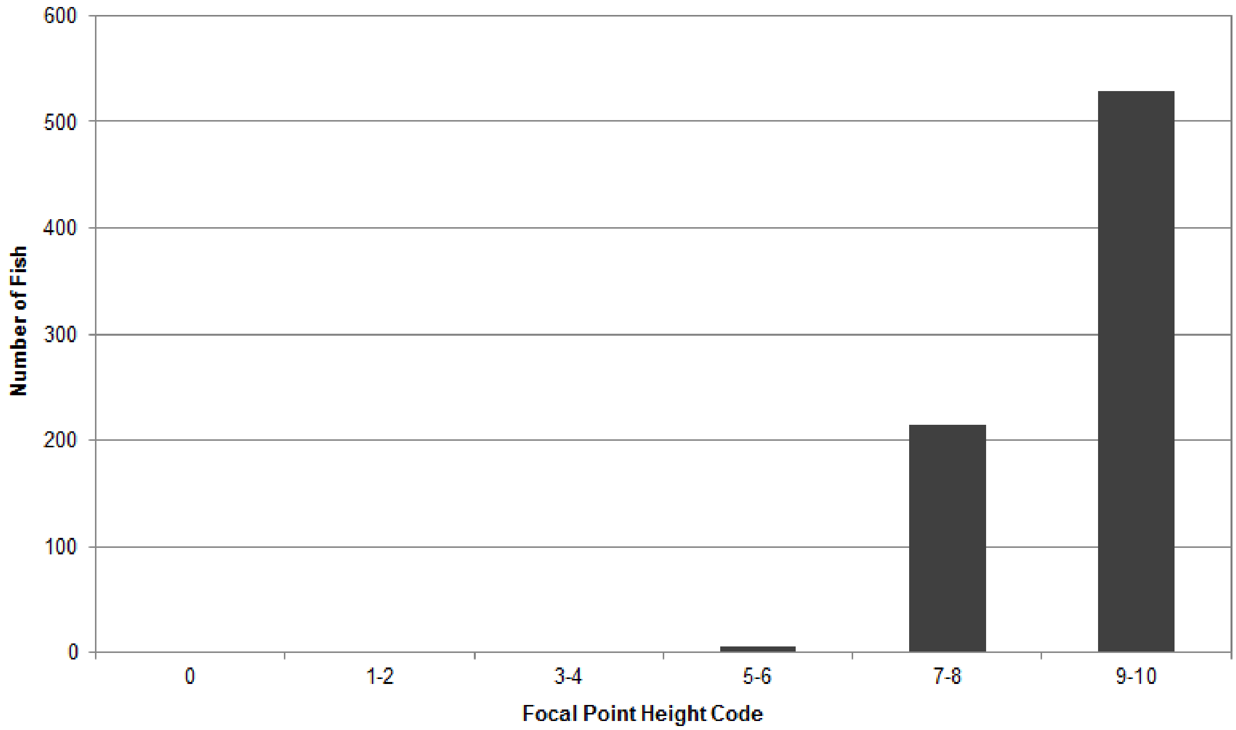


Figure 46. Frequency distribution of fish focal point height for 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.

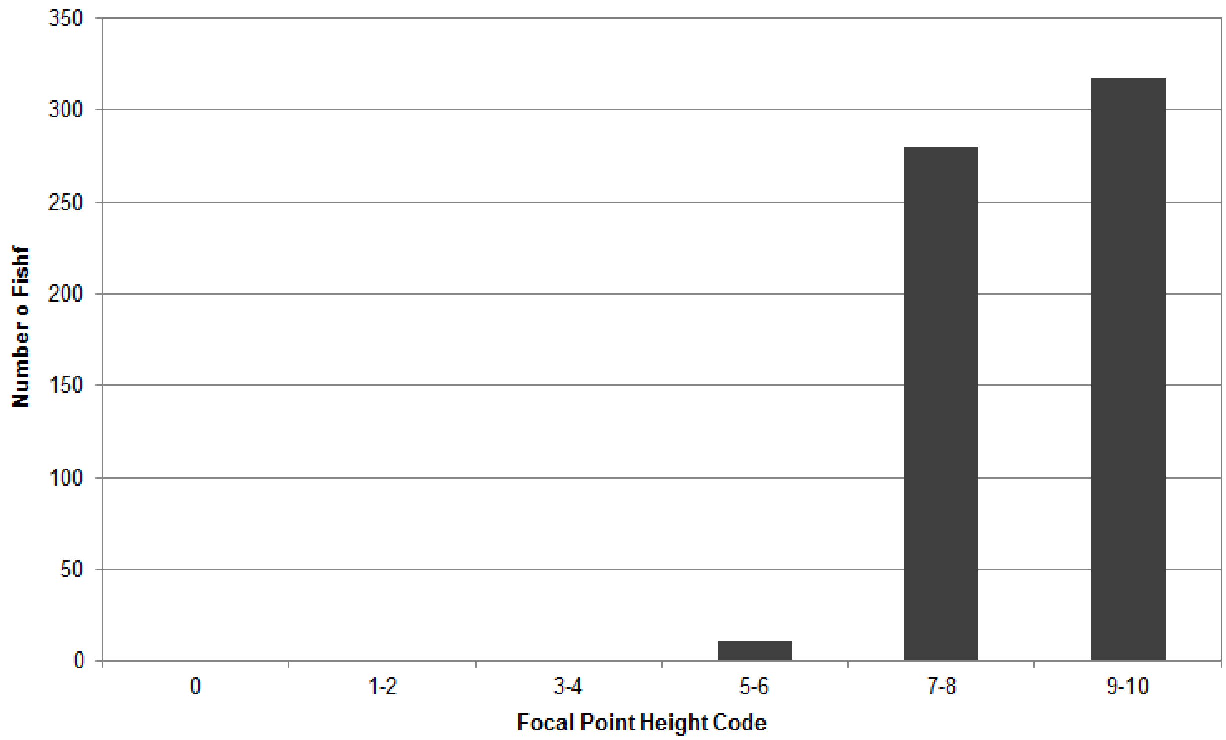


Figure 47. Frequency distribution of fish focal point height for 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.

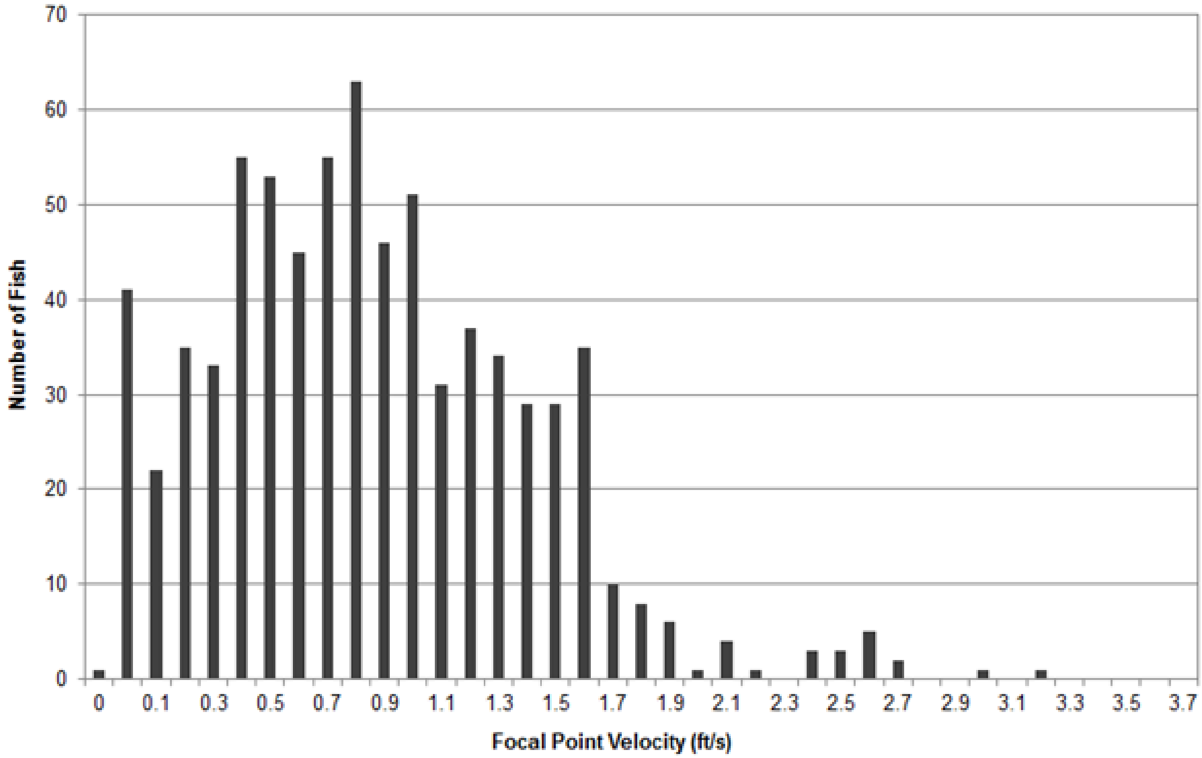


Figure 48. Frequency distribution for fish focal point water velocity used by 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.

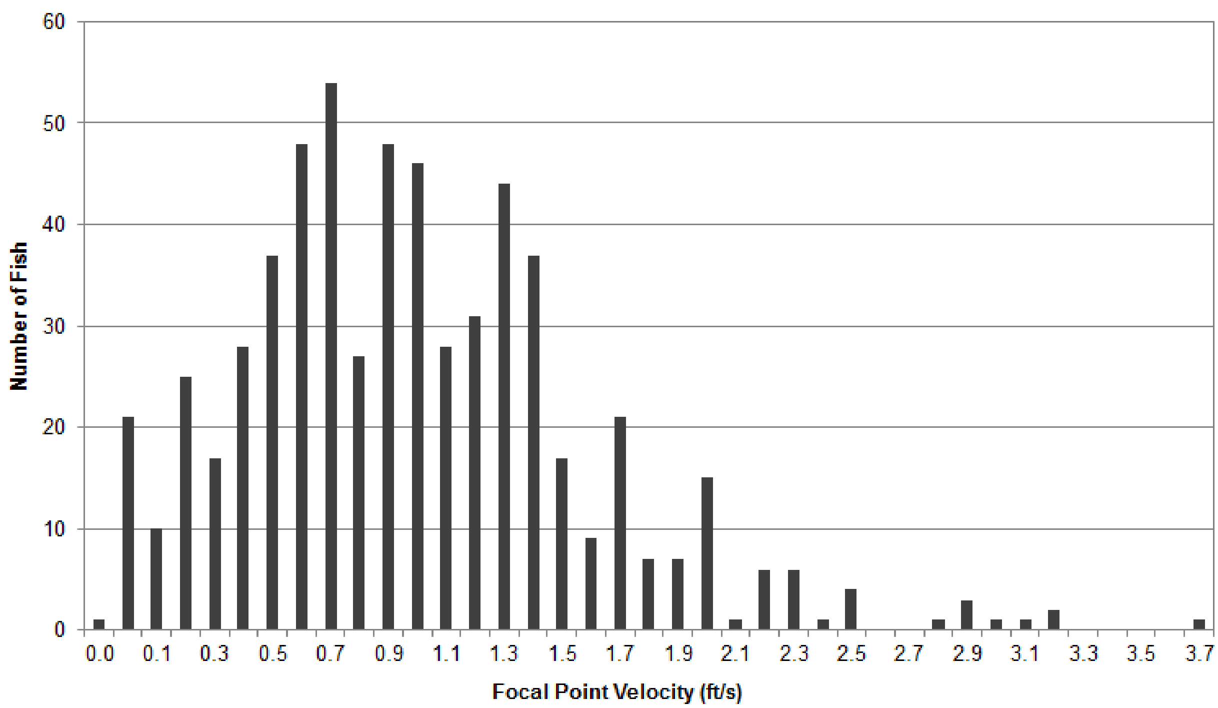
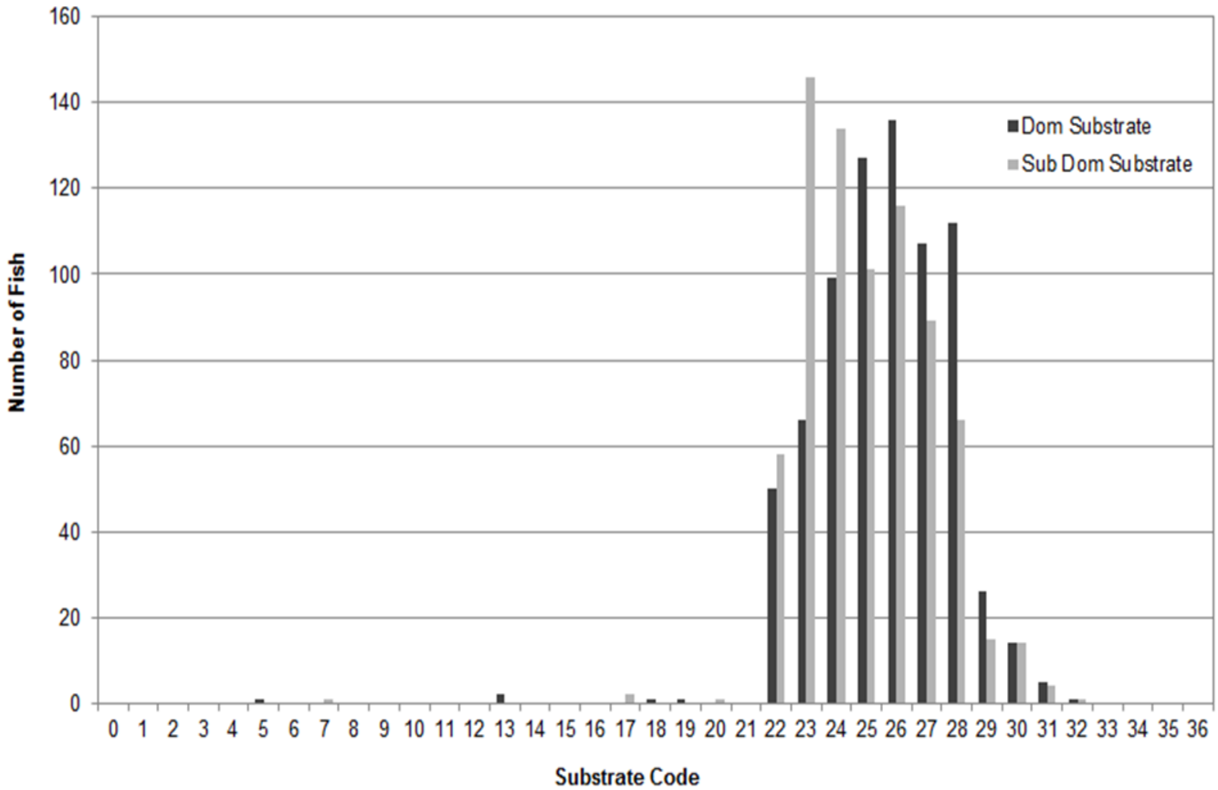


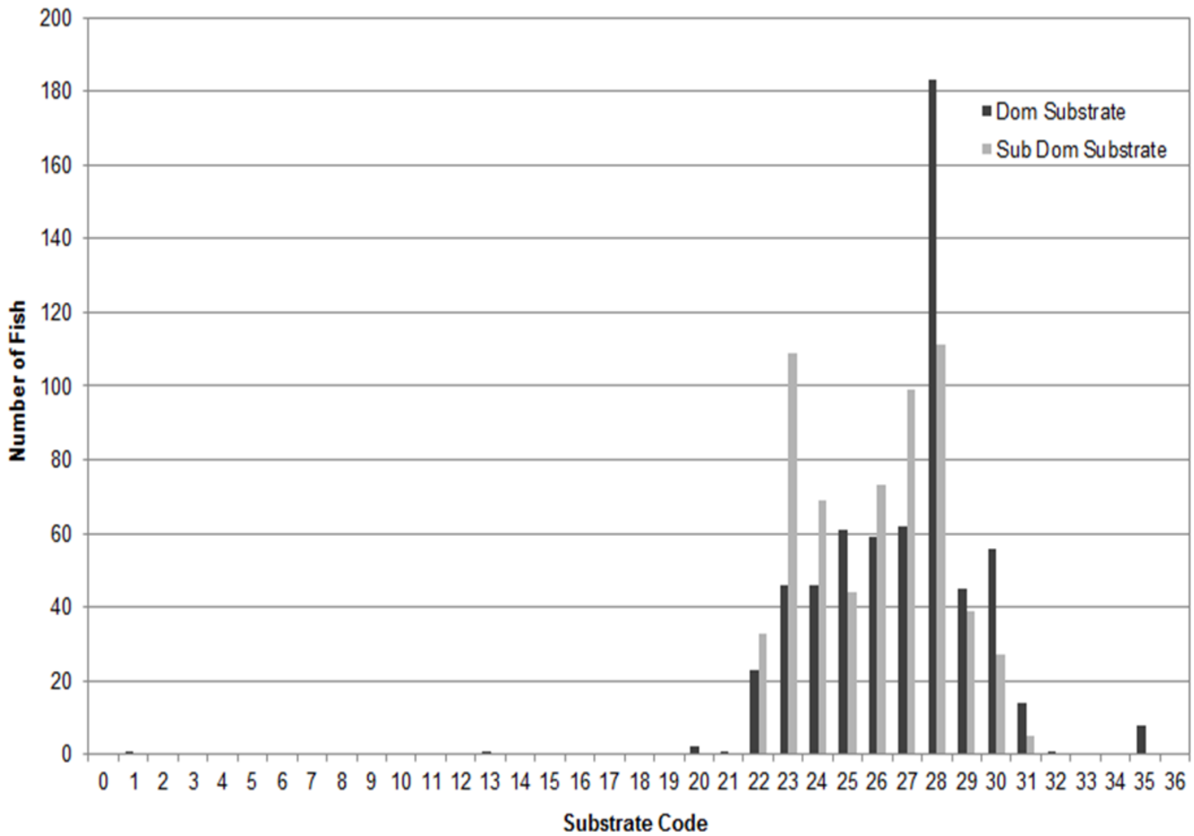
Figure 49. Frequency distribution for fish focal point water velocity used by 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 50. Frequency distribution for substrate types used by 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
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13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 51. Frequency distribution for substrate types used by 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.

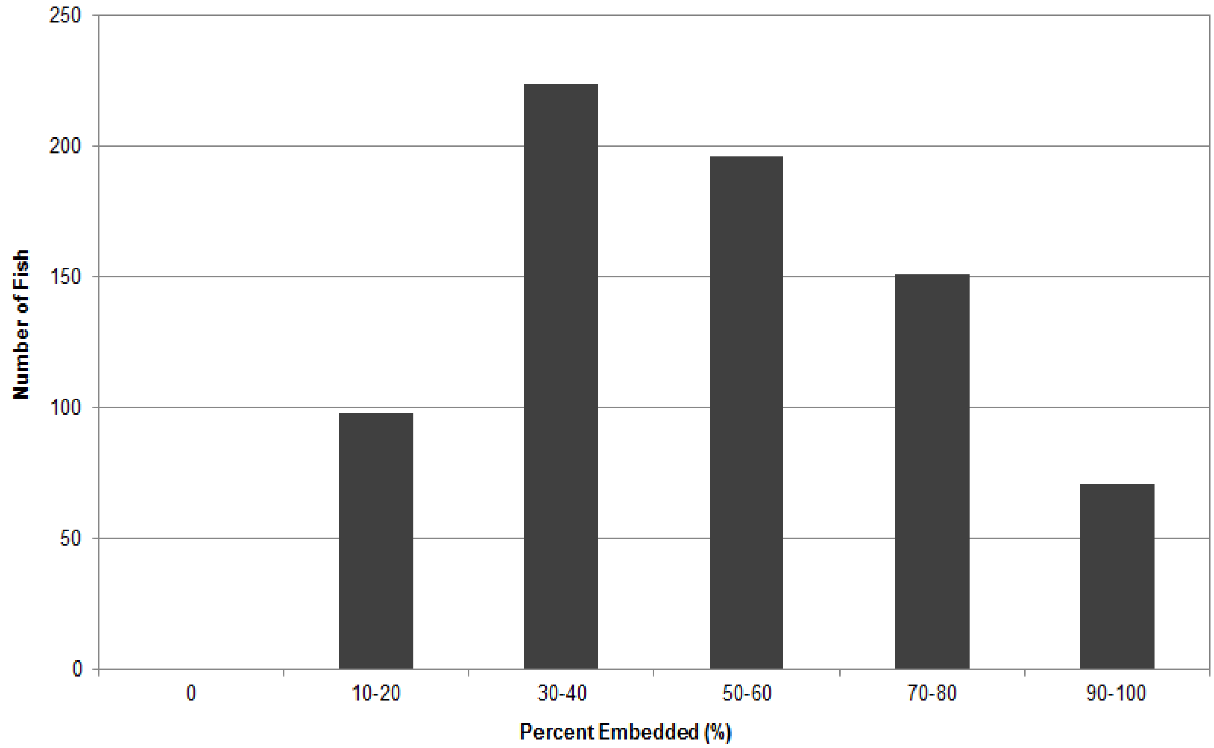


Figure 52. Frequency distribution for substrate percent embedded used by 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.

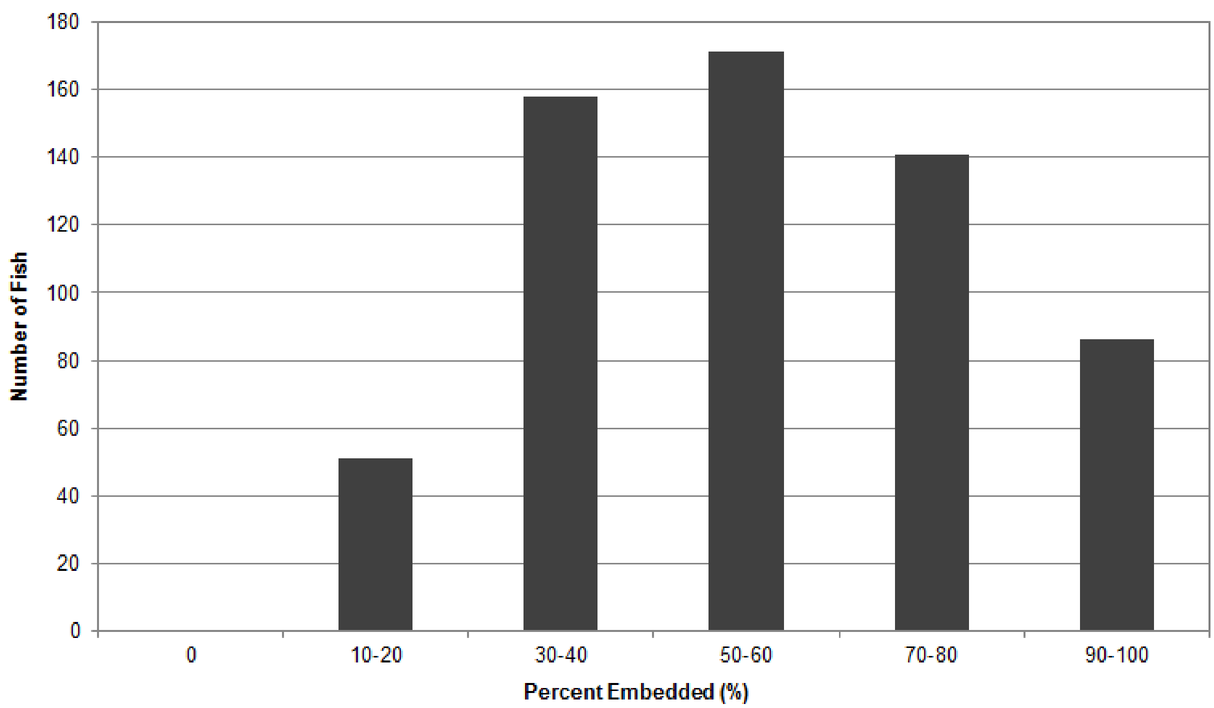


Figure 53. Frequency distribution for substrate percent embedded used by 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.

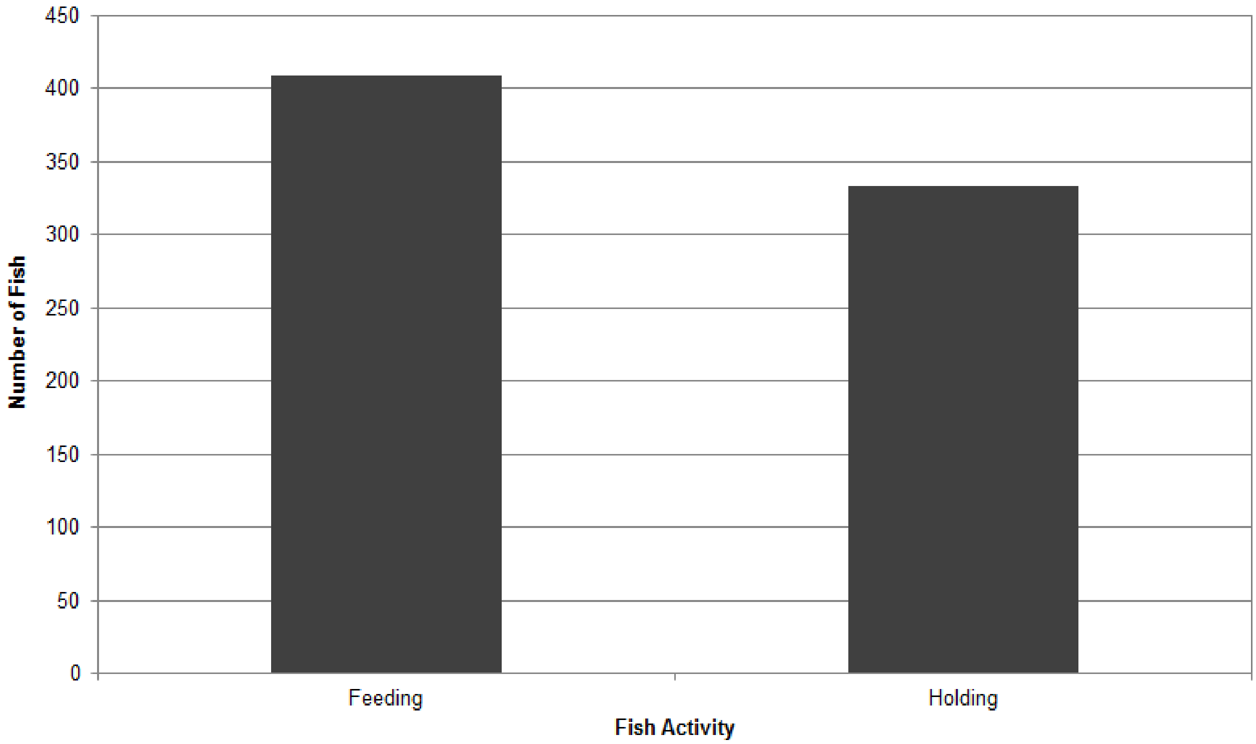


Figure 54. Frequency distribution of fish activity for 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.

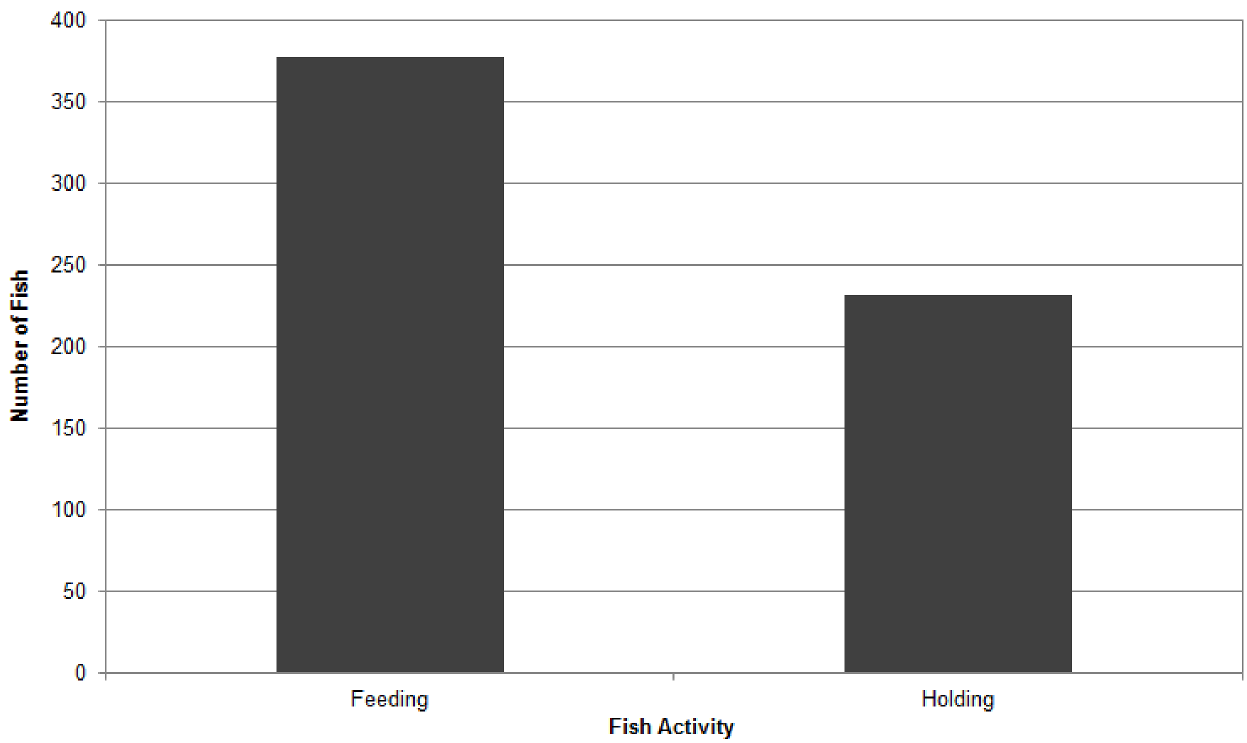
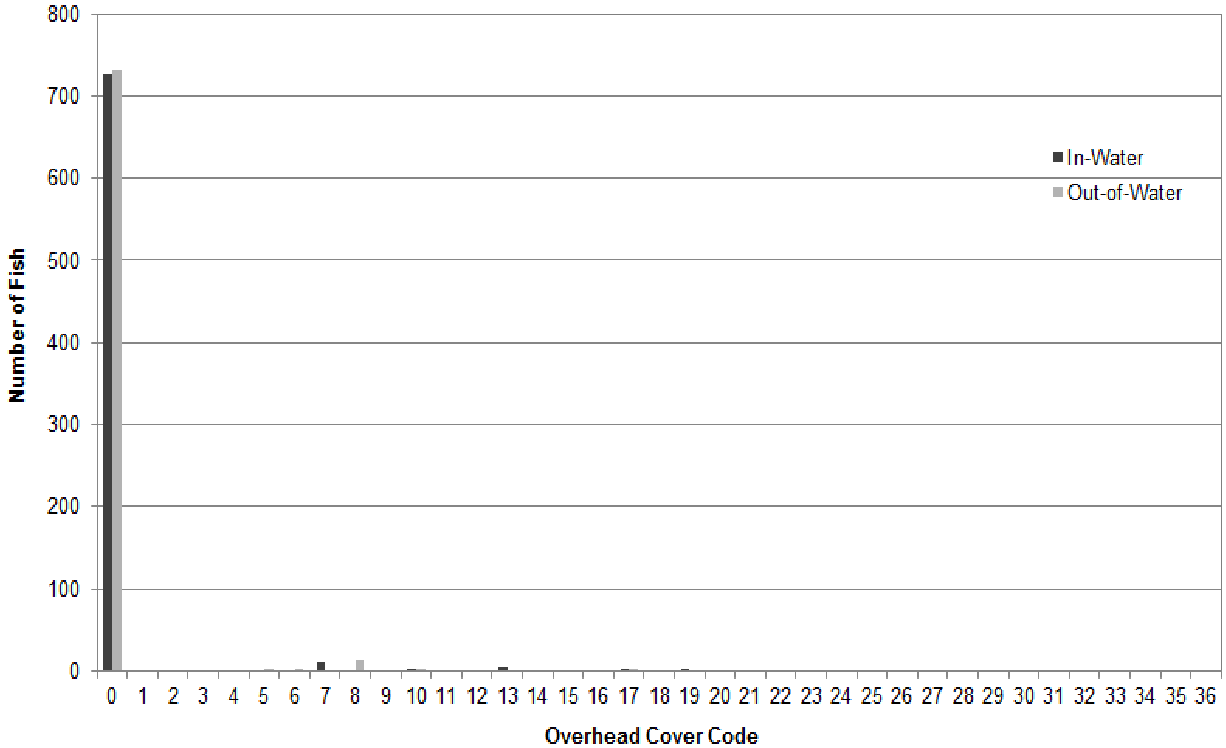


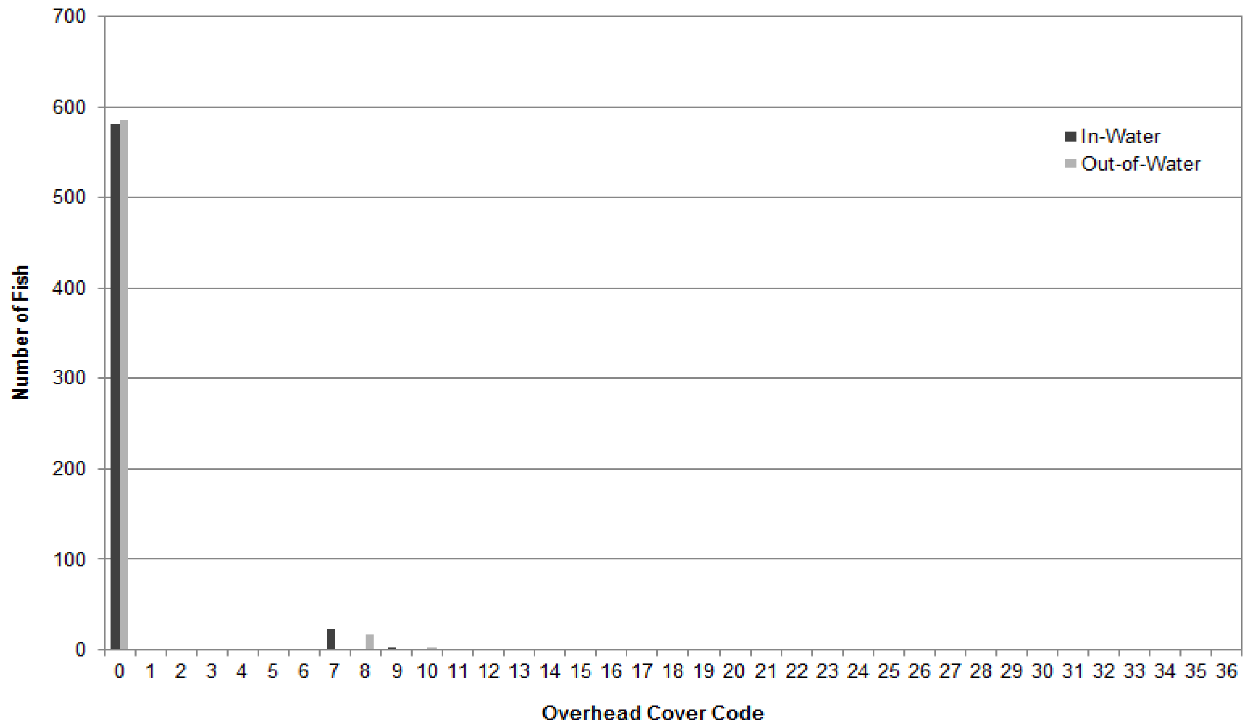
Figure 55. Frequency distribution of fish activity for 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

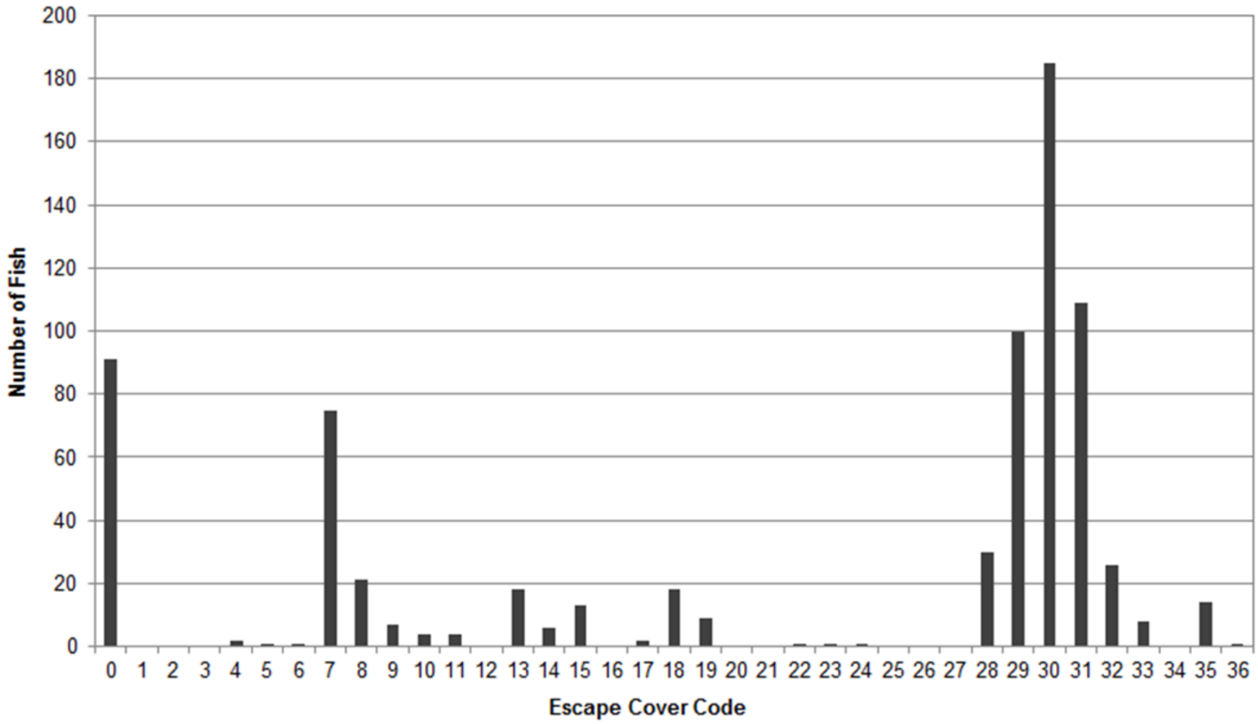
Figure 56. Frequency distribution of nearest in-water and out-of-water overhead cover for 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

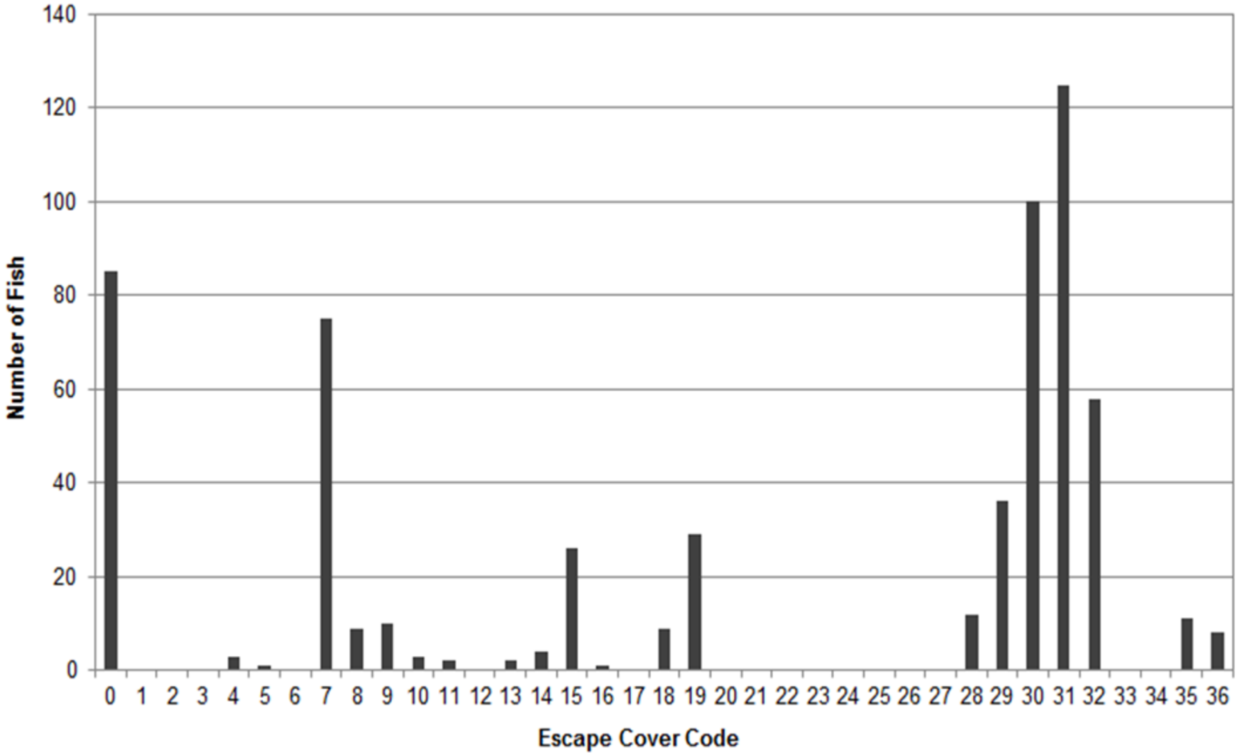
Figure 57. Frequency distribution of nearest in-water and out-of-water overhead cover for 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 58. Frequency distribution for escape cover used by 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 59. Frequency distribution for escape cover used by 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.

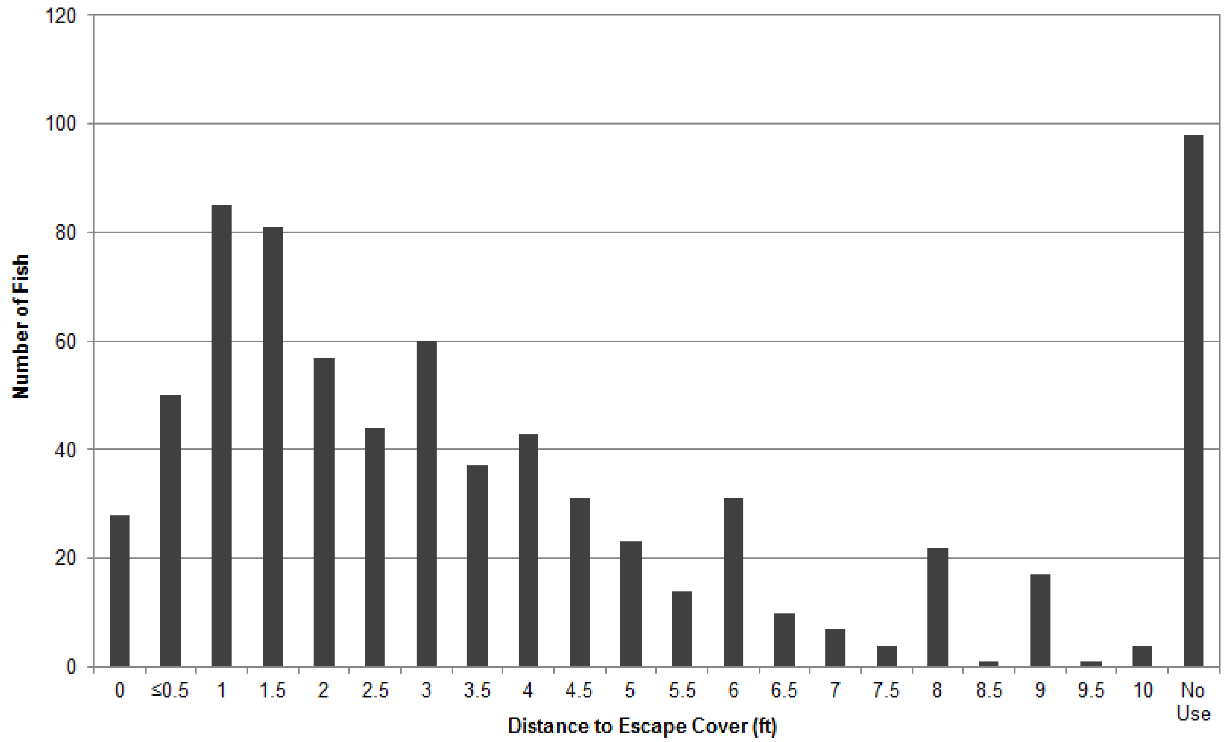


Figure 60. Frequency distribution for distance to escape cover for 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.

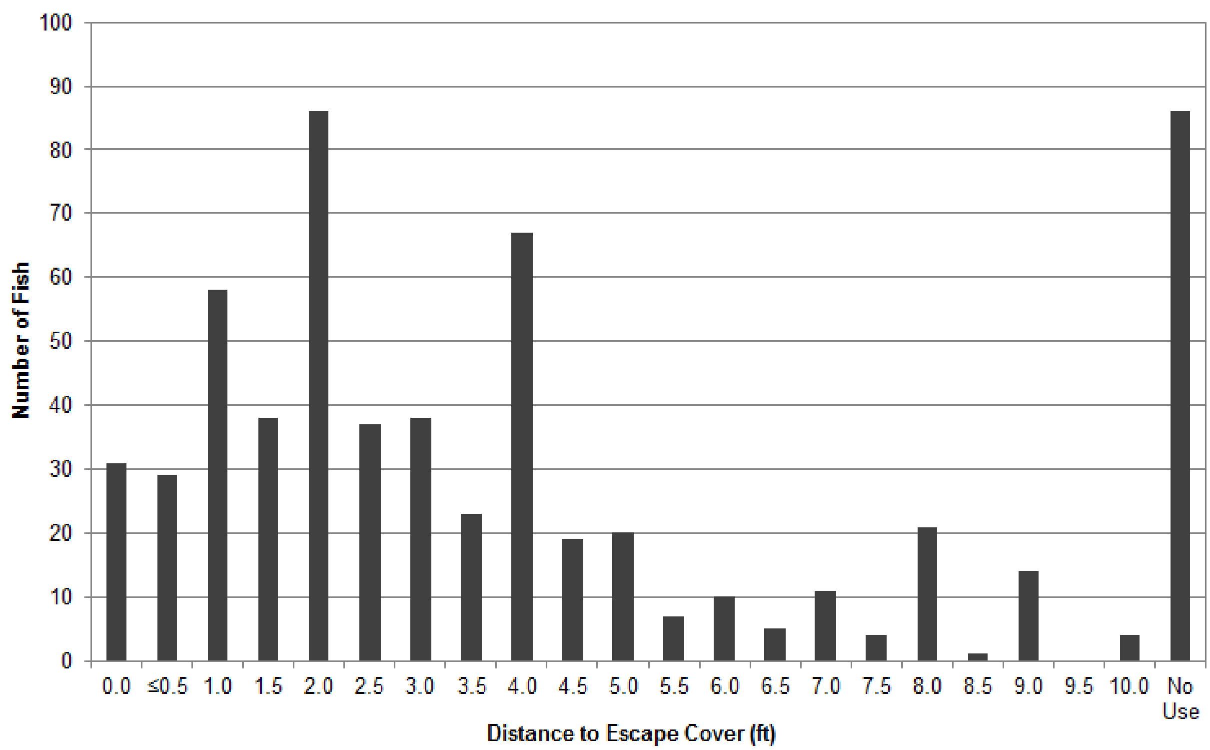


Figure 61. Frequency distribution for distance to escape cover for 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.

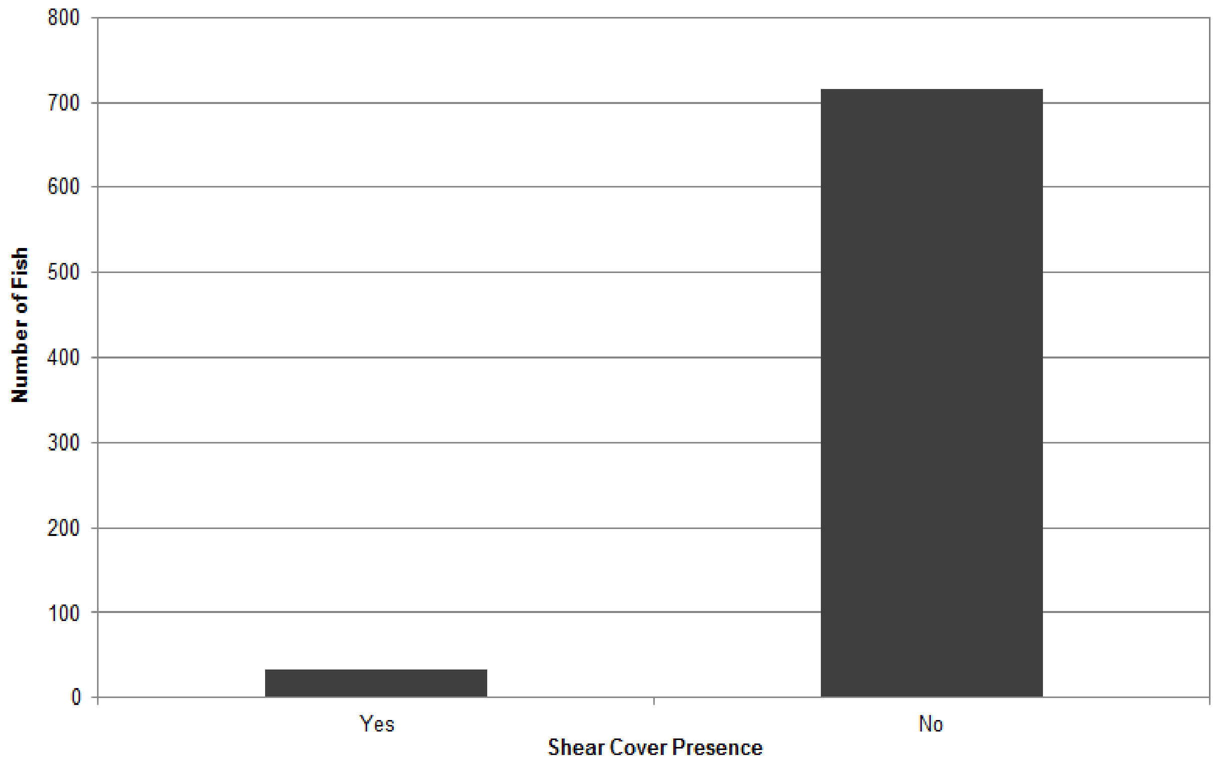


Figure 62. Frequency distribution for shear cover presence used by 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.

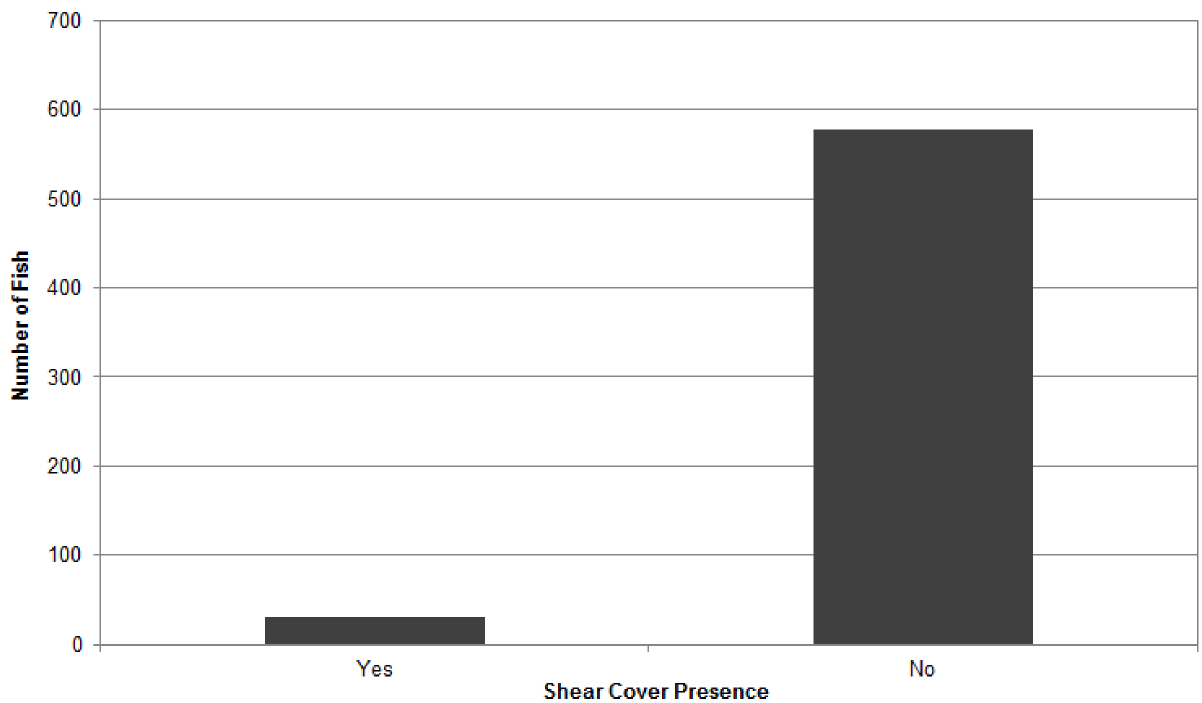
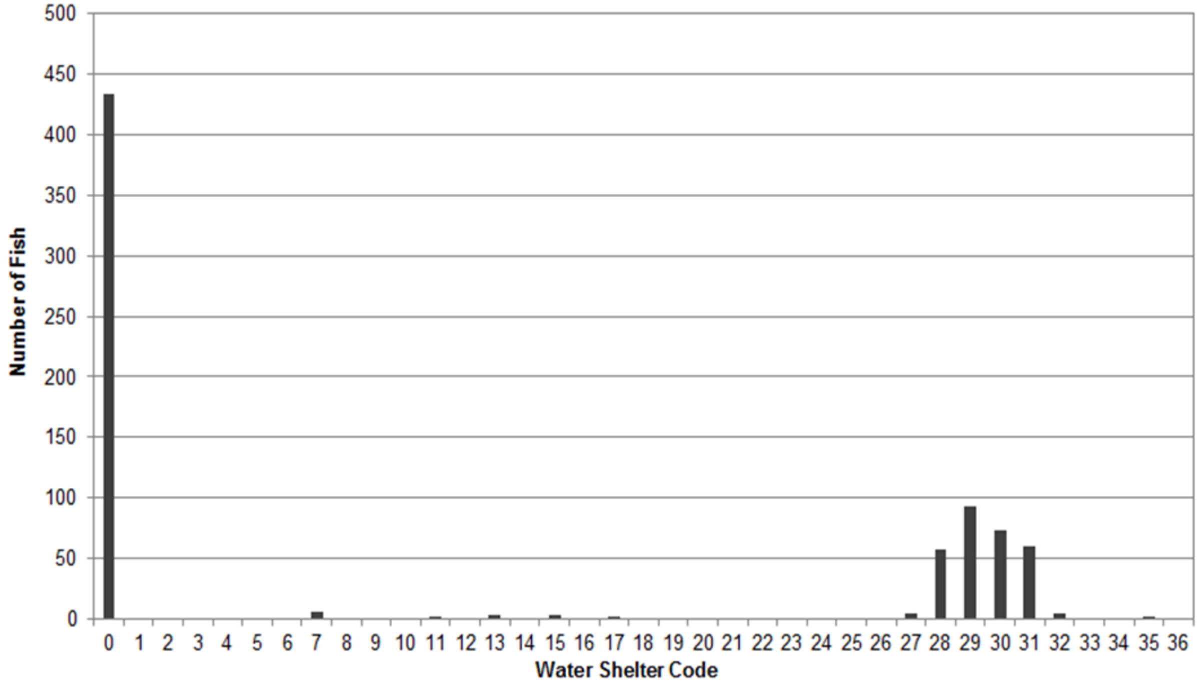


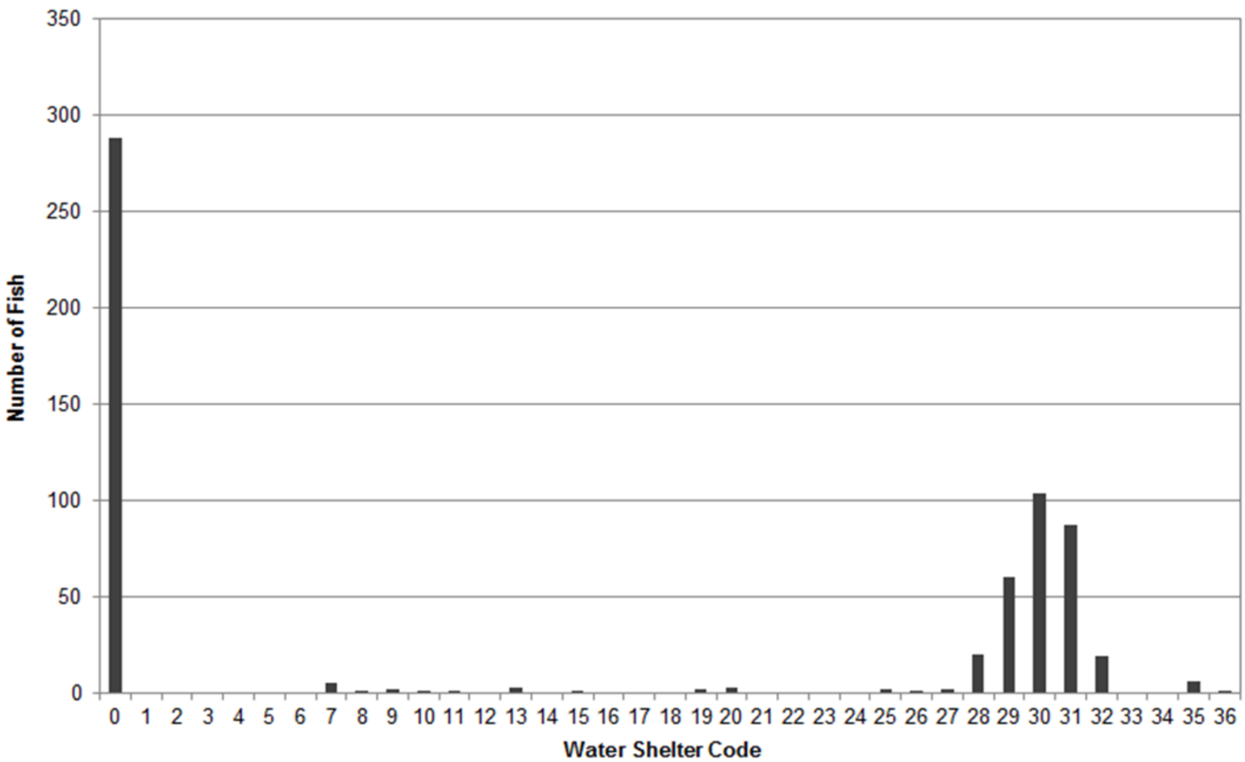
Figure 63. Frequency distribution for shear cover presence used by 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 64. Frequency distribution for water shelter used by 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 65. Frequency distribution for water shelter used by 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.

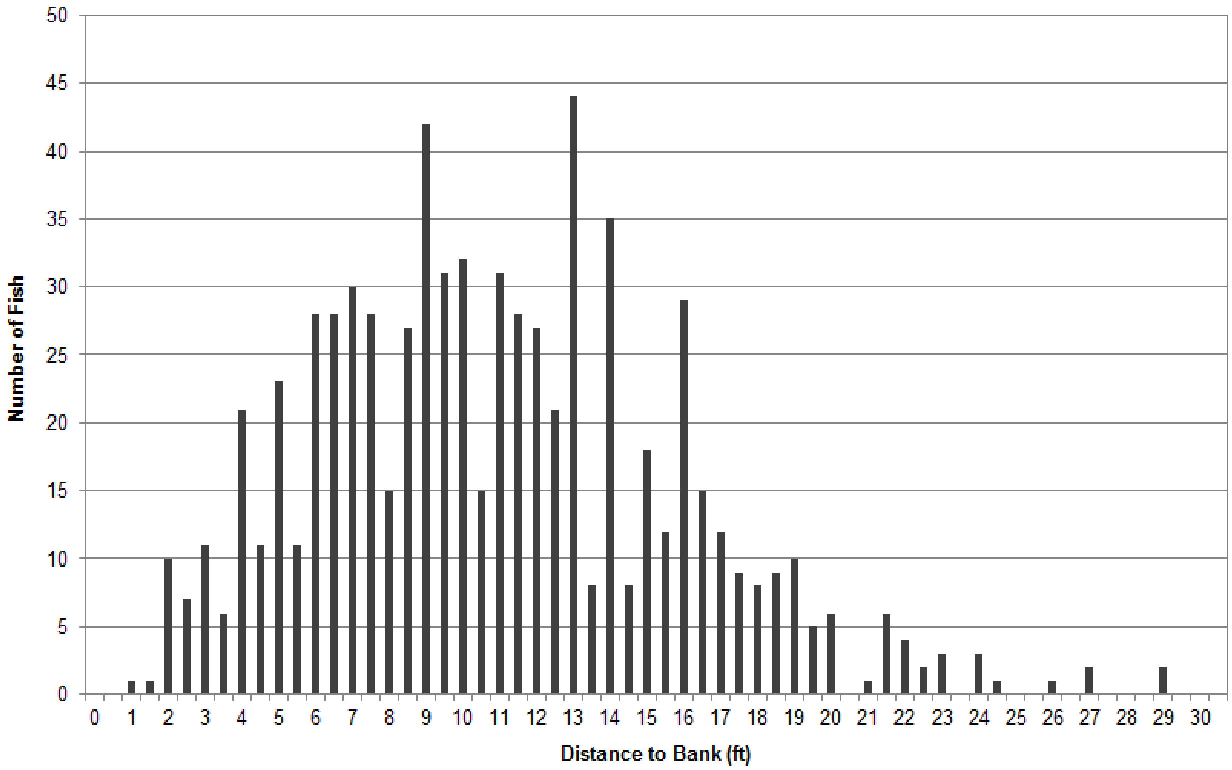


Figure 66. Frequency distribution for distance to bank for 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.

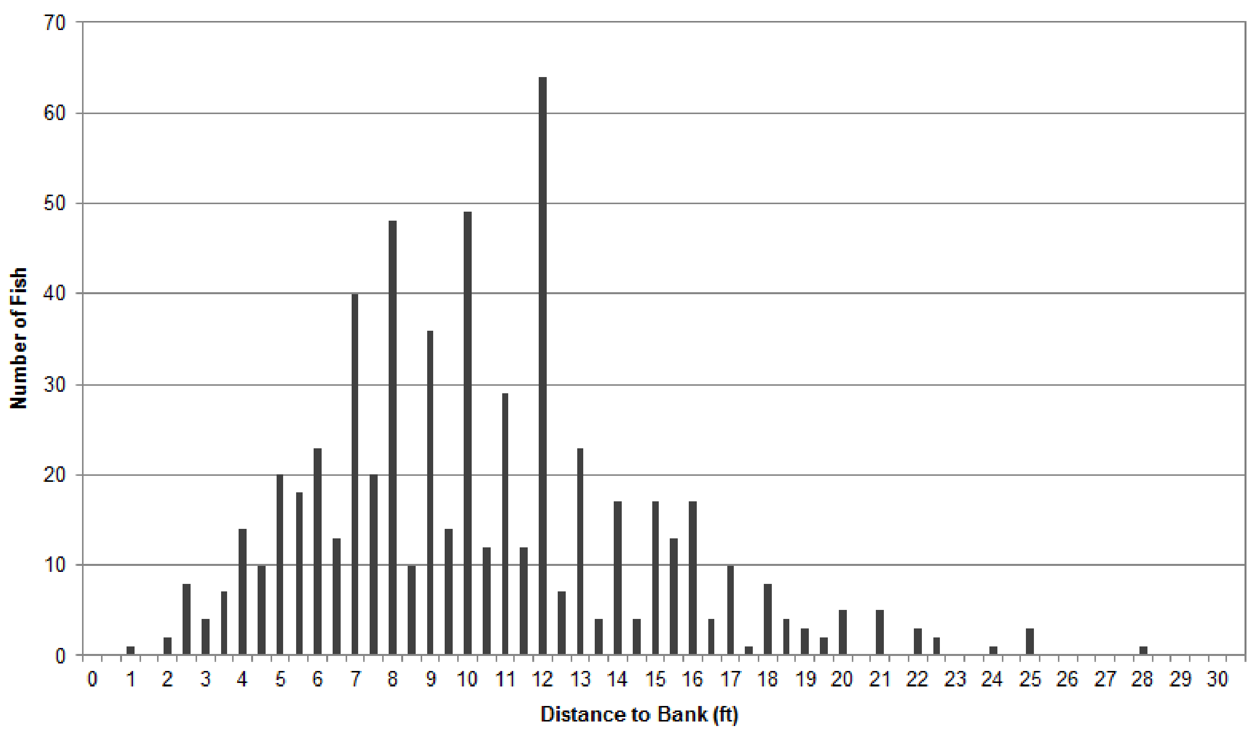
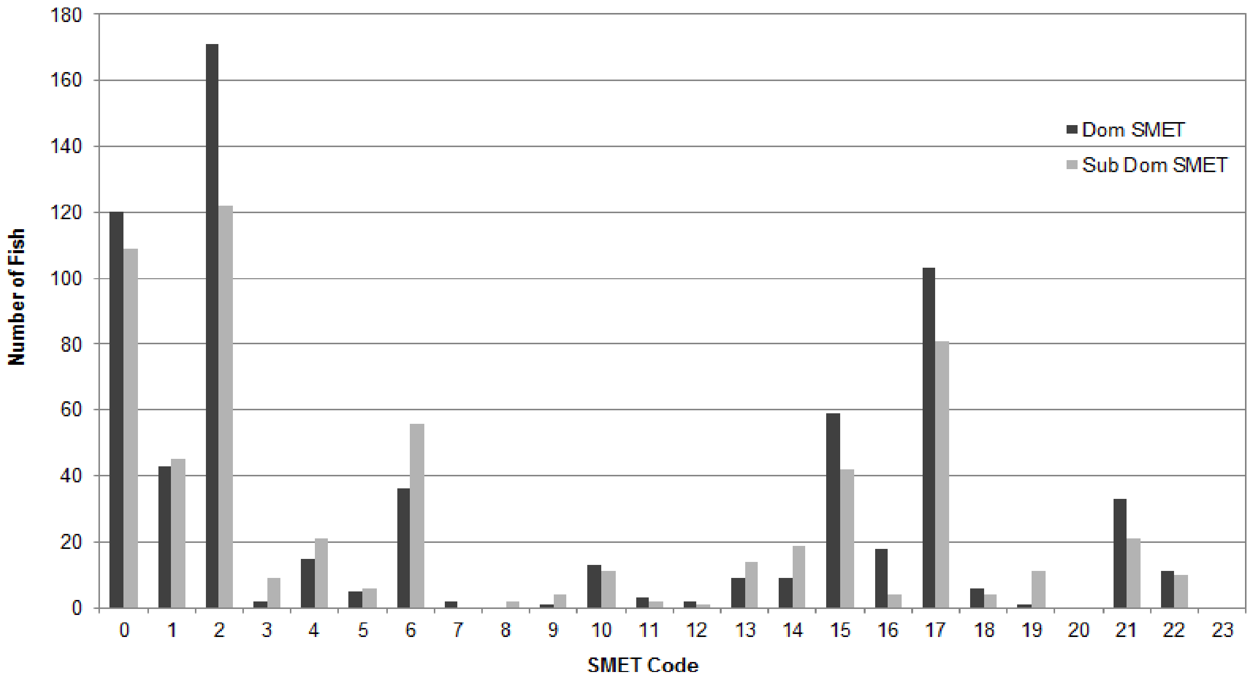
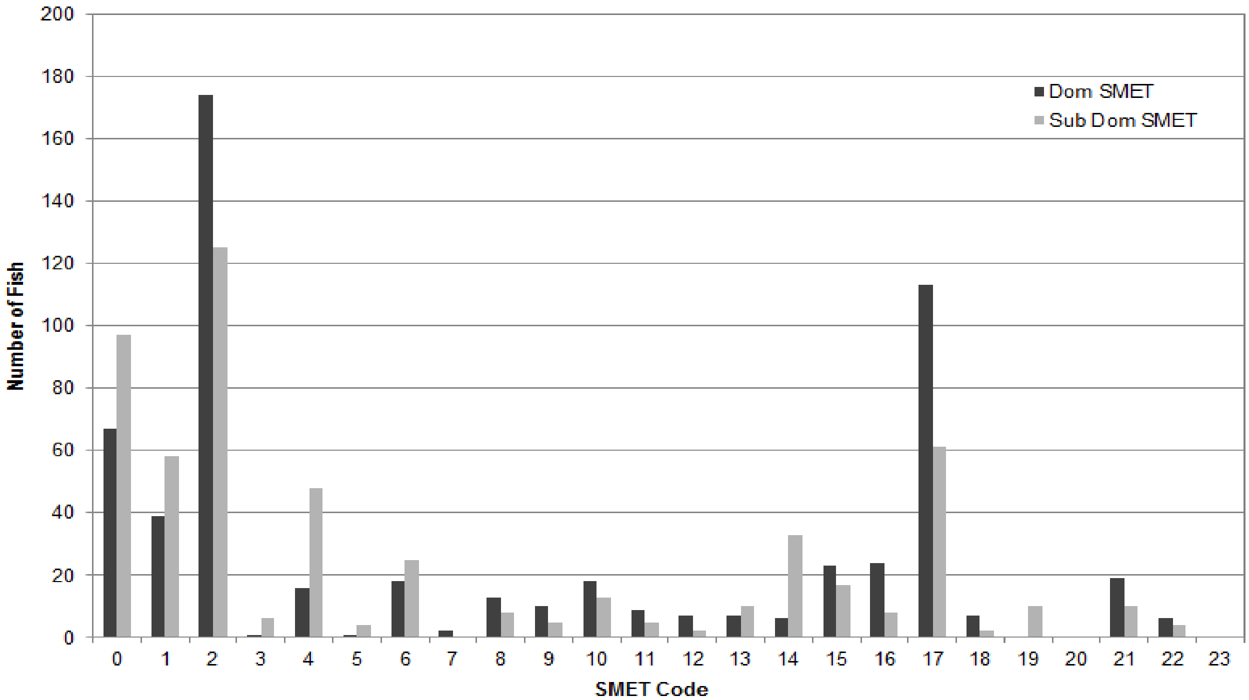


Figure 67. Frequency distribution for distance to bank for 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.



Code	SMET
0	Open
1	Gravel
2	Cobble/boulder
3	Sparse shrubs/herbs/vines/poison oak, IW
4	Sparse shrubs/herbs/vines/poison oak, OW
5	Sparse branches < 4 inches, IW
6	Sparse branches < 4 inches, OW
7	Sparse branches > 4 inches, IW
8	Sparse branches > 4 inches, OW
9	Dense branches < 4 inches, IW
10	Dense branches < 4 inches, OW
11	Dense branches > 4 inches, IW
12	Dense branches > 4 inches, OW
13	Trees < 4 inches
14	Trees > 4 inches
15	Small wood debris < 4 inches (dead)
16	Large woody debris > 4 inches (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

Figure 68. Distribution for stream margin edge type (SMET) used by 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.



Code	SMET
0	Open
1	Gravel
2	Cobble/boulder
3	Sparse shrubs/herbs/vines/poison oak, IW
4	Sparse shrubs/herbs/vines/poison oak, OW
5	Sparse branches < 4 inches, IW
6	Sparse branches < 4 inches, OW
7	Sparse branches > 4 inches, IW
8	Sparse branches > 4 inches, OW
9	Dense branches < 4 inches, IW
10	Dense branches < 4 inches, OW
11	Dense branches > 4 inches, IW
12	Dense branches > 4 inches, OW
13	Trees < 4 inches
14	Trees > 4 inches
15	Small wood debris < 4 inches (dead)
16	Large woody debris > 4 inches (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

Figure 69. Distribution for stream margin edge type (SMET) used by 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.

Fall Habitat Use

Habitat use statistics for 6-9 cm and 10-15 cm juvenile steelhead observed in the Big Sur River in fall (October) 2010 are outlined in Table 13. Number of 6-9 cm and 10-15 cm fish per a mesohabitat type in fall 2010 are in Figures 70 and 71, respectively. Steelhead 6-9 cm and 10-15 cm were found in all habitat types, with most occurring in pool and run mesohabitat types in the fall. Frequencies of fish sizes observed in fall for 6-9 cm and 10-15 cm are in Figures 72 and 73, respectively.

Table 13. Habitat use statistics for 6-9 cm and 10-15 cm juvenile steelhead observed in the Big Sur River in fall 2010.

Fish Size	Statistic	N	Minimum	Maximum	Average	Median	Std. Dev.
6-9 cm	Water Depth (ft)	166	0.45	4.30	1.71	1.55	0.86
	Water Velocity (ft/s)	166	0.03	2.74	1.15	1.13	0.57
	Fish Focal Point Height	166	6	10	9.04	9.00	0.84
	Fish Focal Point Water Velocity (ft/s)	166	0.00	2.42	0.71	0.69	0.47
	Distance to Escape Cover (ft)	146	0.00	10.00	3.85	3.50	2.88
	Distance to Bank (ft)	166	1.00	24.00	8.87	8.00	4.72
10-15 cm	Water Depth (ft)	570	0.55	4.90	1.80	1.70	0.79
	Water Velocity (ft/s)	570	0.00	5.36	1.27	1.14	0.81
	Fish Focal Point Height	570	6	10	8.74	9.00	0.84
	Fish Focal Point Water Velocity (ft/s)	570	0.00	3.35	0.80	0.65	0.57
	Distance to Escape Cover (ft)	500	0.00	10.00	3.34	3.00	2.87
	Distance to Bank (ft)	570	0.50	24.00	8.54	8.00	4.00

Fish Activity: Most 6-9 cm and 10-15 cm steelhead were observed feeding, as opposed to holding (Figures 74 and 75).

Total Water Depth: Juvenile steelhead 6-9 cm were observed in locations with water depths ranging from 0.45 ft to 4.30 ft (Table 13). Juvenile steelhead 10-15 cm were observed in locations with water depths ranging from 0.55 ft to 4.90 ft. The average water depths where juvenile steelhead 6-9 cm and 10-15 cm were observed were 1.7 ft and 1.8 ft, respectively. The histograms of water depth frequencies for 6-9 cm and 10-15 cm steelhead are shown in Figures 76 and 77, respectively.

Average Water Velocity: Juvenile steelhead 6-9 cm were observed in locations with average water velocities ranging from 0.03 ft/s to 2.74 ft/s (Table 13). Juvenile steelhead 10-15 cm were observed in locations with average water velocities ranging from 0.0 ft/s to 5.36 ft/s. The average water velocities where juvenile steelhead 6-9 cm and 10-15 cm were observed were 1.15 ft/s and 1.27 ft/s, respectively. The histograms of average water velocity frequencies are shown in Figures 78 and 79, respectively.

Fish Focal Point Position: The focal point position (from the water surface to the fish with 0 = water surface and 10 = on stream bottom) of juvenile 6-9 cm and 10-15 cm steelhead at which the fish were observed ranged from 6 to 10. The median fish focal point position was 9 for both 6-9 cm and 10-15 cm juvenile steelhead (Table 13).The histograms of fish focal point water depth frequencies are shown in Figures 80 and 81, respectively.

Fish Focal Point Velocity: Water velocities at the fish focal point were about half the average water column velocities. Focal point velocities ranged from 0.00 ft/s to 3.42 ft/s and 0.00 ft/s to 3.35 ft/s for juvenile 6-9 cm and 10-15 cm steelhead, respectively (Table 13). The histograms of fish focal point velocity frequencies are shown in Figures 82 and 83, respectively.

Substrate: Juvenile 6-9 cm and 10-15 cm steelhead were predominately observed occupying sites with gravel and cobble substrates (Figures 84 and 85).

Embeddedness: Juvenile 6-9 cm and 10-15 cm steelhead were predominately observed at locations with embeddedness values ranging from 30-80 percent (Figures 86 and 87).

Overhead Cover: Over 95 percent of 6-9 cm and 10-15 cm juvenile steelhead during fall were observed at locations with no overhead cover (Figures 88 and 89). Branches and/or small vegetation (both in-water and out-of-water) were used occasionally by both size groups of fish.

Escape Cover: Juvenile steelhead 6-9 cm and 10-15 cm during fall were observed in proximity to a variety of escape cover types (Figures 90 and 91). The most common types of escape cover near the fish observation locations for both 6-9 cm and 10-15 cm fish were branches and/or small vegetation (both in-water and out-of-water) and boulders. Approximately 11 and 12 percent of 6-9 cm and 10-15 cm steelhead were observed selecting habitat locations without any type of escape cover, respectively.

Distance to Escape Cover: Although distance to escape cover ranged from 0 to 10 ft, most juvenile 6-9 cm and 10-15 steelhead were observed to be within approximately 0 - 3 ft of escape cover (Figures 92 and 93). Approximately 12 percent of both 6-9 cm and 10-15 cm steelhead were observed selecting habitat locations not near (>10 ft) any type of escape cover.

Shear Zone: Over 95 percent of 6-9 cm and 10-15 cm steelhead were observed to not be selecting locations with a discernable shear zone present (Figures 94 and 95).

Water Velocity Shelter: Most juvenile 6-9 cm and 10-15 cm steelhead were selecting sites that did not contain a water velocity shelter (Figures 96 and 97).

Distance to Bank: Juvenile steelhead 6-9 cm and 10-15 cm were observed from approximately 1-29 feet from the bank (Figures 98 and 99).

SMET: Juvenile 6-9 cm and 10-15 cm steelhead were observed selecting locations adjacent to a variety of SMET types (Figures 100 and 101). The most common types of SMET fish were observed adjacent to were open, cobble, and root types.

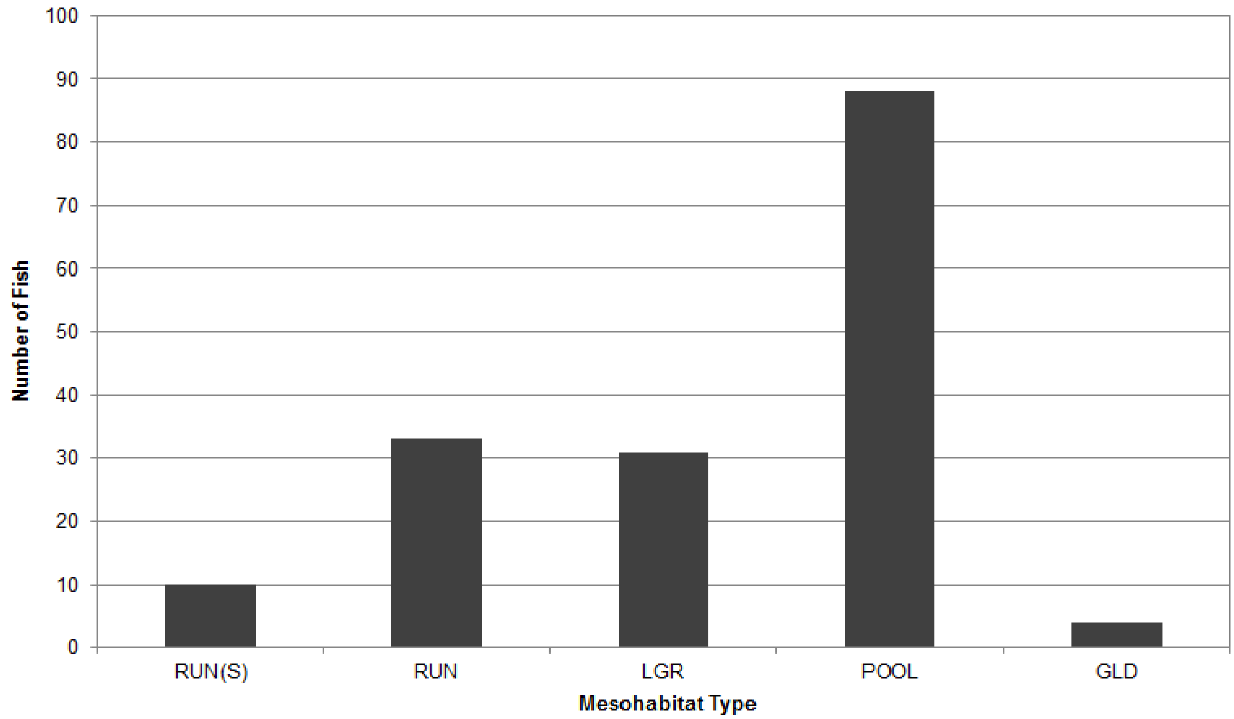


Figure 70. Frequency distribution of 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.

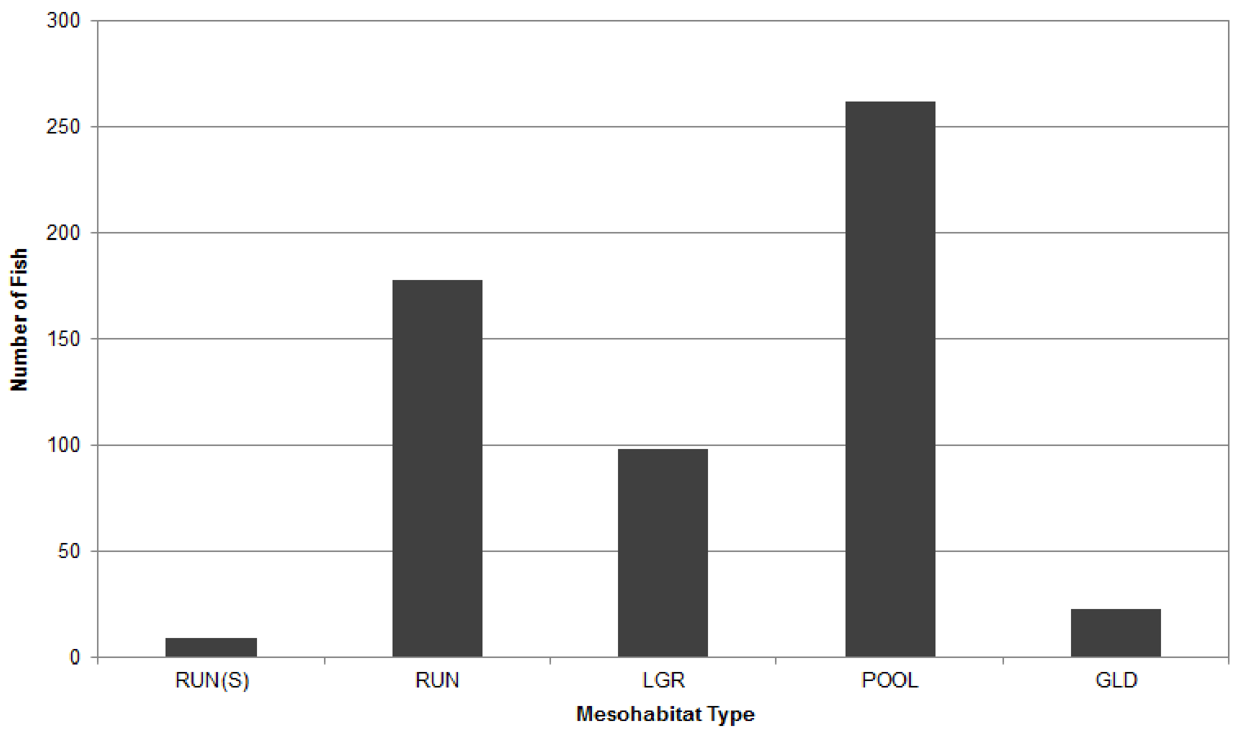


Figure 71. Frequency distribution of 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.

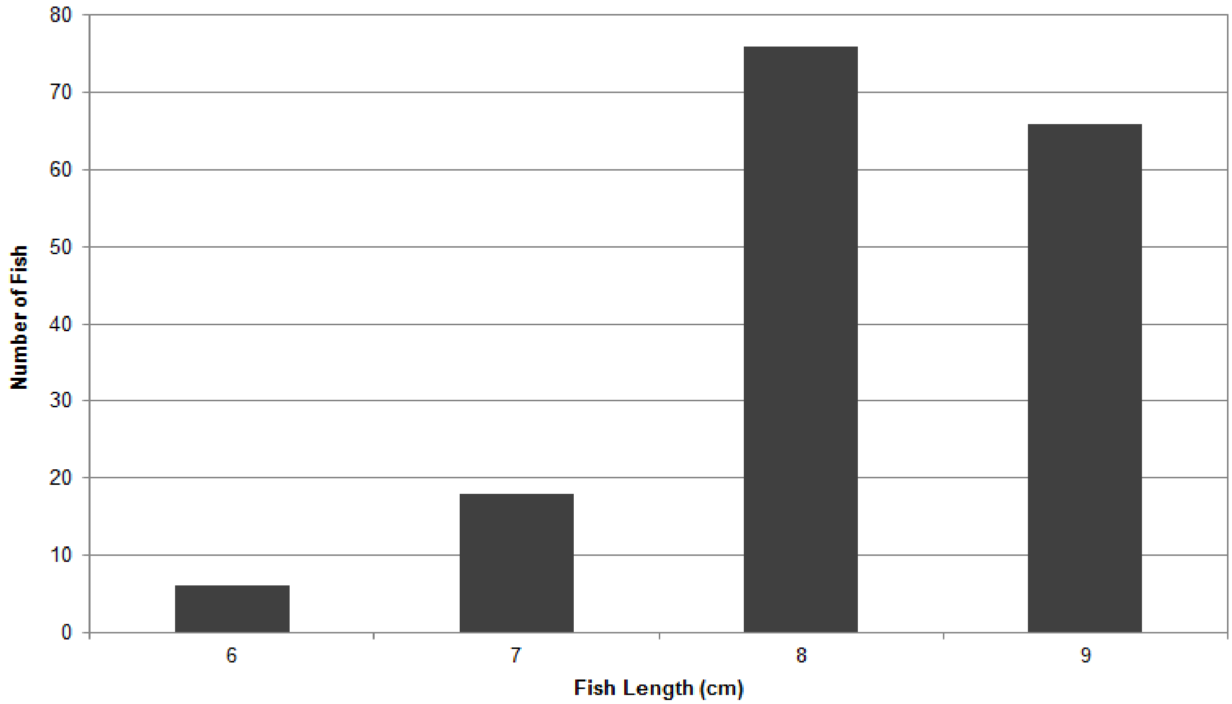


Figure 72. Frequency distribution of fish length for 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.

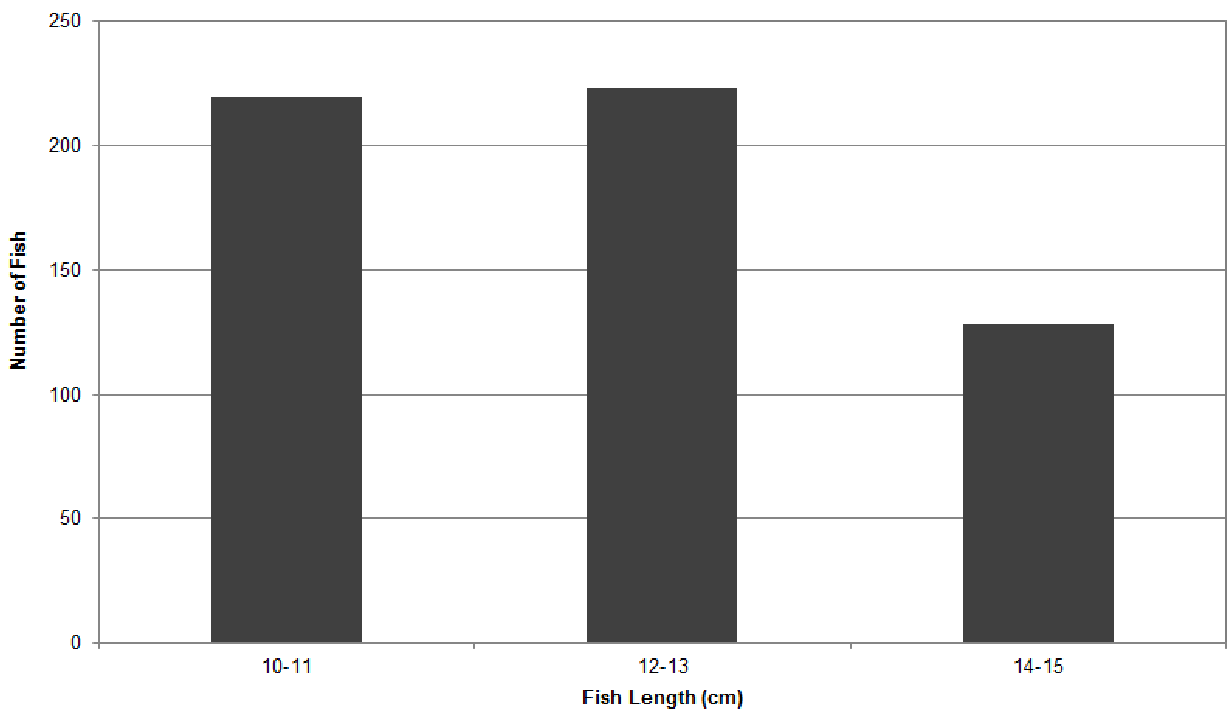


Figure 73. Frequency distribution of fish length for 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.

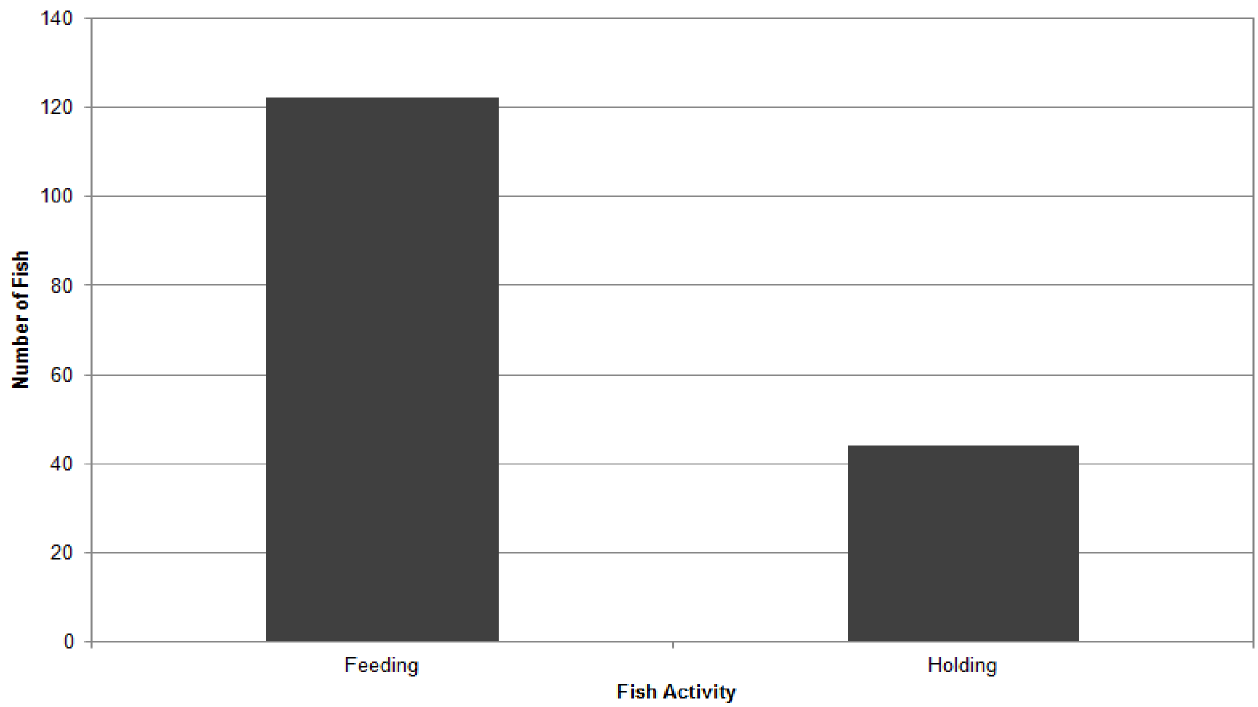


Figure 74. Frequency distribution of fish activity for 6-9cm juvenile steelhead observed in the Big Sur River, fall 2010.

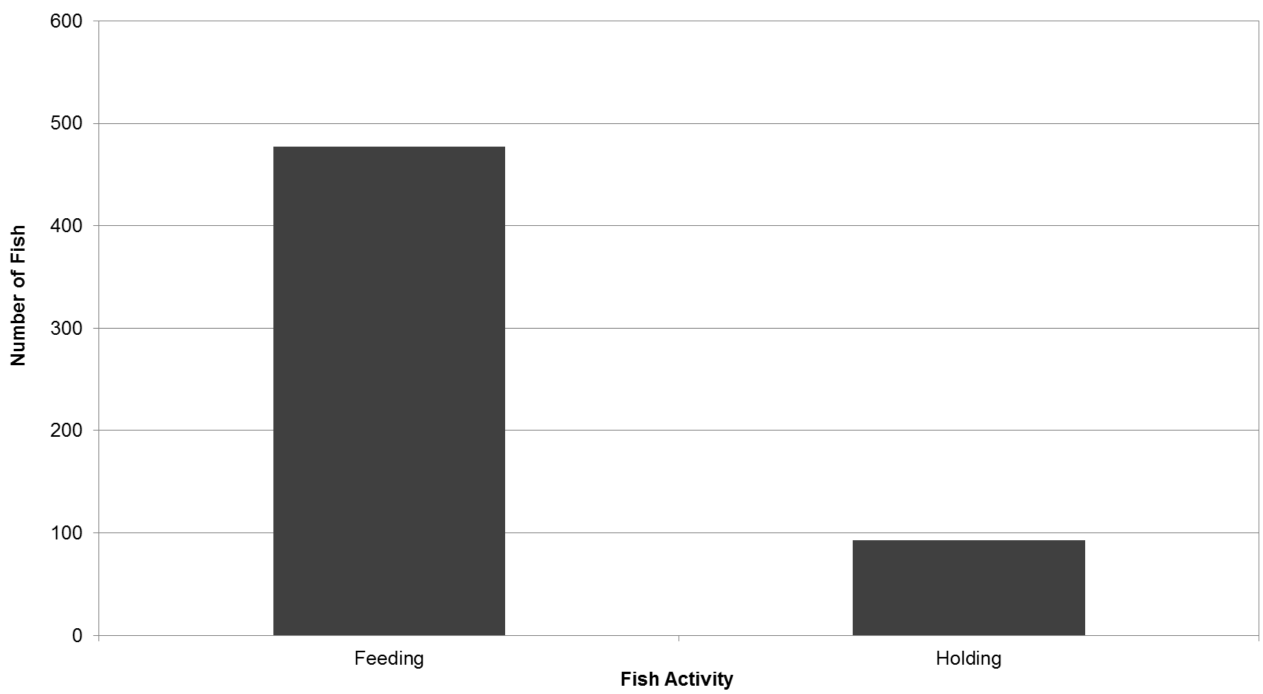


Figure 75. Frequency distribution of fish activity for 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.

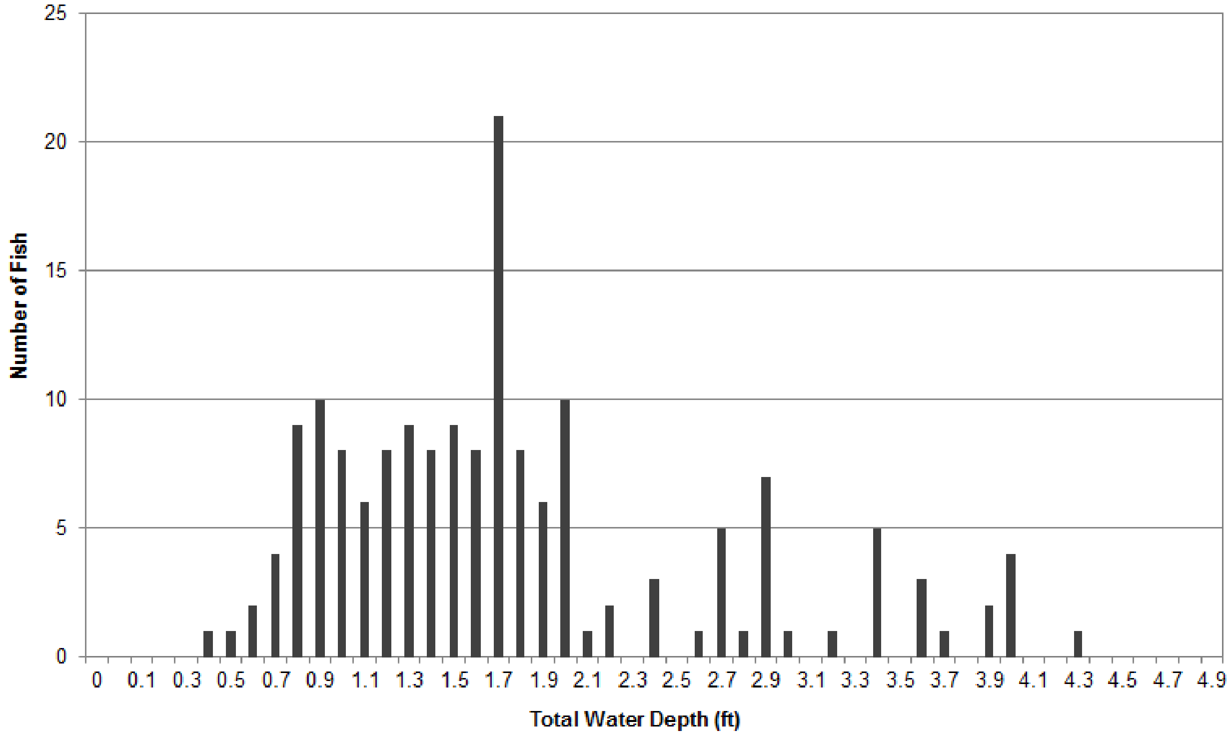


Figure 76. Total water depth frequency distribution 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.

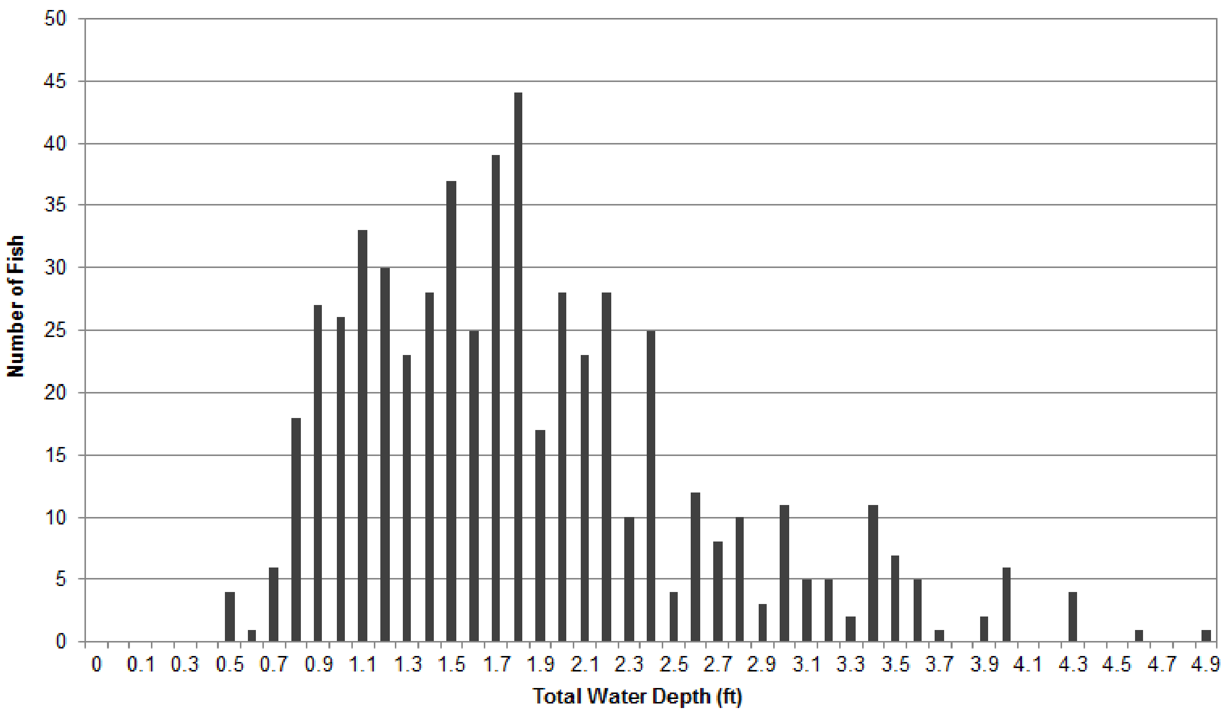


Figure 77. Total water depth frequency distribution 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.

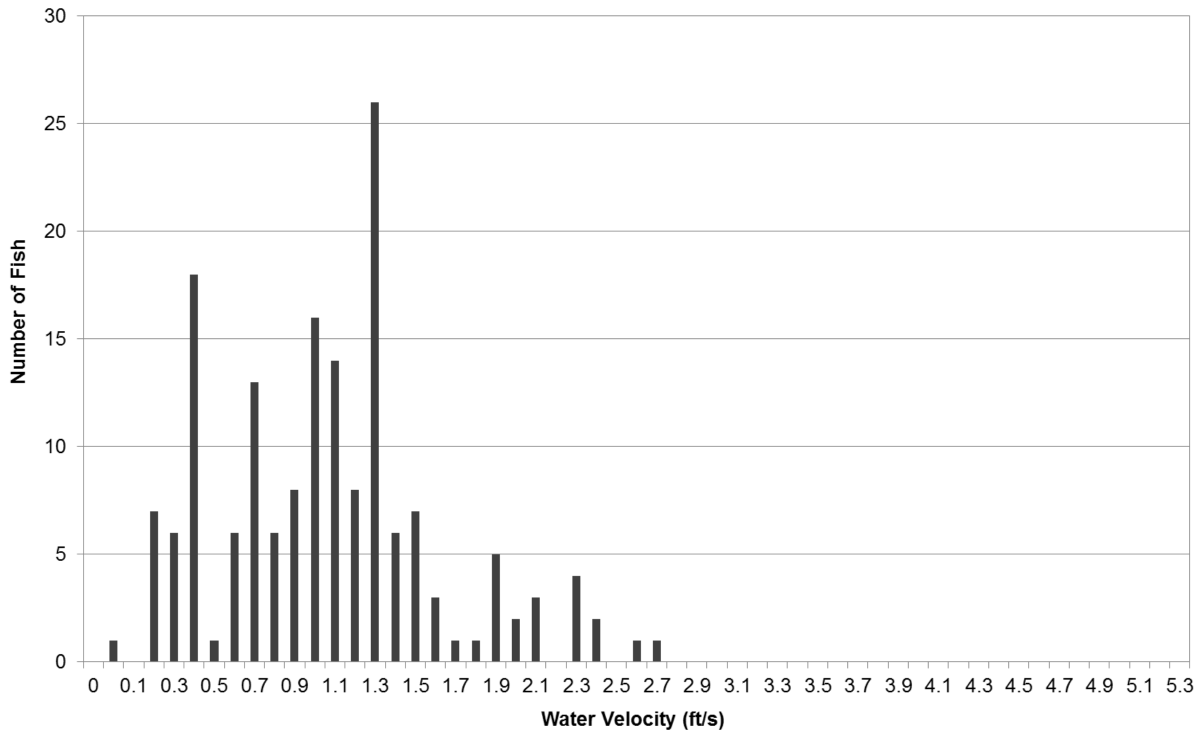


Figure 78. Frequency distribution for average water velocities used by 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.

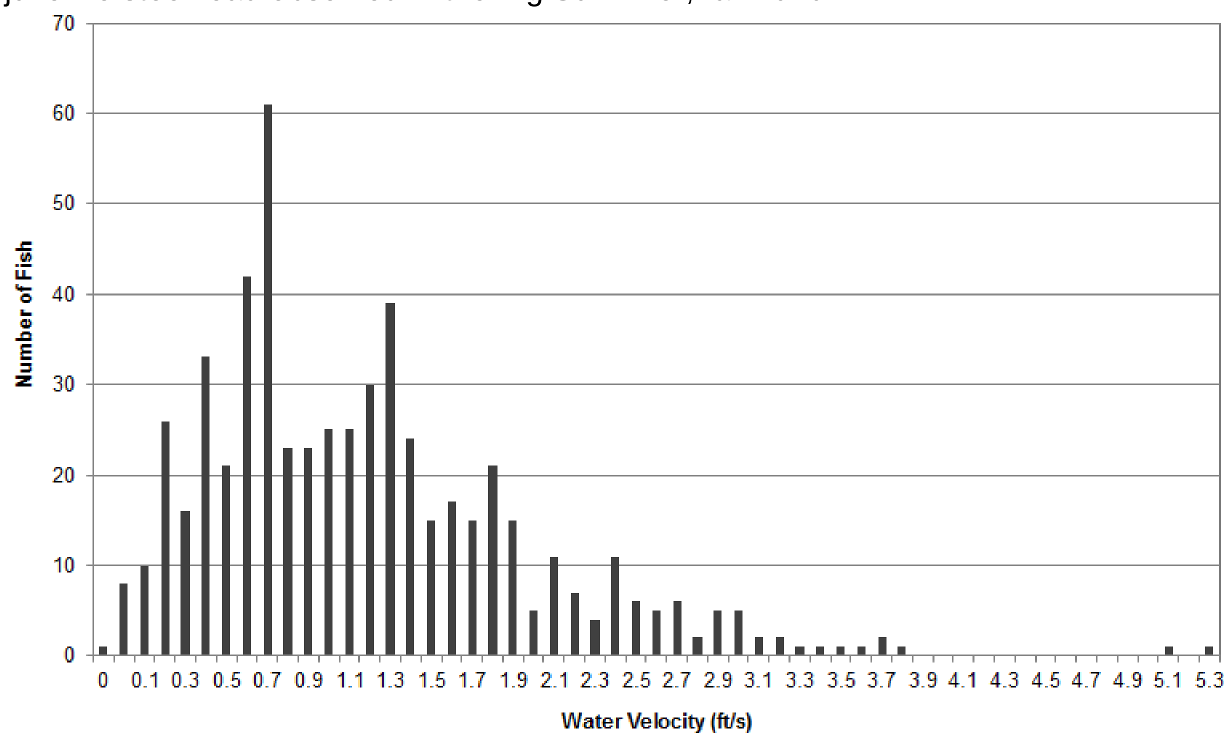


Figure 79. Frequency distribution for average water velocities used by 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.

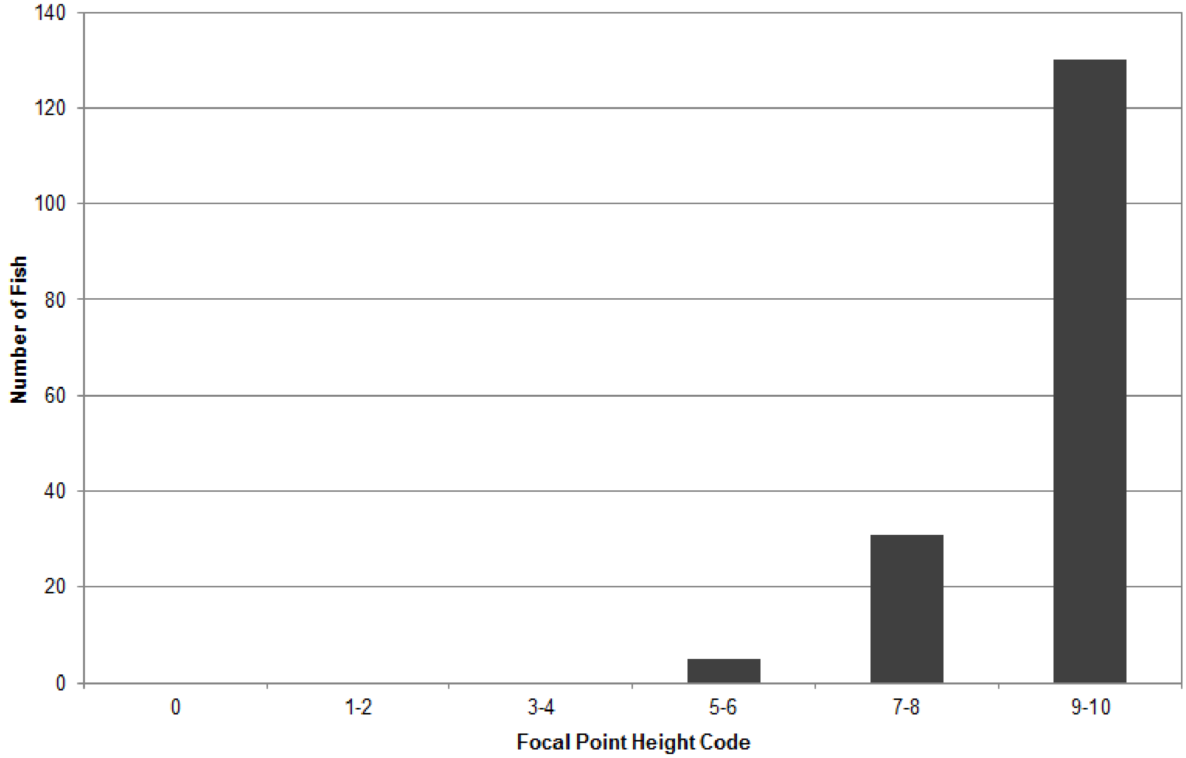


Figure 80. Frequency distribution of fish focal point height for 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.

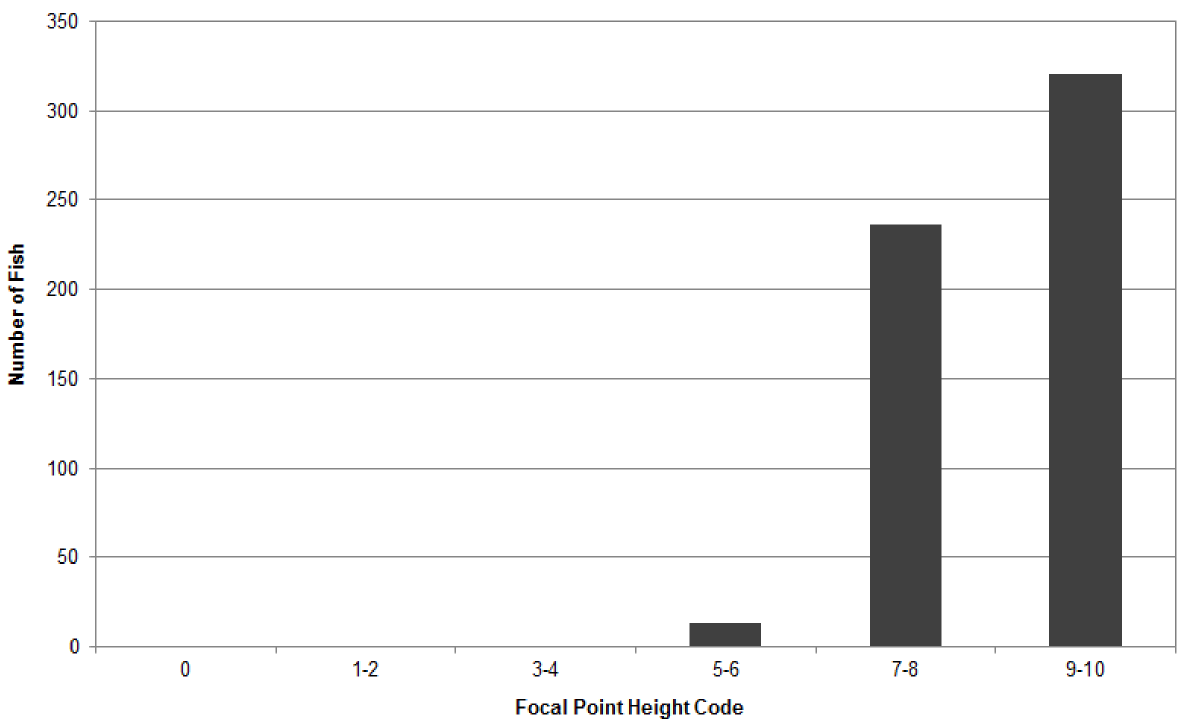


Figure 81. Frequency distribution of fish focal point height for 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.

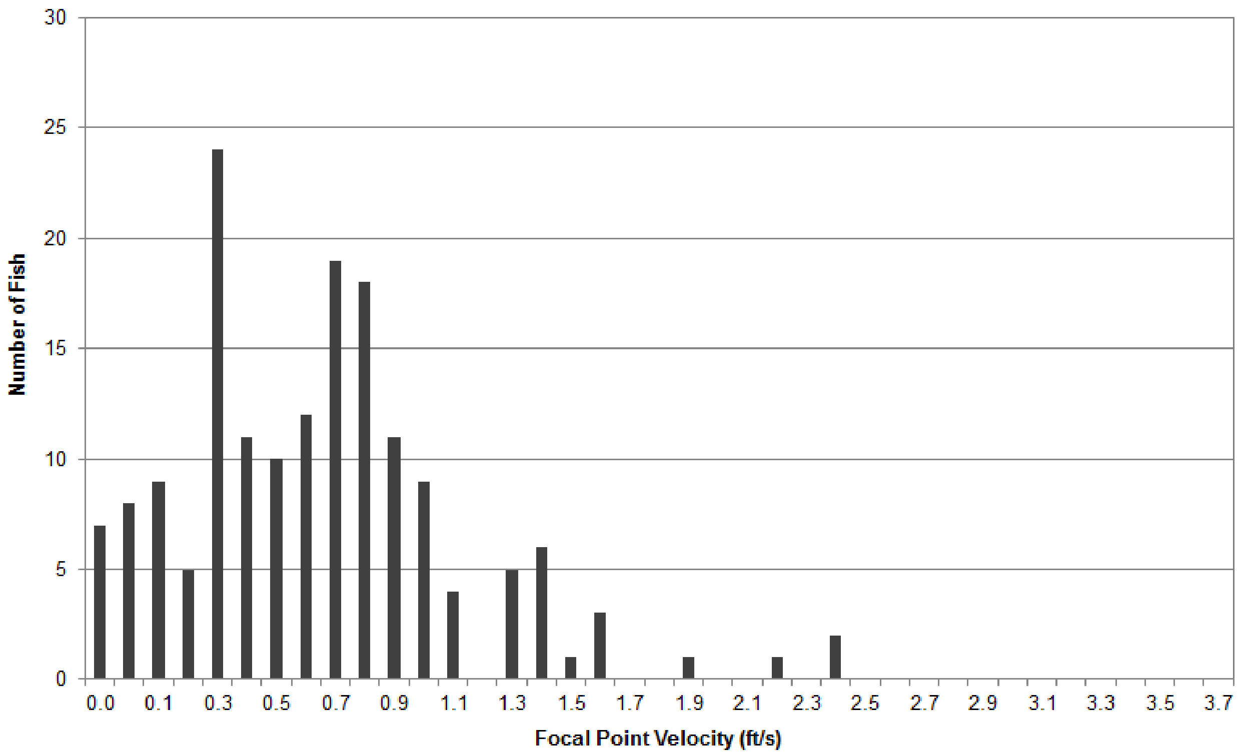


Figure 82. Frequency distribution for fish focal point water velocity used by 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.

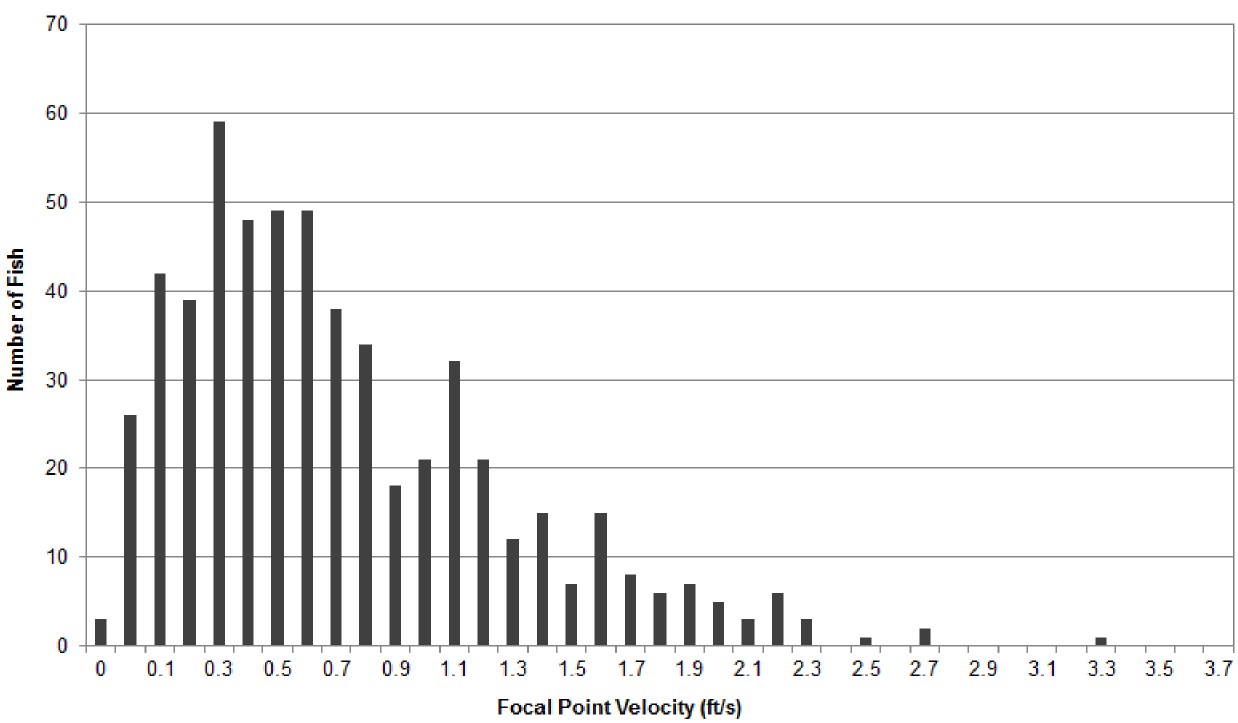
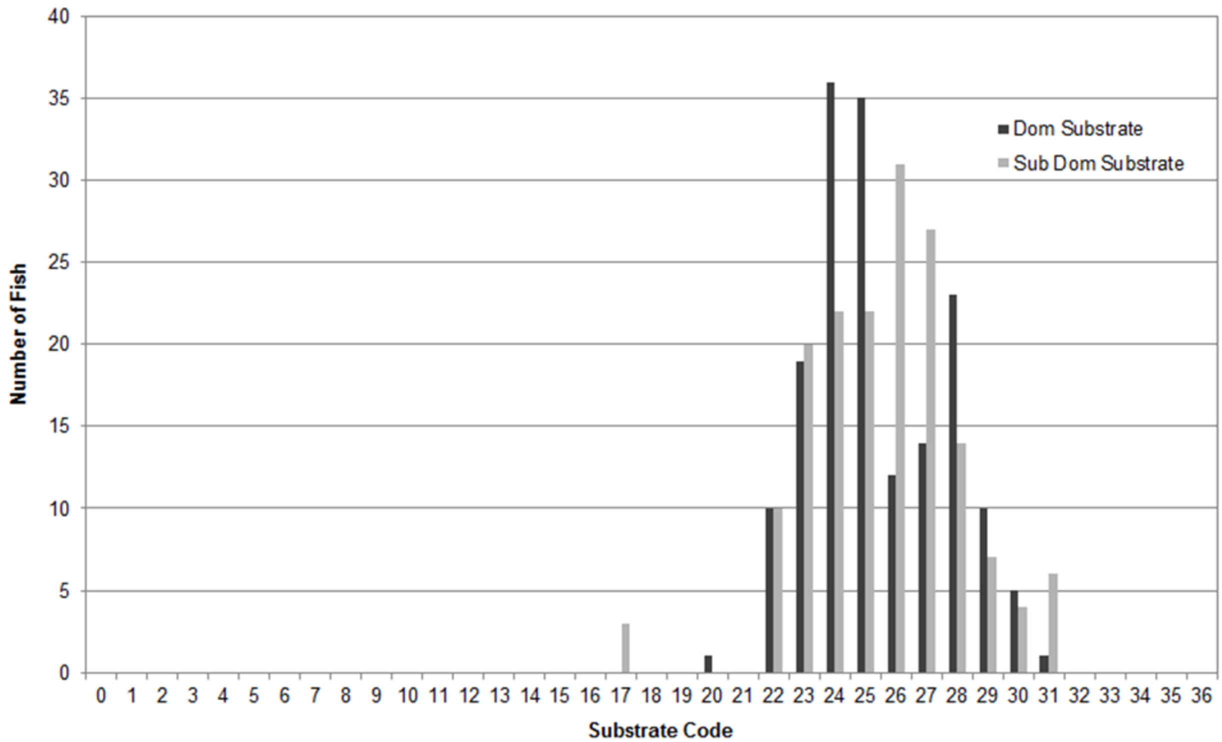


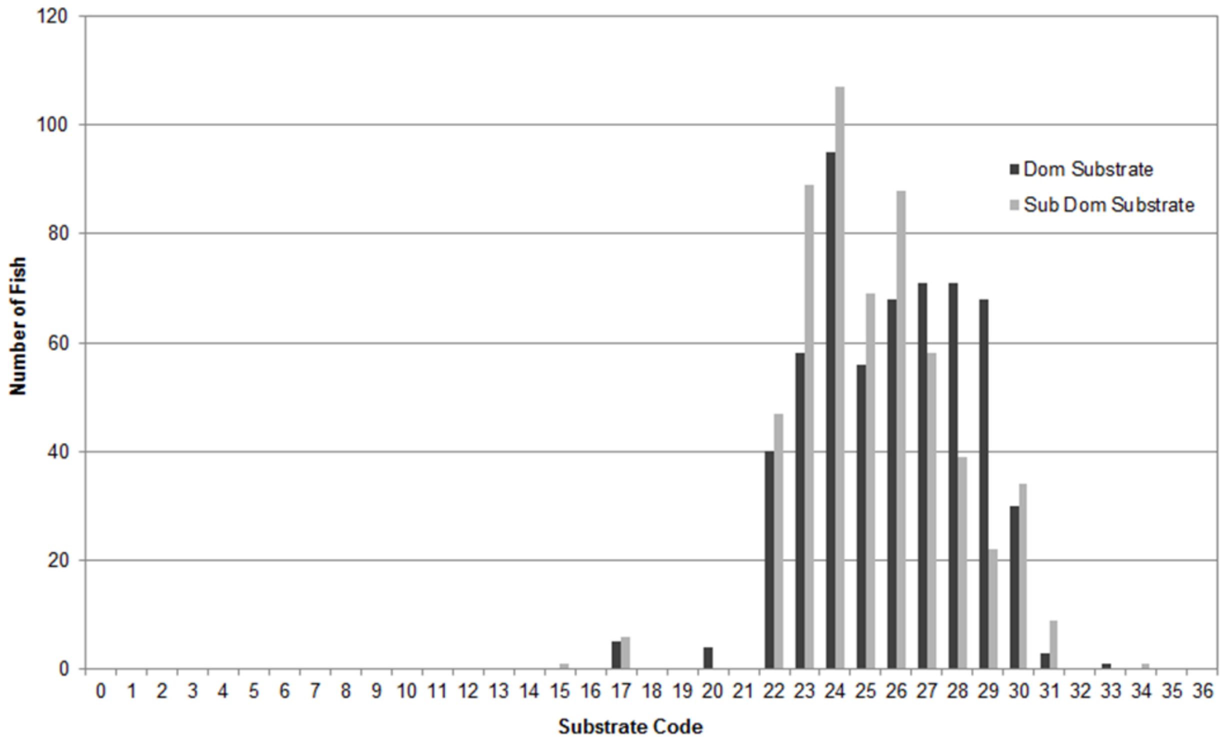
Figure 83. Frequency distribution for fish focal point water velocity used by 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 84. Frequency distribution for substrate types used by 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 85. Frequency distribution for substrate types used by 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.

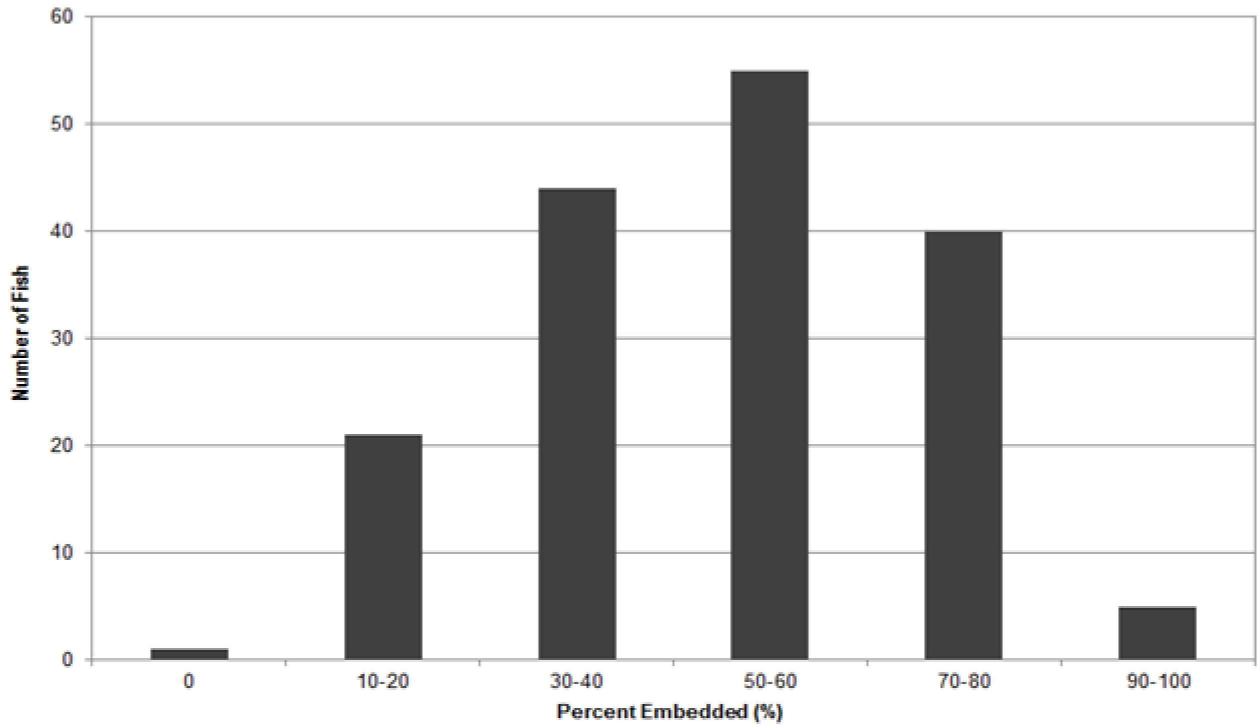


Figure 86. Frequency distribution for substrate percent embedded used by 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.

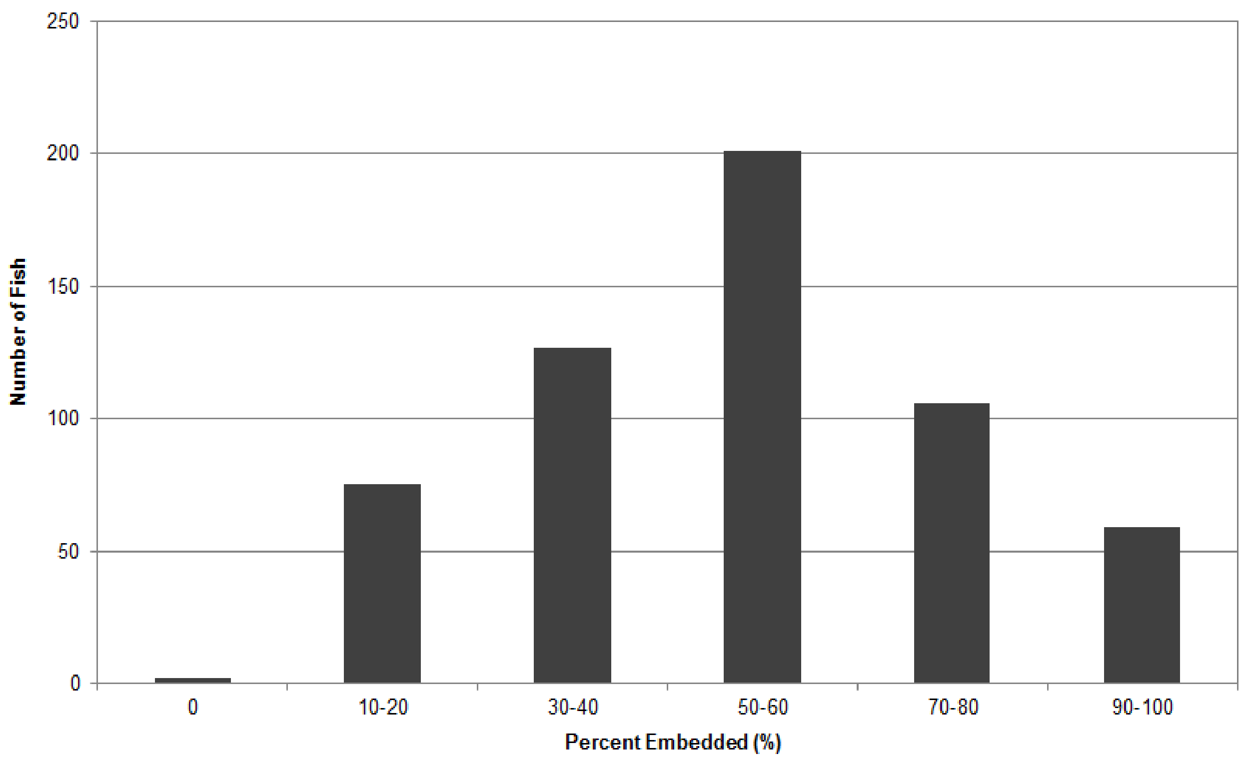
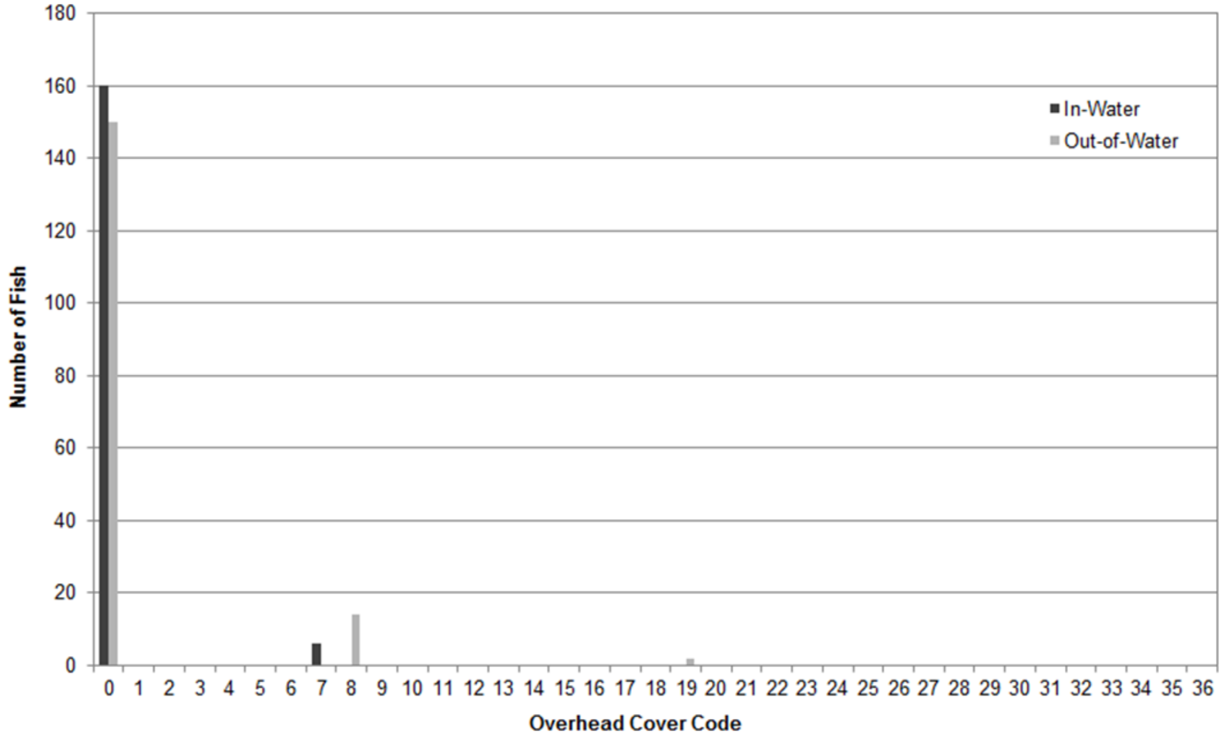


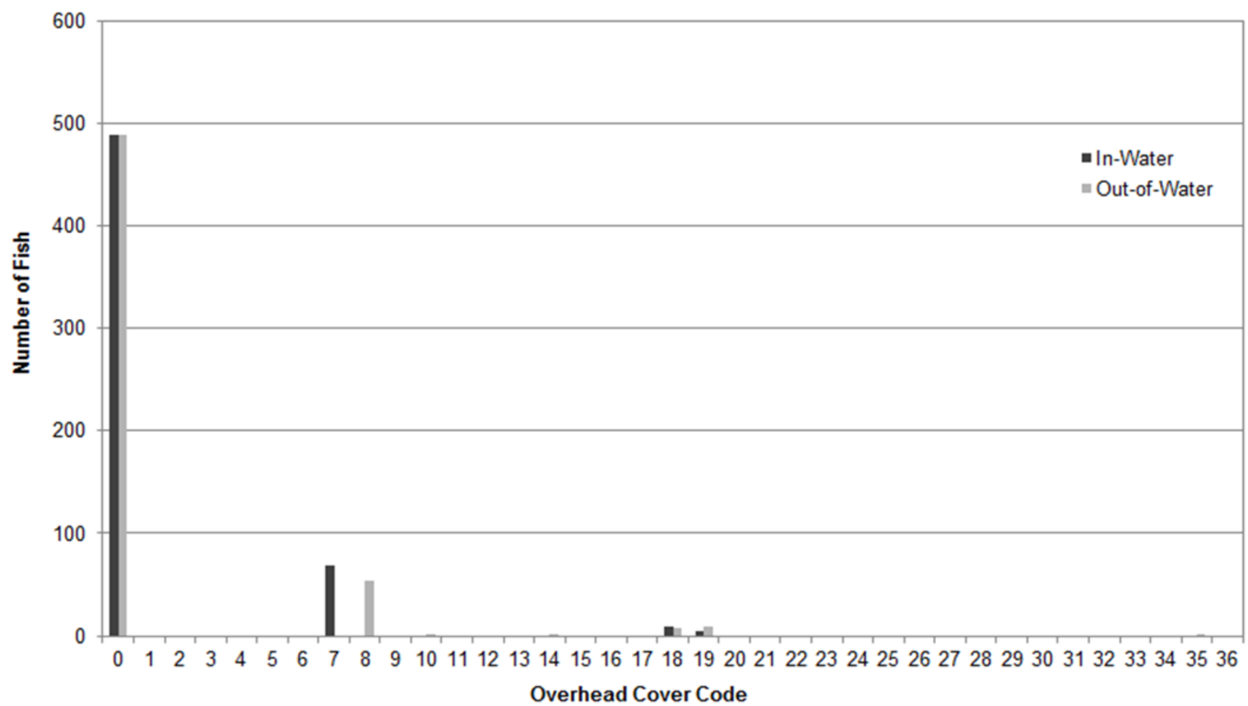
Figure 87. Frequency distribution for substrate percent embedded used by 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

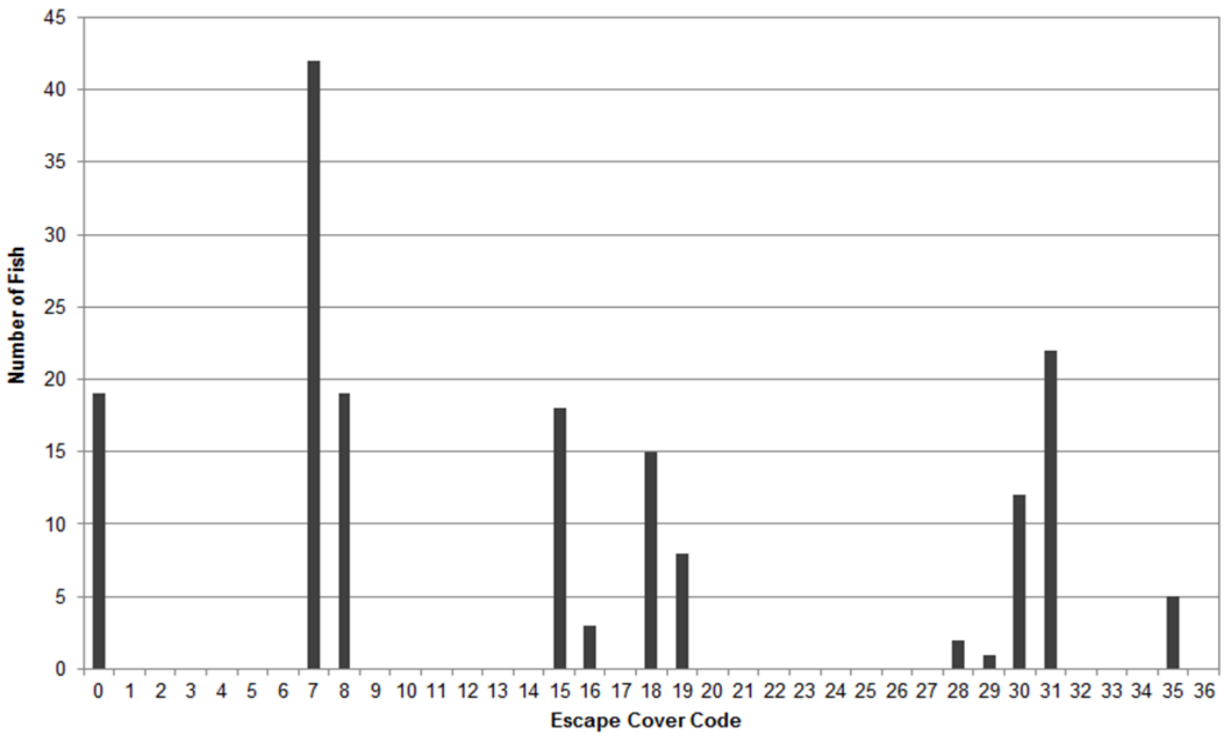
Figure 88. Frequency distribution of nearest in-water and out-of-water overhead cover for 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

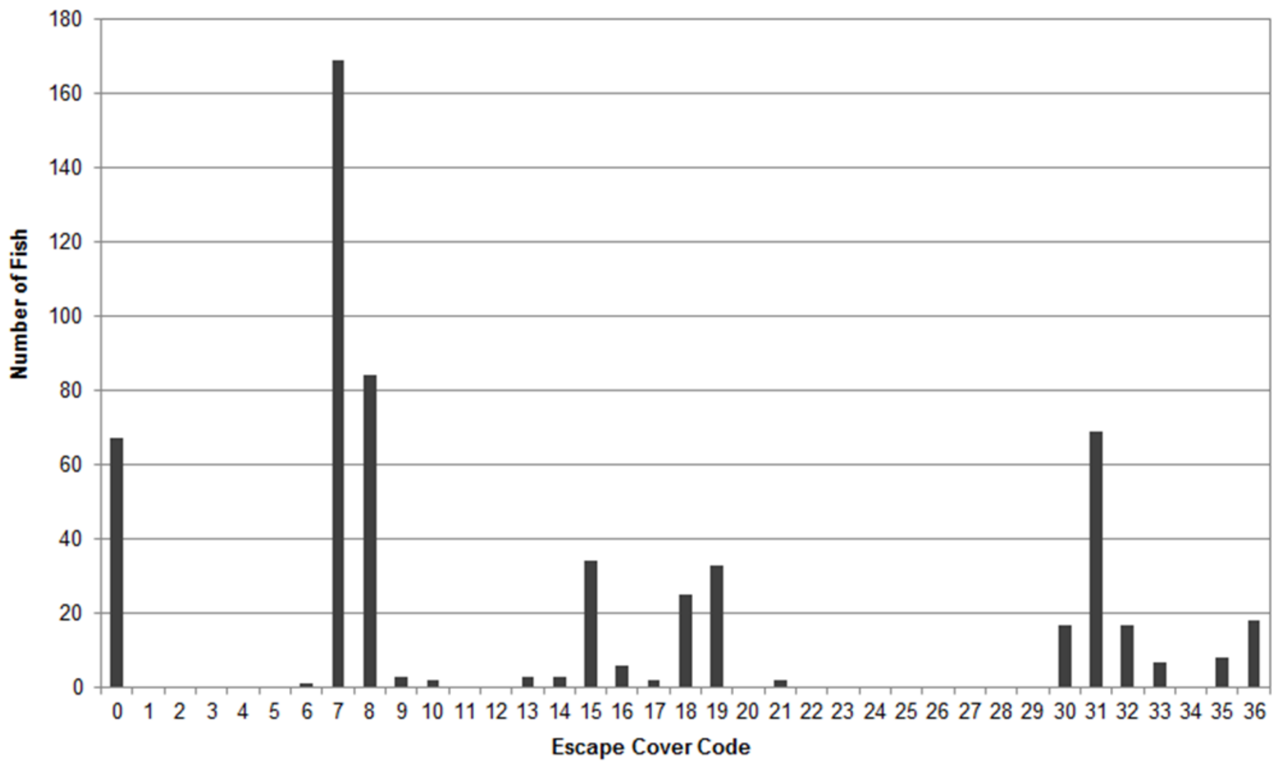
Figure 89. Frequency distribution of nearest in-water and out-of-water overhead cover for 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 90. Frequency distribution for escape cover used by 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 91. Frequency distribution for escape cover used by 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.

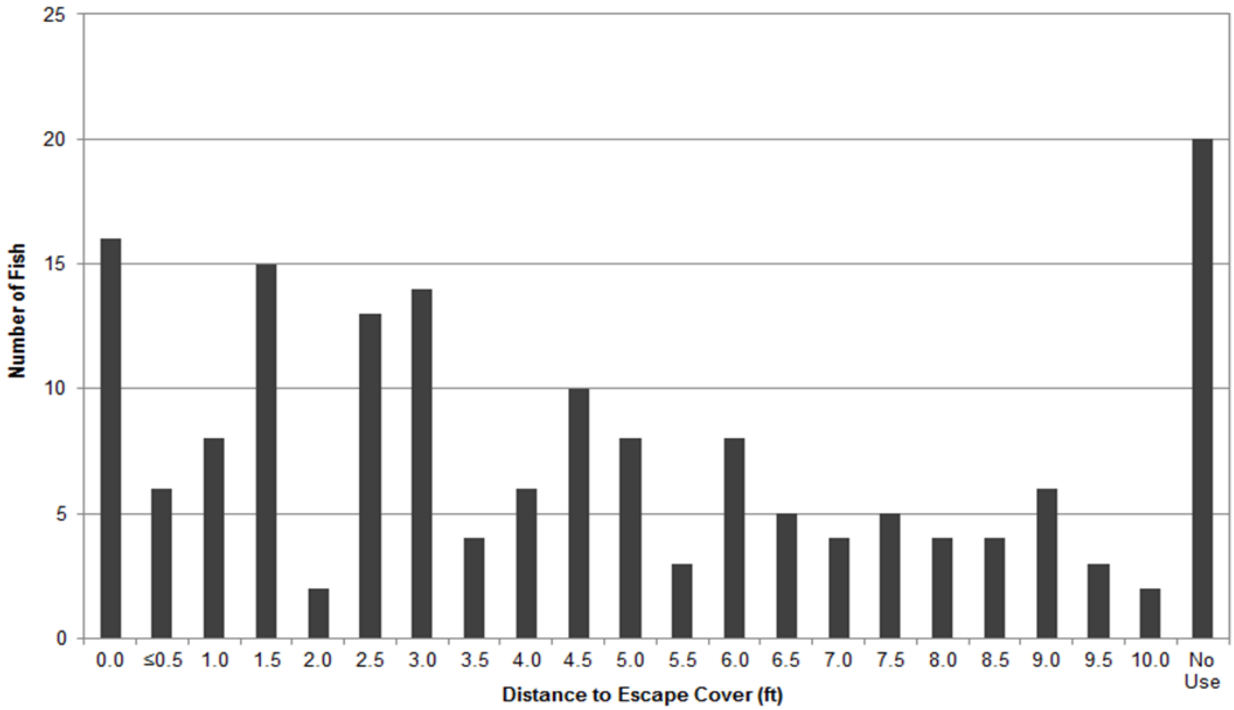


Figure 92. Frequency distribution for distance to escape cover for 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.

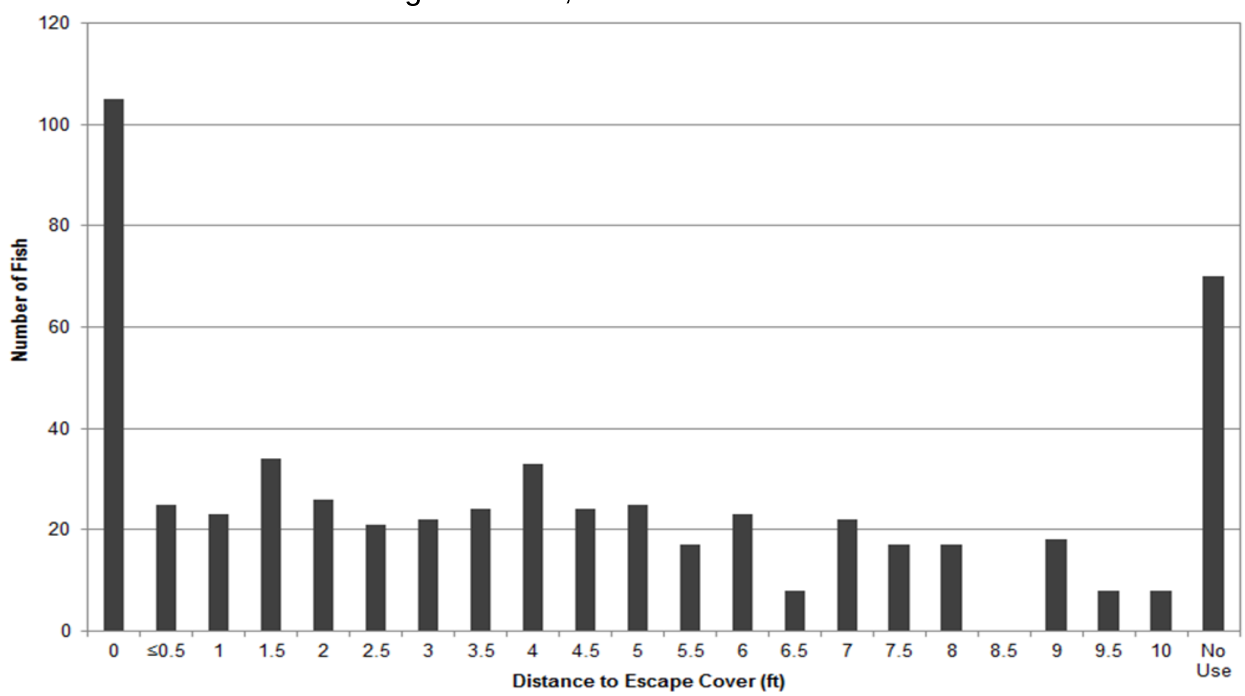


Figure 93. Frequency distribution for distance to escape cover for 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.

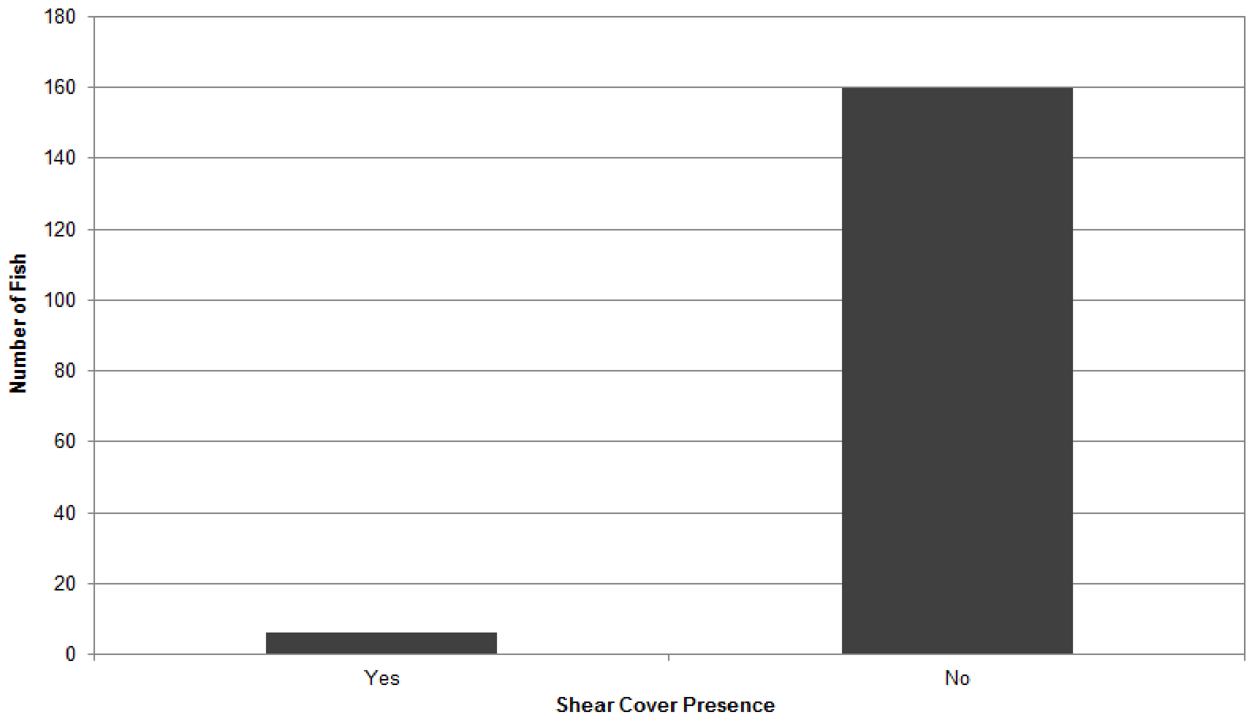


Figure 94. Frequency distribution for shear cover presence used by 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.

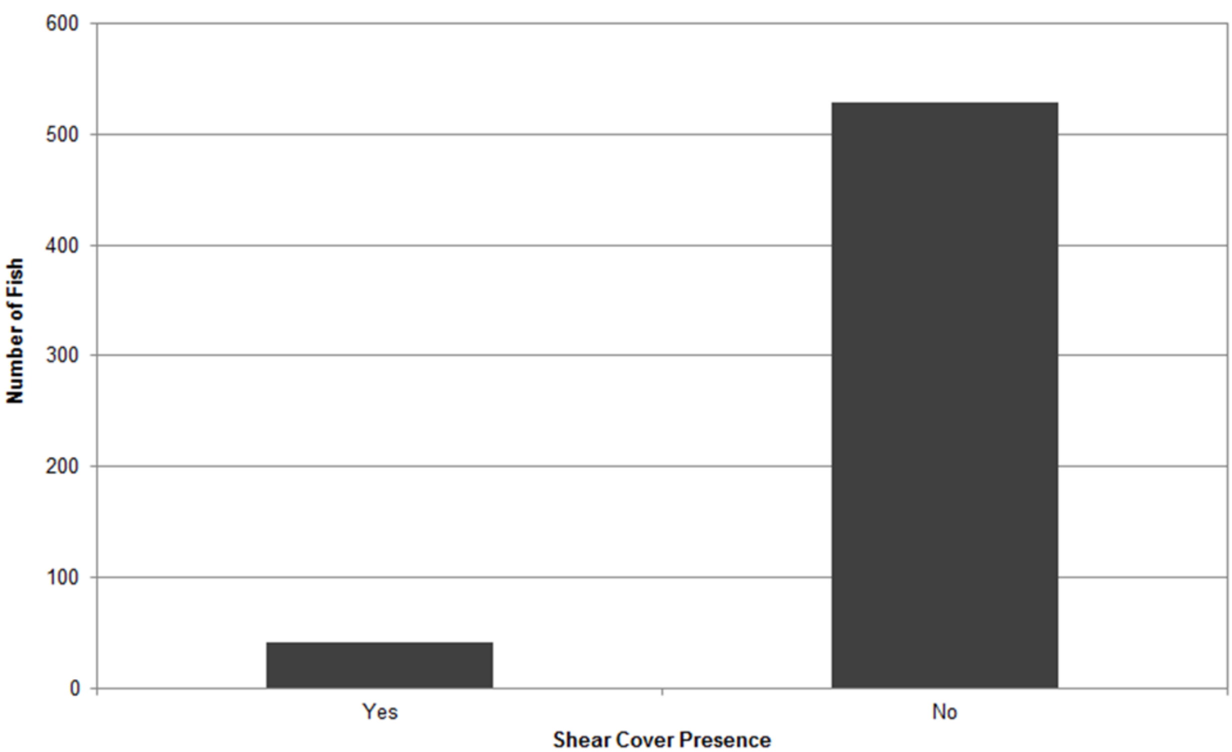
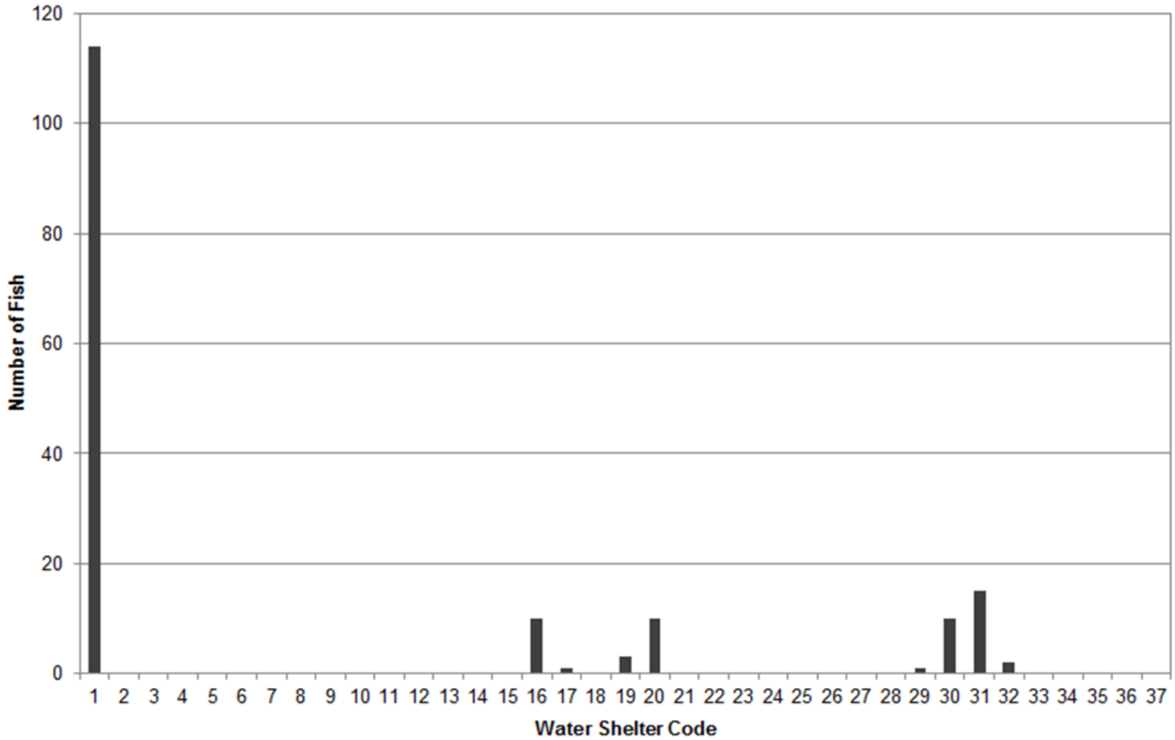


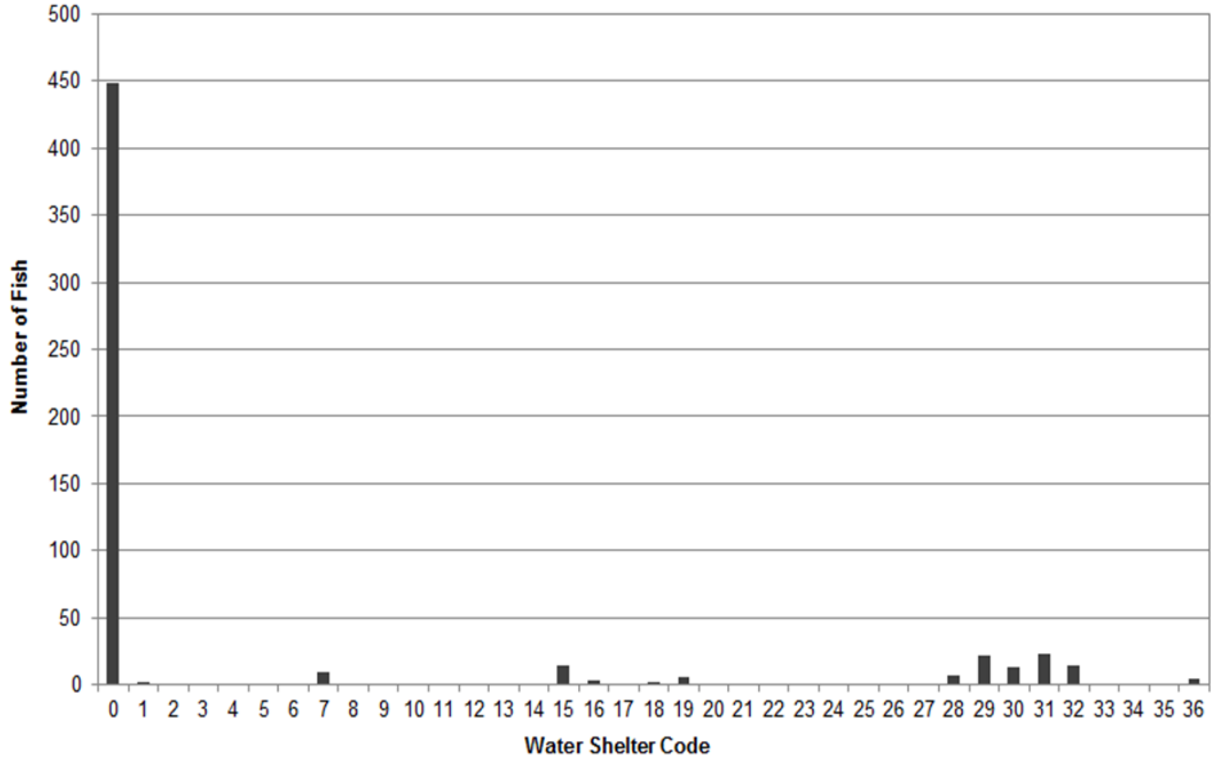
Figure 95. Frequency distribution for shear cover presence used by 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 96. Frequency distribution for water shelter used by 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 97. Frequency distribution for water shelter used by 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.

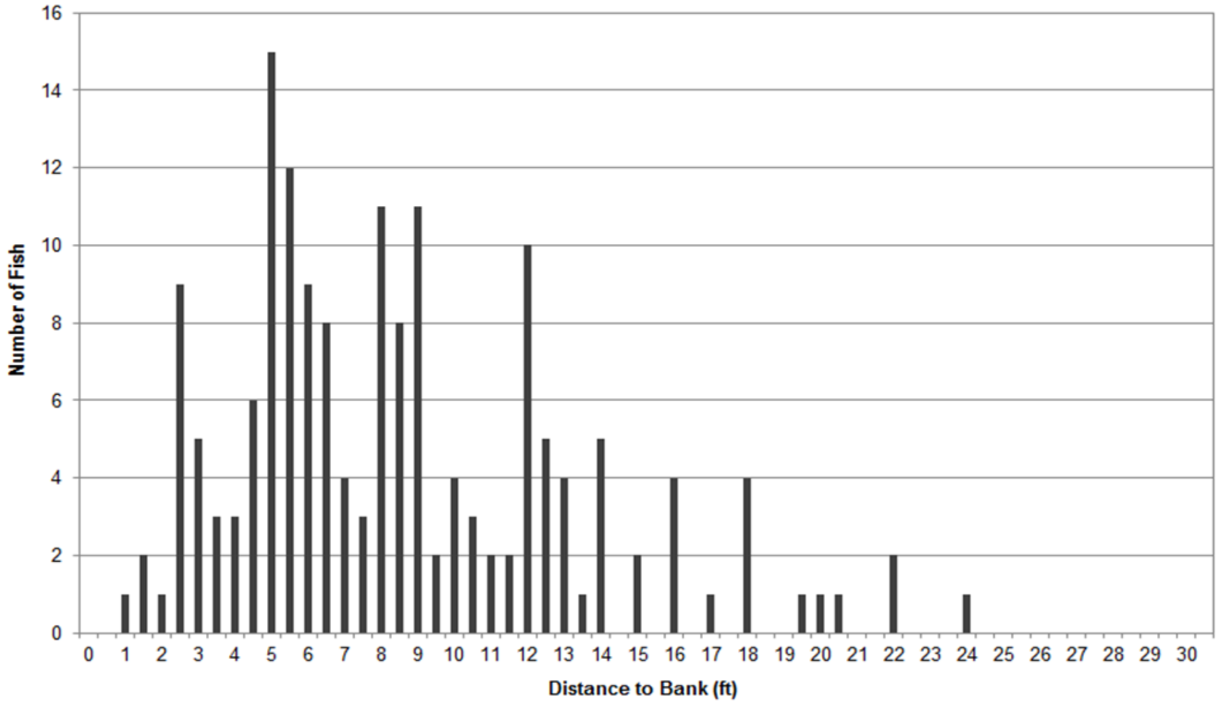


Figure 98. Frequency distribution for distance to bank for 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.

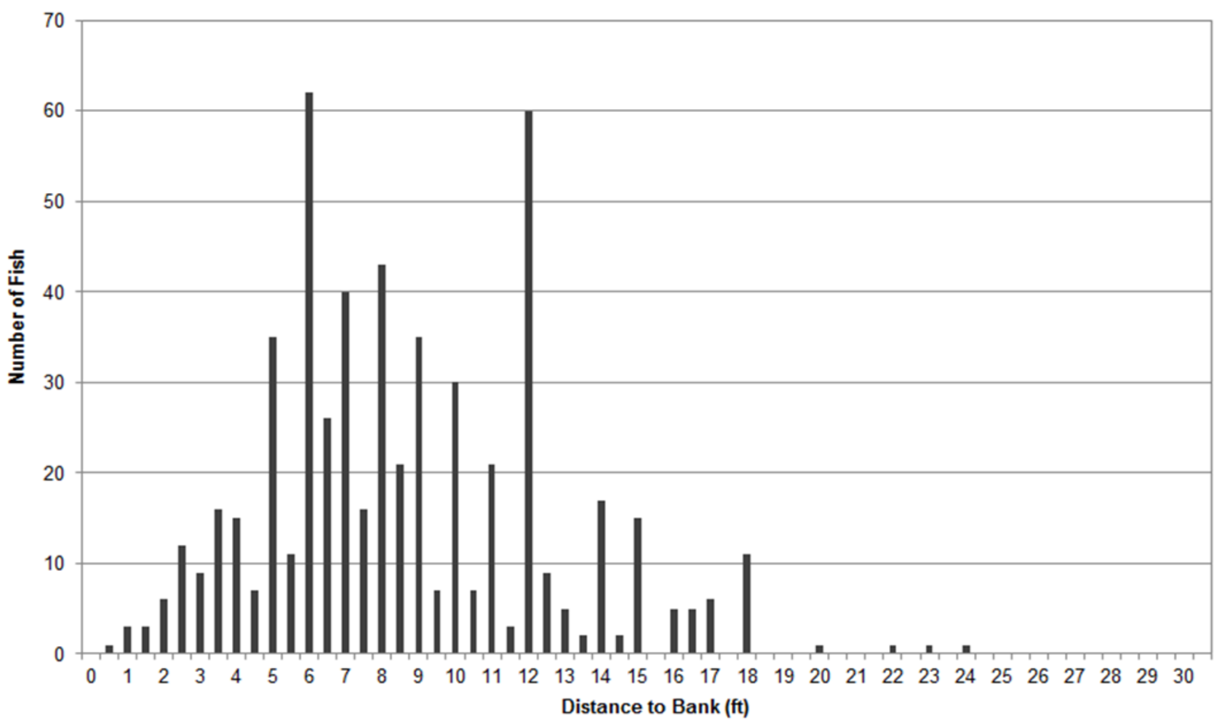
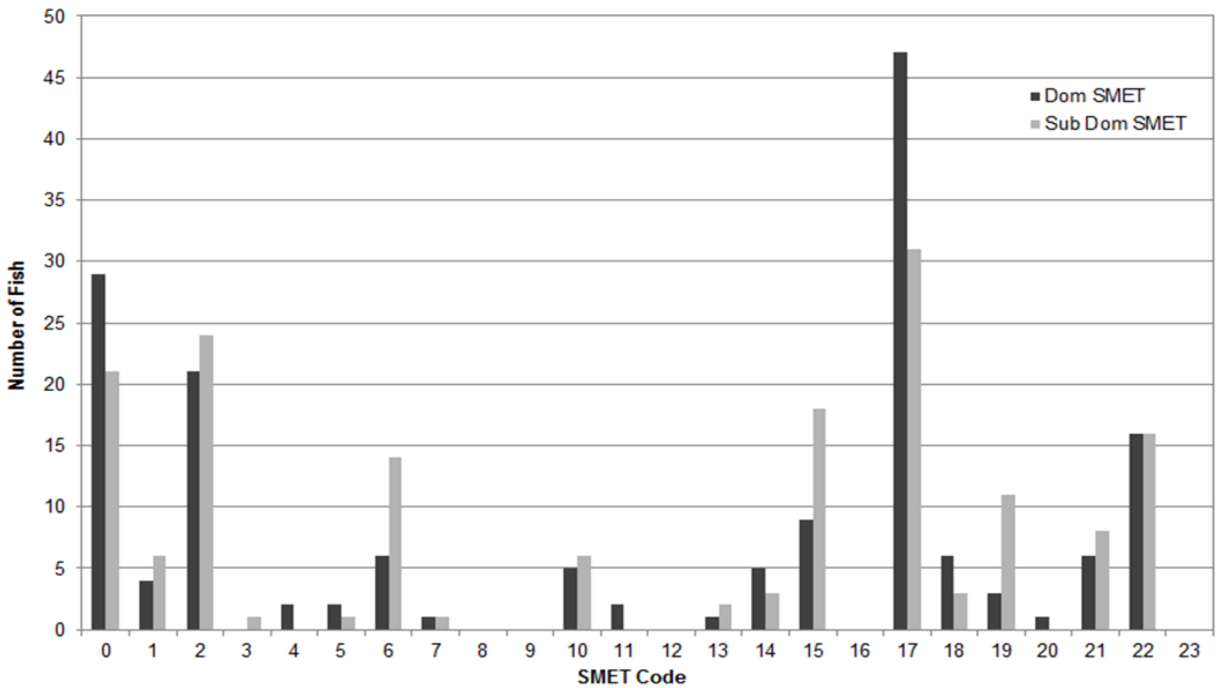
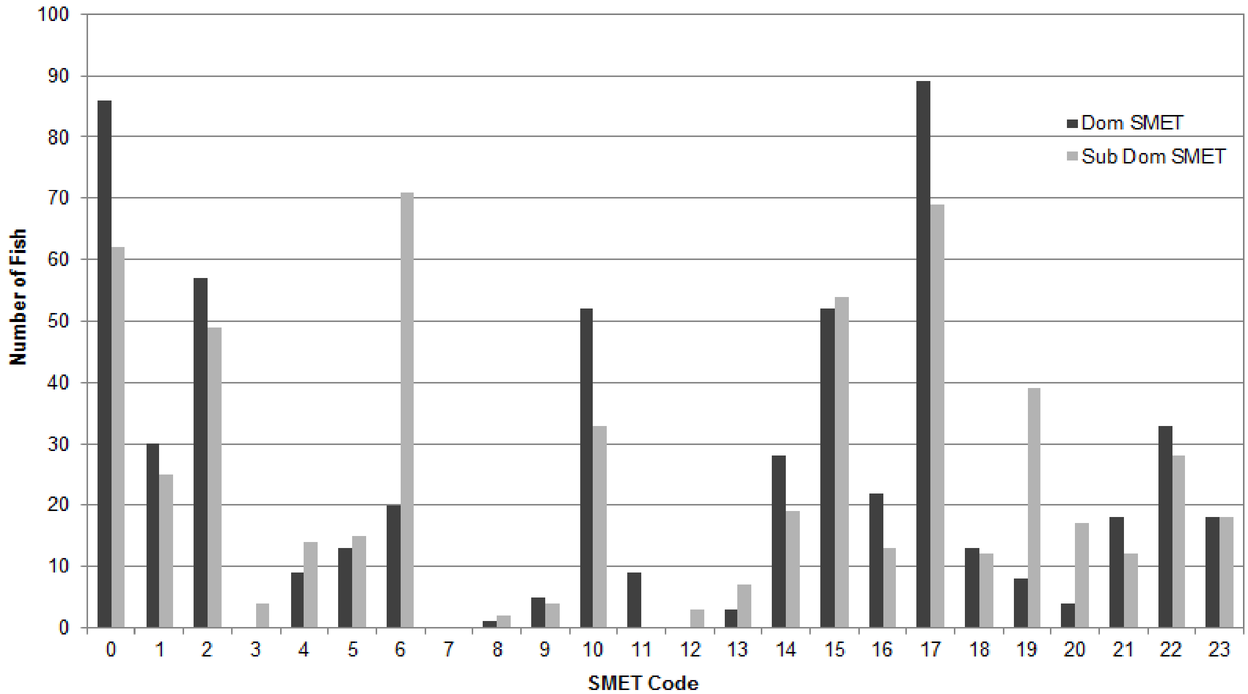


Figure 99. Frequency distribution for distance to bank for 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.



Code	SMET
0	Open
1	Gravel
2	Cobble/boulder
3	Sparse shrubs/herbs/vines/poison oak, IW
4	Sparse shrubs/herbs/vines/poison oak, OW
5	Sparse branches < 4 inches, IW
6	Sparse branches < 4 inches, OW
7	Sparse branches > 4 inches, IW
8	Sparse branches > 4 inches, OW
9	Dense branches < 4 inches, IW
10	Dense branches < 4 inches, OW
11	Dense branches > 4 inches, IW
12	Dense branches > 4 inches, OW
13	Trees < 4 inches
14	Trees > 4 inches
15	Small wood debris < 4 inches (dead)
16	Large woody debris > 4 inches (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

Figure 100. Distribution for stream margin edge type (SMET) used by 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.



Code	SMET
0	Open
1	Gravel
2	Cobble/boulder
3	Sparse shrubs/herbs/vines/poison oak, IW
4	Sparse shrubs/herbs/vines/poison oak, OW
5	Sparse branches < 4 inches, IW
6	Sparse branches < 4 inches, OW
7	Sparse branches > 4 inches, IW
8	Sparse branches > 4 inches, OW
9	Dense branches < 4 inches, IW
10	Dense branches < 4 inches, OW
11	Dense branches > 4 inches, IW
12	Dense branches > 4 inches, OW
13	Trees < 4 inches
14	Trees > 4 inches
15	Small wood debris < 4 inches (dead)
16	Large woody debris > 4 inches (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

Figure 101. Distribution for stream margin edge type (SMET) used by 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.

Habitat Availability

Habitat availability sample results are summarized by season and reach in Table 14. A grand total of 1,452 habitat availability samples were collected with 414, 522, and 516 samples collected in the spring, summer, and fall sample seasons, respectively. Sample sizes were generally consistent among seasons and reaches.

Table 14. Number of habitat availability samples collected during spring, summer, and fall in the Lower Molera, Molera, and Campground reaches of the Big Sur River.

Season	Reach	Number of Samples
	Lower Molera	162
Spring	Molera	117
	Campground	135
		Total: 414
	Lower Molera	165
Summer	Molera	162
	Campground	195
		Total: 522
	Lower Molera	162
Fall	Molera	159
	Campground	195
		Total: 516
		Grand Total: 1,452

Habitat availability statistics for depth and velocity measurements collected in spring, summer, and fall are summarized in Table 15. These statistics represent the availability measurements made at the same mesohabitat sites where the fish surveys were conducted. Table 15 also outlines a second set of habitat availability measurements which were obtained from data collected from 118 transects spanning the three-reach study area. The transect locations were selected through a stratified random process to be used as part of a one-dimensional (1D) physical habitat hydraulic model analysis. The 1D transect data were collected at comparable flows (i.e., 24-30 cfs) to the flows (23-26 cfs) the fall fish survey and associated habitat availability data were collected. Also, the 1D data were based upon proportional, not equal area, habitat representation for hydraulic habitat modeling.

Table 15. Statistics for depth and velocity habitat availability measurements taken in the Big Sur River during spring, summer, and fall fish observation sampling events and taken from measurements at 118 transects used for a 1D hydraulic habitat model.

Season	Statistic	N	Minimum	Maximum	Average	Median	Std. Dev.
Spring	Water Depth (ft)	414	0.00	3.80	1.09	1.00	0.64
	Water Velocity (ft/s)	411	0.00	6.24	1.17	1.06	0.90
Summer	Water Depth (ft)	522	0.05	4.00	1.10	1.00	0.64
	Water Velocity (ft/s)	522	0.00	5.67	1.37	1.26	0.92
Fall	Water Depth (ft)	516	0.10	4.00	0.93	0.80	0.58
	Water Velocity (ft/s)	516	0.00	4.32	0.92	0.81	0.69
1D (Fall)	Water Depth (ft)	4273	0.01	3.50	0.85	0.80	0.50
	Water Velocity (ft/s)	4273	0.00	4.45	0.91	0.78	0.72

Minimum and maximum water depth habitat availability were comparable during the spring, summer, and fall sample events. Maximum water velocity, on the other hand, showed a general decrease from spring through summer and fall. Similarly, average water depth and average water velocity were less in fall when compared to the spring and summer sample events. Because the 1D availability data represent a much larger data set (N = 4273) compared to the availability data from the fall fish surveys (N = 516), these data allow greater insight into habitat availability conditions at the flows when the fish surveys were conducted. Comparing the 1D habitat availability data to the fall fish survey habitat availability data indicates the same general occurrence of habitat availability conditions and further indicates a decrease in availability of the higher velocities in fall when compared to summer. Comparing fall fish survey depth availability to fall 1D depth availability indicates the rareness of depths greater than 3.50 ft.

Habitat Availability and Fish Use

Spring habitat availability results for depth and velocity were compared to fish use and displayed as frequency distributions by fish size and season. The distribution of water depth availability indicated slightly deeper water habitats available in spring then what the <6 cm juvenile steelhead were using (Figure 102). A similar trend was observed with water velocity habitat availability and <6 cm fish use (Figure 103), although the highest frequencies of <6 cm fish velocity use and availability coincided at velocities of 0.00 ft/s. Figure 104 and Figure 105 depict escape cover use and availability, and distance to escape cover use and availability, respectively.

The distribution of water depth availability indicated slightly shallower water habitats available in summer then what the 6-9 cm juvenile steelhead were using (Figure 106). Velocity habitat availability and juvenile fish velocity use were generally consistent in summer (Figure 107). However, the highest frequencies of velocity use occurred at slightly higher velocities than what was available for 6-9 cm juvenile steelhead. Figure 108 and Figure 109 depict 6-9 cm juvenile steelhead escape cover use and availability, and distance to escape cover use and availability, respectively.

The distribution of water depth availability indicated slightly shallower water habitats available in summer then what the 10-15 cm juvenile steelhead were using (Figure 110). Velocity habitat availability and juvenile fish velocity use were generally consistent in summer (Figure 111). However, the highest frequencies of velocity use occurred at slightly higher velocities than what was available for 6-9 cm juvenile steelhead. Further, the greatest difference between the highest frequencies of velocity use and velocity availability occurred with the larger (10-15 cm) juvenile fish. Figure 112 and Figure 113 depict 10-15 cm juvenile steelhead escape cover use and availability, and distance to escape cover use and availability, respectively.

The distribution of water depth availability indicated a larger usage of deeper habitats then what were available in the fall sample event for the 6-9 cm juvenile steelhead (Figure 114). The highest frequency of velocity availability (0.7-0.8 ft/s range) was less than the highest frequency of velocity use (1.2-1.3 ft/s) by 6-9 cm juvenile steelhead (Figure 115). Figure 116 and Figure 117 depict 6-9 cm juvenile steelhead escape cover use and availability, and distance to escape cover use and availability in the fall, respectively.

The distribution of water depth availability indicated a much larger usage of deeper habitats then what were available in the fall sample event for the 10-15 cm juvenile steelhead (Figure 118). A comparison of velocity availability and juvenile steelhead usage indicated mostly the same overall pattern of velocity availability and pattern of fish usage of velocity in fall for 10-15 cm juvenile steelhead in fall (Figure 119). Figure 120 and Figure 121 depict 10-15 cm juvenile steelhead escape cover use and availability, and distance to escape cover use and availability in the fall, respectively.

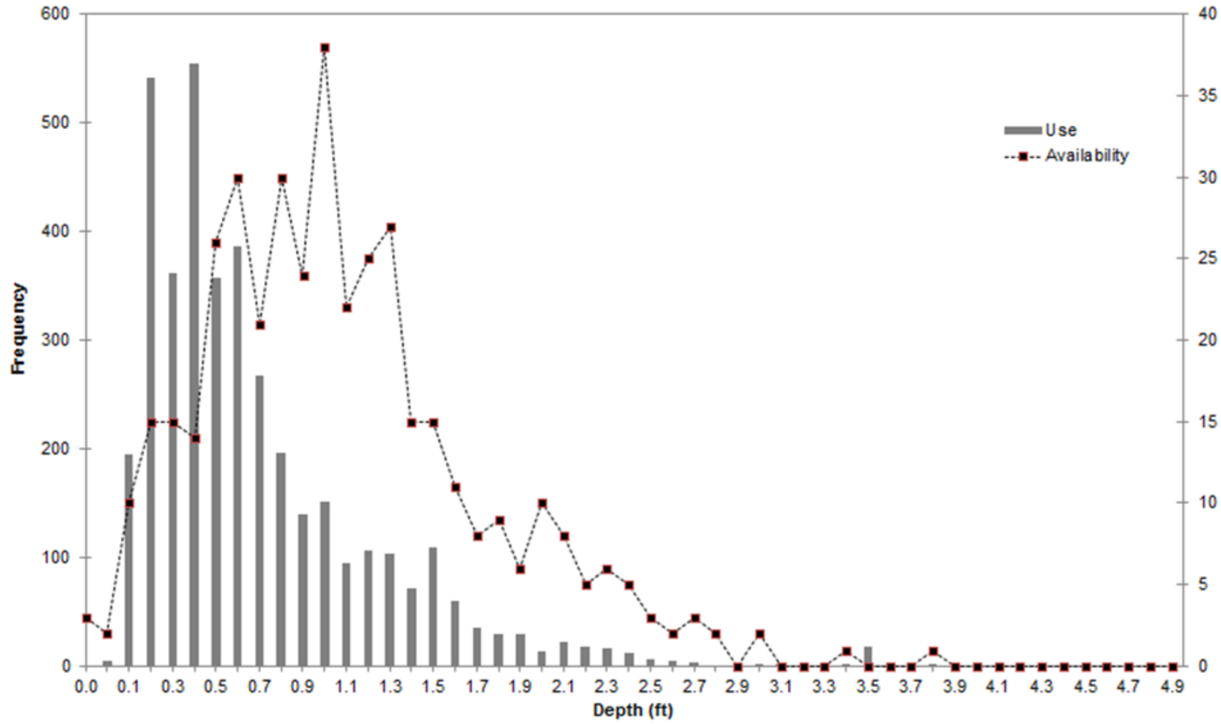


Figure 102. Frequency distribution of water depth for use vs. availability for <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.

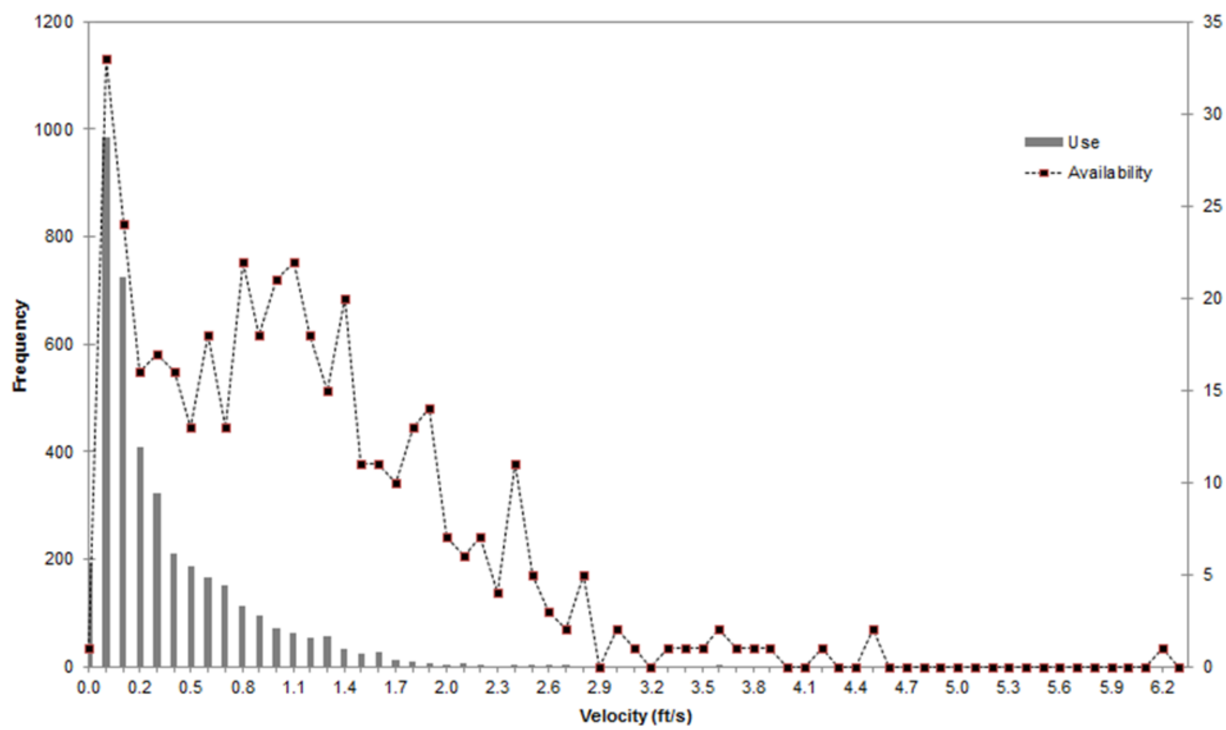
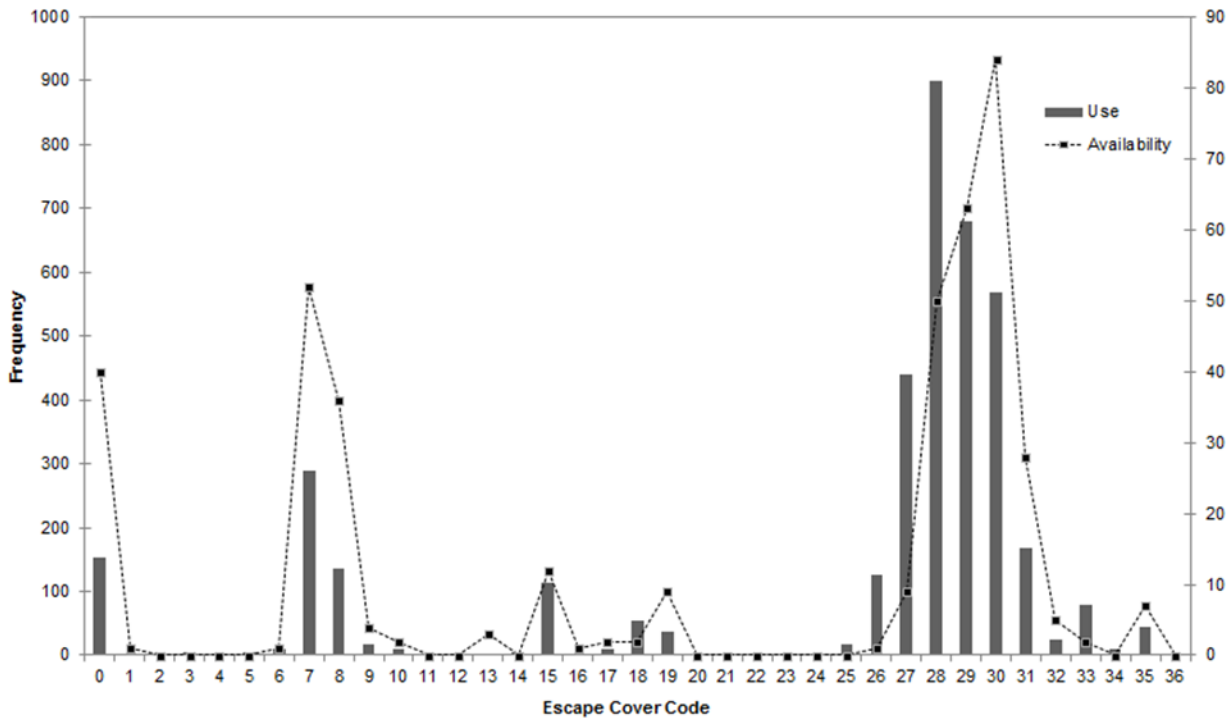


Figure 103. Frequency distribution of water velocity for use vs. availability for <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 104 . Frequency distribution of escape cover type use vs. availability for <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.

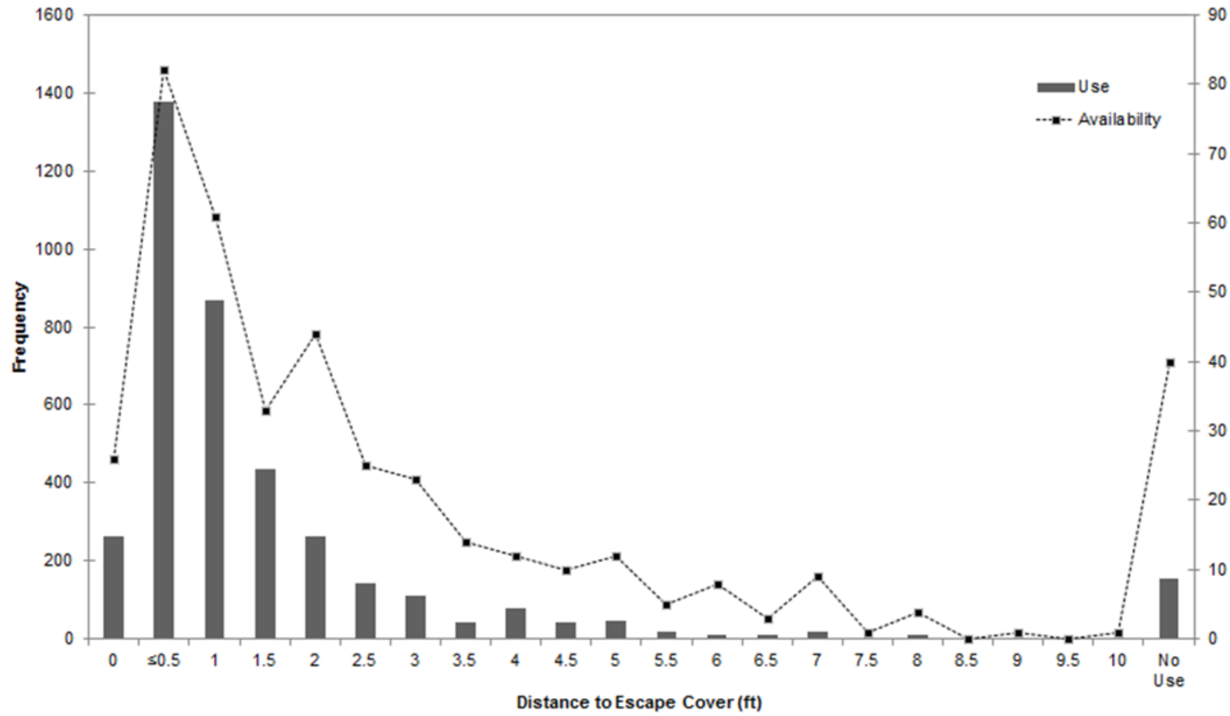


Figure 105 . Frequency distribution of escape cover distance use vs. availability for <6 cm juvenile steelhead observed in the Big Sur River, spring 2012.

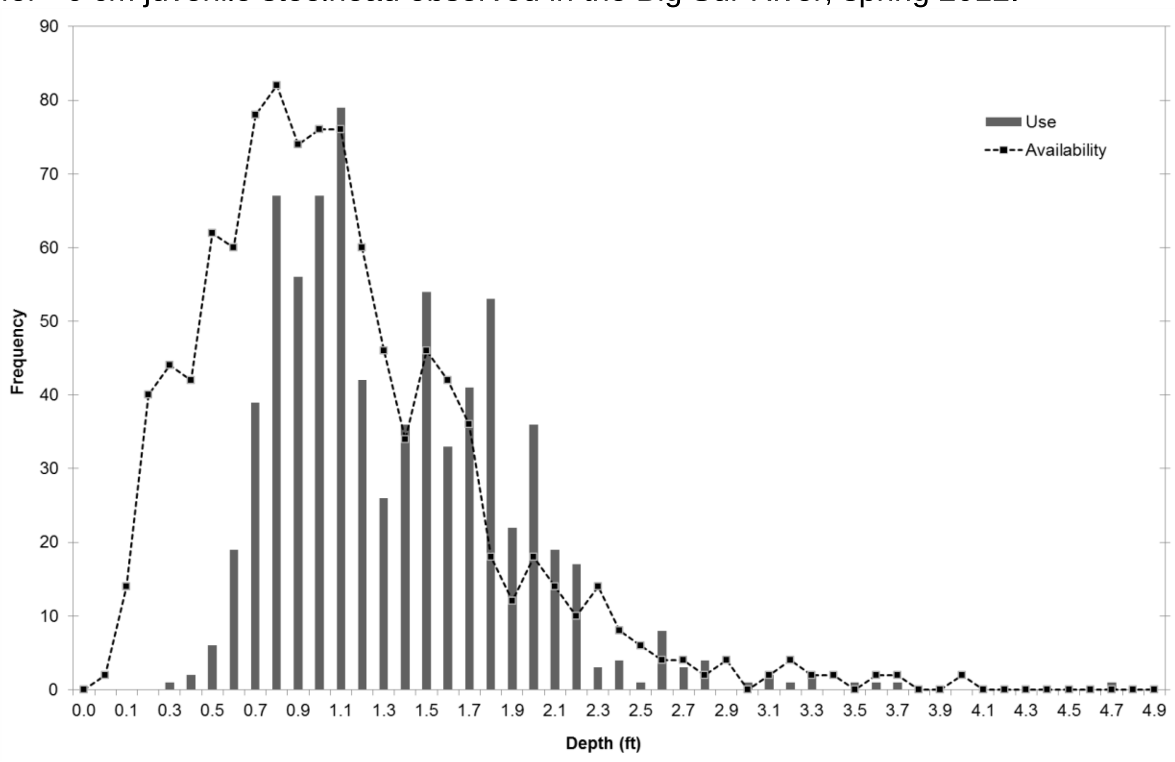


Figure 106. Frequency distribution of water depth for use vs. availability for 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.

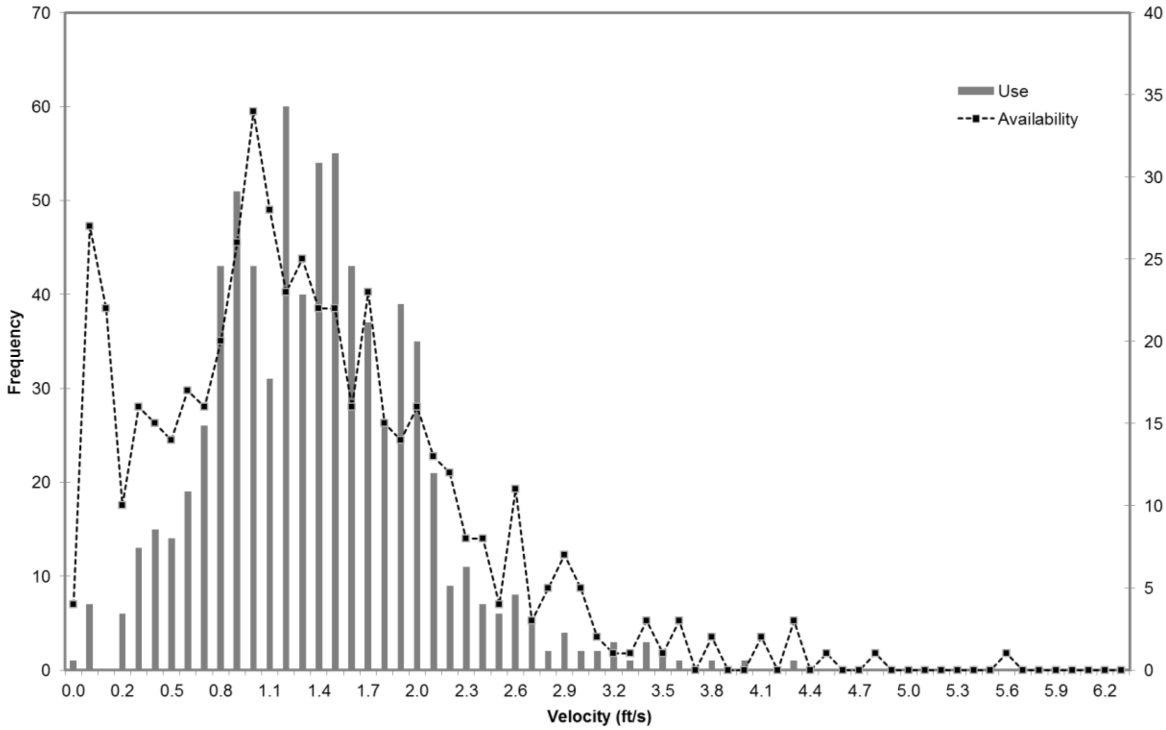
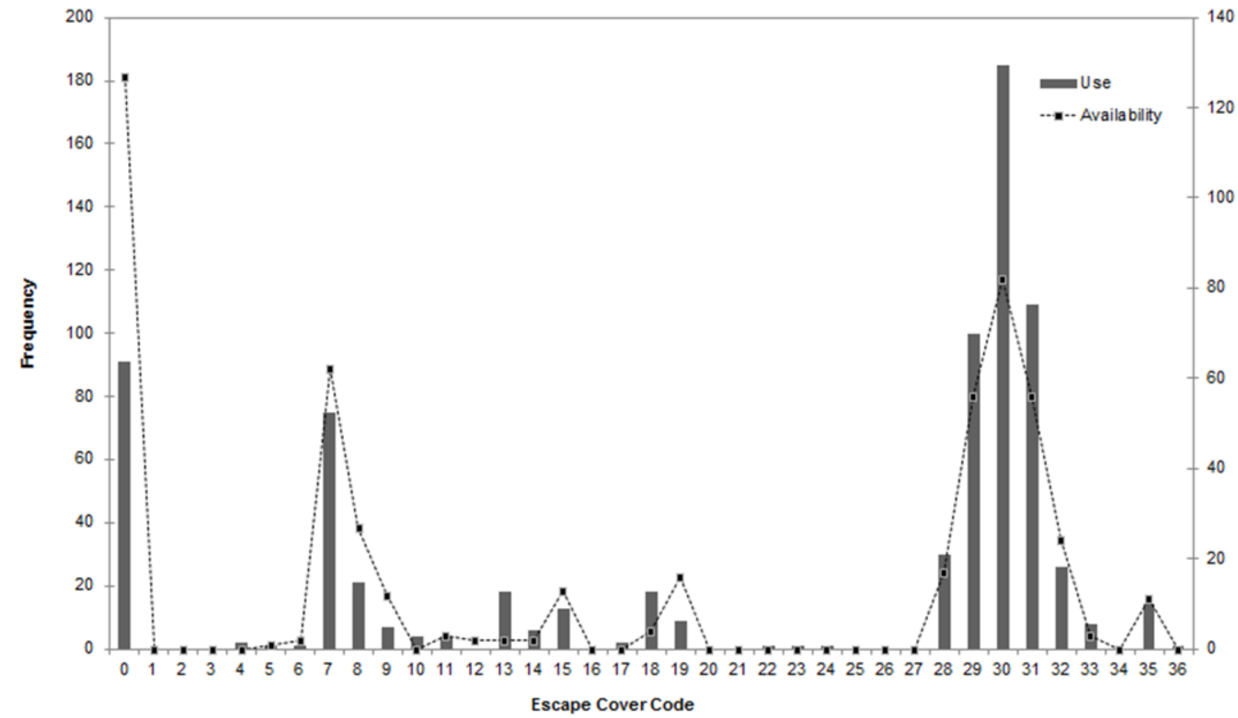


Figure 107. Frequency distribution of water velocity for use vs. availability for 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 108. Frequency distribution of escape cover type use vs. availability for 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.

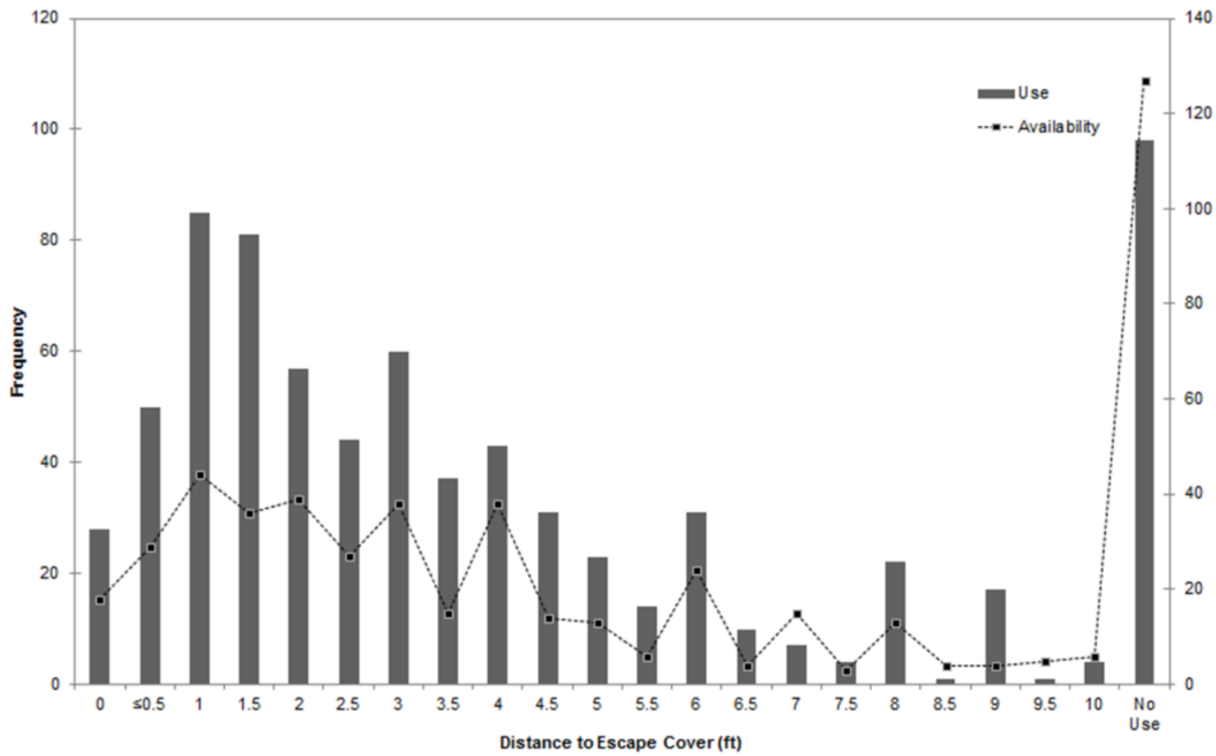


Figure 109. Frequency distribution of escape cover distance use vs. availability for 6-9 cm juvenile steelhead observed in the Big Sur River, summer 2010.

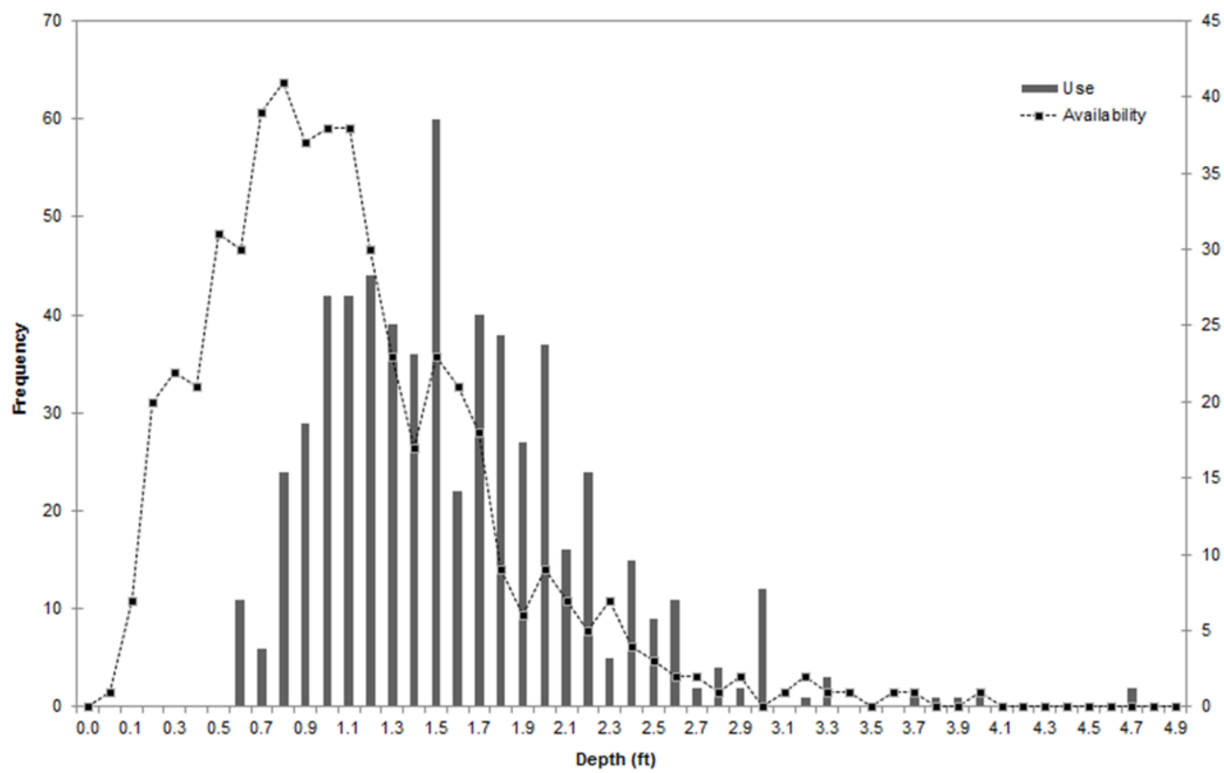


Figure 110. Frequency distribution of water depth for use vs. availability for 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.

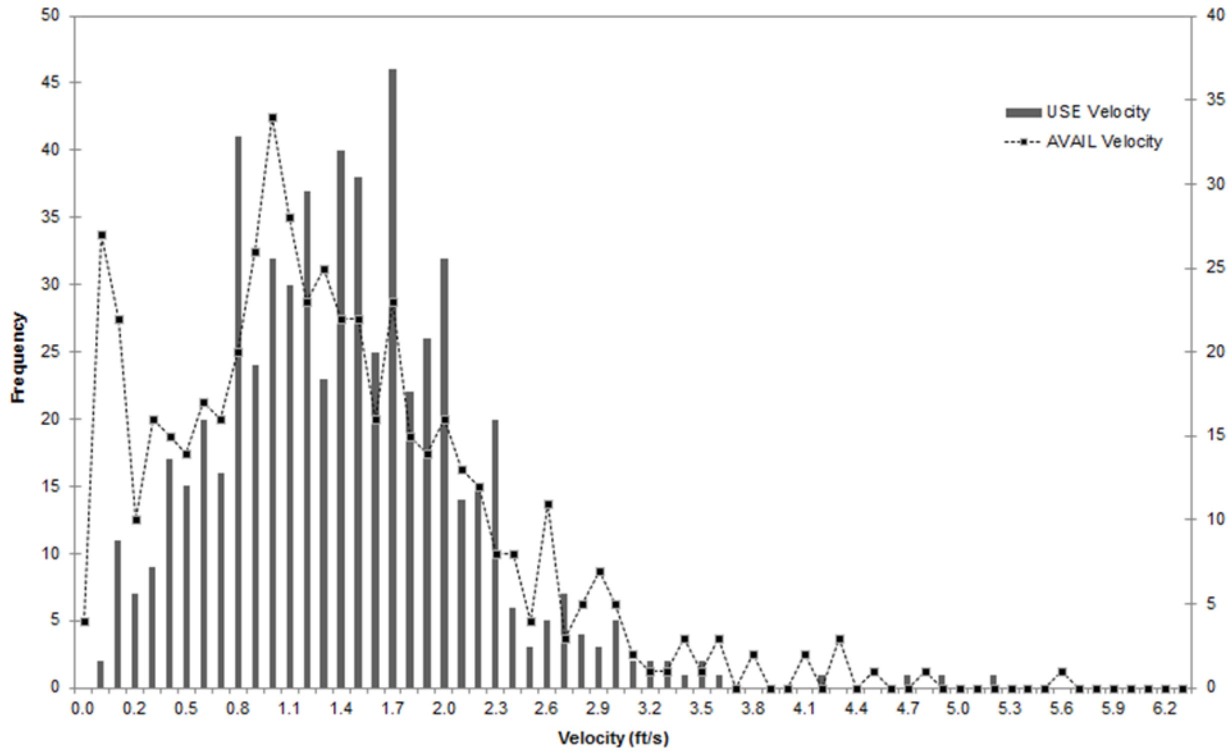
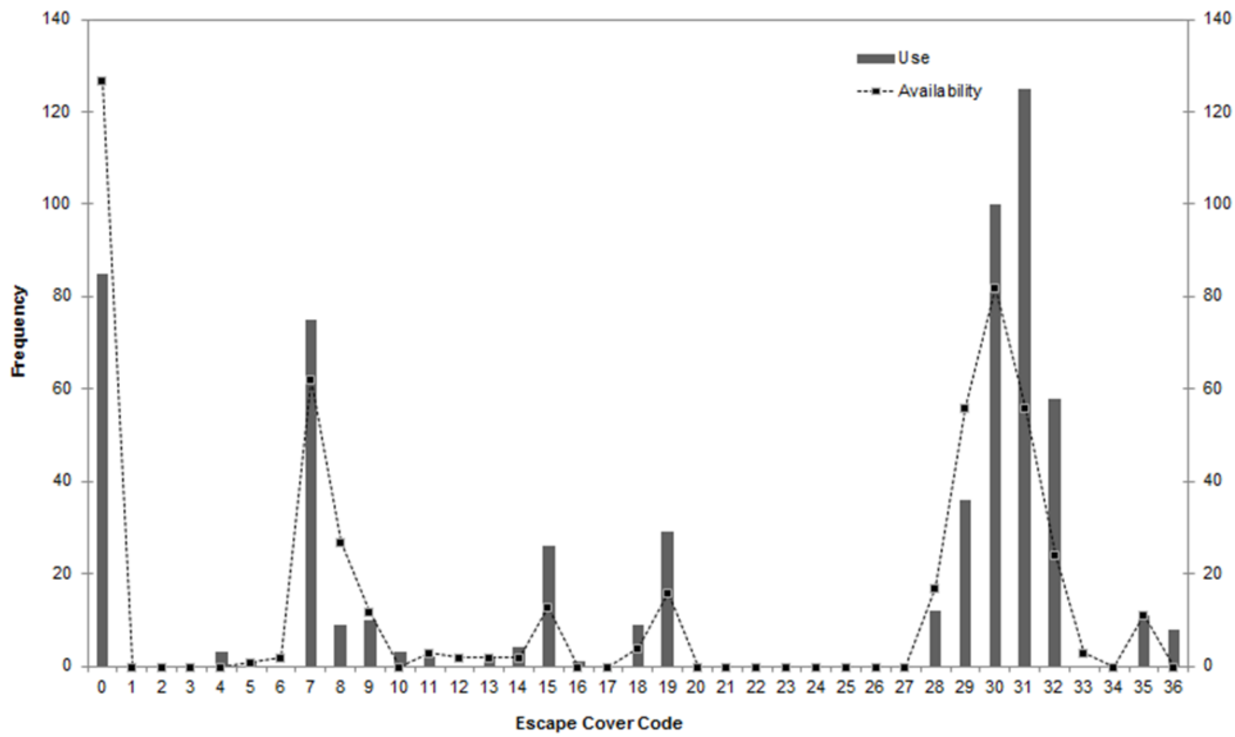


Figure 111. Frequency distribution of water velocity for use vs. availability for 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 112 . Frequency distribution of escape cover type use vs. availability for 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.

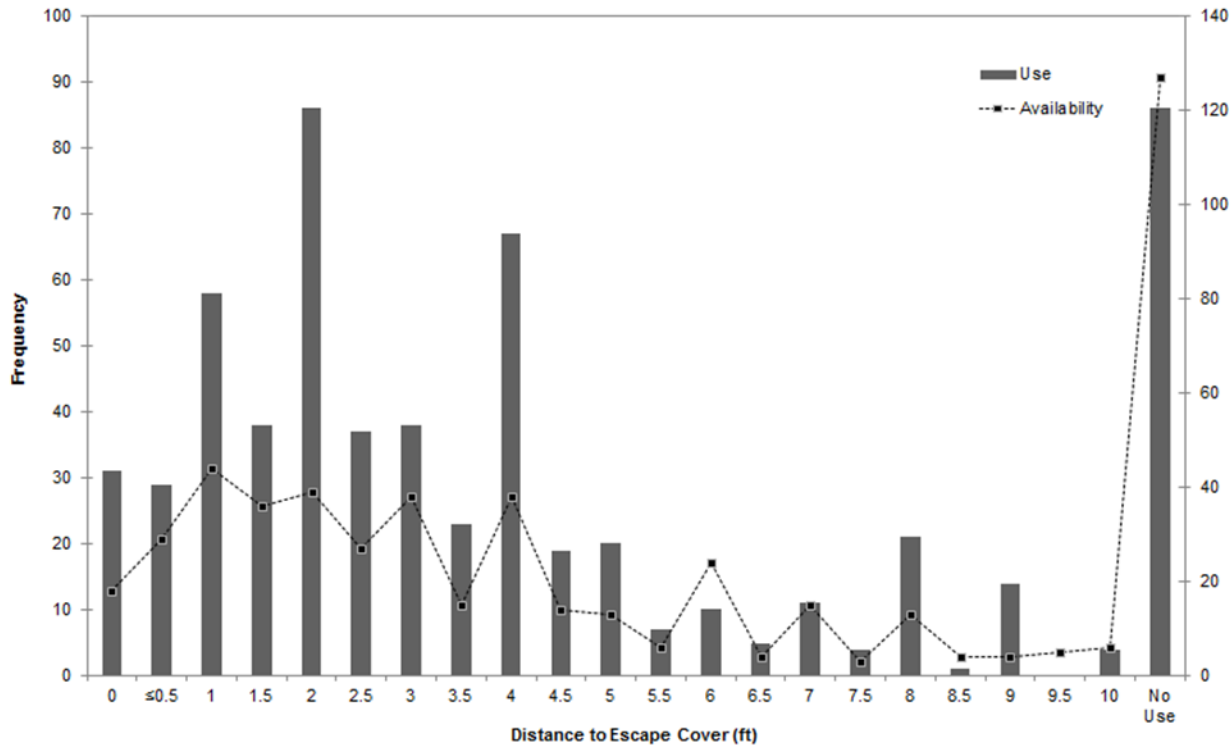


Figure 113. Frequency distribution of escape cover distance use vs. availability for 10-15 cm juvenile steelhead observed in the Big Sur River, summer 2010.

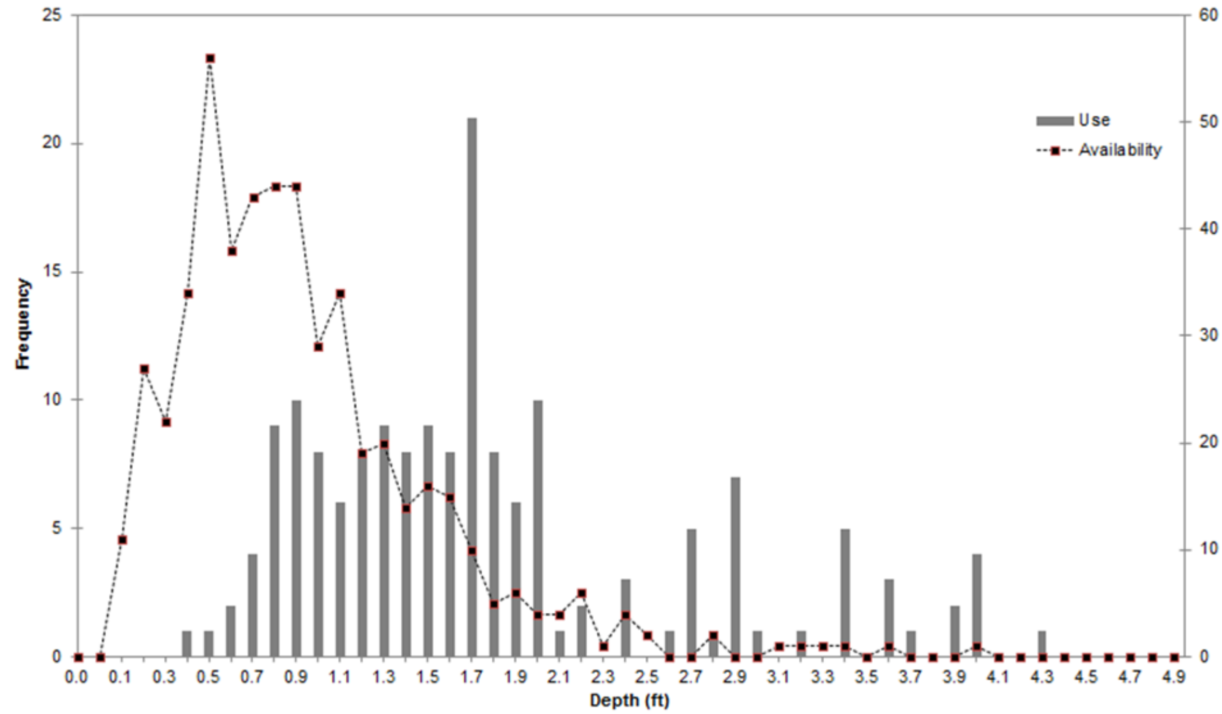


Figure 114. Frequency distribution of water depth for use vs. availability for 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.

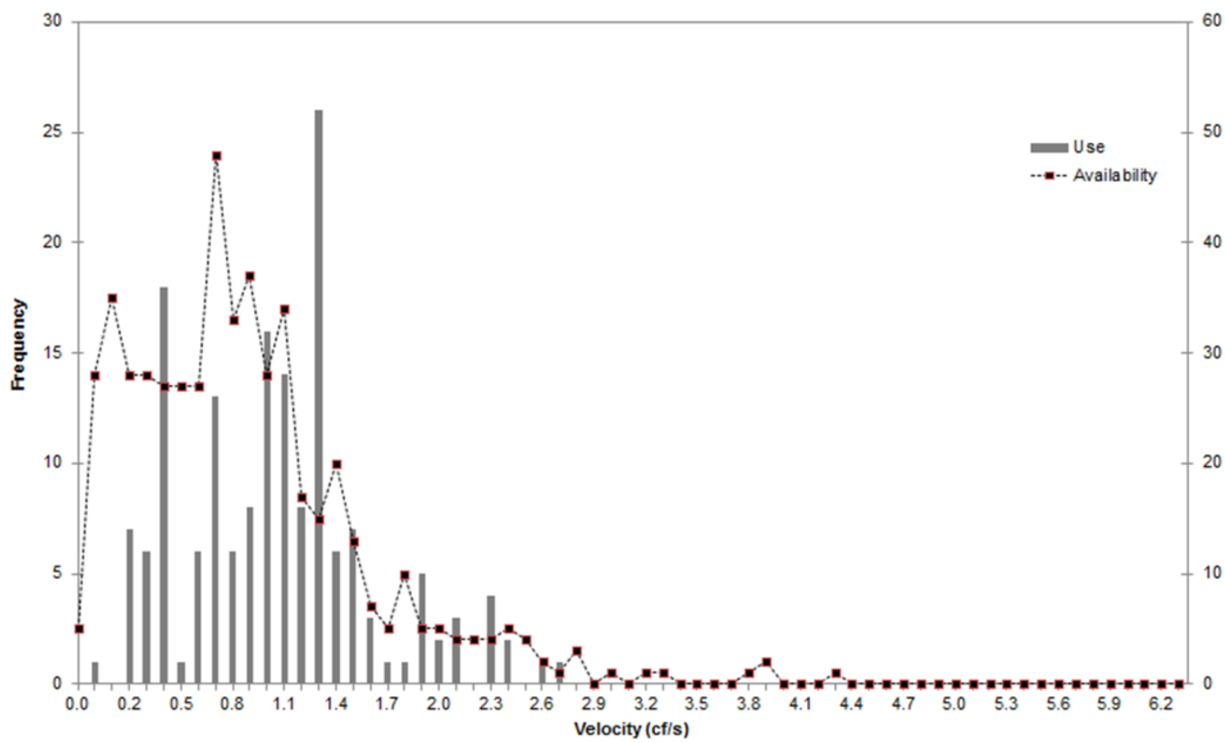
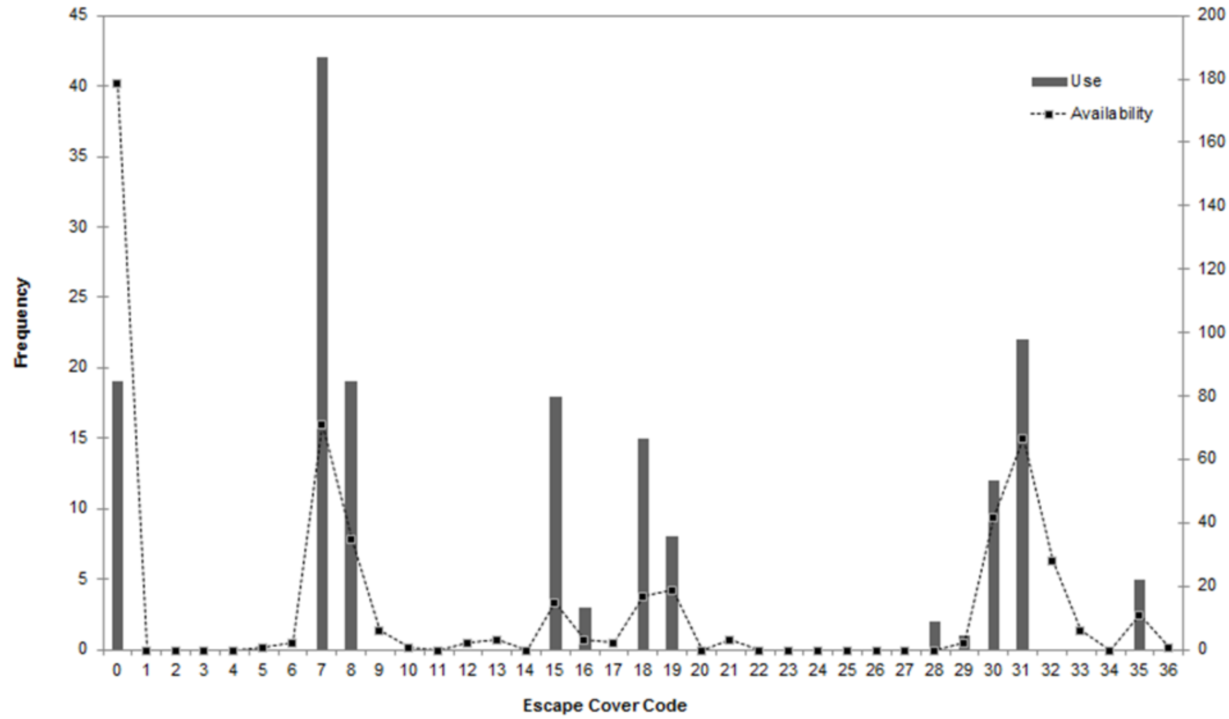


Figure 115. Frequency distribution of water velocity for use vs. availability for 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 116 . Frequency distribution of escape cover type use vs. availability for 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.

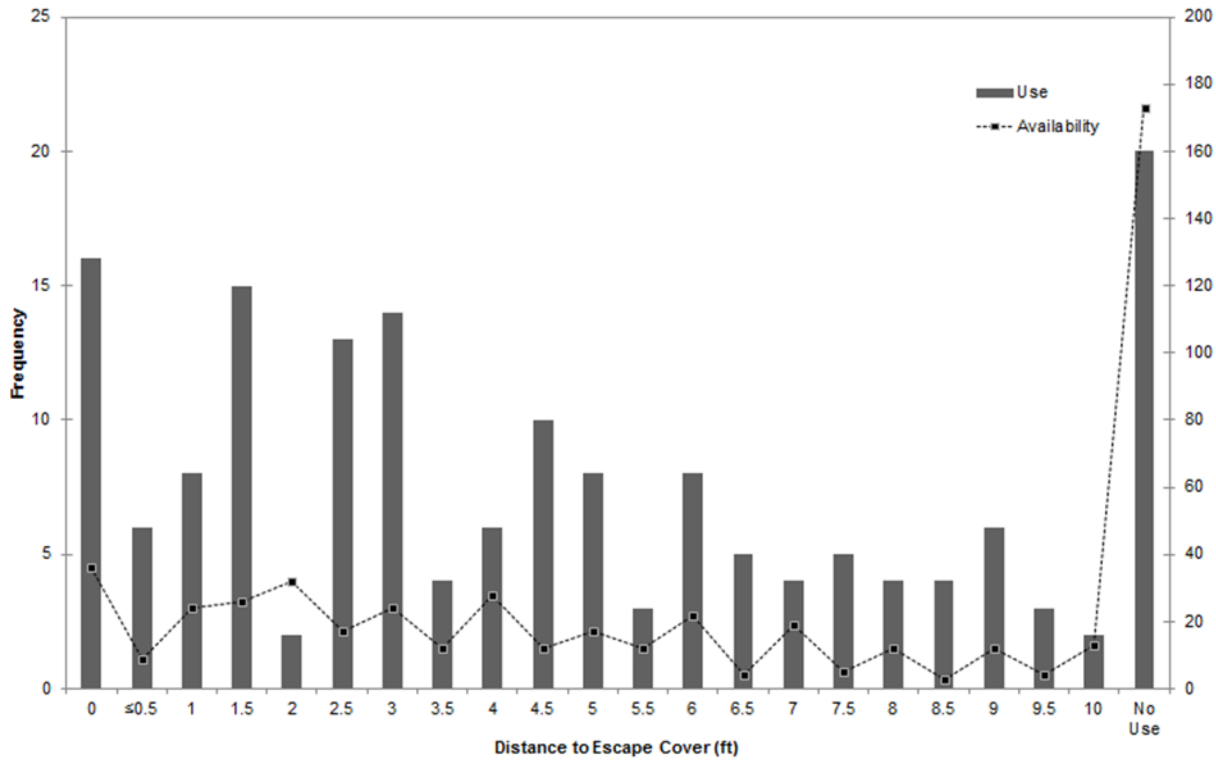


Figure 117. Frequency distribution of escape cover distance use vs. availability for 6-9 cm juvenile steelhead observed in the Big Sur River, fall 2010.

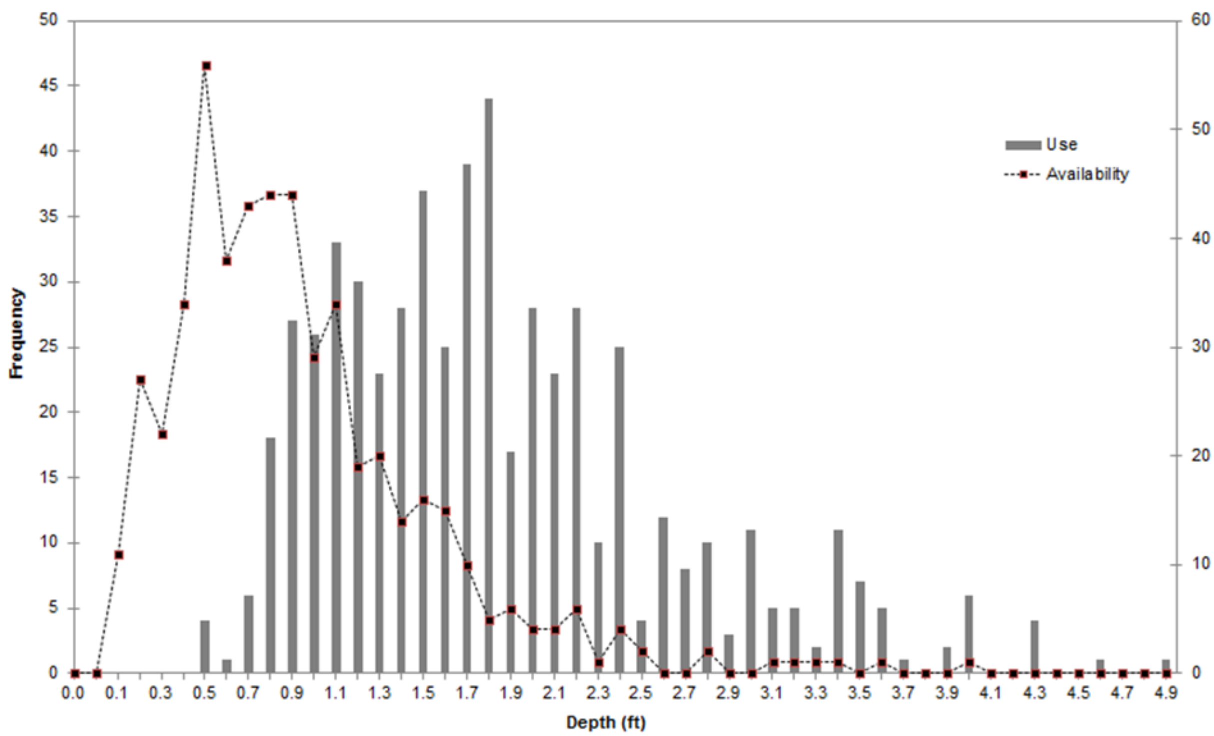


Figure 118. Frequency distribution of water depth for use vs. availability for 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.

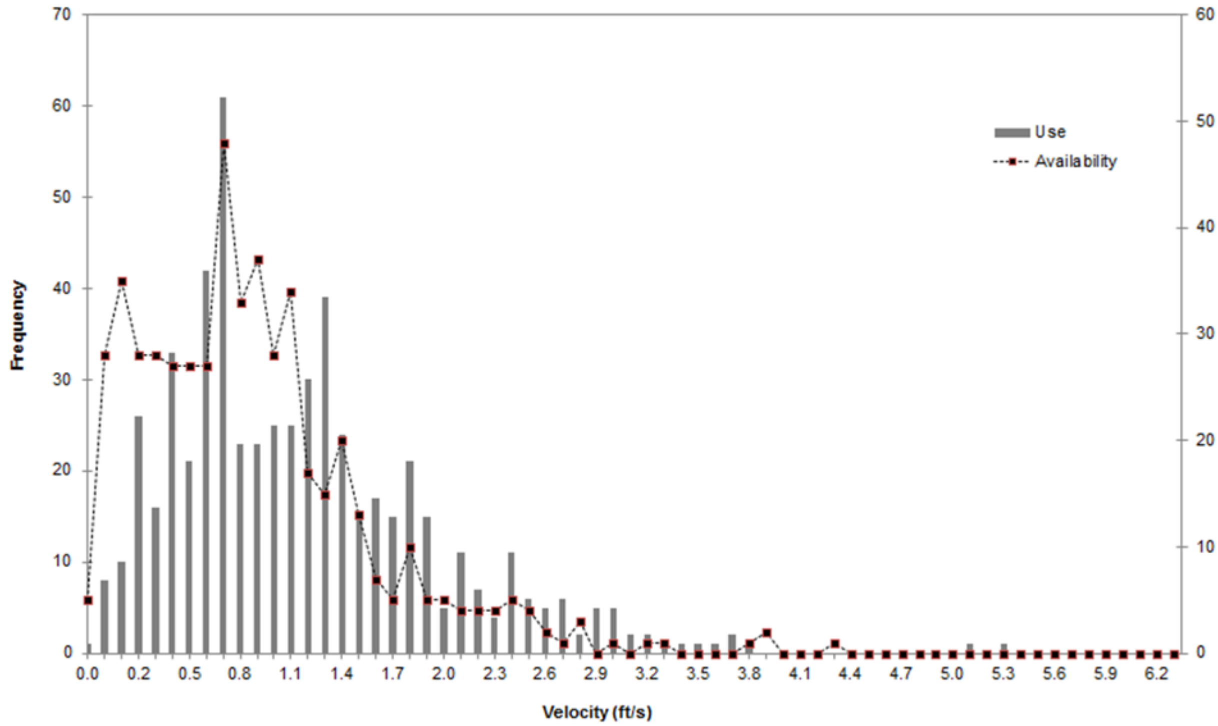


Figure 119. Frequency distribution of water velocity for use vs. availability for 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.

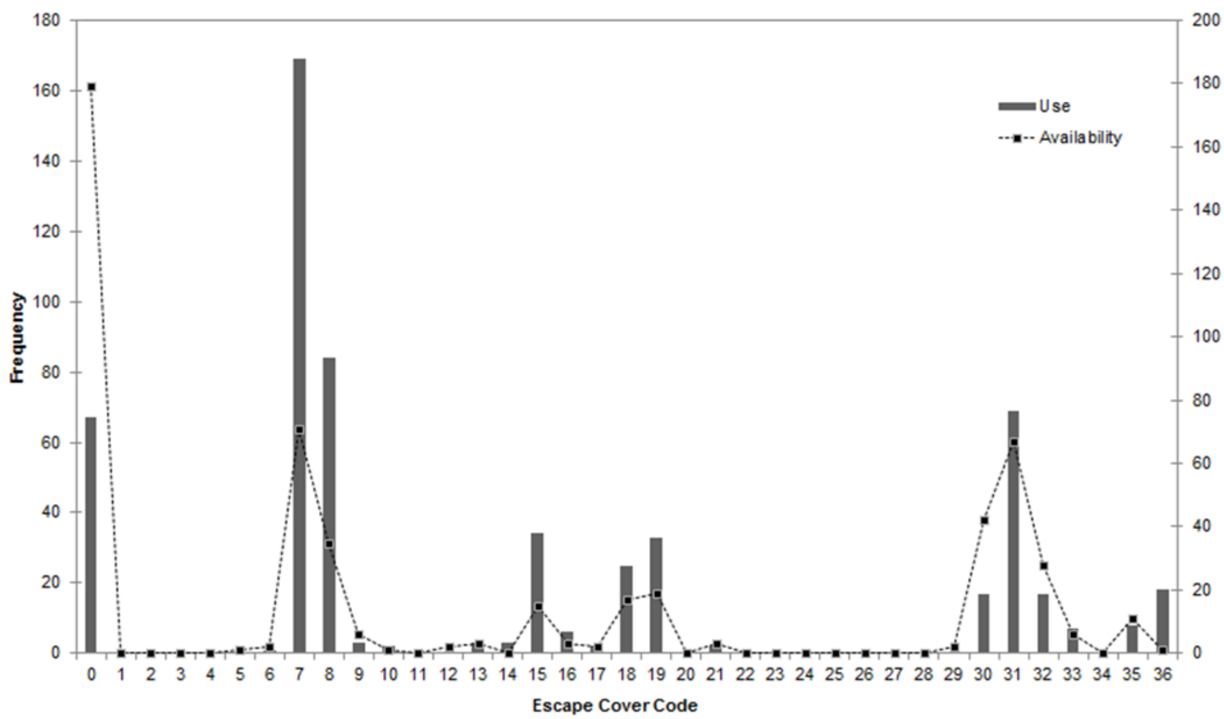


Figure 120. Frequency distribution of escape cover type use vs. availability for 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.

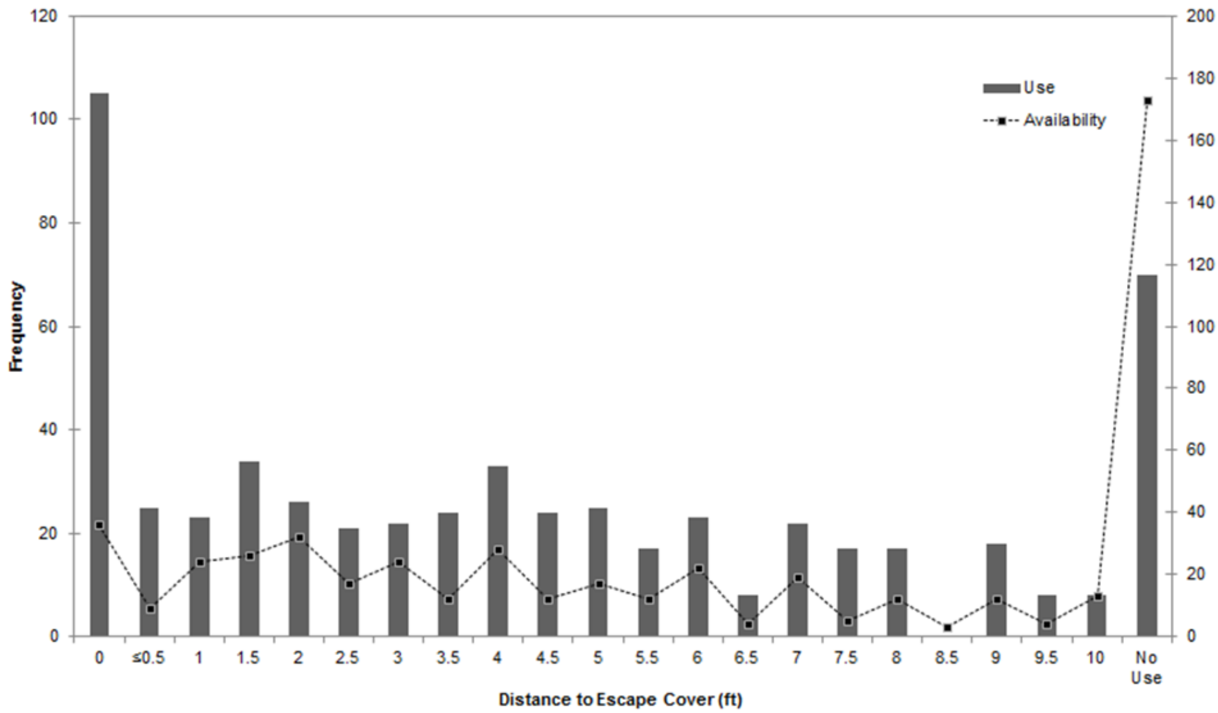


Figure 121. Frequency distribution of escape cover distance use vs. availability for 10-15 cm juvenile steelhead observed in the Big Sur River, fall 2010.

Habitat Availability and Fish Use - Statistical Results

The primary question of the statistical analyses was focused on assessing whether habitat availability differed from the habitat characteristics where fish were observed (habitat used). The basic strategy for analysis was to test whether mean values for continuous measures differed between habitat characteristics where fish were observed and the available sites; if there are differences, the fish are selecting habitat based on those variables. Separate analyses were conducted for each of the fish length classes (<6 cm, 6-9cm, and 10-15 cm).

The factors in the analysis were data type (fish use, available), mesohabitat (runs, riffles, pools and glides) and, for the 6-9 cm and 10-15 cm fish length size classes, sample period (spring, summer, and fall for 6-9 cm fish, summer and fall only for 10-15 cm fish). All initial analyses included river reach (Lower Molera, Molera, Campground) as a blocking factor, however reach was found to be insignificant in most all cases so all analyses were re-tested without using reach as a blocking factor. The scale of conclusions was therefore at the individual locations of the fish. Significant effects associated with the data type variable would indicate habitat selectivity. Loglinear analyses were also conducted to determine whether there were any three way interactions between the presence or absence of fish and overhead cover (in and out of water).

<u><6 cm Juvenile Steelhead</u>

Water Depth
There was no significant interaction (p=0.416, F = 0.950, df = 3, 2266, 2-Way ANOVA) between data type and mesohabitat indicating that differences between habitat used by fish <6cm and available habitat were consistent among mesohabitats. The data type effect was highly significant (p<0.001, F = 145.978, df = 1, 2266, 2-Way ANOVA). The mean water depth at which fish <6 cm in length were found was shallower than the mean water depth of available habitat. Therefore fish <6 cm in length selected more shallow water than what was available. The mesohabitat effect was highly significant (p<0.001, F = 101.889, df = 3, 2266, 2-Way ANOVA), with depth use greater in pools and glides than in runs or riffles.

Water Velocity
There was a highly significant interaction (p<0.001, F = 27.521, df = 3, 2265, 2-Way ANOVA) between data type and mesohabitat. In general, fish <6 cm in length selected slower moving water than was available, especially in runs and riffles.

Percent Embedded Substrate
There was a highly significant interaction (p=0.003, F = 4.699, df = 3, 2266, 2-Way ANOVA) between data type and mesohabitat. In run and riffle mesohabitat, fish <6 cm in length selected areas with more embedded substrate than was available.

Escape Distance
There was a highly significant interaction (p<0.001, F = 10.344, df = 3, 2266, 2-Way ANOVA) between data type and mesohabitat. In general, fish <6 cm in length selected shorter distances to escape cover than was available, but especially in the pool and glide mesohabitats.

Distance to Bank
There was a highly significant interaction (p<0.001, F = 5.969, df = 3, 2129, 2-Way ANOVA) between data type and mesohabitat. Fish <6 cm in length generally showed selectivity for edge habitat where depth was shallow and water velocities slower, however also tended to be found further from the bank on the inside bend of pools and as a result selected a longer distance to bank than was available in pool mesohabitat, but not in the other habitats.

Overhead Cover
Juvenile steelhead <6 cm are more likely to be present if there is no overhead cover (P<0.001).

<u>6-9 cm Juvenile Steelhead</u>

Water Depth
There was a significant (p=0.030, F = 65.560, df = 6, 2340, 3-Way ANOVA) data type*sample period*mesohabitat interaction. In the run mesohabitat, fish 6-9 cm in length increased their selectivity for deeper water over time (i.e., spring, summer, fall). In the riffle and pool mesohabitats, fish 6-9 cm were found in the deeper water relative to what was available particularly in the fall and, to a lesser extent, in summer. In the glide mesohabitat, the strongest selection for deeper water occurred in summer.

Water Velocity
The data type*sample period*mesohabitat interaction was not significant (p=0.650, F = 0.700, df = 6, 2340, 3-Way ANOVA). The sample period*mesohabitat interaction was not significant (p=0.318, F = 1.173, df = 6, 2340, 3-way ANOVA) indicating that the differences in water velocity among mesohabitats remained consistent among sample periods (i.e., spring, summer, fall). The data type*mesohabitat interaction was not significant (p=0.060, F = 2.477, df = 3, 2340, 3-Way ANOVA) indicating that selectivity for water velocity were consistent among mesohabitats. The data type*sample period interaction was highly significant (p=0.007, F = 4.999, df = 2, 2340, 3-Way ANOVA) indicating that selectivity for water velocity differed among sample periods. Fish 6-

9 cm in length showed a slight selectivity for slower water in spring, no selectivity in summer and selectivity for faster water in fall. The mesohabitat effect was highly significant (p<0.001, F = 75.812, df = 3, 2340, 3-Way ANOVA) indicating that water velocities differed among mesohabitats, generally with the greatest velocities occurring in riffle and run mesohabitats.

Percent Embedded Substrate
The data type*sample period*mesohabitat interaction was not significant (p=0.612, F = 0.746, df = 6, 2317, 3-Way ANOVA). The sample period*mesohabitat interaction was not significant (p=0.094, F = 1.809, df = 6, 2317, 3-Way ANOVA) indicating that differences in percent embedded substrate among mesohabitats were consistent among sample periods. The data type*mesohabitat interaction was highly significant (p<0.001, F =7.344, df = 3, 2317, 3-Way ANOVA). In run, pool and glide mesohabitat, 6-9cm length fish selected slightly less embedded substrate than was available. The data type*sample period interaction was highly significant (p<0.001, F = 12.924, df = 2, 2317, 3-Way ANOVA). In summer and fall, fish 6-9 cm in length selected less embedded substrate.

Distance to Escape Cover
The sample period*mesohabitat interaction was highly significant (p=0.008, F = 2.923, df = 6, 2340, 3-Way ANOVA). In run and riffle mesohabitat, distance to escape cover was greatest in fall and least in spring. In pool and glide mesohabitat, the differences in distance to escape cover between summer and fall were negligible but distance to escape cover for both periods was greater than spring. The data type*mesohabitat interaction was highly significant (p=0.001, F = 5.908, df = 3, 2340, 3-Way ANOVA). In general, fish 6-9 cm in length selected locations with a shorter distance to escape cover than was available and the difference was most pronounced in glide and run mesohabitat). The data type*sample period interaction was significant (p=0.024, F = 3.717, df = 2, 2340, 3-Way ANOVA). In general, fish 6-9 cm in length selected a shorter distance to escape cover than was available, especially in the fall.

Distance to Bank
The datatype* sample period*mesohabitat interaction was highly significant (p<0.001, F = 4.584, df = 6, 2170, 3-Way ANOVA). In run, riffle and pool mesohabitats, fish with lengths 6-9 cm strongly selected for habitats farther from the bank in spring and, to a lesser extent in summer but, in fall, there was little to no selectivity. In glide mesohabitat, fish 6-9 cm in length selected habitat with shorter distances to bank in spring and fall but the reverse was true in summer.

Overhead Cover
Juvenile steelhead 6-9 cm are more likely to be present in run and riffle habitat if overhead cover is absent, and less likely to be present in glide habitat if overhead cover is absent (P=0.002). In addition, juvenile steelhead 6-9 cm are more likely

to be present in summer if overhead cover is absent, and less likely to be present in fall if overhead cover is absent (p=0.018).

<u>10-15 cm Juvenile Steelhead</u>

Water Depth

The data type*sample period*mesohabitat interaction was not significant (p=0.489, F = 0.808, df = 6, 1920, 3-way ANOVA). The sample period*mesohabitat interaction was highly significant (p=0.007, F = 4.008, df = 6, 1920, 3-Way ANOVA). Water depth in riffle, glide and run mesohabitats was slightly deeper in summer but, in pool mesohabitat, water depth was consistent between sample periods. The data type*mesohabitat interaction was highly significant (p<0.001, F = 8.980, df = 3, 1920, 3-Way ANOVA), with fish 10-15 cm in length selecting deeper water than was available, especially in pool mesohabitat. The data type*sample period interaction was highly significant (p=0.001, F = 10.220, df = 2, 1920, 3-Way ANOVA). In general, fish 10-15 cm in length selected deeper water than was available, but the difference was most pronounced in fall.

Water Velocity

The data type*sample period*mesohabitat interaction was highly significant (p=0.009, F = 3.836, df = 6, 1920, 3-Way ANOVA). In summer, there was a slight selection for faster water in run, pool and glide mesohabitats, and in fall there was a stronger selection for faster water in all mesohabitats.

Percent Embedded Substrate

The data type*sample period*mesohabitat interaction was highly significant (p=0.038, F = 2.815, df = 6, 1903, 3-Way ANOVA). In run mesohabitat and, to a lesser extent, in glide mesohabitat, there was selectivity for less embedded substrate than was available in summer, but the opposite occurred in fall. In riffle mesohabitat there was a slight selection for less embedded substrate in summer and a much stronger selectivity for less embedded substrate in fall. In pool mesohabitat there was no selection in summer but a strong selection for less embedded substrate in fall.

Distance to Escape Cover

The data type*sample period* mesohabitat interaction was not significant (p=0.256, F = 1.351, df = 6, 1920, 3-way ANOVA). The sample period*mesohabitat interaction was highly significant (p=0.003, F = 8.913, df = 2, 1920, 3-Way ANOVA). In run mesohabitat and riffle mesohabitat, there were shorter distances to escape cover in summer than in fall. In pool and glide mesohabitat there were no differences in distances to escape cover. The data type*mesohabitat interaction was not significant (p=0.101, F = 2.081, df = 3, 1920, 3-Way ANOVA) indicating that any selectivity was consistent across mesohabitats. The data type*sample period interaction was highly significant (p=0.003, F = 4.585, df = 6, 1920, 3-Way ANOVA). In general, fish 10-15 cm in length selected sites with shorter distances to escape cover than was available, but the difference was more pronounced in fall.

Distance to Bank

The data type*sample period* mesohabitat interaction was not significant (p=0.219, F = 1.478, df = 6, 1896, 3-Way ANOVA). The sample period*mesohabitat interaction was significant (p=0.026, F 3.099, df = 6, 1896, 3-Way ANOVA). In run mesohabitat and riffle mesohabitat, there were longer distances to the bank in summer than in fall. In pool and glide mesohabitat there were no real differences in distances to bank. The data type*mesohabitat interaction was not significant (p=0.827, F = 0.298, df = 3, 1896, 3-Way ANOVA) indicating that any selectivity was consistent across mesohabitats. The data type*sample period interaction was highly significant (p=0.005, F = 7.755, df = 2, 1896, 3-Way ANOVA). In summer, fish 10-15 cm in length selected sites with a longer distance to bank than was available, but in fall that selectivity was not maintained.

Overhead Cover

Juvenile steelhead 10-15 cm were found less often if overhead cover was absent, and more often if overhead was small branches (p<0.001).

Habitat Suitability Criteria

Type II ½ HSC were developed for total water depth, average water velocity, fish focal point velocity, distance to escape cover, and escape cover components for <6 cm, 6-9 cm, and 10-15 cm juvenile steelhead. Umbrella use HSC were used for 6-9 cm and 10-15 cm steelhead total water depth and average water velocity to encompass seasonal use patterns of these variables during the core summer (June/August) and fall (October) rearing period. Because of overlapping use curves, velocity HSC for 6-9 cm and 10-15 cm were developed by combining the respective umbrella use curves for each size group into one umbrella use curve. Depth HSC on the other hand, were developed as separate curves for each size group of larger juvenile fish (e.g., 6-9 cm and 10-15 cm) because of the separate distinct avoidances of shallow depths between the two size groups. Fish focal point velocity HSC for 6-9 cm and 10-15 cm steelhead were developed from summer observations since fall velocities and associated focal velocities are naturally limited, while distance to escape cover HSC and escape cover HSC type were developed individually for summer and fall due to the observed shifts in selectivity between seasons. HSC for depth and velocity were dropped to zero after the last observation if the HSC was not already at zero. Distance to escape cover HSC was not assessed at distances greater than 10 ft, and therefore HSC did not extend beyond 10 ft.

The following selectivity HSC accounts for differences in fish size, accounts for sampling period effects by using spring data for fry and summer vs. fall umbrella curves for larger juveniles, and accounts for mesohabitat and habitat availability effects through the use of the equal-area sampling approach.

Juvenile <6 cm Steelhead

<u>Total Water Depth:</u> Juvenile <6 cm steelhead HSC indicates no use of water <0.08 ft deep (Figure 122, Table16). Water depth is most suitable (i.e., an index of 1.00) for juvenile <6 cm steelhead at 0.46 – 0.53 ft deep. Suitability declines to 0.20 at 1.75 ft depth, and to 0.01 at 3.00 ft.

<u>Average Water Velocity:</u> Suitability for average water velocity is 1.00 from 0.18 - 0.25 ft/s (Figure 123, Table 16) for juvenile <6 cm steelhead. Suitability is 0.50 at 0.86 ft/s, declines to 0.20 at 1.32 ft/s, and to 0.00 at 2.71 ft/s.

<u>Fish Focal Point Velocity:</u> Fish focal point water velocity HSC for juvenile <6 cm steelhead is 1.00 from 0.16 – 0.21 ft/s (Figure 124, Table 16). Focal point water velocity suitability is 0.50 at 0.66 ft/s, declines to 0.20 at 0.98 ft/s, and to 0.00 at 2.08 ft/s.

<u>Distance to Escape Cover:</u> Approximately 98% of <6 cm juvenile steelhead were observed be in close proximity to escape cover in summer. Juvenile < 6 cm steelhead distance to escape cover HSC is 1.00 suitability from 0.8-0.9 ft (Figure

125, Table17). Suitability is 0.50 at 2.35 ft, declines to 0.20 at 3.45 ft, and to 0.00 at distances of 9.5 ft and greater.

Escape Cover Components: Juvenile <6 cm steelhead escape cover HSC components includes vegetative and hard substrate types (Figure 126) with the highest suitabilities for small cobble in the 4-6 inch size range. In general, hard substrate types (large gravel to large cobble sizes) were the most common types of escape cover observed near the fish observation locations and had the highest HSC.

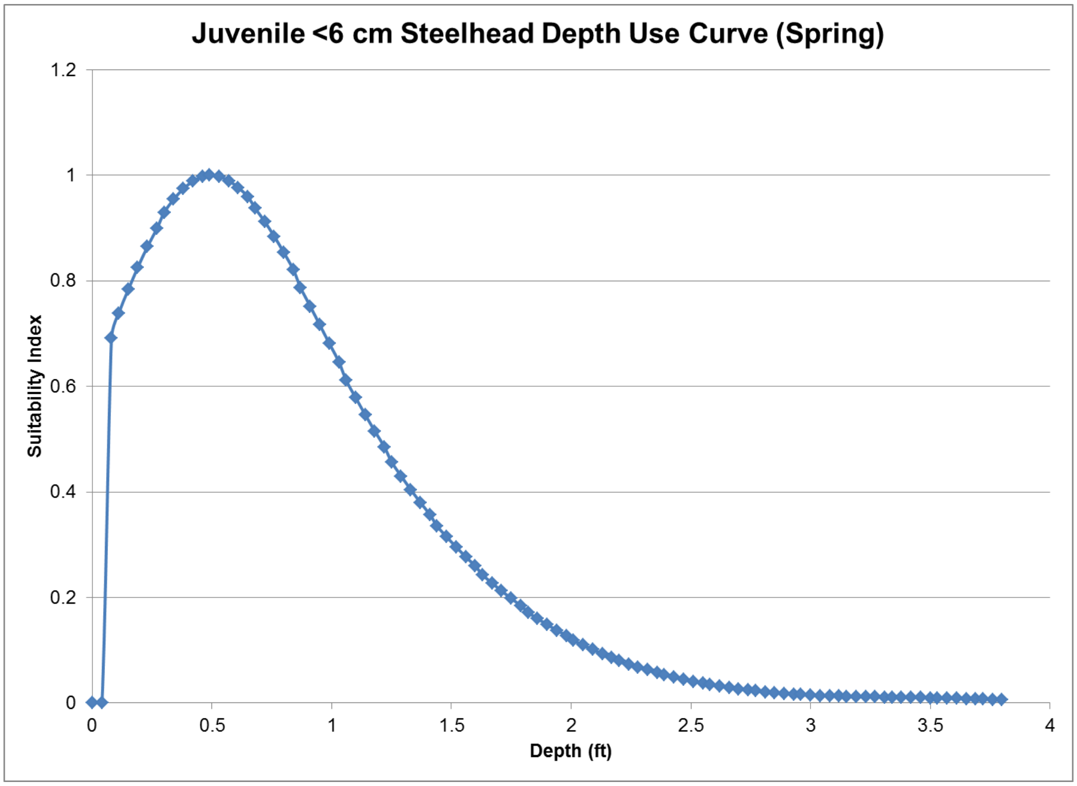


Figure 122. Juvenile <6 cm steelhead depth use HSC curve spring 2012.

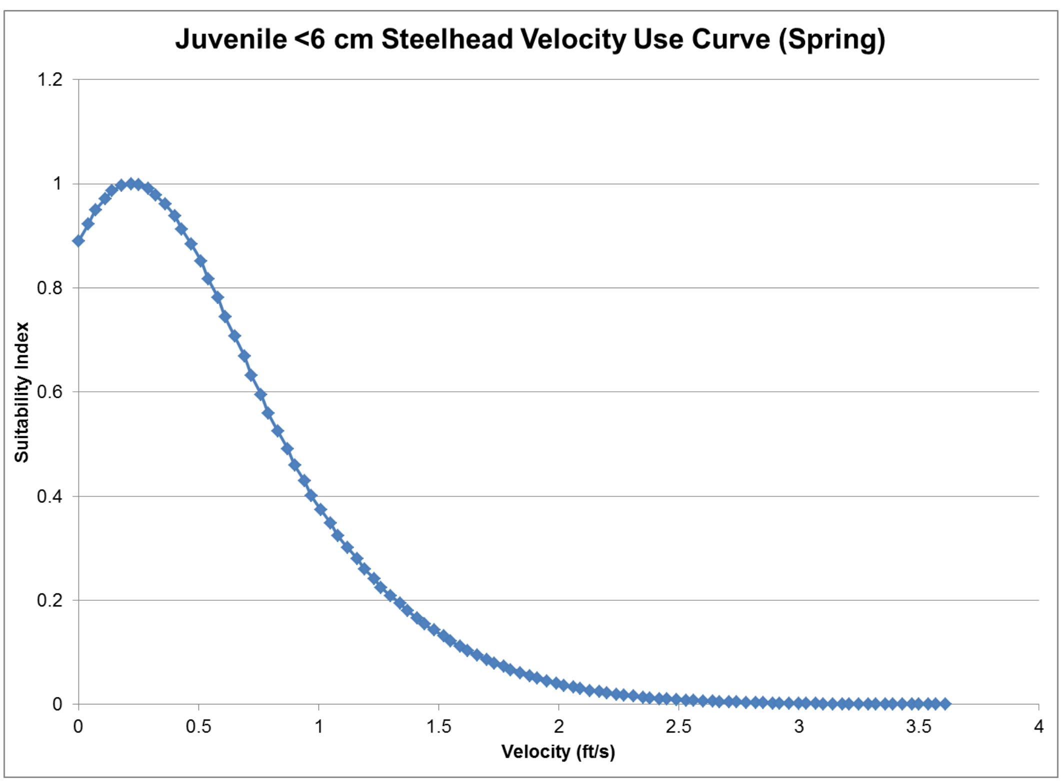


Figure 123. Juvenile <6 cm steelhead velocity use HSC curve spring 2012.

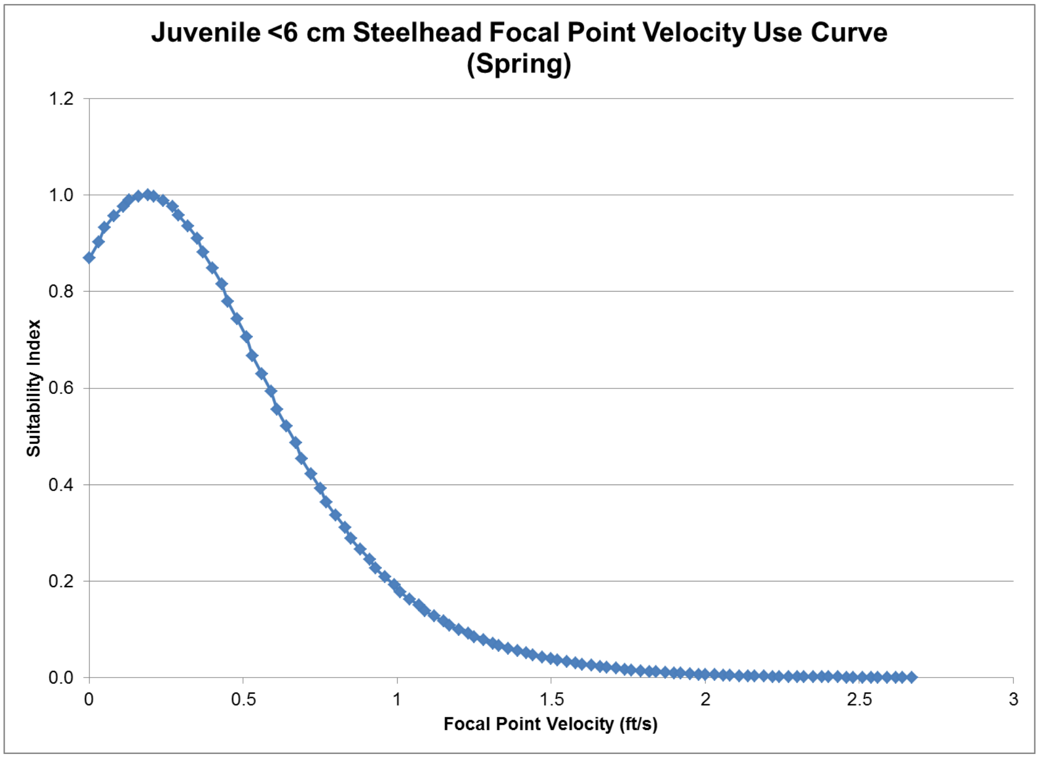


Figure 124. Juvenile <6 cm steelhead focal point velocity use HSC curve spring 2012.

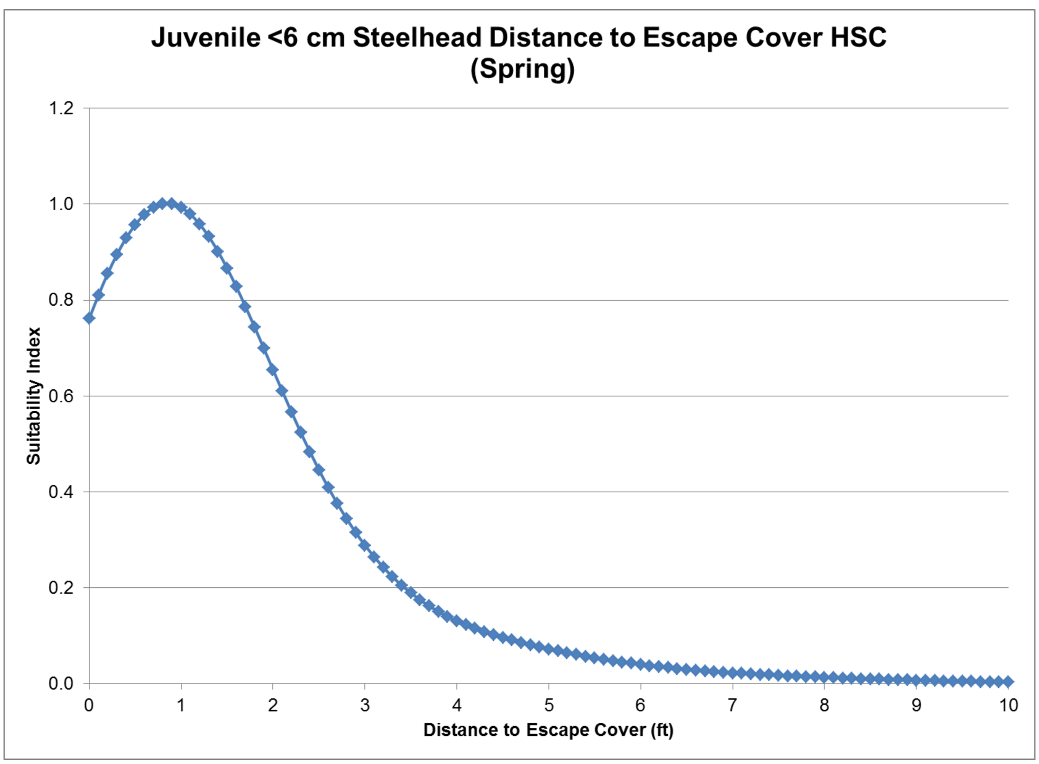


Figure 125. Juvenile <6 cm steelhead distance to escape cover use HSC curve spring 2012.

Table 16. Depth, velocity, and focal point velocity HSC for juvenile <6 cm steelhead in the Big Sur River.

<6 cm Depth HSC			<6 cm Velocity HSC			<6 cm Focal Point Velocity HSC	
Depth (ft)	HSC		Velocity (ft/s)	HSC		Focal Point Velocity (ft/s)	HSC
0.00	0.00		0.00	0.89		0	0.87
0.04	0.00		0.04	0.92		0.03	0.90
0.08	0.69		0.07	0.95		0.05	0.93
0.11	0.74		0.11	0.97		0.08	0.96
0.15	0.78		0.14	0.99		0.11	0.98
0.19	0.83		0.18	1.00		0.13	0.99
0.23	0.86		0.22	1.00		0.16	1.00
0.27	0.90		0.25	1.00		0.19	1.00
0.30	0.93		0.29	0.99		0.21	1.00
0.34	0.95		0.32	0.98		0.24	0.99
0.38	0.97		0.36	0.96		0.27	0.98
0.42	0.99		0.40	0.94		0.29	0.96
0.46	1.00		0.43	0.91		0.32	0.94
0.49	1.00		0.47	0.88		0.35	0.91
0.53	1.00		0.51	0.85		0.37	0.88
0.57	0.99		0.54	0.82		0.4	0.85
0.61	0.98		0.58	0.78		0.43	0.82
0.65	0.96		0.61	0.74		0.45	0.78
0.68	0.94		0.65	0.71		0.48	0.74
0.72	0.91		0.69	0.67		0.51	0.71
0.76	0.88		0.72	0.63		0.53	0.67
0.80	0.85		0.76	0.60		0.56	0.63
0.84	0.82		0.79	0.56		0.59	0.59
0.87	0.79		0.83	0.52		0.61	0.56
0.91	0.75		0.87	0.49		0.64	0.52
0.95	0.72		0.90	0.46		0.67	0.49
0.99	0.68		0.94	0.43		0.69	0.45
1.03	0.65		0.97	0.40		0.72	0.42
1.06	0.61		1.01	0.37		0.75	0.39
1.10	0.58		1.05	0.35		0.77	0.36
1.14	0.55		1.08	0.32		0.8	0.34
1.18	0.51		1.12	0.30		0.83	0.31
1.22	0.49		1.16	0.28		0.85	0.29
1.25	0.46		1.19	0.26		0.88	0.27
1.29	0.43		1.23	0.24		0.91	0.25

Depth (ft)	HSC		Velocity (ft/s)	HSC		Focal Point Velocity (ft/s)	HSC
1.33	0.40		1.26	0.22		0.93	0.23
1.37	0.38		1.30	0.21		0.96	0.21
1.41	0.36		1.34	0.19		0.99	0.19
1.44	0.34		1.37	0.18		1.01	0.18
1.48	0.31		1.41	0.17		1.04	0.16
1.52	0.30		1.44	0.15		1.07	0.15
1.56	0.28		1.48	0.14		1.09	0.14
1.60	0.26		1.52	0.13		1.12	0.13
1.63	0.24		1.55	0.12		1.15	0.12
1.67	0.23		1.59	0.11		1.17	0.11
1.71	0.21		1.62	0.10		1.2	0.10
1.75	0.20		1.66	0.09		1.23	0.09
1.79	0.18		1.70	0.09		1.25	0.08
1.82	0.17		1.73	0.08		1.28	0.08
1.86	0.16		1.77	0.07		1.31	0.07
1.90	0.15		1.80	0.07		1.33	0.07
1.94	0.14		1.84	0.06		1.36	0.06
1.98	0.13		1.88	0.05		1.39	0.06
2.01	0.12		1.91	0.05		1.42	0.05
2.05	0.11		1.95	0.05		1.44	0.05
2.09	0.10		1.99	0.04		1.47	0.04
2.13	0.09		2.02	0.04		1.5	0.04
2.17	0.09		2.06	0.03		1.52	0.04
2.20	0.08		2.09	0.03		1.55	0.03
2.24	0.07		2.13	0.03		1.58	0.03
2.28	0.07		2.17	0.02		1.6	0.03
2.32	0.06		2.20	0.02		1.63	0.03
2.36	0.06		2.24	0.02		1.66	0.02
2.39	0.05		2.27	0.02		1.68	0.02
2.43	0.05		2.31	0.02		1.71	0.02
2.47	0.04		2.35	0.01		1.74	0.02
2.51	0.04		2.38	0.01		1.76	0.02
2.55	0.04		2.42	0.01		1.79	0.01
2.58	0.03		2.45	0.01		1.82	0.01
2.62	0.03		2.49	0.01		1.84	0.01
2.66	0.03		2.53	0.01		1.87	0.01
2.70	0.03		2.56	0.01		1.9	0.01
2.74	0.02		2.60	0.01		1.92	0.01
2.77	0.02		2.64	0.01		1.95	0.01
2.81	0.02		2.67	0.01		1.98	0.01

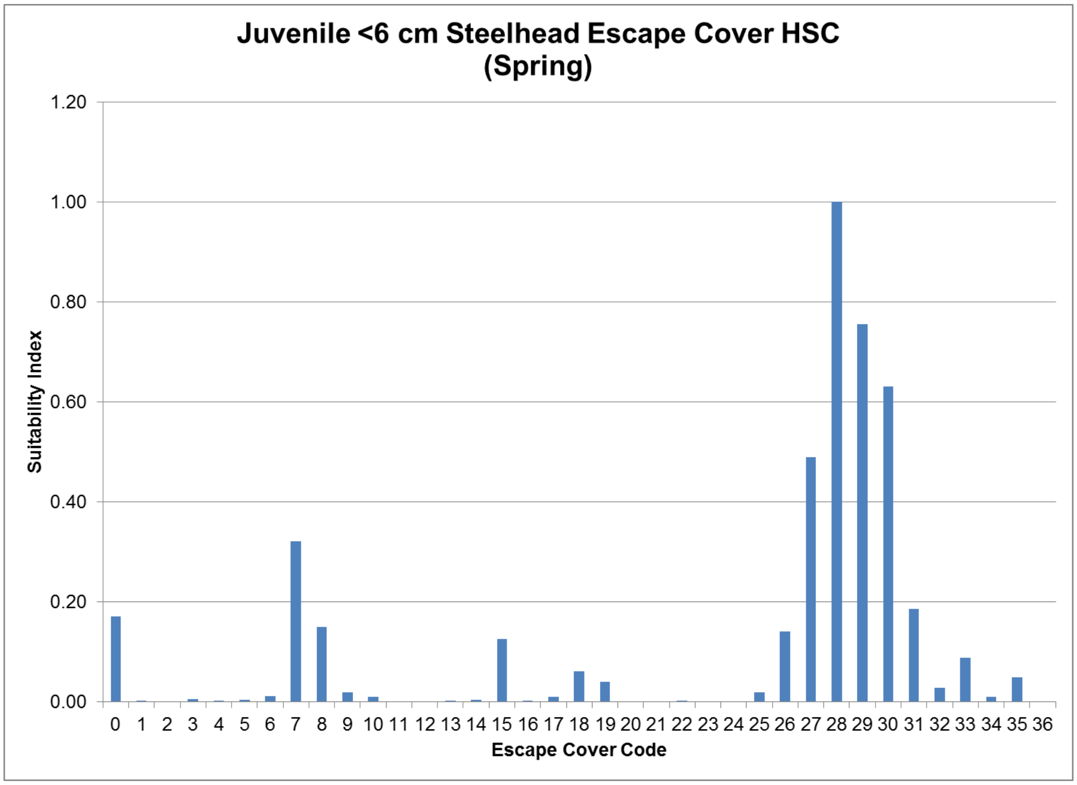
Depth (ft)	HSC		Velocity (ft/s)	HSC		Focal Point Velocity (ft/s)	HSC
2.85	0.02		2.71	0.00		2	0.01
2.89	0.02		2.74	0.00		2.03	0.01
2.93	0.02		2.78	0.00		2.06	0.01
2.96	0.02		2.82	0.00		2.08	0.00
3.00	0.01		2.85	0.00		2.11	0.00
3.04	0.01		2.89	0.00		2.14	0.00
3.08	0.01		2.92	0.00		2.16	0.00
3.12	0.01		2.96	0.00		2.19	0.00
3.15	0.01		3.00	0.00		2.22	0.00
3.19	0.01		3.03	0.00		2.24	0.00
3.23	0.01		3.07	0.00		2.27	0.00
3.27	0.01		3.10	0.00		2.3	0.00
3.31	0.01		3.14	0.00		2.32	0.00
3.34	0.01		3.18	0.00		2.35	0.00
3.38	0.01		3.21	0.00		2.38	0.00
3.42	0.01		3.25	0.00		2.4	0.00
3.46	0.01		3.29	0.00		2.43	0.00
3.50	0.01		3.32	0.00		2.46	0.00
3.53	0.01		3.36	0.00		2.48	0.00
3.57	0.01		3.39	0.00		2.51	0.00
3.61	0.01		3.43	0.00		2.54	0.00
3.65	0.01		3.47	0.00		2.56	0.00
3.69	0.01		3.50	0.00		2.59	0.00
3.72	0.01		3.54	0.00		2.62	0.00
3.76	0.01		3.57	0.00		2.64	0.00
3.80	0.01		3.61	0.00		2.67	0.00
3.81	0.00						

Table 17. Distance to escape cover HSC for <6 cm juvenile steelhead.

	Spring
Distance (ft)	<6 cm Distance to Escape Cover HSC
0	0.76
0.1	0.81
0.2	0.86
0.3	0.89
0.4	0.93
0.5	0.96
0.6	0.98
0.7	0.99
0.8	1.00
0.9	1.00
1	0.99
1.1	0.98
1.2	0.96
1.3	0.93
1.4	0.90
1.5	0.87
1.6	0.83
1.7	0.79
1.8	0.74
1.9	0.70
2	0.65
2.1	0.61
2.2	0.57
2.3	0.52
2.4	0.48
2.5	0.45
2.6	0.41
2.7	0.38
2.8	0.34
2.9	0.32
3	0.29
3.1	0.26
3.2	0.24
3.3	0.22
3.4	0.21

Distance (ft)	<6 cm Distance to Escape Cover HSC
3.5	0.19
3.6	0.17
3.7	0.16
3.8	0.15
3.9	0.14
4	0.13
4.1	0.12
4.2	0.12
4.3	0.11
4.4	0.10
4.5	0.10
4.6	0.09
4.7	0.09
4.8	0.08
4.9	0.08
5	0.07
5.1	0.07
5.2	0.06
5.3	0.06
5.4	0.06
5.5	0.05
5.6	0.05
5.7	0.05
5.8	0.04
5.9	0.04
6	0.04
6.1	0.04
6.2	0.04
6.3	0.03
6.4	0.03
6.5	0.03
6.6	0.03
6.7	0.03
6.8	0.03
6.9	0.02
7	0.02
7.1	0.02

Distance (ft)	<6 cm Distance to Escape Cover HSC (ft)
7.2	0.02
7.3	0.02
7.4	0.02
7.5	0.02
7.6	0.02
7.7	0.02
7.8	0.01
7.9	0.01
8	0.01
8.1	0.01
8.2	0.01
8.3	0.01
8.4	0.01
8.5	0.01
8.6	0.01
8.7	0.01
8.8	0.01
8.9	0.01
9	0.01
9.1	0.01
9.2	0.01
9.3	0.01
9.4	0.01
9.5	0.00
9.6	0.00
9.7	0.00
9.8	0.00
9.9	0.00
10	0.00



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 126. Juvenile <6 cm steelhead escape cover HSC (spring 2012).

Juvenile 6-9 cm Steelhead

Total Water Depth: A comparison of summer and fall juvenile steelhead 6-9 cm depth HSC curves are located in Figure 127 and indicates high suitability for deeper water in the fall when compared to summer. The juvenile 6-9 cm steelhead umbrella HSC indicates no use of water <0.33 ft. deep. Further, water depth is most suitable (i.e., an index of 1.00) for juvenile 6-9 cm steelhead at 1.19 – 1.50 ft deep during the summer and fall rearing period. Suitability declines to 0.20 at 3.57 ft depth, and to 0.01 at >4.3 ft in the summer and fall rearing period (Table 18).

Average Water Velocity: A comparison of summer and fall juvenile steelhead 6-9 cm average water velocity HSC curves is located in Figure 128 and indicates high suitability for faster water velocities in the summer when compared to the fall. The juvenile 6-9 cm steelhead umbrella HSC indicates suitability for average water velocity is 1.00 from 0.91 -1.47 ft/s for juvenile 6-9 cm steelhead during the summer and fall rearing period. Suitability is 0.50 at 2.46 ft/s, declines to 0.20 at 3.07 ft/s, and to 0.10 at 3.46 ft/s in the summer and fall rearing period (Table 18).

Fish Focal Point Velocity: Fish focal point water velocity HSC for juvenile 6-9 cm steelhead is 1.00 from 0.72 – 0.81 ft/s (Figure 129). Focal point water velocity suitability is 0.50 at 1.60 ft/s, declines to 0.20 at 2.02 ft/s, and to 0.10 at 2.27 ft/s (Table 18).

Distance to Escape Cover: Juvenile 6-9 cm steelhead distance to escape cover HSC is 1.00 suitability in summer and fall from 1.5 - 1.8 ft and 1.9 – 2.4 ft, respectively (Figure 130, Figure131, and Table 19). Suitability is 0.50 at 4.7 ft in summer, and 7.5 ft in fall. Distance to escape cover suitability declines to 0.10 at distances greater than 9 ft and 10 ft in summer and fall, respectively.

Escape Cover Components: Juvenile 6-9 cm steelhead escape cover HSC components includes vegetative and hard substrate types in summer and fall (Figure 132, Figure133) with the highest suitability (1.00) for large cobble in the 9-12 inch size range in the summer, and 1.00 suitability for small branches or vegetation <4 inches in water in the fall.

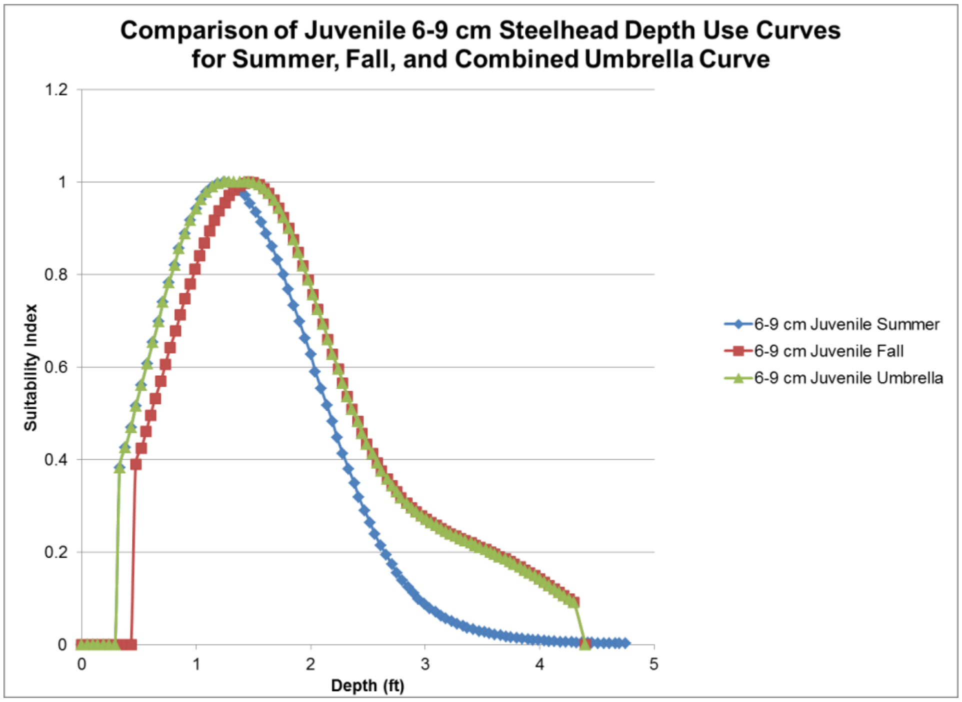


Figure 127. Comparison of juvenile 6-9 cm steelhead depth use curves for summer, fall, and combined umbrella use curve.

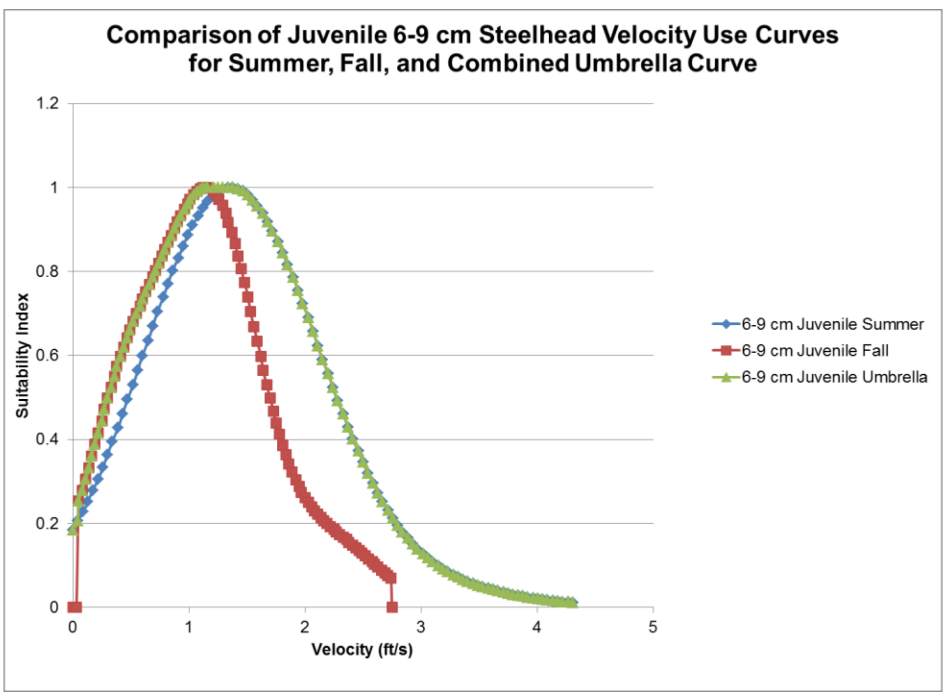


Figure 128. Comparison of juvenile 6-9 cm steelhead velocity use curves for summer, fall, and combined umbrella use curve.

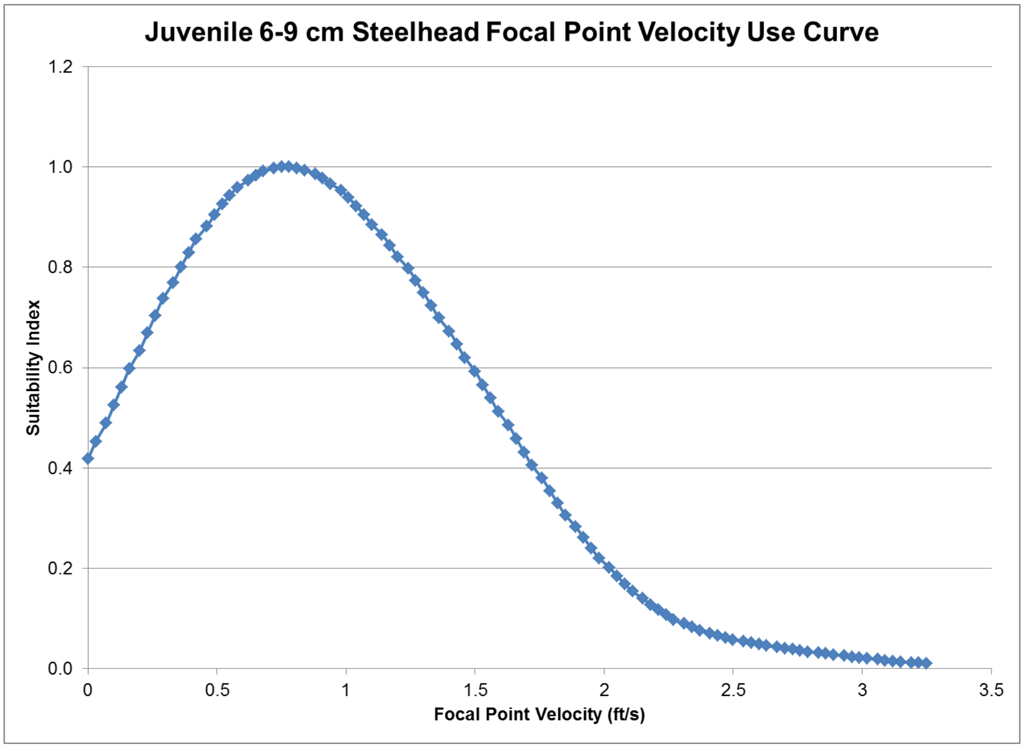


Figure 129. Juvenile 6-9 cm steelhead focal velocity use curve.

Table 18. Depth and velocity HSC for juvenile 6-9 cm steelhead in the Big Sur River.

6-9 cm Depth HSC			6-9 cm Velocity HSC			6-9 cm Focal Point Velocity HSC	
Depth (ft)	HSC		Velocity (ft/s)	HSC		Focal Point Velocity (ft/s)	HSC
0	0.00		0	0.48		0	0.42
0.05	0.00		0.05	0.53		0.03	0.45
0.1	0.00		0.11	0.57		0.07	0.49
0.14	0.00		0.16	0.61		0.1	0.53
0.19	0.00		0.21	0.65		0.13	0.56
0.24	0.00		0.27	0.70		0.16	0.60
0.29	0.00		0.32	0.74		0.2	0.63
0.33	0.38		0.38	0.77		0.23	0.67
0.38	0.43		0.43	0.81		0.26	0.70
0.43	0.47		0.48	0.84		0.29	0.74
0.47	0.52		0.54	0.88		0.33	0.77
0.52	0.56		0.59	0.90		0.36	0.80
0.57	0.61		0.64	0.93		0.39	0.83
0.62	0.65		0.7	0.95		0.42	0.86
0.67	0.70		0.75	0.97		0.46	0.88
0.71	0.74		0.8	0.98		0.49	0.90
0.76	0.78		0.86	0.99		0.52	0.93
0.81	0.82		0.91	1.00		0.55	0.94
0.85	0.86		0.96	1.00		0.58	0.96
0.9	0.89		1	1.00		0.62	0.97
0.95	0.92		1.05	1.00		0.65	0.98
1	0.94		1.1	1.00		0.68	0.99
1.04	0.96		1.15	1.00		0.72	1.00
1.09	0.98		1.21	1.00		0.75	1.00
1.14	0.99		1.26	1.00		0.78	1.00
1.19	1.00		1.31	1.00		0.81	1.00
1.24	1.00		1.36	1.00		0.84	0.99
1.25	1.00		1.41	1.00		0.88	0.99
1.29	1.00		1.47	1.00		0.91	0.98
1.33	1.00		1.52	0.99		0.94	0.97
1.38	1.00		1.57	0.98		0.98	0.95
1.42	1.00		1.62	0.97		1.01	0.94
1.46	1.00		1.68	0.95		1.04	0.92
1.5	1.00		1.73	0.94		1.07	0.90
1.55	0.99		1.78	0.92		1.1	0.89

Depth (ft)	HSC	Velocity (ft/s)	HSC	Focal Point Velocity (ft/s)	HSC
1.59	0.99	1.83	0.89	1.14	0.86
1.63	0.98	1.89	0.87	1.17	0.84
1.68	0.96	1.94	0.84	1.2	0.82
1.72	0.94	1.99	0.81	1.24	0.80
1.76	0.92	2.04	0.78	1.27	0.77
1.81	0.90	2.1	0.74	1.3	0.75
1.85	0.88	2.15	0.71	1.33	0.72
1.89	0.85	2.2	0.68	1.36	0.70
1.93	0.82	2.25	0.64	1.4	0.67
1.98	0.79	2.31	0.61	1.43	0.65
2.02	0.76	2.36	0.57	1.46	0.62
2.06	0.72	2.41	0.54	1.5	0.59
2.11	0.69	2.46	0.50	1.53	0.57
2.15	0.66	2.52	0.47	1.56	0.54
2.19	0.63	2.57	0.44	1.59	0.51
2.24	0.60	2.62	0.41	1.63	0.48
2.28	0.57	2.67	0.38	1.66	0.46
2.32	0.54	2.72	0.35	1.69	0.43
2.36	0.51	2.78	0.32	1.72	0.41
2.41	0.48	2.83	0.30	1.76	0.38
2.45	0.46	2.88	0.27	1.79	0.35
2.49	0.43	2.93	0.25	1.82	0.33
2.54	0.41	2.99	0.23	1.85	0.31
2.58	0.39	3.04	0.21	1.89	0.28
2.62	0.37	3.09	0.19	1.92	0.26
2.67	0.36	3.14	0.17	1.95	0.24
2.71	0.34	3.2	0.16	1.98	0.22
2.75	0.33	3.25	0.14	2.02	0.20
2.79	0.32	3.3	0.13	2.05	0.18
2.84	0.31	3.35	0.12	2.08	0.17
2.88	0.30	3.41	0.11	2.11	0.15
2.92	0.29	3.46	0.10	2.15	0.14
2.97	0.28	3.51	0.09	2.18	0.13
3.01	0.27	3.56	0.08	2.21	0.12
3.05	0.26	3.62	0.07	2.24	0.11
3.1	0.26	3.67	0.06	2.27	0.10
3.14	0.25	3.72	0.06	2.31	0.09
3.18	0.25	3.77	0.05	2.34	0.08
3.22	0.24	3.83	0.05	2.37	0.08
3.27	0.23	3.88	0.04	2.41	0.07

Depth (ft)	HSC		Velocity (ft/s)	HSC		Focal Point Velocity (ft/s)	HSC
3.31	0.23		3.93	0.04		2.44	0.07
3.35	0.22		3.98	0.03		2.47	0.06
3.4	0.22		4.03	0.03		2.5	0.06
3.44	0.21		4.09	0.03		2.54	0.05
3.48	0.21		4.14	0.02		2.57	0.05
3.53	0.21		4.19	0.02		2.6	0.05
3.57	0.20		4.24	0.02		2.63	0.05
3.61	0.20		4.3	0.02		2.67	0.04
3.65	0.19		4.35	0.02		2.7	0.04
3.7	0.18		4.4	0.02		2.73	0.04
3.74	0.18		4.45	0.01		2.76	0.04
3.78	0.17		4.51	0.01		2.79	0.03
3.83	0.17		4.56	0.01		2.83	0.03
3.87	0.16		4.61	0.01		2.86	0.03
3.91	0.15		4.66	0.01		2.89	0.03
3.96	0.15		4.72	0.01		2.93	0.03
4	0.14		4.77	0.01		2.96	0.02
4.04	0.13		4.82	0.01		2.99	0.02
4.08	0.13		4.87	0.01		3.02	0.02
4.13	0.12		4.93	0.01		3.06	0.02
4.17	0.11		4.98	0.01		3.09	0.02
4.21	0.11		5.03	0.01		3.12	0.02
4.26	0.10		5.08	0.01		3.15	0.01
4.3	0.09		5.14	0.01		3.19	0.01
			5.19	0.01		3.22	0.01
			5.24	0.01		3.25	0.01
			5.25	0.00		3.26	0.00

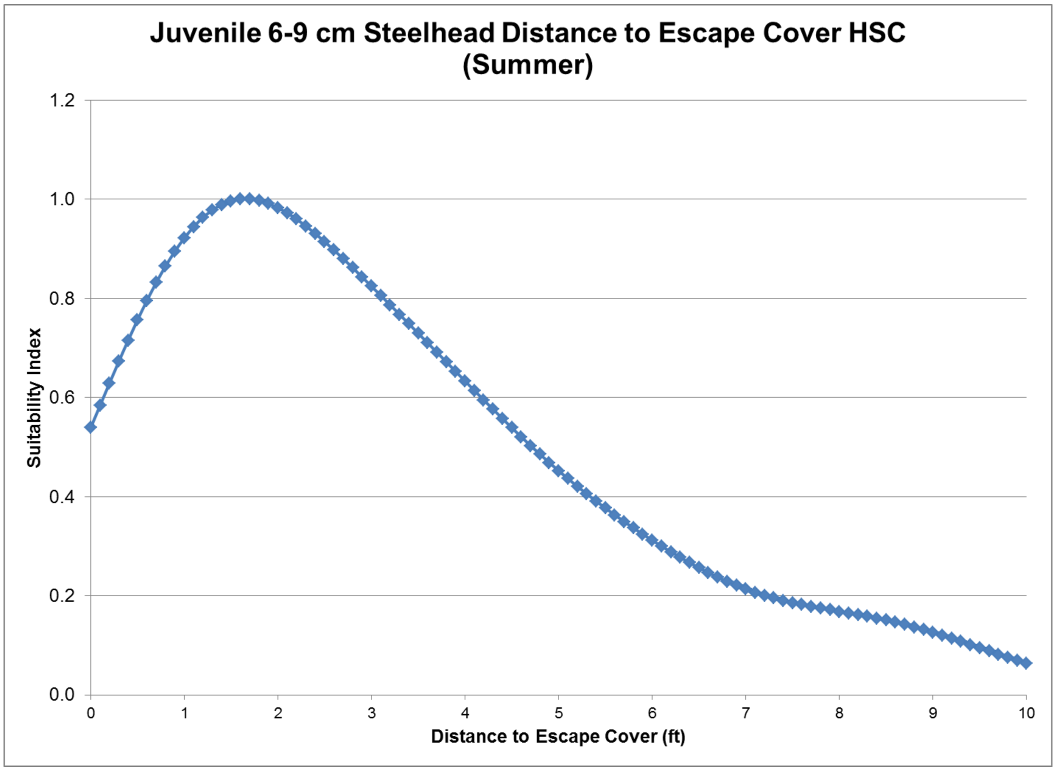


Figure 130. Juvenile 6-9 cm steelhead distance to escape cover HSC (summer).

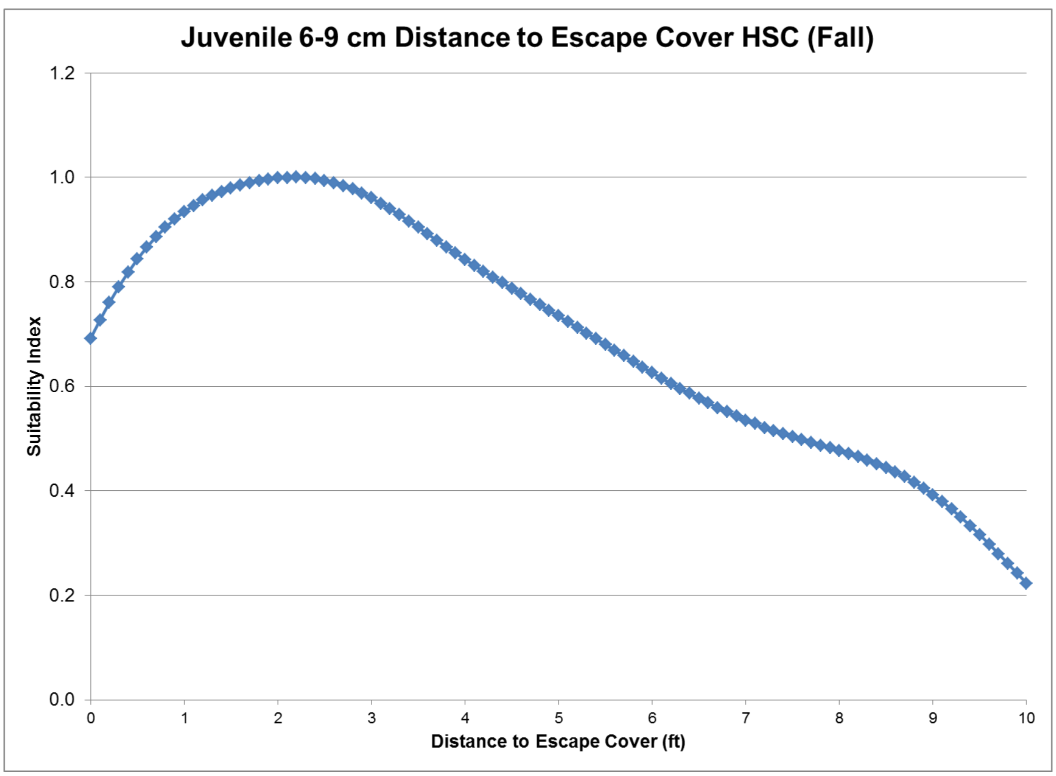


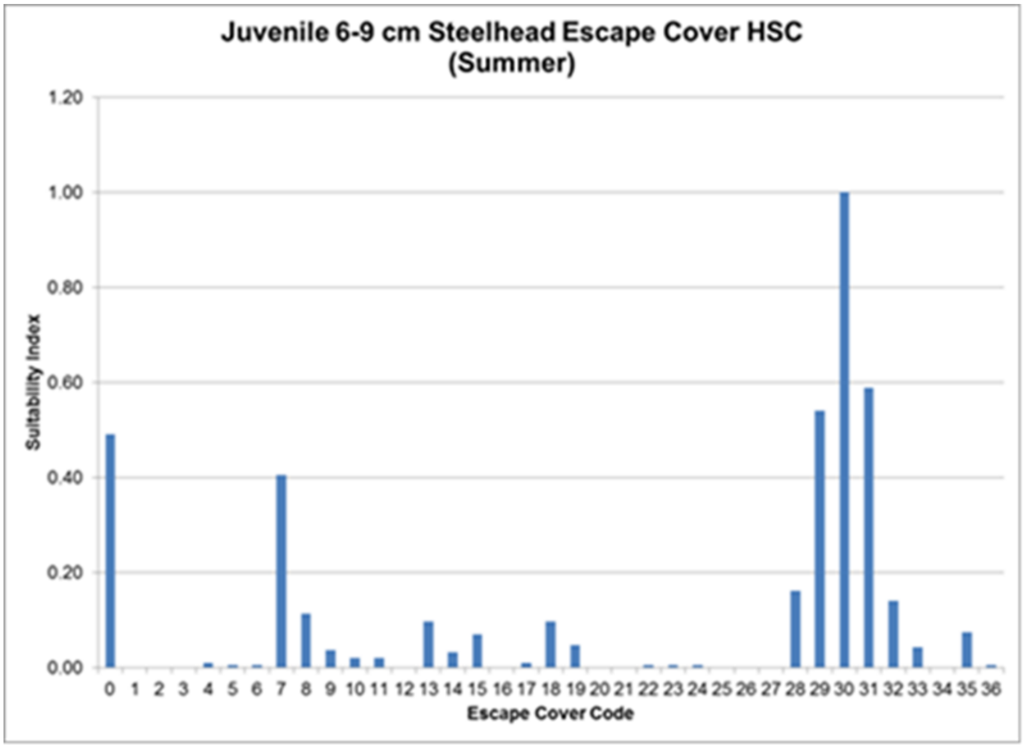
Figure 131. Juvenile 6-9 cm steelhead distance to escape cover HSC (fall).

Table 19. Distance to escape cover HSC for juvenile 6-9 cm steelhead in summer and fall.

	Summer 2010			Fall 2010
Distance (ft)	6-9 cm Distance to Escape Cover HSC		Distance (ft)	6-9 cm Distance to Escape Cover HSC
0	0.54		0	0.69
0.1	0.58		0.1	0.73
0.2	0.63		0.2	0.76
0.3	0.67		0.3	0.79
0.4	0.72		0.4	0.82
0.5	0.76		0.5	0.84
0.6	0.80		0.6	0.87
0.7	0.83		0.7	0.89
0.8	0.87		0.8	0.90
0.9	0.90		0.9	0.92
1	0.92		1	0.93
1.1	0.94		1.1	0.95
1.2	0.96		1.2	0.96
1.3	0.98		1.3	0.97
1.4	0.99		1.4	0.97
1.5	1.00		1.5	0.98
1.6	1.00		1.6	0.99
1.7	1.00		1.7	0.99
1.8	1.00		1.8	0.99
1.9	0.99		1.9	1.00
2	0.98		2	1.00
2.1	0.97		2.1	1.00
2.2	0.96		2.2	1.00
2.3	0.95		2.3	1.00
2.4	0.93		2.4	1.00
2.5	0.91		2.5	0.99
2.6	0.90		2.6	0.99
2.7	0.88		2.7	0.98
2.8	0.86		2.8	0.98
2.9	0.84		2.9	0.97
3	0.82		3	0.96
3.1	0.81		3.1	0.95
3.2	0.79		3.2	0.94

Distance (ft)	6-9 cm Distance to Escape Cover HSC (Summer)		Distance (ft)	6-9 cm Distance to Escape Cover HSC (Fall)
3.3	0.77		3.3	0.93
3.4	0.75		3.4	0.92
3.5	0.73		3.5	0.90
3.6	0.71		3.6	0.89
3.7	0.69		3.7	0.88
3.8	0.67		3.8	0.87
3.9	0.65		3.9	0.85
4	0.63		4	0.84
4.1	0.61		4.1	0.83
4.2	0.59		4.2	0.82
4.3	0.58		4.3	0.81
4.4	0.56		4.4	0.80
4.5	0.54		4.5	0.79
4.6	0.52		4.6	0.78
4.7	0.50		4.7	0.77
4.8	0.49		4.8	0.76
4.9	0.47		4.9	0.75
5	0.45		5	0.73
5.1	0.44		5.1	0.72
5.2	0.42		5.2	0.71
5.3	0.41		5.3	0.70
5.4	0.39		5.4	0.69
5.5	0.38		5.5	0.68
5.6	0.36		5.6	0.67
5.7	0.35		5.7	0.66
5.8	0.34		5.8	0.65
5.9	0.32		5.9	0.64
6	0.31		6	0.63
6.1	0.30		6.1	0.62
6.2	0.29		6.2	0.61
6.3	0.28		6.3	0.60
6.4	0.27		6.4	0.59
6.5	0.26		6.5	0.58
6.6	0.25		6.6	0.57
6.7	0.24		6.7	0.56
6.8	0.23		6.8	0.55
6.9	0.22		6.9	0.54

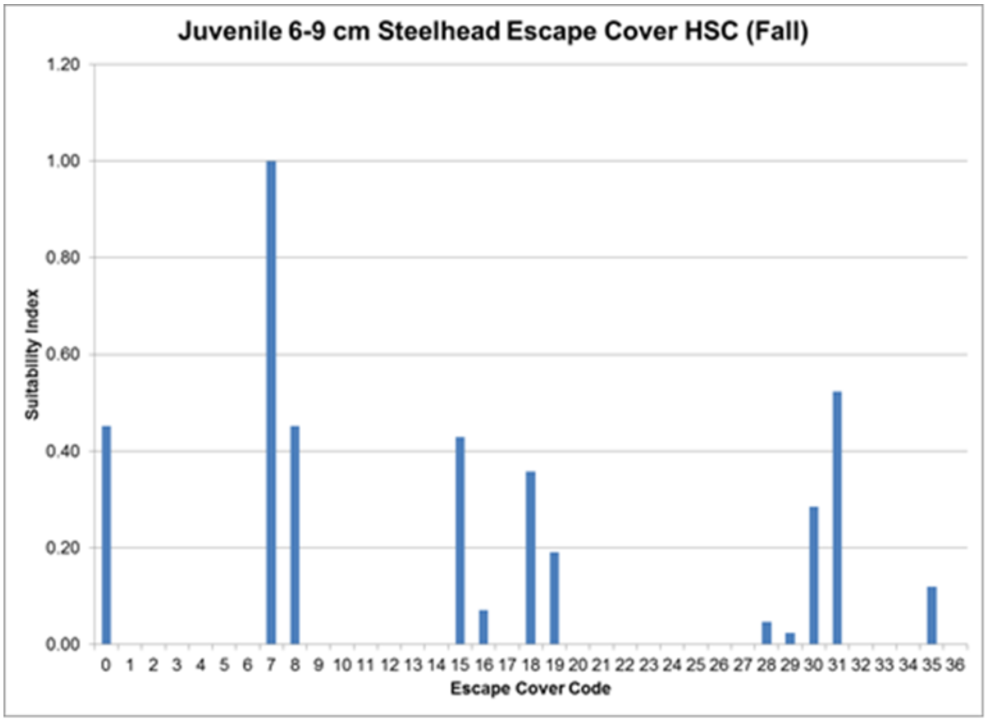
Distance (ft)	6-9 cm Distance to Escape Cover HSC (Summer)		Distance (ft)	6-9 cm Distance to Escape Cover HSC (Fall)
7	0.21		7	0.54
7.1	0.21		7.1	0.53
7.2	0.20		7.2	0.52
7.3	0.20		7.3	0.51
7.4	0.19		7.4	0.51
7.5	0.19		7.5	0.50
7.6	0.18		7.6	0.50
7.7	0.18		7.7	0.49
7.8	0.17		7.8	0.49
7.9	0.17		7.9	0.48
8	0.17		8	0.48
8.1	0.16		8.1	0.47
8.2	0.16		8.2	0.46
8.3	0.16		8.3	0.46
8.4	0.15		8.4	0.45
8.5	0.15		8.5	0.44
8.6	0.15		8.6	0.44
8.7	0.14		8.7	0.43
8.8	0.14		8.8	0.42
8.9	0.13		8.9	0.41
9	0.13		9	0.39
9.1	0.12		9.1	0.38
9.2	0.11		9.2	0.36
9.3	0.11		9.3	0.35
9.4	0.10		9.4	0.33
9.5	0.09		9.5	0.32
9.6	0.09		9.6	0.30
9.7	0.08		9.7	0.28
9.8	0.08		9.8	0.26
9.9	0.07		9.9	0.24
10	0.06		10	0.22



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 132. Juvenile 6-9 cm steelhead escape cover HSC (summer).



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 133. Juvenile 6-9 cm steelhead escape cover HSC (fall).

Juvenile 10-15 cm Steelhead

Total Water Depth: A comparison of summer and fall juvenile steelhead 10-15 cm depth HSC curves are located in Figure 134 and indicates high suitability for deeper water in the fall when compared to summer. The juvenile 10-15 cm steelhead umbrella HSC indicates no use of water <0.59 ft. Further, water depth is most suitable (i.e., an index of 1.00) for juvenile 10-15 cm steelhead at 1.43 – 1.67 ft deep during the summer and fall rearing period. Suitability declines to 0.20 at 3.43 ft depth, and to 0.02 at >4.75 ft in the summer and fall rearing period (Table 20).

Average Water Velocity: A comparison of summer and fall juvenile steelhead 10-15 cm average water velocity HSC curves is located in Figure 135 and indicates high suitability for faster water velocities in the summer when compared to the fall. The juvenile 10-15 cm steelhead umbrella HSC indicates suitability for average water velocity is 1.00 from 0.91 -1.47 ft/s for juvenile 10-15 cm steelhead during the summer and fall rearing period. Suitability is 0.50 at 2.46 ft/s, declines to 0.20 at 3.07 ft/s, and to 0.10 at 3.46 ft/s in the summer and fall rearing period (Table 20).

Fish Focal Point Velocity: Fish focal point water velocity HSC for juvenile 10-15 cm steelhead is 1.00 from 0.86 – 0.97 ft/s (Figure 136). Focal point water velocity suitability is 0.50 at 1.73 ft/s, declines to 0.20 at 2.23 ft/s, and to 0.10 at 2.55 ft/s (Table 20).

Distance to Escape Cover: Juvenile 10-15 cm steelhead distance to escape cover HSC is 1.00 suitability in summer and fall from 1.8 – 2.1 ft and 0.4 – 0.7 ft, respectively (Figure 137, Figure 138, Table 21). Suitability is 0.50 at 4.8 ft in Summer, and 6.7 ft in Fall. Distance to escape cover suitability declines to 0.10 at distances greater than 9 ft and 10 ft in summer and fall, respectively.

Escape Cover Components: Juvenile 10-15 cm steelhead escape cover HSC components includes vegetative and hard substrate types in summer and fall (Figure 139, Figure 140) with the highest suitability (1.00) for small boulders in the 12-24 inch size range in the Summer, and 1.00 suitability for small branches or vegetation <4 inches in water in the Fall.

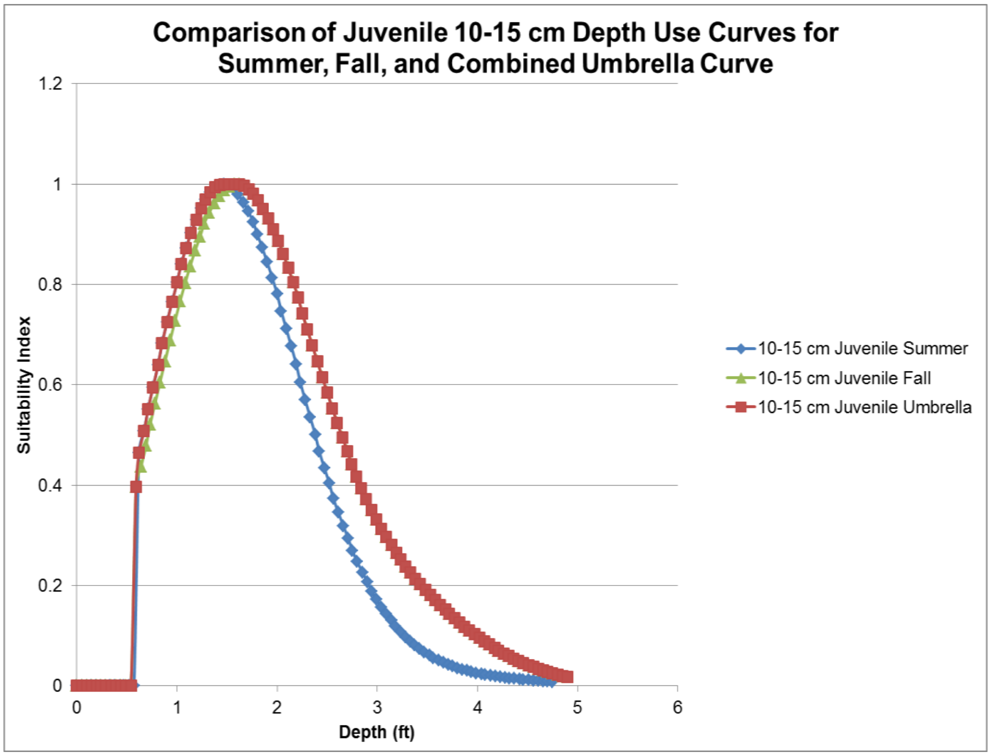


Figure 134. Comparison of juvenile 10-15 cm depth use curves for summer, fall, and combined umbrella curve.

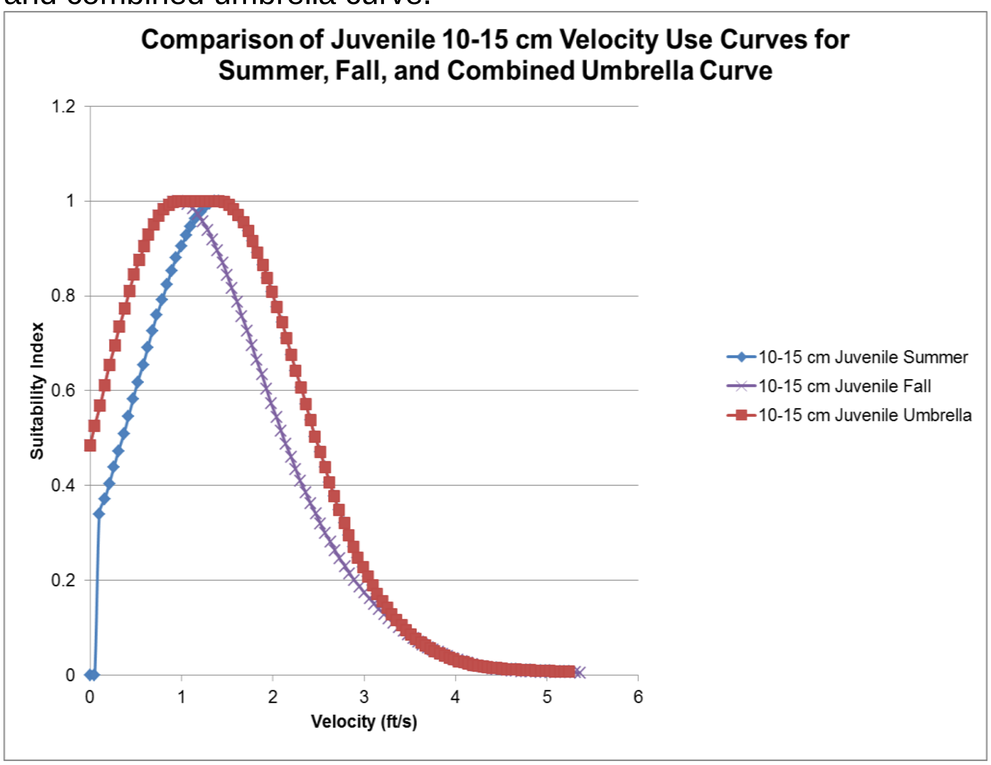


Figure 135. Comparison of juvenile 10-15 cm velocity use curves for summer, fall, and combined umbrella curve.

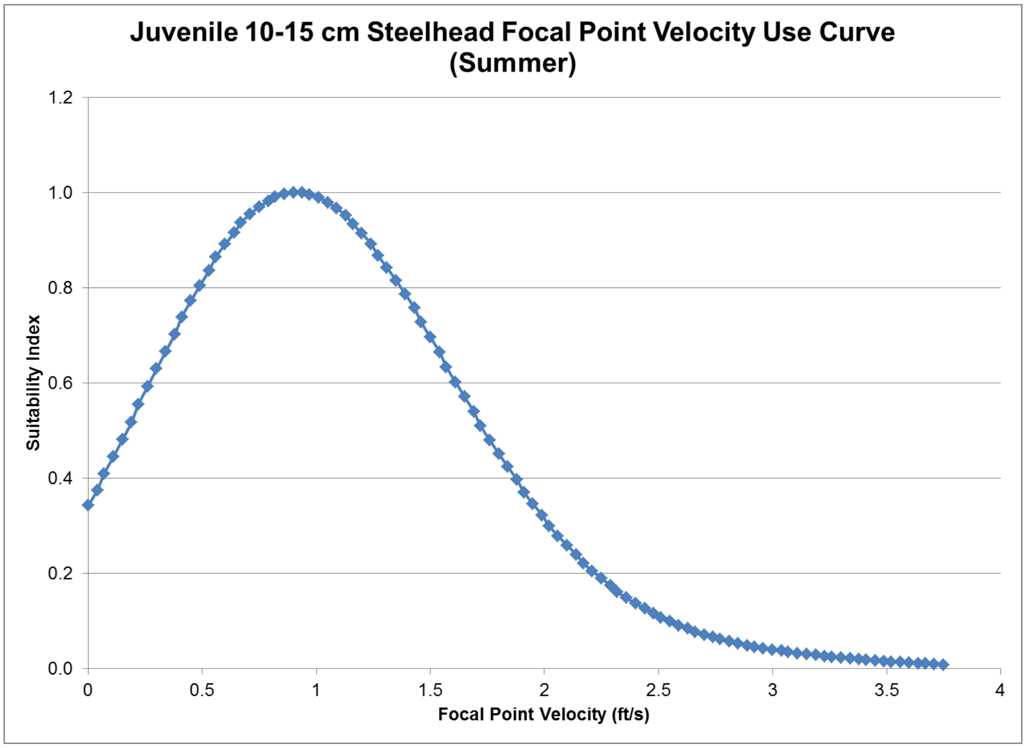


Figure 136. Juvenile 10-15 cm steelhead fish focal water velocity.

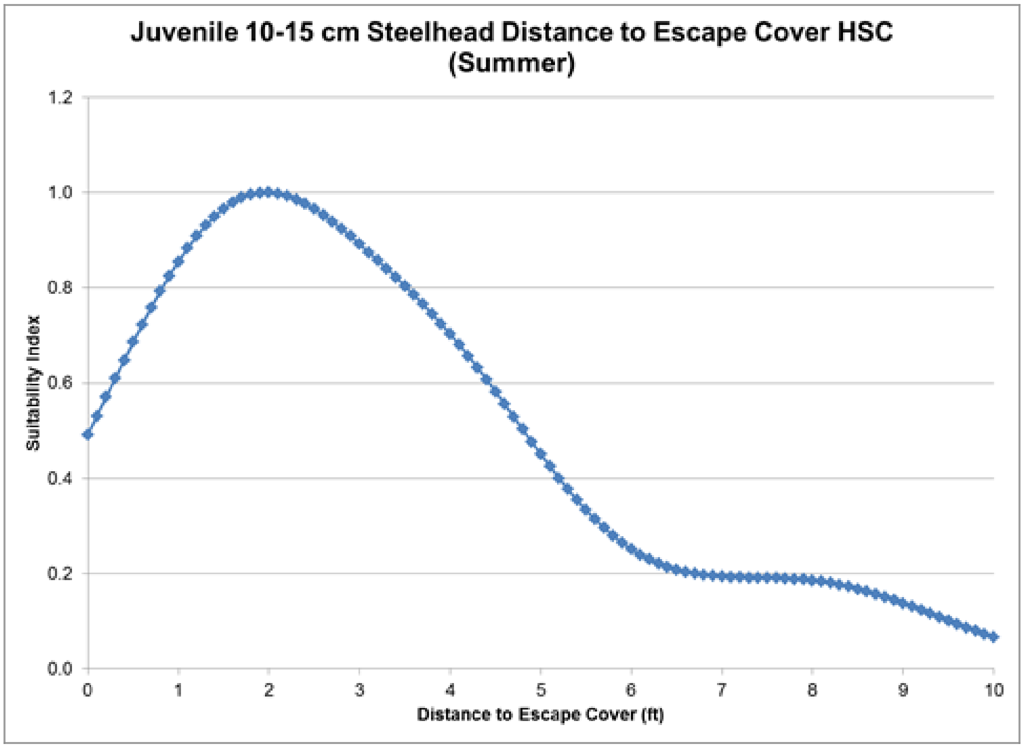


Figure 137. Juvenile 10-15 cm Steelhead distance to escape cover HSC (summer).

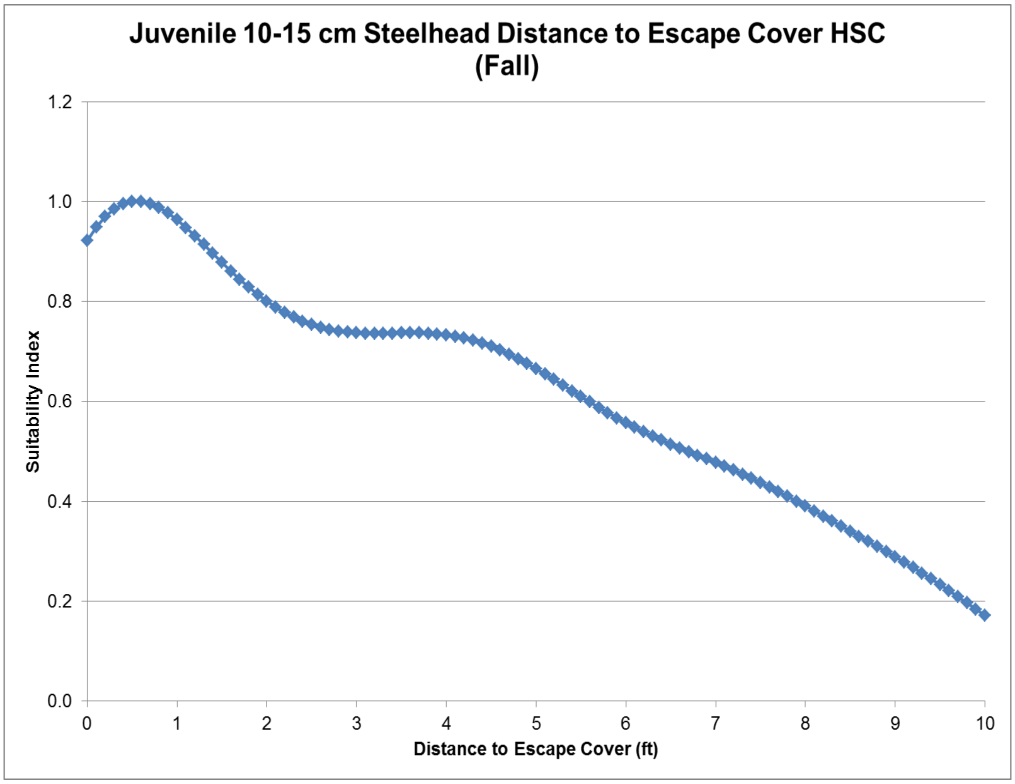


Figure 138. Juvenile 10-15 cm Steelhead distance to escape cover HSC (fall).

Table 20. Depth and velocity HSC for juvenile 10-15 cm steelhead in the Big Sur River.

10-15 Depth HSC			10-15 cm Velocity HSC			10-15 cm Focal Point Velocity HSC	
Depth (ft)	HSC		Velocity (ft/s)	HSC		Focal Point Velocity (ft/s)	HSC
0.00	0.00		0.00	0.48		0	0.34
0.05	0.00		0.05	0.53		0.04	0.38
0.10	0.00		0.11	0.57		0.07	0.41
0.15	0.00		0.16	0.61		0.11	0.44
0.20	0.00		0.21	0.65		0.15	0.48
0.24	0.00		0.27	0.70		0.19	0.52
0.29	0.00		0.32	0.74		0.22	0.55
0.34	0.00		0.38	0.77		0.26	0.59
0.39	0.00		0.43	0.81		0.3	0.63
0.44	0.00		0.48	0.84		0.34	0.67
0.49	0.00		0.54	0.88		0.38	0.70
0.54	0.00		0.59	0.90		0.41	0.74
0.59	0.40		0.64	0.93		0.45	0.77
0.62	0.46		0.70	0.95		0.49	0.81
0.67	0.51		0.75	0.97		0.53	0.84
0.71	0.55		0.80	0.98		0.56	0.86
0.76	0.60		0.86	0.99		0.6	0.89
0.81	0.64		0.91	1.00		0.64	0.92
0.85	0.68		0.96	1.00		0.67	0.94
0.90	0.73		1.00	1.00		0.71	0.95
0.95	0.77		1.05	1.00		0.75	0.97
1.00	0.80		1.10	1.00		0.79	0.98
1.04	0.84		1.15	1.00		0.82	0.99
1.09	0.87		1.21	1.00		0.86	1.00
1.14	0.90		1.26	1.00		0.9	1.00
1.19	0.93		1.31	1.00		0.94	1.00
1.24	0.95		1.36	1.00		0.97	1.00
1.28	0.97		1.41	1.00		1.01	0.99
1.33	0.98		1.47	1.00		1.05	0.98
1.38	0.99		1.52	0.99		1.09	0.97
1.43	1.00		1.57	0.98		1.13	0.95
1.47	1.00		1.62	0.97		1.16	0.93
1.52	1.00		1.68	0.95		1.2	0.91
1.57	1.00		1.73	0.94		1.24	0.89
1.62	1.00		1.78	0.92		1.27	0.87

Depth (ft)	HSC		Velocity (ft/s)	HSC		Focal Point Velocity (ft/s)	HSC
1.67	1.00		1.83	0.89		1.31	0.84
1.72	0.99		1.89	0.87		1.35	0.82
1.76	0.98		1.94	0.84		1.39	0.79
1.81	0.97		1.99	0.81		1.43	0.76
1.86	0.95		2.04	0.78		1.46	0.73
1.91	0.93		2.10	0.74		1.5	0.70
1.96	0.91		2.15	0.71		1.54	0.66
2.01	0.89		2.20	0.68		1.57	0.63
2.06	0.86		2.25	0.64		1.61	0.60
2.11	0.83		2.31	0.61		1.65	0.57
2.16	0.80		2.36	0.57		1.69	0.54
2.21	0.77		2.41	0.54		1.72	0.51
2.25	0.74		2.46	0.50		1.76	0.48
2.30	0.71		2.52	0.47		1.8	0.45
2.35	0.68		2.57	0.44		1.84	0.42
2.40	0.65		2.62	0.41		1.88	0.40
2.45	0.62		2.67	0.38		1.91	0.37
2.50	0.58		2.72	0.35		1.95	0.35
2.55	0.55		2.78	0.32		1.99	0.32
2.60	0.52		2.83	0.30		2.02	0.30
2.65	0.50		2.88	0.27		2.06	0.28
2.70	0.47		2.93	0.25		2.1	0.26
2.74	0.44		2.99	0.23		2.14	0.24
2.79	0.42		3.04	0.21		2.17	0.22
2.84	0.39		3.09	0.19		2.21	0.21
2.89	0.37		3.14	0.17		2.25	0.19
2.94	0.35		3.20	0.16		2.29	0.17
2.99	0.33		3.25	0.14		2.32	0.16
3.04	0.31		3.30	0.13		2.36	0.15
3.09	0.30		3.35	0.12		2.4	0.14
3.14	0.28		3.41	0.11		2.44	0.13
3.19	0.27		3.46	0.10		2.48	0.12
3.23	0.25		3.51	0.09		2.51	0.11
3.28	0.24		3.56	0.08		2.55	0.10
3.33	0.23		3.62	0.07		2.59	0.09
3.38	0.21		3.67	0.06		2.63	0.08
3.43	0.20		3.72	0.06		2.66	0.08
3.48	0.19		3.77	0.05		2.7	0.07
3.53	0.18		3.83	0.05		2.74	0.07
3.58	0.17		3.88	0.04		2.77	0.06

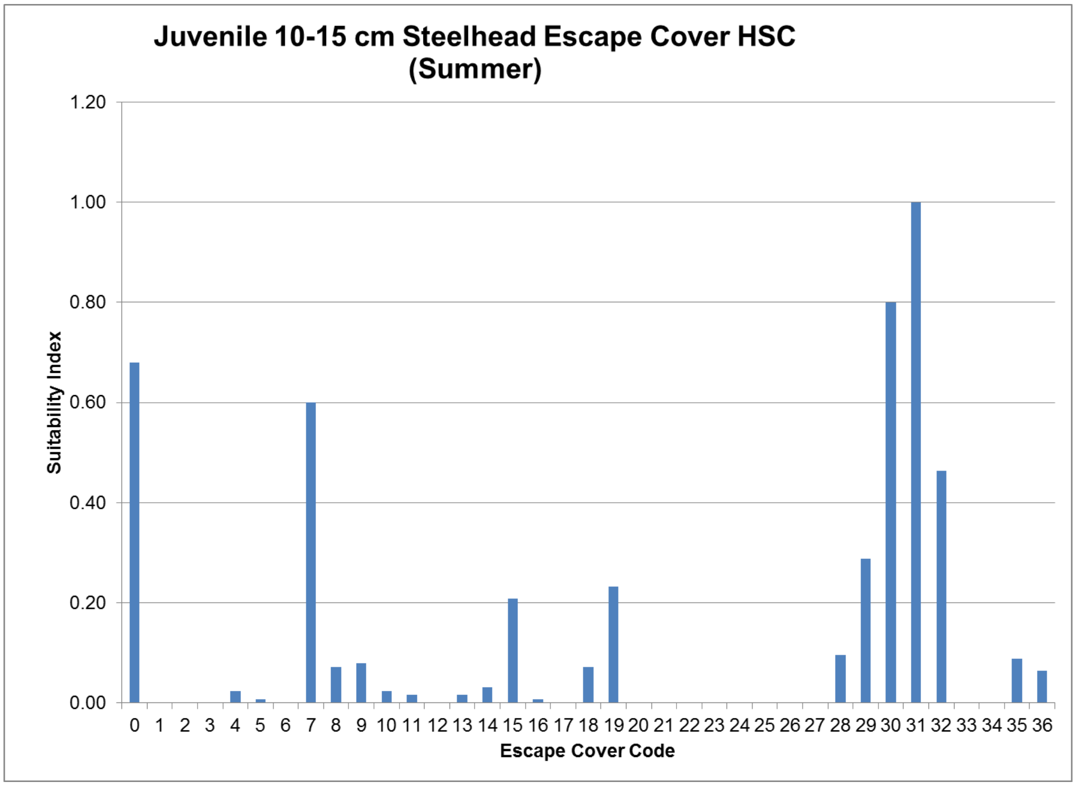
Depth (ft)	HSC		Velocity (ft/s)	HSC		Focal Point Velocity (ft/s)	HSC
3.63	0.16		3.93	0.04		2.81	0.06
3.68	0.15		3.98	0.03		2.85	0.05
3.72	0.14		4.03	0.03		2.89	0.05
3.77	0.13		4.09	0.03		2.92	0.05
3.82	0.13		4.14	0.02		2.96	0.04
3.87	0.12		4.19	0.02		3	0.04
3.92	0.11		4.24	0.02		3.04	0.04
3.97	0.10		4.30	0.02		3.07	0.03
4.02	0.10		4.35	0.02		3.11	0.03
4.07	0.09		4.40	0.02		3.15	0.03
4.12	0.08		4.45	0.01		3.19	0.03
4.17	0.08		4.51	0.01		3.23	0.03
4.21	0.07		4.56	0.01		3.26	0.02
4.26	0.06		4.61	0.01		3.3	0.02
4.31	0.06		4.66	0.01		3.34	0.02
4.36	0.05		4.72	0.01		3.38	0.02
4.41	0.05		4.77	0.01		3.41	0.02
4.46	0.05		4.82	0.01		3.45	0.02
4.51	0.04		4.87	0.01		3.49	0.02
4.56	0.04		4.93	0.01		3.52	0.01
4.61	0.03		4.98	0.01		3.56	0.01
4.66	0.03		5.03	0.01		3.6	0.01
4.70	0.03		5.08	0.01		3.64	0.01
4.75	0.02		5.14	0.01		3.67	0.01
4.80	0.02		5.19	0.01		3.71	0.01
4.85	0.02		5.24	0.01		3.75	0.01
4.90	0.02		5.25	0.00		3.76	0.00
4.91	0.00						

Table 21. Distance to escape cover HSC for juvenile 10-15 cm steelhead in summer and fall.

	Summer 2010			Fall 2010
Distance (ft)	10-15 cm Distance to Escape Cover HSC		Distance (ft)	10-15 cm Distance to Escape Cover HSC
0	0.49		0	0.92
0.1	0.53		0.1	0.95
0.2	0.57		0.2	0.97
0.3	0.61		0.3	0.99
0.4	0.65		0.4	1.00
0.5	0.69		0.5	1.00
0.6	0.72		0.6	1.00
0.7	0.76		0.7	1.00
0.8	0.79		0.8	0.99
0.9	0.83		0.9	0.98
1	0.86		1	0.96
1.1	0.88		1.1	0.95
1.2	0.91		1.2	0.93
1.3	0.93		1.3	0.91
1.4	0.95		1.4	0.90
1.5	0.97		1.5	0.88
1.6	0.98		1.6	0.86
1.7	0.99		1.7	0.84
1.8	1.00		1.8	0.83
1.9	1.00		1.9	0.81
2	1.00		2	0.80
2.1	1.00		2.1	0.79
2.2	0.99		2.2	0.78
2.3	0.99		2.3	0.77
2.4	0.98		2.4	0.76
2.5	0.97		2.5	0.75
2.6	0.95		2.6	0.75
2.7	0.94		2.7	0.74
2.8	0.92		2.8	0.74
2.9	0.91		2.9	0.74
3	0.89		3	0.74
3.1	0.87		3.1	0.74
3.2	0.86		3.2	0.74

Distance (ft)	10-15 cm Distance to Escape Cover HSC (Summer)		Distance (ft)	10-15 cm Distance to Escape Cover HSC (Fall)
3.3	0.84		3.3	0.74
3.4	0.82		3.4	0.74
3.5	0.80		3.5	0.74
3.6	0.78		3.6	0.74
3.7	0.77		3.7	0.74
3.8	0.75		3.8	0.74
3.9	0.72		3.9	0.74
4	0.70		4	0.73
4.1	0.68		4.1	0.73
4.2	0.66		4.2	0.73
4.3	0.63		4.3	0.72
4.4	0.61		4.4	0.72
4.5	0.58		4.5	0.71
4.6	0.56		4.6	0.70
4.7	0.53		4.7	0.69
4.8	0.50		4.8	0.69
4.9	0.48		4.9	0.68
5	0.45		5	0.67
5.1	0.42		5.1	0.65
5.2	0.40		5.2	0.64
5.3	0.38		5.3	0.63
5.4	0.35		5.4	0.62
5.5	0.33		5.5	0.61
5.6	0.31		5.6	0.60
5.7	0.30		5.7	0.59
5.8	0.28		5.8	0.58
5.9	0.26		5.9	0.57
6	0.25		6	0.56
6.1	0.24		6.1	0.55
6.2	0.23		6.2	0.54
6.3	0.22		6.3	0.53
6.4	0.21		6.4	0.52
6.5	0.21		6.5	0.51
6.6	0.20		6.6	0.51
6.7	0.20		6.7	0.50
6.8	0.20		6.8	0.49

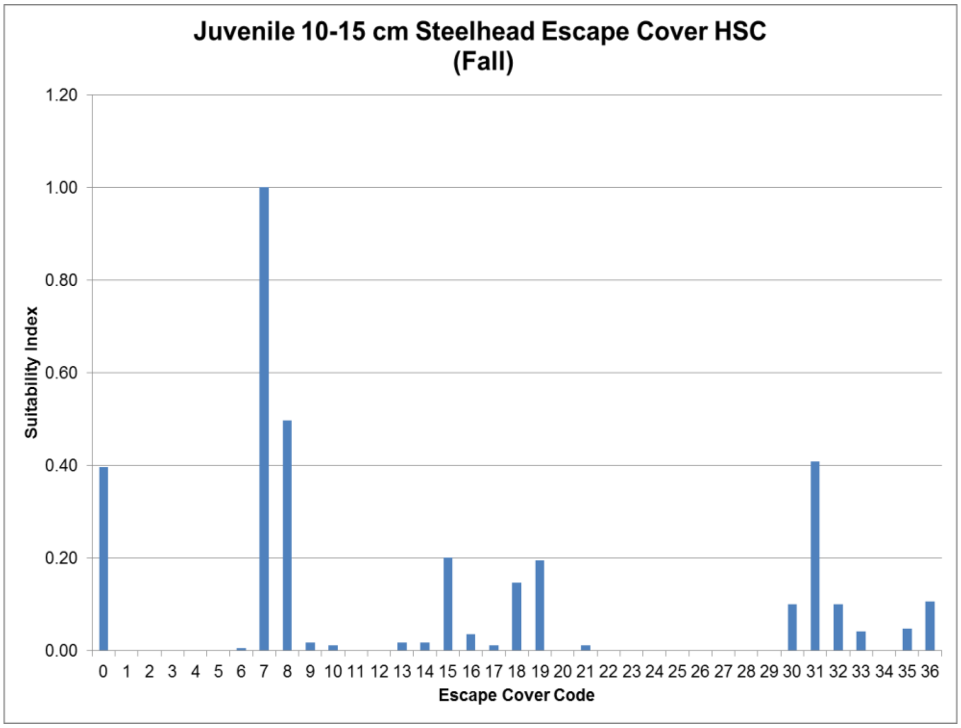
Distance (ft)	10-15 cm Distance to Escape Cover HSC (Summer)		Distance (ft)	10-15 cm Distance to Escape Cover HSC (Fall)
6.9	0.20		6.9	0.48
7	0.19		7	0.48
7.1	0.19		7.1	0.47
7.2	0.19		7.2	0.46
7.3	0.19		7.3	0.45
7.4	0.19		7.4	0.45
7.5	0.19		7.5	0.44
7.6	0.19		7.6	0.43
7.7	0.19		7.7	0.42
7.8	0.19		7.8	0.41
7.9	0.19		7.9	0.40
8	0.19		8	0.39
8.1	0.18		8.1	0.38
8.2	0.18		8.2	0.37
8.3	0.18		8.3	0.36
8.4	0.17		8.4	0.35
8.5	0.17		8.5	0.34
8.6	0.16		8.6	0.33
8.7	0.16		8.7	0.32
8.8	0.15		8.8	0.31
8.9	0.14		8.9	0.30
9	0.14		9	0.29
9.1	0.13		9.1	0.28
9.2	0.12		9.2	0.27
9.3	0.12		9.3	0.26
9.4	0.11		9.4	0.25
9.5	0.10		9.5	0.23
9.6	0.09		9.6	0.22
9.7	0.09		9.7	0.21
9.8	0.08		9.8	0.20
9.9	0.07		9.9	0.18
10	0.07		10	0.17



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 139. Juvenile 10-15 cm steelhead escape cover HSC (summer).



Substrate and Cover Components

Code	Vegetation	Code	Substrate
0	None	0	None
1	Filamentous algae	21	Clay
2	Non-emergent rooted aquatic vegetation	22	Sand or silt/sand (< 0.1 inches)
3	Emergent rooted aquatic vegetation	23	Coarse sand/DG (0.1 - 0.2 inches)
4	Grass	24	Small gravel (0.2 - 1 inches)
5	Sedges/rushes	25	Medium gravel (1 - 2 inches)
6	Vines/poison oak	26	Large gravel (2 - 3 inches)
7	Branches &/or small vegetation < 4 inches, IW	27	Gravel/cobble (3 - 4 inches)
8	Branches &/or small vegetation < 4 inches, OW	28	Small cobble (4 - 6 inches)
9	Branches > 4 inches, IW	29	Medium cobble (6 - 9 inches)
10	Branches > 4 inches, OW	30	Large cobble (9 - 12 inches)
11	Tree trunks < 4 inches dbh, IW	31	Small boulder (12 - 24 inches)
12	Tree trunks < 4 inches dbh, OW	32	Medium boulder (24 - 48 inches)
13	Tree trunks > 4 inches dbh, IW	33	Large boulder (> 48 inches)
14	Tree trunks > 4 inches dbh, OW	34	Bedrock
15	Roots and root-wads	35	Undercut bank
16	Shrubs < 4 inches	36	Rip-rap bank
17	Duff, leaf litter, organic debris		
18	Small woody debris (< 4 inches), dead		
19	Large woody debris (> 4 inches), dead		

Figure 140. Juvenile 10-15 cm steelhead escape cover HSC (fall).

Type II ½ vs. Type III HSC Curves

To further evaluate the representativeness of the equal area selectivity (Type II ½) HSC curves, and the potential effects of habitat availability on these curves, alternative HSC curves were derived using the U/A forage ratio methodology. The smoothed habitat available curve for depth (1.00 = 0.87-0.95 ft) exceeded the depth selectivity suitability index (1.00 = 0.46-0.53 ft) for juvenile <6 cm steelhead, and resulted in a shift of the preference curve to the left with a peak suitability index for depth of approximately 0.10 ft (Figure 141). Conversely, the smoothed habitat available curve (1.00 = 0.86-1.00 ft) for depth was less than the depth selectivity suitability index for juvenile 6-9 cm and 10-15 cm steelhead (1.00 = 1.19-1.28 ft, and 1.43-1.52 ft), and resulted in a radical shift of the preference curves to peak (1.00) suitability indices for depth to approximately 2.19-2.33 and 2.71-2.85 ft., respectively (Figure 142, Figure 143).

The smoothed habitat available curve for velocity (1.00 = ft/s) exceeded the velocity selectivity suitability index (1.00 = ft/s) for juvenile <6 cm steelhead, and resulted in a shift of the preference curve to a peak suitability index for velocity to approximately 0.00 ft/s (Figure 144). Conversely, the smoothed habitat available curve (1.00 = ft/s) for velocity was less than the velocity selectivity suitability index for juvenile 6-9 cm and 10-15 cm steelhead (1.00 = ft/s, and ft/s), and resulted in shifts of the preference curves to peak to the right, respectively (Figure145, Figure 146).

Comparison of the equal area selectivity curves with the U/A ratio (preference) curves showed similar results for depth and velocity in the fall as in the summer except the shifts in preference were more radical and further to the right to the deeper water and faster velocities for juvenile 6-9 cm and 10-15 cm steelhead preference (Figure 147, Figure 148, Figure 149, Figure 150). Further, the preference calculations with the fall data resulted in high suitability for velocities greater than 3.5 ft/s. Clearly, the U/A results produced unreliable estimates of maximum suitability at 4-5 ft for both size classes, and at 4-5 ft/s for larger juveniles. Perhaps more significantly, the U/A ratios severely deflated suitabilities where the majority of the fish were observed.

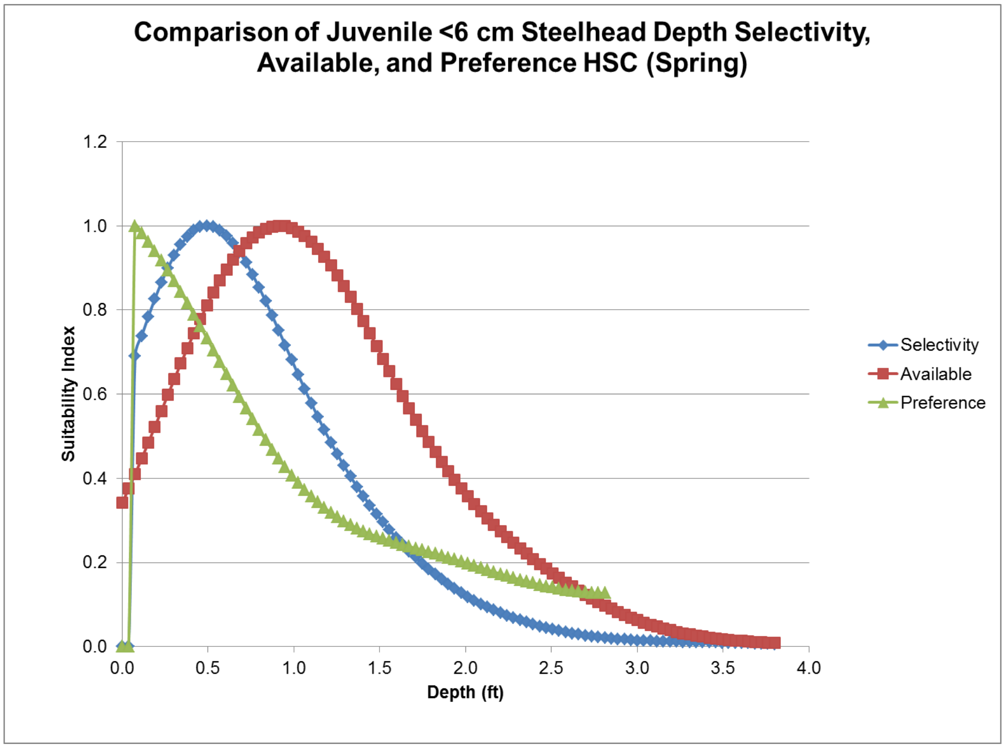


Figure 141. Comparison of juvenile <6 cm steelhead depth selectivity, available, and preference HSC (spring).

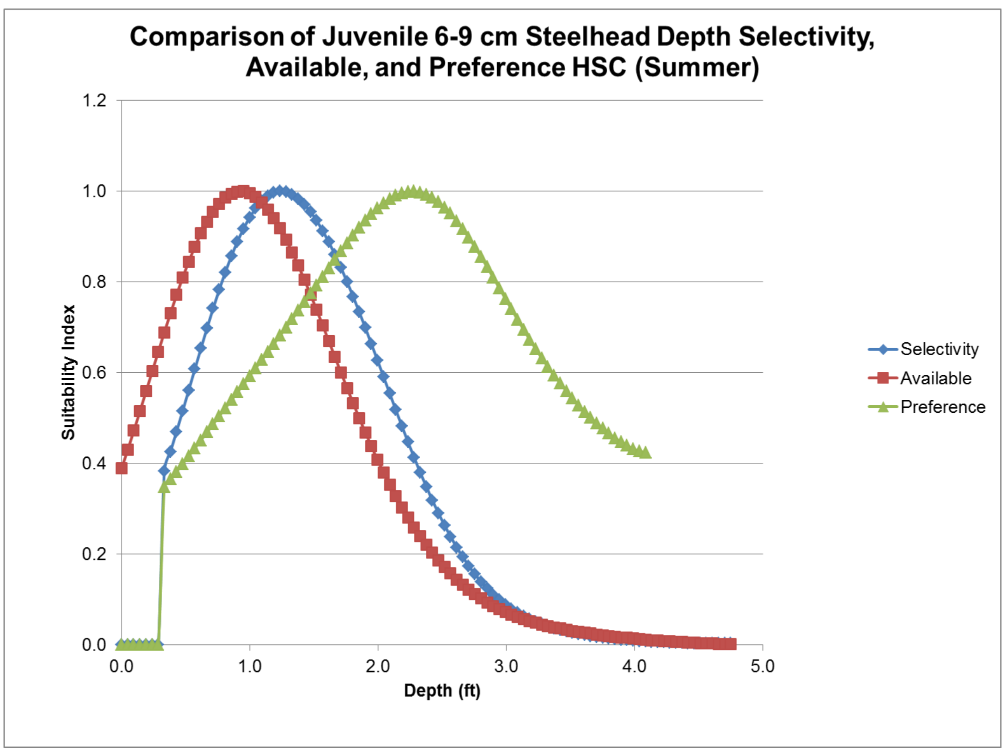


Figure 142. Comparison of juvenile 6-9 cm steelhead depth selectivity, available, and preference HSC (summer).

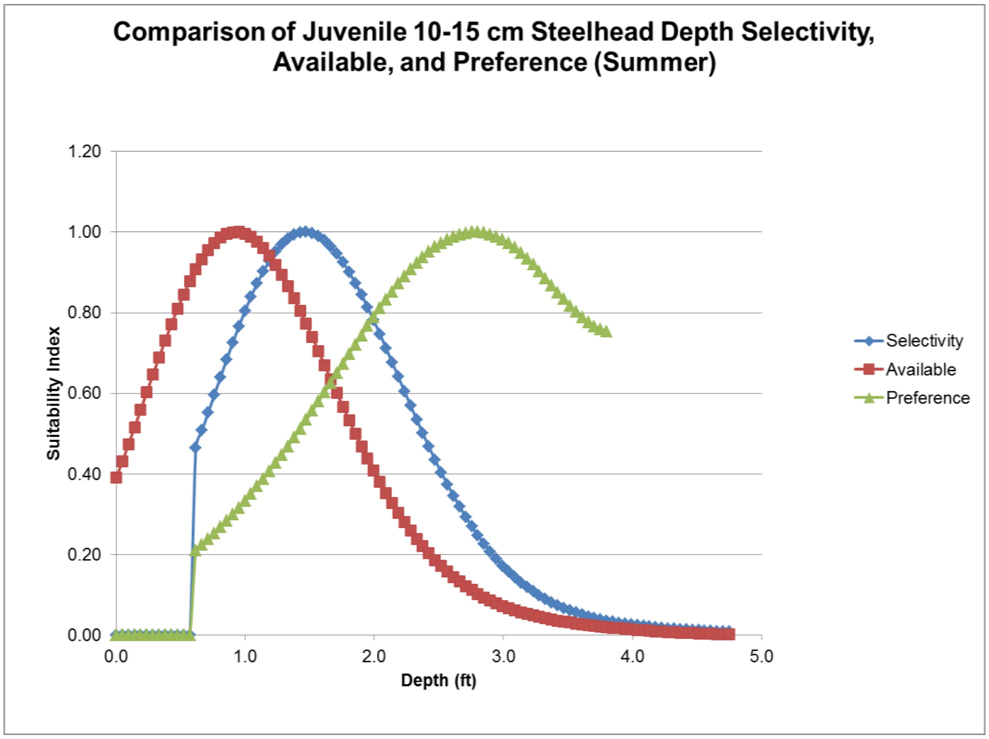


Figure 143. Comparison of juvenile 10-15 cm steelhead depth selectivity, available, and preference (summer).

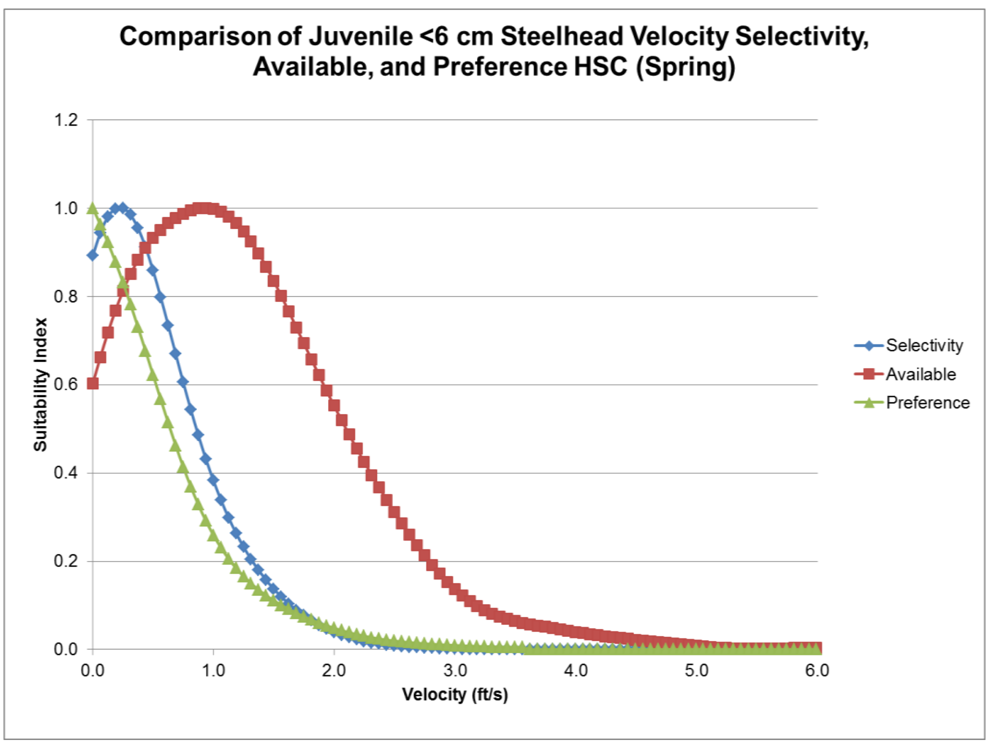


Figure 144. Comparison of juvenile <6 cm steelhead velocity selectivity, available, and preference HSC (spring).

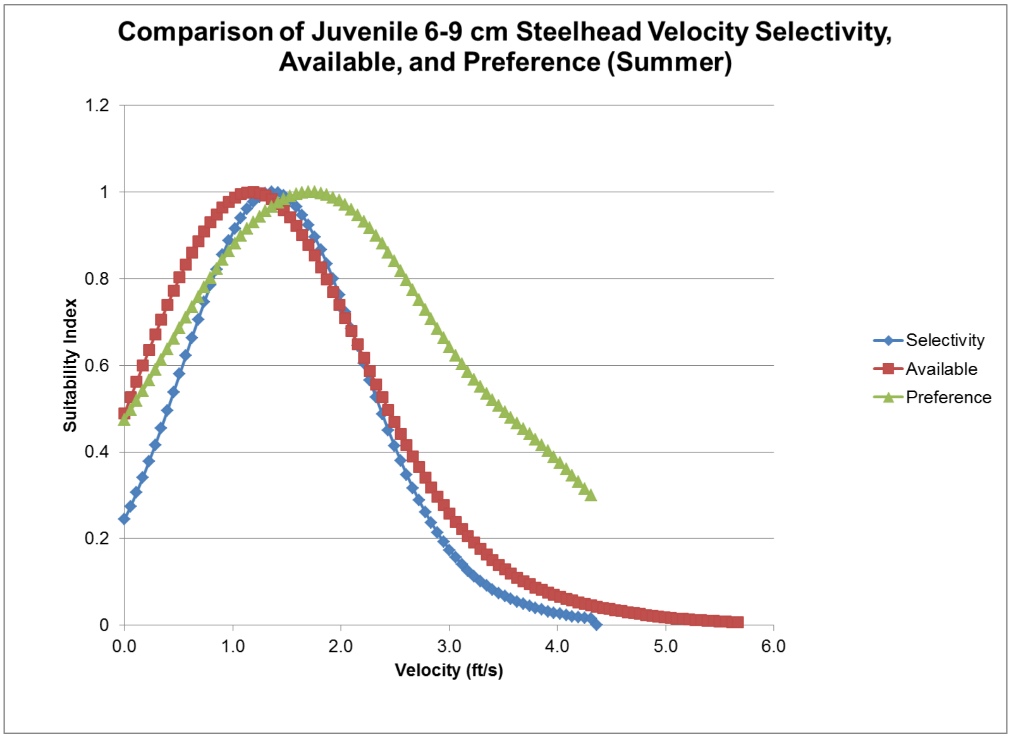


Figure 145. Comparison of juvenile 6-9 cm steelhead velocity selectivity, available, and preference (summer).

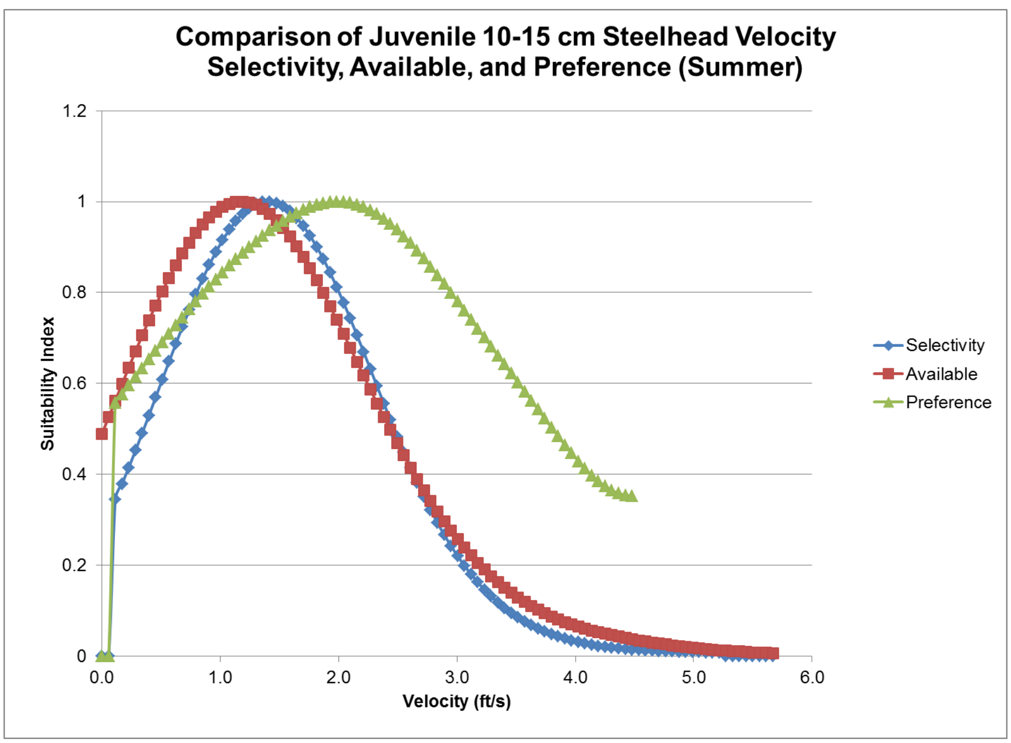


Figure 146. Comparison of juvenile 10-15 cm steelhead velocity selectivity, available, and preference (summer).

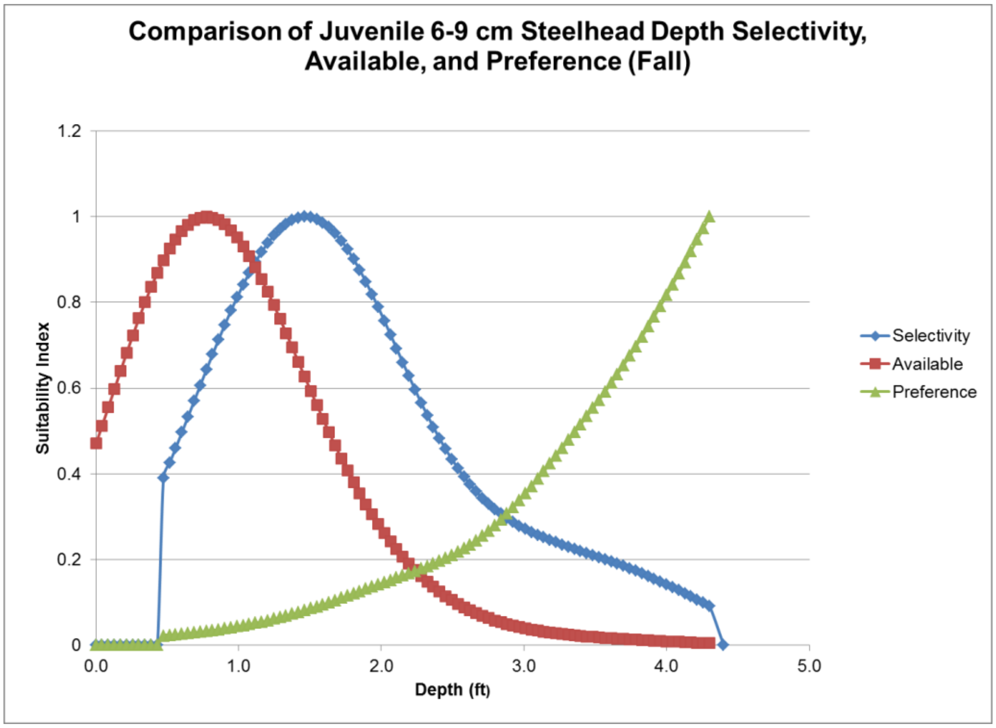


Figure 147. Comparison of juvenile 6-9 cm steelhead depth selectivity, available, and preference (fall).

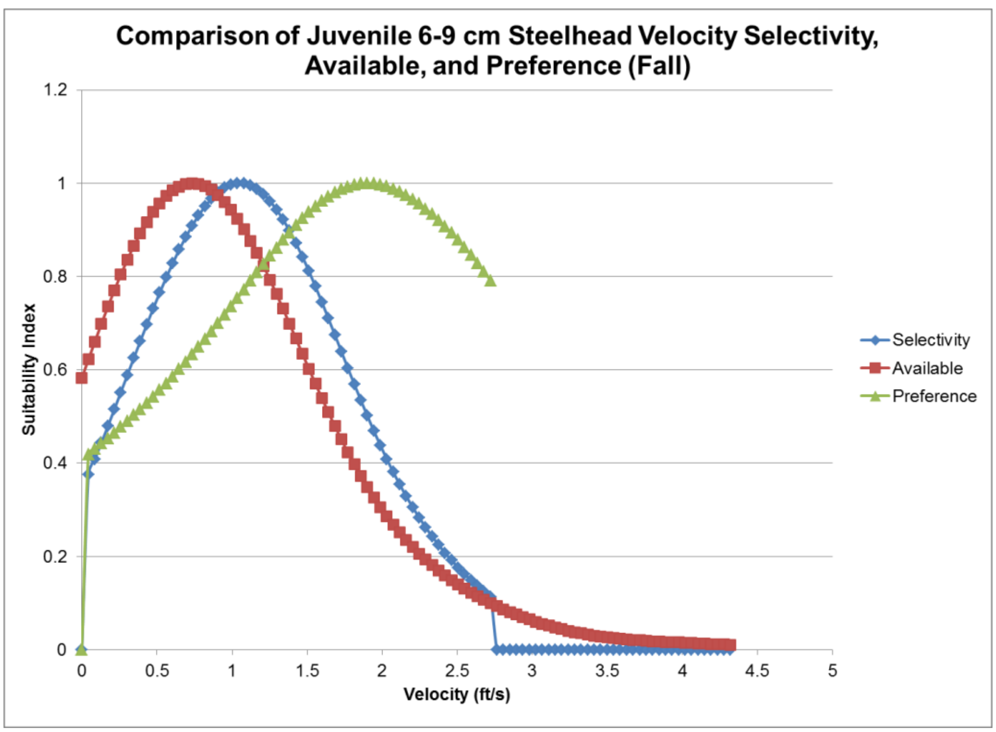


Figure 148. Comparison of juvenile 6-9 cm steelhead velocity selectivity, available, and preference (fall).

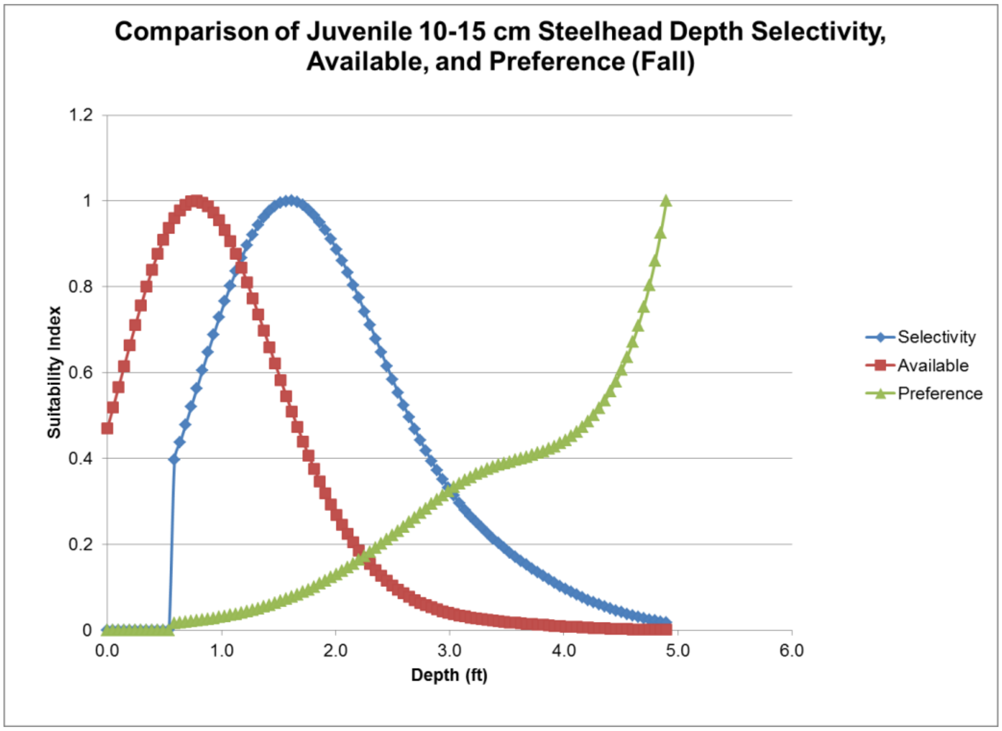


Figure 149. Comparison of juvenile 10-15 cm steelhead depth selectivity, available, and preference (fall).

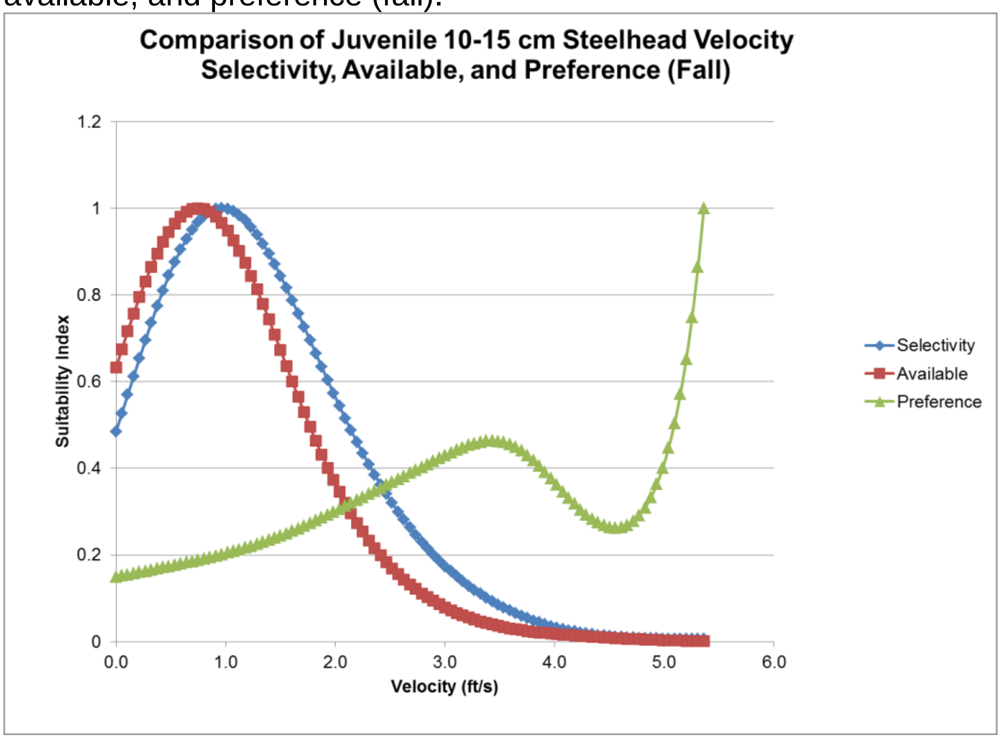


Figure 150. Comparison of juvenile 10-15 cm steelhead velocity selectivity, available, and preference (fall).

DISCUSSION

Juvenile Steelhead Life History Tactics and Thresholds

Big Sur River juvenile steelhead were observed selecting faster velocity habitats as the rearing fish grew during the spring and summer seasons. These findings are consistent with classic historical salmonid studies (Everest and Chapman 1972) as well as by more recent observations by Hardy and Addley (2001) on the Klamath River, where juvenile steelhead selected slower velocity habitats in the spring and faster velocity habitats in the fall. Given that the spring surveys conducted on Klamath River took place in March it is likely that many of those observations were of steelhead fry (i.e., <6 cm FL) and comparable to the spring surveys on the Big Sur River which were predominately comprised of steelhead fry. Hardy and Addley (2001) did not conduct a survey during the summer. The fastest velocities selected by juvenile steelhead on the Big Sur River were observed to occur in the summer, not the fall rearing period.

Peak velocities (HSC = 1.0) selected by juvenile 6-9 cm and 10-15 cm steelhead shifted slightly to the left to slower velocities in the fall when compared to the summer water velocities selected by the juvenile steelhead (Table 22). While the velocity selectivity umbrella curves for each size group of the larger juvenile steelhead indicate a slightly increased selectivity for the faster velocities by the 10-15 cm over the 6-9 cm juvenile steelhead (Figure 151), there is generally good overlap of the curves. Overall, the larger 10-15 cm juvenile steelhead were showing a slightly increased selectivity for faster velocities greater than 2.0-3.0 ft/s over the smaller 6-9 cm juvenile steelhead in the summer, while also showing higher selectivity for slower velocities than the 6-9 cm fish in the fall. These findings are generally consistent with Spina (2003) in which larger juvenile steelhead age 1 and age 2 were observed selecting slower water velocity habitats than young-of-year in Santa Rosa Creek, approximately 80 miles south of the Big Sur River. As flows receded in the Big Sur River during fall, the larger (10+ cm steelhead) and older (1 year old and 2 year old) juvenile steelhead show higher selectivity for the deeper, and hence slow water velocity habitats in pools. The smaller young-of-year 6-9 cm juvenile steelhead, on the other hand, were selecting faster velocity habitats in the fall compared to summer. Increased use of pools and deeper habitats by the larger juveniles may be related to other factors such as bioenergetics, temperature, and/or predation.

Table 22. Comparison of peak and umbrella depth and velocity suitability for juvenile 6-9 cm and 10-15 cm steelhead.

	6-9 cm Depth (ft) Peak 1.0 HSC	6-9 cm Velocity (ft/s) Peak 1.0 HSC
Summer	1.24	1.38
Fall	1.46	1.15
Umbrella	1.24-1.46	1.15-1.38
Min. Depth Threshold	0.33-0.47	
	10-15 cm Depth (ft) Peak 1.0 HSC	**10-15 cm Velocity (ft/s) Peak 1.0 HSC**
Summer	1.47	1.41
Fall	1.62	0.96
Umbrella	1.47-1.62	0.96-1.41
Min. Depth Threshold	0.59	

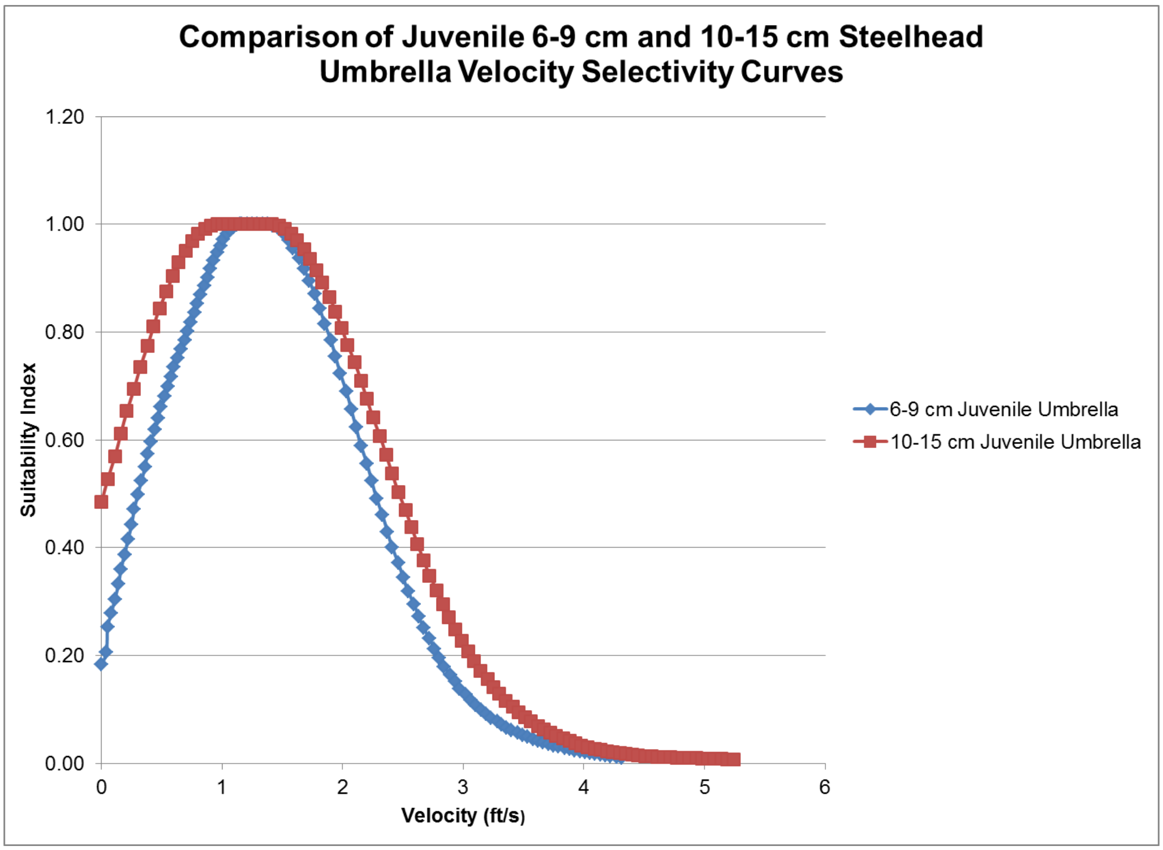


Figure 151. Comparison of juvenile 6-9 cm and 10-15 cm steelhead umbrella velocity selectivity curves.

Review of our habitat availability data confirm that the faster water velocities of 2.0 - 3.0 ft/s that were occasionally selected in summer by juvenile steelhead are extremely rare to almost nonexistent in the fall. These findings are further supported by review of the data collected from one hundred and eighteen 1-

dimensional (1D) physical habitat simulation (Bovee 1997) transects that were placed throughout the study area using a stratified random process for use in evaluating flow and habitat relationships. The 1D transect data were collected at flows ranging from 24 to 33 cfs, which were comparable to the fall fish survey flows which were conducted at 23 to 26 cfs, and provide an additional unbiased assessment of habitat availability during the fall rearing period. Figure 152 and Figure 153 demonstrate the comparability, using smoothed curves of depth and velocity availability during the fall, of the availability data collected during the fall fish surveys and the availability obtained from the 1D transect sampling effort, respectively.

The habitat availability measurements collected in the current study were done so in proportion to the size of the habitat size of each fish survey site, which ensured habitat availability data were collected in the same locations and in the same proportions as the habitat use data. The 1D transect data provided further validity for our habitat availability data with respect to availability of water velocities occurring in the Big Sur River in the fall. Similarly, a comparison of water depth availability in the summer versus the fall rearing period indicates the rareness of deeper water (i.e. >3.00 ft) in the fall. However, the depth availability data collected during the fish surveys shows a slightly higher availability of deeper water habitats between 1.5 ft and 3.0 ft in the fall then does the much larger 1D availability data set for the fall.

Hardy and Addley (2001) also observed juvenile steelhead selecting deeper water habitats in fall versus spring on the Klamath River, as it is no surprise that juvenile steelhead select deeper water (and faster velocity) habitats as they grow. However, the depth thresholds set by the rearing juvenile (non-fry) steelhead in the Big Sur River were not found to occur by other researchers or be as distinct between juvenile size groups in studies on other coastal California streams and rivers. On the Big Sur River, ninety-five percent of all juvenile non-fry (i.e., >5 cm FL) steelhead (n = 2,093) were observed avoiding water depths shallower than 0.75 ft during the core rearing period of summer and fall (Figure 154). This minimum water depth threshold represents an important species- and lifestage-specific biological consideration for future flow management decisions on the Big Sur River, and other coastal rivers.

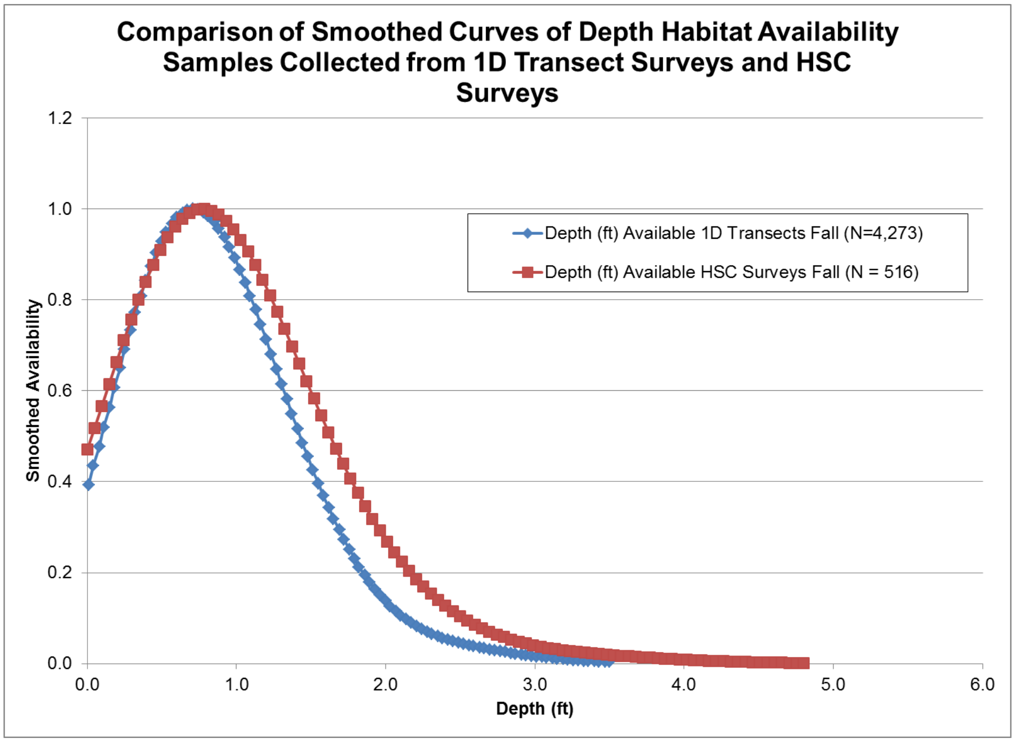


Figure 152. Comparison of smoothed curves of depth habitat availability samples collected from 1D transect surveys and HSC surveys fall.

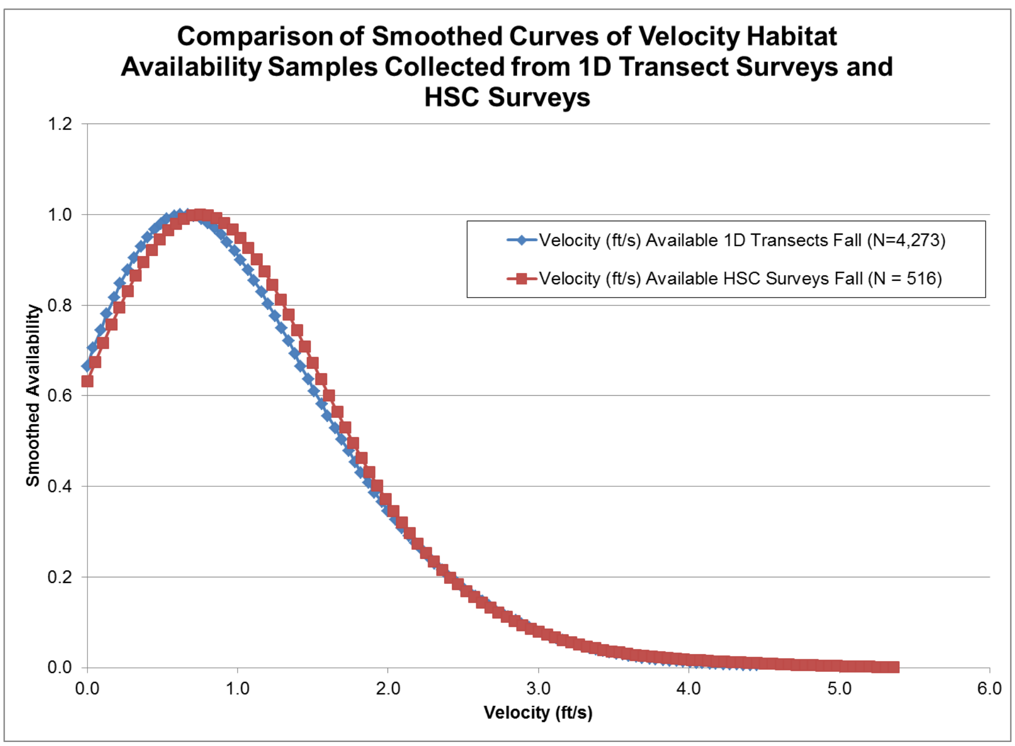


Figure 153. Comparison of smoothed curves of velocity habitat availability samples collected from 1D transect surveys and HSC surveys fall.

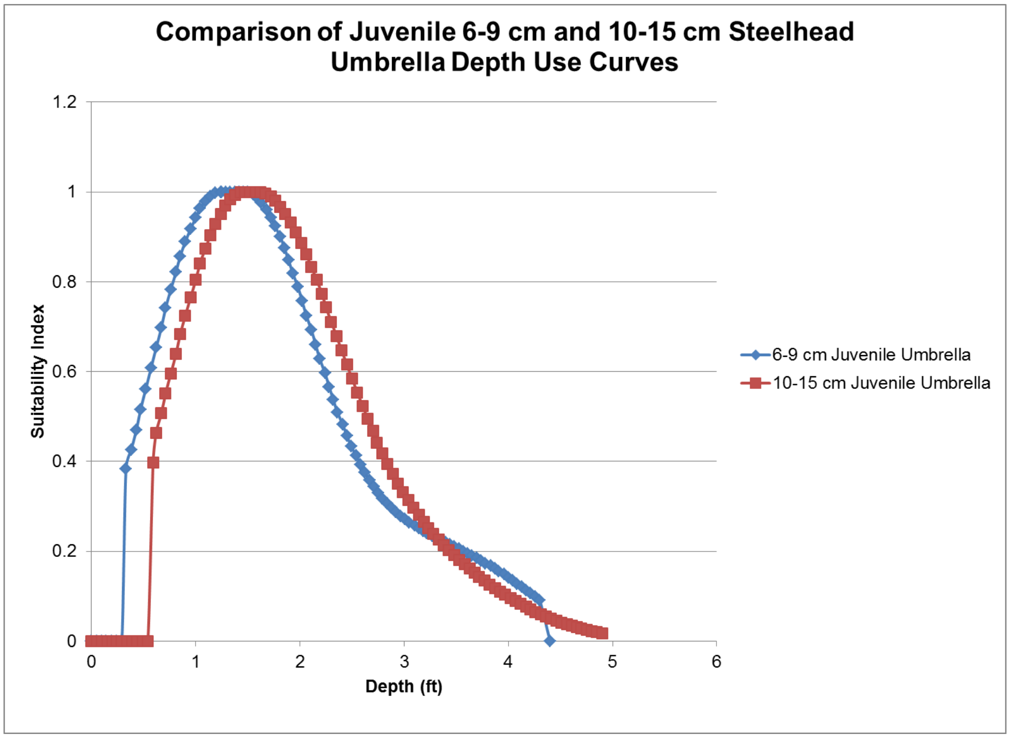


Figure 154. Comparison of juvenile 6-9 cm and 10-15 cm steelhead umbrella depth use curves.

In addition to hydraulic microhabitat conditions (I.e., water depth and velocity), juvenile steelhead rearing site selection is influenced by factors such as proximity and type of in-water escape cover. Despite some juvenile steelhead not being observed near (I.e., < 10 ft) any type of escape cover, all size groups of juveniles were predominately observed in close proximity to some type of in-water escape cover with types ranging from gravel/cobble (2-4 inches) for <6 cm steelhead to larger cobble (9-12 inches) and small boulders (12-24 inches) for larger juvenile steelhead, respectively. Although proximity and type of escape cover and associated influence on habitat selection and use by juvenile steelhead shifted with fish size, it also shifted with season and associated flow conditions.

We observed juvenile steelhead shifting selection of rearing sites in close proximity to hard substrate escape cover types (I.e., cobble and boulder) in summer to selection of rearing sites in close proximity to predominately vegetative escape cover components (I.e., branches < 4.0 inches in-water) in the fall. This seasonal shift was apparently not directly due to respective availability of sites in proximity to those escape cover types between summer and fall (Figure 155). Instead, we attribute this shift to be linked to the decreased availability of the faster water velocities in the fall. For example, juvenile steelhead were observed selecting feeding locations in the summer with faster water velocities near hard substrates, which may act as both in-water escape cover and water velocity shelter. In the fall, however, flow levels decline naturally on coastal California streams and rivers and the corresponding water velocities also slow.

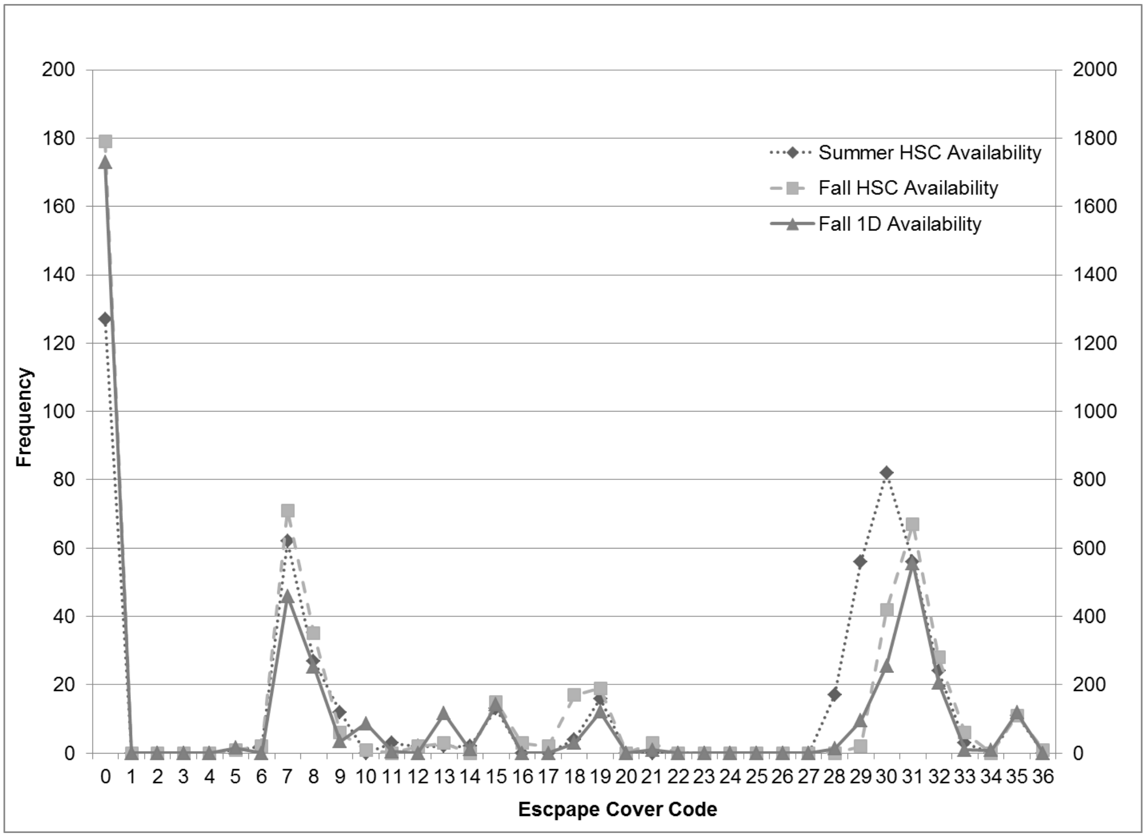


Figure 155. Comparison of habitat availability collected during summer and fall fish surveys, with availability collected during Fall from 1D transect surveys.

Observations of juvenile steelhead on the Big Sur River in fall indicate peak suitability for rearing locations that provide close proximity to in-water vegetative escape cover that consisted of branches less than 4 inches. Hardy and Addley (2001) also observed seasonal shifts in juvenile steelhead selection of rearing habitats between being in close proximity to hard substrates (i.e., small boulders) and vegetative-type (shrubs, grass, sedges, herbs) escape cover on the Klamath River, although the trend was opposite of what we observed on the Big Sur River. The opposite trends are likely related to the fact that Klamath vegetative cover was only available under high spring flows as well as the physical channel and riparian edge habitat differences between each river as the Klamath River Basin (i.e., 40,790 km^2) is much larger than the Big Sur River Watershed (i.e., 160 km^2).

Shapovalov and Taft (1954) found that trout of various ages migrated out of Waddell Creek, a Central California Coast stream located approximately 90 miles north of the Big Sur River, in all months of the year but the majority migrated in the spring and early summer (I.e., April, May and June). The downstream migration of YOY steelhead in Waddell Creek observed by Shapovalov and Taft (1954) extended from late April through the following spring. However, it was unclear if the downstream movement by YOY, versus older juvenile, steelhead was dispersal to downstream rearing habitats or actual seaward migration. We observed a general trend of habitat use indicative of the downstream movement by juvenile steelhead on the Big Sur River, which is generally consistent with Shapovalov and Taft (1954). Titus et al. (2010) reported abundance estimates for juvenile steelhead in the Lower Molera Reach and reported an average fish length of 8.2 cm (range, 5.5-14 cm) in the 1988 November surveys. These findings were generally consistent with our fall observations except that average size in fall 2010 was of larger juveniles with an average size of 11.7 cm (range, 6-35 cm) using direct observation techniques. The average size of juvenile steelhead observed earlier in the summer 2010 surveys was 9.3 cm (range, 4-42 cm) using direct observation techniques.

Allen and Riley (2012) surveyed the Big Sur River lagoon during the spring, summer, and fall of 2010 and reported index estimates of steelhead abundance >10 cm were similar in spring and summer, but were significantly more abundant in the fall (i.e. October). Allen and Riley (2012) noted that many of the 10 cm steelhead observed in the fall were likely young-of-year fish that had grown out of the smaller size class. Further, most of the observations of steelhead greater than 10 cm were also generally less than 15 cm, which is consistent with our observations of juvenile steelhead in the fall in upstream habitats. Total juvenile steelhead index estimates of 45 fish, 490 fish, and 1,494 fish were reported for the lagoon during the spring, summer, and fall surveys, respectively. Hayes et al. (2008) reported juvenile fish moving downstream and experiencing rapid and high growth rates from rearing in the estuarine habitat of Scott Creek (80 miles north of the Big Sur River).

The timing of the movement of juvenile fish on the Big Sur was pronounced in the fall. This observation is supported by the lagoon surveys conducted by Allen and Riley (2012). A snorkel survey was also conducted in the first week of January after the fall surveys of the lower river and lagoon in which all but only 10 juvenile steelhead were observed in the entire lower 0.5 mile of river and entire lagoon. Based upon these observations it was likely that the downstream movement of juvenile steelhead observed on the Big Sur River in fall was linked to smoltification and staging for true seaward migration of which many of those fish were likely young-of-year (age 0) fish. Shapovalov and Taft's (1954) observations on Waddell Creek, on the other hand, were that most returning adult steelhead were of fish that emigrated after 2 or 3 years in freshwater, suggesting smolting at age 1. Sogard et al. (2011) reported, based upon steelhead growth data from another Central California Coast stream (Soquel Creek), that fish rearing in upstream freshwater habitats could not emigrate or undergo smoltification until they are at least age 2. Using a condition-dependent life history model, Satterthwaite et al. (2009), indicated predictions of similar ages of smolting steelhead in Central Coast streams as Shapovalov and Taft (1954) and Sogard et al. (2011).

It is unclear if the higher than average flow conditions observed in summer and fall 2010 on the Big Sur River might have enhanced steelhead rearing conditions and associated food supplies, and hence influenced steelhead growth, fitness, and timing of seaward migration. A small freshet occurred just prior to the fall sampling event which may have had influence on increased observations of juvenile steelhead in the lower river and lagoon in the fall, although the change in the flow volume was only an increase of approximately 3 cfs. Nonetheless, practically all the juvenile steelhead observed in October in the lower river and lagoon were not observed by the following January.

Equal Area Sampling of Habitat Use vs. Forage Ratio Adjustments

Flow conditions during the fish surveys, with the exception of the fall sampling event, occurred at annual exceedance probability flows below the Big Sur River's 50 percent annual exceedance probability benchmark (I.e., > 30 cfs; Table 23). Further comparison of timing of fish surveys with monthly exceedance probability flows indicates sampling occurred for the summer and fall surveys at above average flows with monthly exceedance probabilities ranging from 5 to 24 exceedance probability. Since sampling flows during the core rearing period of summer and fall were comparable to those of above average or wet months we conclude habitat availability was good to optimal based upon site-specific water availability alone. An underlying principle of developing HSC is that all micro- and macrohabitats should be equally available to choose from (Bovee 1986). Since stream flow is associated with juvenile steelhead survival (Grantham et al. 2012) and to salmonid habitat use (Ptolemy 2013), sampling for HSC development at lower than average natural flows may not provide equal availability of all habitats and as such result in the need to apply corrective methods to adjust for habitat availability.

Table 23. Sampling season and corresponding flow and monthly and annual exceedance probabilities.

Month	Season	Flow (cfs)	Monthly Exceedance Probability	Annual Exceedance Probability
May 2012	Spring	35-51	50-65	35-46
June 2010	Summer	54-62	16-24	30-34
August 2010	Summer	31-36	5-11	45-49
October 2010	Fall	23-26	9-15	54-58

The Big Sur River juvenile steelhead selectivity HSC, which exceeded minimum sample size requirements as outlined by Bovee (1986), were developed using the steelhead habitat utilization data unadjusted for habitat availability. We employed a rigorous effort to maintain equal area sampling among habitat types, river reaches, and sampling seasons (and flows). Equal area sampling within habitat types helps minimize biases by allowing relative quality of the different habitat types to dictate the form of the HSC (Allen 2000). In other words, if a species or lifestage prefers deep and fast habitat, and all habitats types are sampled with equal effort, most fish observations would probably occur in runs and fewest would occur in shallow and slow habitats (e.g., glides). When the data are pooled among mesohabitat types, the numerous deep/fast observations from the runs would dominate the HSC form, and the fish's selectivity would be evident. Further, use of the equal area sampling design under natural unimpaired flow conditions accounts for potential biases of flow-related habitat availability influences (i.e., avoids confusing selection or use of optimal habitat with selection or use of merely tolerable habitat) on development of site-specific HSC. Our study design using equal area sampling allows the species and respective life stages to inform us of their biological habitat requirements, without the need to rely on performing mathematical adjustments (I.e., forage ratio adjustments) of habitat use with habitat availability data.

Using the Type "2 ½" equal area HSC approach as done with development of the Big Sur River therefore avoids potential pitfalls associated with development of Type III HSC other researchers have identified (Bovee and Zuboy 1988; Hayes and Jowett 1994; Payne and Allen 2009). For example, small samples sizes particularly at the tails or extremes of the frequency distributions could result in potential overcorrection for habitat availability when using the forage ratio adjustments to the Big Sur River HSC (Figure 147, Figure 148, Figure 149, Figure 150). Our observations were therefore consistent with those of Hayes and Jowett (1994) which indicates performing the forage ratio adjustment for habitat availability when populations are not limited by habitat or when sampling bias is not suspected (Payne and Allen, 2009) may result in inaccurate HSC, in addition to flow recommendations for more water than what is naturally available. Other researchers have also justified use of development of HSC based upon the utilization data without a preference adjustment for habitat availability (Johnson 1980). We contend that development of Type III "preference" HSC, which relies on mathematical adjustments of habitat use from the habitat availability using the forage ratio, may well be a viable option for development of HSC particularly in those instances when sampling conditions of habitat use are known or suspected to be limited by habitat availability or where inequalities in sampling effort among habitat types leads to biases in the use data. In addition, there are other viable options that account for habitat availability such as using presence-absence sampling and/or density sampling (Gard, 2010; Hayes and Jowett 1994; McHugh and Budy 2004; Rubin et al. 1991; Thielke 1985).

Comparisons of Big Sur Juvenile Steelhead HSC with other Coastal California Rivers

The Big Sur River juvenile steelhead HSC were compared with juvenile steelhead HSC from other coastal California rivers that include the Trinity River (Hampton 1997), the Klamath River (Hardy and Addley 2001), and with juvenile steelhead HSC developed by Bovee (1978) which were developed from Oregon and Idaho data. Comparison of Big Sur River <6 cm steelhead HSC for depth is generally consistent with the Trinity River fry HSC and Bovee (1997), although the Klamath River fry (Type I) HSC show higher suitability for deeper water than the Big Sur HSC (Figure 156). A similar pattern of overlap is observed with comparisons of the <6 cm steelhead Big Sur velocity HSC with the Trinity River fry velocity HSC, although both the Klamath River and Bovee (1978) fry HSC show higher suitability for faster velocities (Figure 157) than the juvenile <6 cm Big Sur River HSC. The majority of the <6 cm juvenile steelhead observed on Big Sur River primarily consisted of fish in the 2-3 cm range and therefore are likely to select slower velocity habitats that those that may be selected by larger 4-5 cm fry.

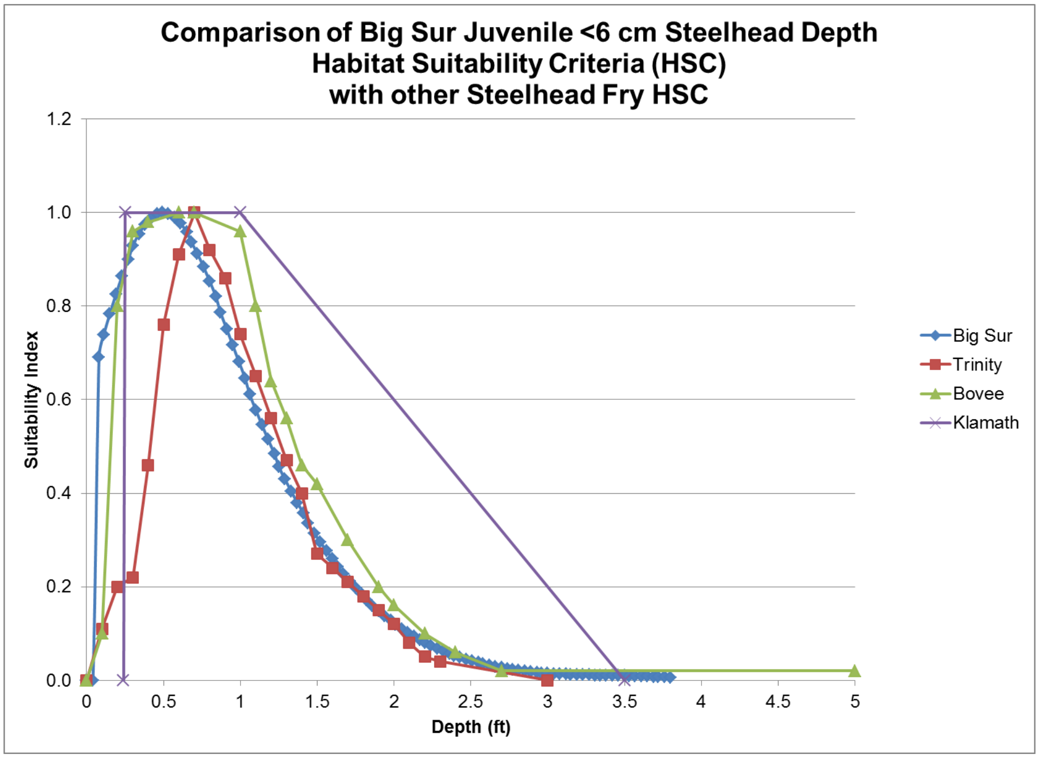


Figure 156. Comparison of Big Sur juvenile <6 cm steelhead depth HSC with other steelhead fry HSC.

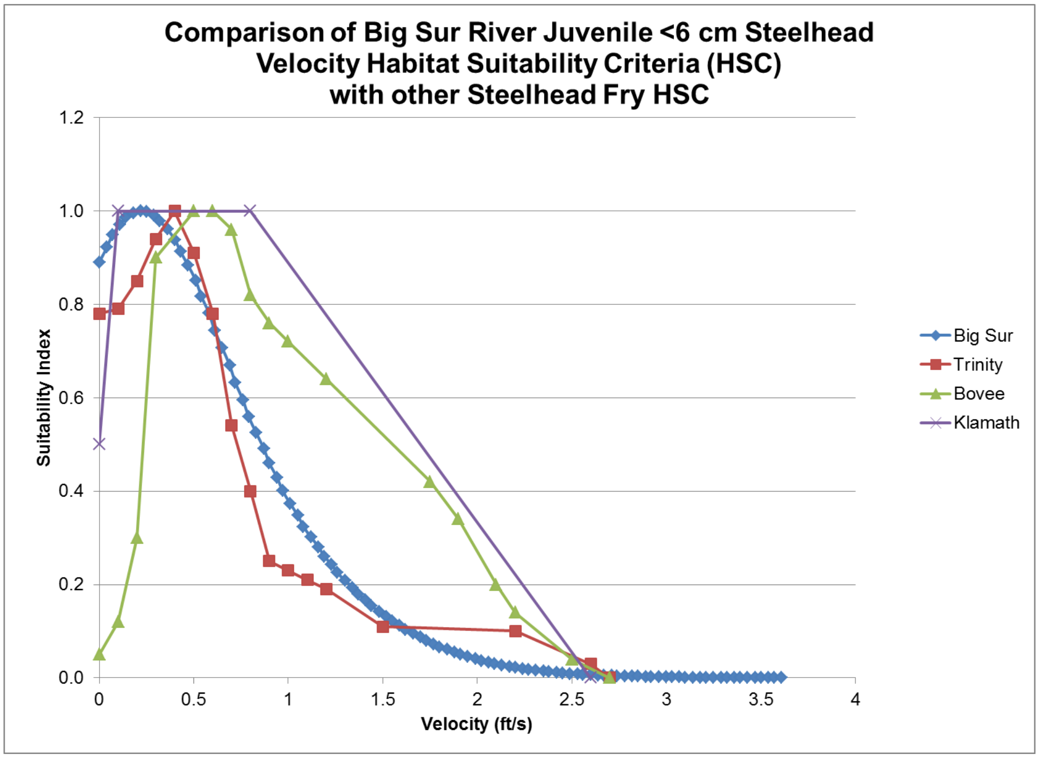


Figure 157. Comparison of Big Sur juvenile <6 cm steelhead velocity HSC with other steelhead fry HSC.

The Big Sur River 6-9 cm and 10-15 cm juvenile steelhead HSC were generally comparable with the other HSC from the Klamath River and Bovee (1978), although the Trinity River juvenile steelhead HSC show higher suitability for deeper water habitats (Figure 158). Contrary, the velocity HSC from the Big Sur River are almost identical with the juvenile steelhead HSC from the Trinity River, the Klamath River (Figure 159), and with Bovee (1978). It seems reasonable that juvenile steelhead in larger rivers such as the Trinity River and the Klamath River might use deeper habitats than juvenile steelhead would use in smaller rivers such as the Big Sur River. Waite and Barnhart (1992) cautioned applying HSC from one stream to another without comparisons of site-specific habitat and hydrology characteristics. Regardless, the nice overlap of juvenile 6-9 cm and 10-15 cm steelhead velocity HSC with juvenile steelhead velocity HSC from the Trinity River and the Klamath River provides justification for development of the Big Sur River velocity umbrella use curves.

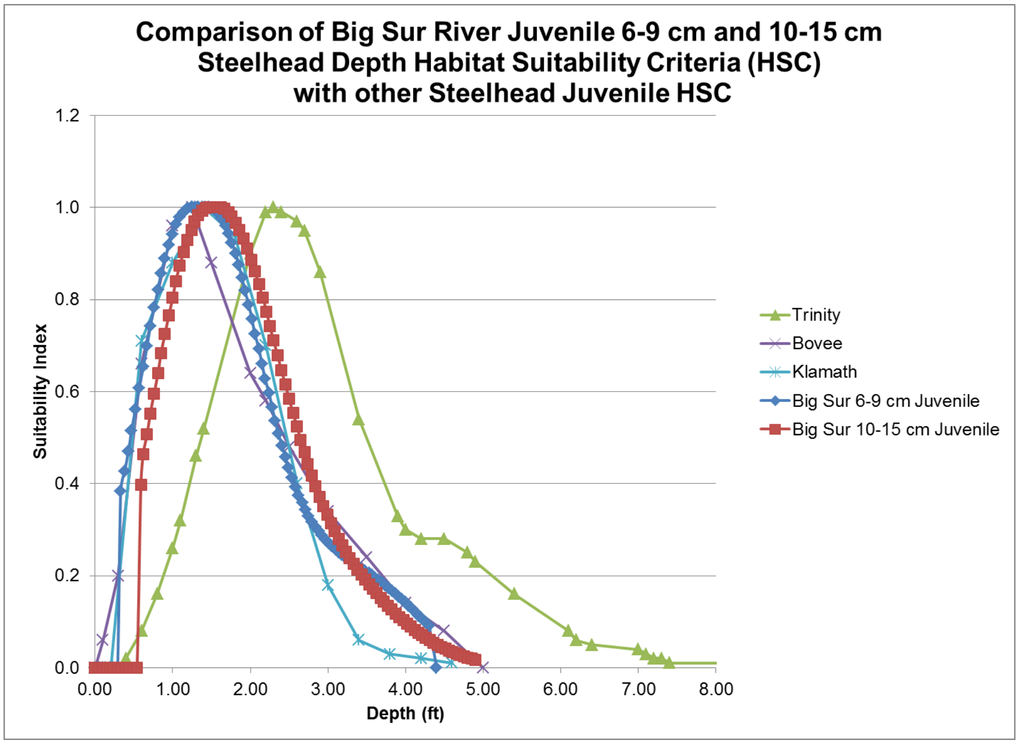


Figure 158.Comparison of Big Sur juvenile 6-9 cm and 10-15 cm steelhead depth HSC with other steelhead juvenile HSC.

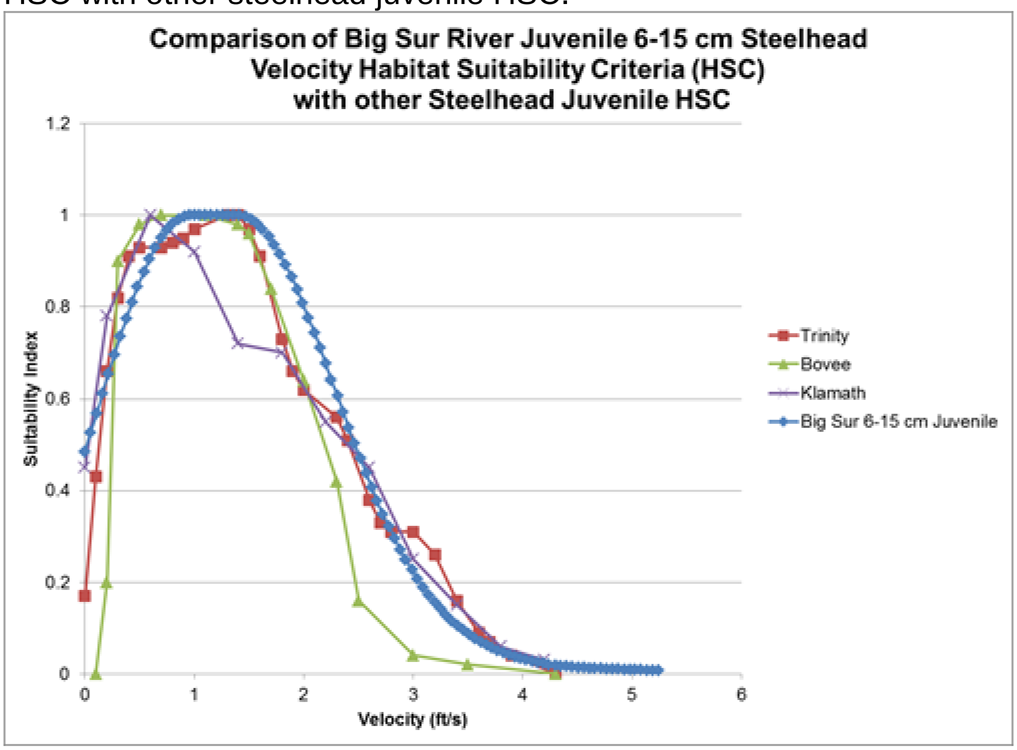


Figure 159. Comparison of Big Sur juvenile 6-15 cm steelhead velocity HSC with other steelhead juvenile HSC.

We observed juvenile steelhead habitat selectivity changing with fish size, season, discharge, and habitat availability. Biologically accurate and unbiased HSC are critical for valid and biologically representative hydraulic habitat modeling of flow and habitat relationships. There are many potential pitfalls in developing site-specific HSC that could contribute to defective HSC and hence unreliable instream flow modeling efforts which include: inadequate overall sample sizes, unequal assessment and/or representation of habitat use, habitat availability being unaccounted for which may mask flow-linked constraints on habitat use, limited temporal sampling such as during one timeframe or season of an important life history component of a species (one timeframe or season may be fine for certain applications such as spring sampling for salmon fry that emigrate soon after emergence), and uncritical application of ratio curves that bear little resemblance to the underlying use data. Our sampling strategy recognized and accounted for potential bias of sampling techniques and habitat availability. Use of corrective mathematical methods (using the availability data) were evaluated, but not utilized since there was no differential in selectivity, or any biases suspected based upon our study design and ambient sampling flow conditions. With proper habitat stratification and non-limiting sampling conditions (e.g., adequate flows and non-degraded habitat), use of an equal area sampling design for site-specific HSC development is therefore a viable option for development of biologically relevant and representative HSC, and ultimately accurate environmental flow recommendations.

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