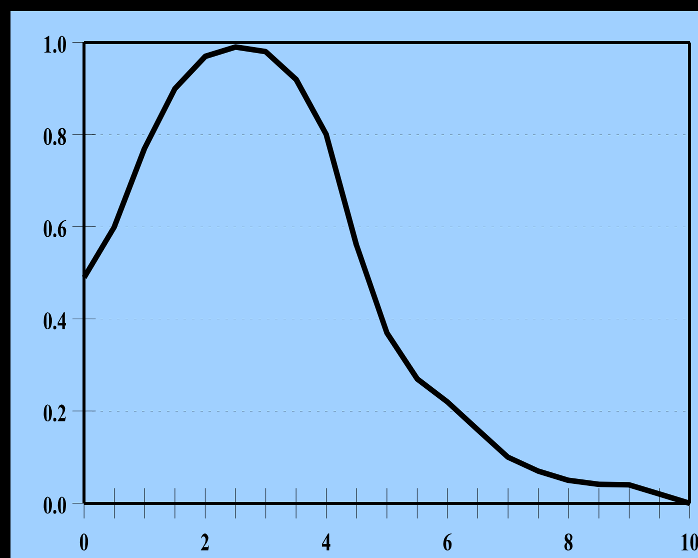
Department of Fish and Game
The Resources Agency
State of California

HABITAT SUITABILITY CRITERIA FOR ANADROMOUS SALMONIDS IN THE KLAMATH RIVER, IRON GATE DAM TO SCOTT RIVER, CALIFORNIA



Stream Evaluation Report No. 05-1

March 2005

Department of Fish and Game
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MARCH 2005

Mike Chrisman	Arnold Schwarzenegger	Ryan Broddrick
Secretary of Resources	Governor	Director
The Resources Agency	State of California	Department of Fish and Game

Habitat Suitability Criteria for Anadromous Salmonids in the Klamath River, Iron Gate Dam to Scott River, California[1]

By

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ABSTRACT

A habitat suitability criteria (HSC) investigation was conducted for anadromous salmonids on the Klamath River, California, from Iron Gate Dam to the confluence with the Scott River, from fall 1999 through fall 2000. Site specific HSC were developed for spawning and juvenile chinook salmon (*Oncorhynchus tshawytscha*). We used direct, out-of-water observation methods from catarafts to locate and measure environmental parameters at 290 active redds. Most spawning activity occurred within the 8 miles immediately downstream of Iron Gate Dam. HSC were prepared for water depth and average velocity, fish focal point water velocity, substrate, and percent of fine substrate in the redds. Klamath River spawning chinook salmon generally used slightly deeper water compared to populations in other rivers; and they used water velocities that were intermediate among values reported in the literature.

Direct underwater observation and underwater videography techniques were used to observe juvenile chinook salmon. Measurements were made at 94 locations where juvenile chinook were observed. We encountered at total of 392 fish. HSC were prepared for water depth and average velocity, fish focal point water velocity, substrate, functional cover, distance to in-water escape cover, specific escape cover components, and distance to the water's edge. Comparisons with HSC from other systems indicated Klamath River juvenile chinook salmon typically selected deeper water than juvenile chinook in most other systems; selected water velocities were intermediate among values reported in the literature.

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1. An investigation for the U.S. Fish and Wildlife Service and California Department of Fish and Game. California Department of Fish and Game Stream Evaluation Report 05-1, March 2005.
2. Hardin-Davis, Incorporated, 460 SW Madison, Number 7, Corvallis, Oregon 97333.
3. RTG Fisheries Research and Photography, P.O. Box 127, Idleyld Park, Oregon 97447.
4. Terraqua, Incorporated, P.O. Box 85, Wauconda, Washington 98859.
5. California Department of Fish and Game, Native Anadromous Fish and Watershed Branch, Stream Requirements Program, 830 S Street, Sacramento, California 95814.

Water visibility prevented obtaining observations sufficient to develop chinook salmon fry HSC. We used direct and indirect underwater observation techniques to test the validity of using an existing habitat use data base, collected by electrofishing, for fry chinook HSC development. We located 88 positions used by fry chinook via direct underwater observation. Microhabitats used by these fish were then compared with microhabitats used by 70 fry located via electrofishing from the same areas. No significant differences (Kolmogorov-Smirnov and t-test, $0.05<p<0.10$) were found between microhabitat use information for the two sampling methods for water depth and average velocity and distance to water's edge. We used underwater videography to examine open water areas away from river banks for fry chinook. The vast majority of fry were concentrated within 15 ft of the banks. These results indicate fry chinook salmon are primarily distributed along the river’s margin, are primarily associated with in-water vegetative escape cover, and that the existing electrofishing data base is suitable for use to develop HSC for Klamath River fry chinook salmon.

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ABBREVIATIONS, ACRONYMS, AND CONVERSIONS

acre ft	acre feet
BIA	U.S. Bureau of Indian Affairs
cfs	cubic feet per second
dbh	diameter breast height
CDFG	California Department of Fish and Game
CESA	California's Endangered Species Act
°F	degrees Fahrenheit; °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)
HSC	habitat suitability criteria
h	hour(s)
inch	inch
inches	inches
IFIM	Instream Flow Incremental Methodology
km^2	square kilometer
lb	pound(s)
μmhos/cm	micromhos per centimeter
mg/L	milligrams per liter
mm	millimeter
n or N	sample size
NPTL	nonparametric tolerance limit
%	percent
PHABSIM	Physical Habitat Simulation Model
pm	parts per million
RFP	request for proposals
RM	river mile
SNTEMP	Stream Network Temperature Model
sq ft	square foot (feet)
SMET	stream margin edge type
SI	suitability index
TL	total length
USNMFS	United States National Marine Fishery Service
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WUA	weighted usable area (sq ft)
YOY	young-of-year

INTRODUCTION

BACKGROUND

Diverse offstream interests have long competed with instream needs for water in California and Oregon's Klamath River Basin (Figure 1). In the basin's headwaters in Oregon, there have been repeated conflicts between irrigation and other offstream uses, and maintenance of Upper Klamath Lake levels for fish and wildlife resources and habitats. Management of water levels in the lake and hydroelectric power projects downstream, affect the amount and timing of streamflow in the mainstem Klamath River in California.

Downstream, in California, Klamath River flow is a significant factor affecting chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), and steelhead trout (*O. mykiss*) habitat quantity and quality. For these salmonids, as well as other aquatic and riparian species, to survive and, at least partially attain potential biological productivity, the timing, magnitude, duration, and frequency of flows in the river must meet habitat needs for each species' life stage. For anadromous salmonids, this includes life stages ranging from upstream migration and spawning of adults to out-migration of juveniles. Water quantity directly affects hydraulic conditions, channel dynamics, and the amount and quality of physical habitat for each species. Streamflow also affects water temperature and other water quality parameters, which in turn strongly influence fish survival and production. Upstream water diversions and management practices often adversely affect river flow and conditions.

Many investigations are being conducted in the Klamath River Basin to define river conditions and resource needs, and to assist in water allocation processes and decisions. This report presents the findings of an investigation of anadromous salmonid life stage habitat suitability criteria (HSC). HSC are functions that define the suitability (on a scale of 0 to 1) of environmental factors such as water depth and velocity, substrate, cover, and other habitat components.

Results of this investigation will be incorporated into broader, concurrent efforts regarding salmonid instream needs in the Klamath River. One such effort is the Instream Flow Incremental Methodology (IFIM) and Physical Habitat Simulation Model (PHABSIM) (Bovee 1982) analyses being employed to quantify the relationship between weighted usable area (WUA) and flow. The IFIM is a widely-accepted approach to the study of riverine habitat, flow regimes, and water allocation. Microhabitat issues are usually addressed within PHABSIM. PHABSIM allows quantification of the relationship between discharge and physical habitat for each life stage of a species. While PHABSIM results can be sensitive to many input variables, reliable HSC are one of the most important components (Bovee 1986).

IFIM/PHABSIM factors may be divided into macro-, meso-, and microhabitat components. Macrohabitat conditions, such as channel structure, water quality, and hydrology influence species' longitudinal distribution. Mesohabitat components generally include river components such as runs, riffles, and pools. Microhabitat refers to factors such as water depth and velocity, substrate, cover, and river margin conditions. Microhabitat factors influence the use of local areas by different life stages of various aquatic species.

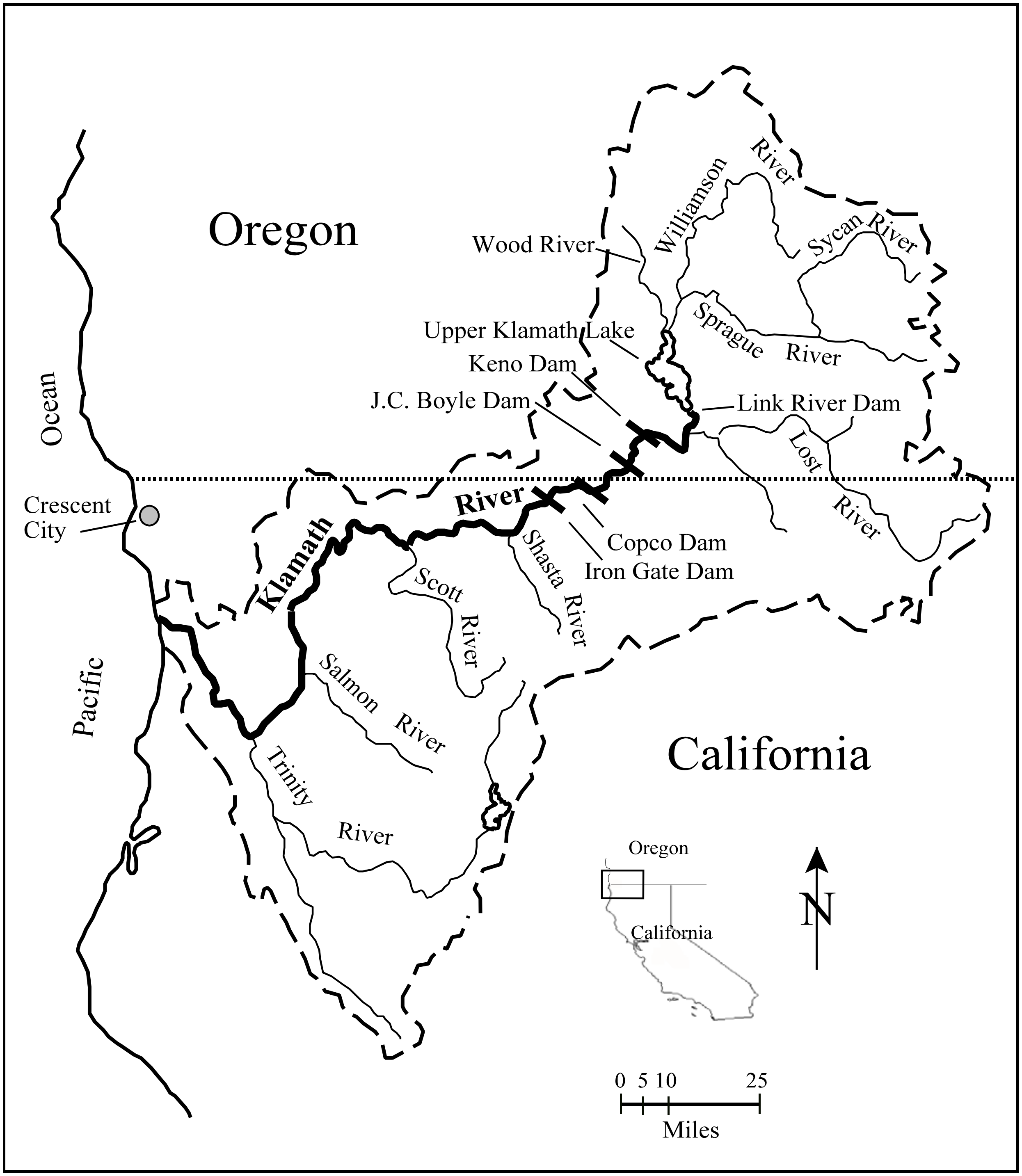

Figure 1. Klamath River watershed and major tributaries, California and Oregon.

It is expected that PHABSIM will play an important role in determining flow regimes for resource management in the Klamath River. The HSC incorporated must be based on the best possible science. For this reason, the California Department of Fish and Game (CDFG) and others have emphasized development of site-specific HSC through the use of direct observation of fish.

OBJECTIVES

The objectives of this investigation were to develop HSC for freshwater life stages of chinook salmon, coho salmon, and steelhead trout in the Klamath River from Iron Gate Dam downstream to the confluence with Scott River (Figure 2). The emphasis was on fall run chinook salmon, with data to be collected for other species as they were encountered during the chinook investigations.

Specific tasks outlined were:

1. Develop study plans and sampling designs.
2. Develop sampling techniques.
3. Develop site-specific HSC for specific life stages, with emphasis on the mesohabitats and sub-mesohabitats occupied by anadromous salmonids. Sub-mesohabitats are small habitat components of mesohabitats, and are more fully identified in the Field Methods segment of the Methods Section of this report.

GENERAL SETTING

Oregon's Upper Klamath Lake is fed by the Wood, Williamson, Sprague, and Sycan rivers. Upper Klamath Lake flows into Link River, and thence into Lake Ewauna, near Klamath Falls, Oregon (FishPro 2000). The mainstem Klamath River officially begins as water flows from Lake Ewauna and begins its 263-mile journey to the Pacific Ocean. The river enters the Pacific near the town of Klamath, about 15 miles south of Crescent City, California. Shasta, Scott, Salmon, and Trinity rivers [River Mile (RM) 177, 143, 66, and 44, respectively] are major tributaries downstream of Lake Ewauna (Pacific Southwest Interagency Committee 1973). These rivers are in California. The Klamath River system drains approximately 15,000 square miles of Oregon and California; about 10,000 square miles of this total are drained by the mainstem Klamath River in California.

Flows in the Klamath River system downstream of Upper Klamath Lake depend largely upon the amount of water in the lake and water diverted for offstream uses. The active storage in Upper Klamath Lake (174,000 acre-ft) is much greater than that of the downstream reservoirs. River flows are also affected by hydroelectric generation. The system passes through six hydroelectric facilities and diversion structures (Table 1) downstream of Upper Klamath Lake. Total generating capacity of the six facilities is 153.8 MW (PacifiCorp 2000). The downstream-most facility, Iron Gate Dam, is located at RM 190. This facility is also used to re-regulate flow in the Klamath River downstream. Iron Gate Dam's hydroelectric turbine flow capacity is 1,735 cfs. When flows upstream exceed this amount, flow control in the Klamath River is achieved at the Copco I project, which has a capacity of 3,200 cfs. Flows greater than 3,200 cfs are not controlled. River flows are monitored at U.S. Geological Survey (USGS) Gage No. 11516530, a short distance downstream of Iron Gate Dam. The river's average monthly flows at Iron Gate Dam for 1960-2000 are in Appendix A-1. These data are actual flows, and reflect upstream depletions and flow management. No major diversions or structures exist between Iron Gate Dam and the river's confluence with the Pacific Ocean. There are, however, a number of significant diversion and/or hydroelectric facilities on most major downstream tributaries, Salmon River being a notable exception.

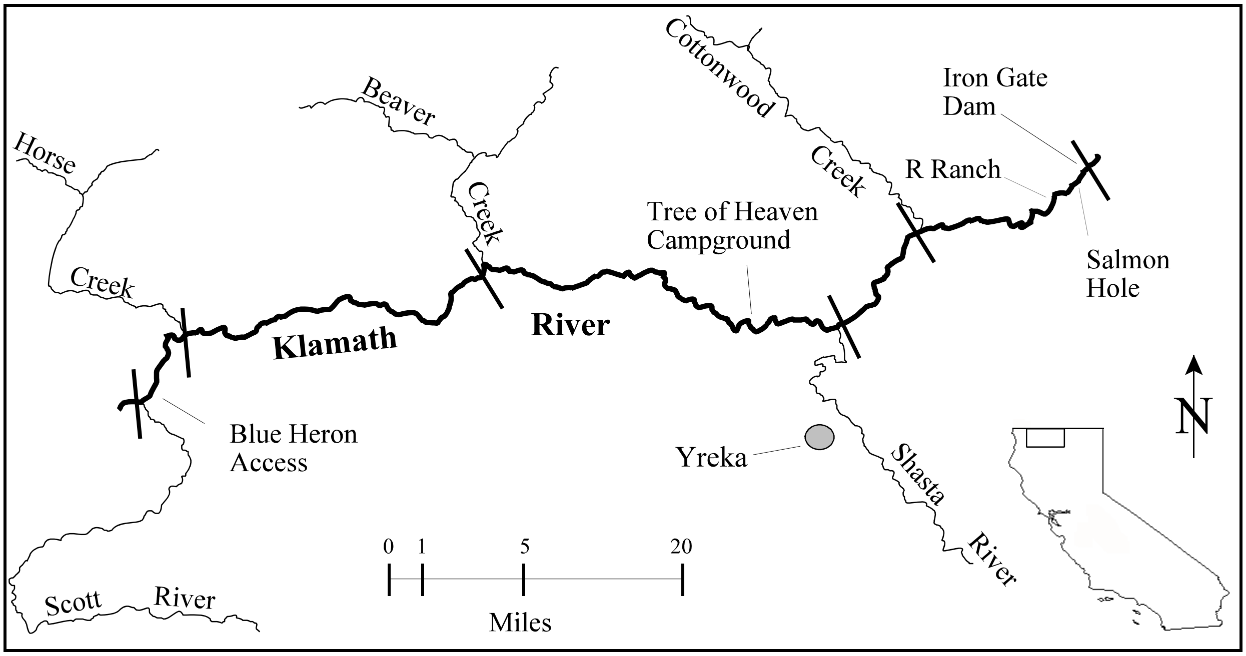

Figure 2. Klamath River, California, anadromous salmonid habitat suitability investigation study area, Iron Gate Dam to Scott River.

The general climate of the Klamath River Basin is characterized by damp, mild winters and dry, hot summers. Coastal areas tend to receive more rainfall precipitation and generally experience milder climate than that of the upper portions of the basin. Precipitation typically ranges from about 15 to 20 inches per year in the lower elevations to 30 to 40 inches per year at the highest hilltops. The basin receives the majority of its precipitation as rain or snow during the winter months.

Human population density within the watershed is generally low, with concentrations in Klamath Falls, Oregon, and Yreka, California. Land uses in the basin include agriculture, ranching, timber harvest, mining, and recreation. Land ownership is a mixture of federal, state, and private lands.

The study reach for this investigation stretches from Iron Gate Dam, at RM 190, downstream to the confluence of Scott River at RM 143. Over this 47-mile reach, the river drops roughly 560 ft, from 2,162 ft above sea level downstream of Iron Gate Dam to 1,600 ft at the Scott River confluence. The average drop over this reach is nearly 12 ft per mile; the average gradient is about 0.22%. The river in this reach generally has a cobble-gravel bed and pool-riffle channel form.

Table 1. Diversion structures on the Klamath River from Upper Klamath Lake, Oregon, to Iron Gate Dam, California.

Structure	River mile[1]	Structure	River mile
Link River Dam	253[2]	Copco I Dam	199
Keno Dam	223	Copco II Dam	198
J.C. Boyle Dam	225	Iron Gate Dam	190

1. River mile measured from the Klamath River's confluence with the Pacific Ocean.
2. Link River Dam is located on Link River rather than the mainstem Klamath River.

FISH RESOURCES

The study area is home to approximately 14 native species of freshwater fishes, including the anadromous chinook salmon, coho salmon, and steelhead trout (Table 2). At least nine introduced species are known to occur in the area as well. Prior to water development, anadromous salmonids migrated as far upstream as the Wood, Williamson, Sprague, and Sycan rivers in Oregon. Today, Iron Gate Dam prevents anadromous migrations upstream, as it does not have fish passage facilities.

The Klamath River Basin once supported highly productive chinook and coho salmon, and steelhead trout fisheries. Klamath River commercial chinook salmon catch data have been collected by CDFG (formerly Division) since 1915. Snyder (1931) reported an annual chinook salmon catch ranging from 11,500 to 61,500 fish in the period 1918-1930. Chinook salmon, as well as coho salmon and steelhead trout, are much less abundant today.

The anadromous fishery is a major component in water allocation decisions within the basin. Chinook salmon, coho salmon, and steelhead all use the study reach of the Klamath year-round for migration, spawning, incubation, and/or rearing (Figure 3). Coho salmon were listed as threatened under the U.S. Endangered Species Act by the National Marine Fisheries Service (USNMFS) in 1998. The status of the coho salmon in northern California was reviewed by CDFG pursuant to California's Endangered Species Act (CESA). In August 2002, CDFG proposed coho salmon in the California portion of the Southern Oregon/Northern California Coasts Unit, an evolutionary significant unit, be listed as threatened pursuant to CESA. The California Fish and Game Commission, the body charged with determining whether to list coho pursuant to CESA, has accepted CDFG's recommendations.

Table 2. A partial list of fish species in the Klamath River downstream of Iron Gate Dam.

Native species		**Introduced species**	
Scientific name	Common name	Scientific name	Common name
Lampetra tridentata	Pacific lamprey	*Notemigonus crysoleucas*	Golden shiner
Lampetra similis	Klamath River lamprey	*Pimephales promelas*	Fathead minnow
Entosohenus lethophagus	Pit-Klamath lamprey	*Ictalurus nebulosus*	Brown bullhead
Oncorhynchus tshawytscha	Chinook salmon	*Perca flavescens*	Yellow perch
Oncorhynchus kisutch	Coho salmon	*Micropterus salmoides*	Largemouth bass
Oncorhynchus mykiss	Steelhead	*Lepomis cyanellus*	Green sunfish
Oncorhynchus clarkii	Cutthroat trout	*Pomoxis nigromaculatus*	Black crappie
Rhinychthys osculus	Speckled dace	*Archoplites interruptas*	Sacramento perch
Catostomus rimiculus	Klamath smallscale sucker	*Alosa sapidissima*	American shad
Catostomus snyderi	Klamath largescale sucker		
Cottus asper	Prickly sculpin		
Acipenser medirostris	Green Sturgeon		
Acipenser transmontanous	White Sturgeon		
Thaleichthys pacificus	Eulachon		
Gasterosteus aculeatus	Three-spine stickleback		

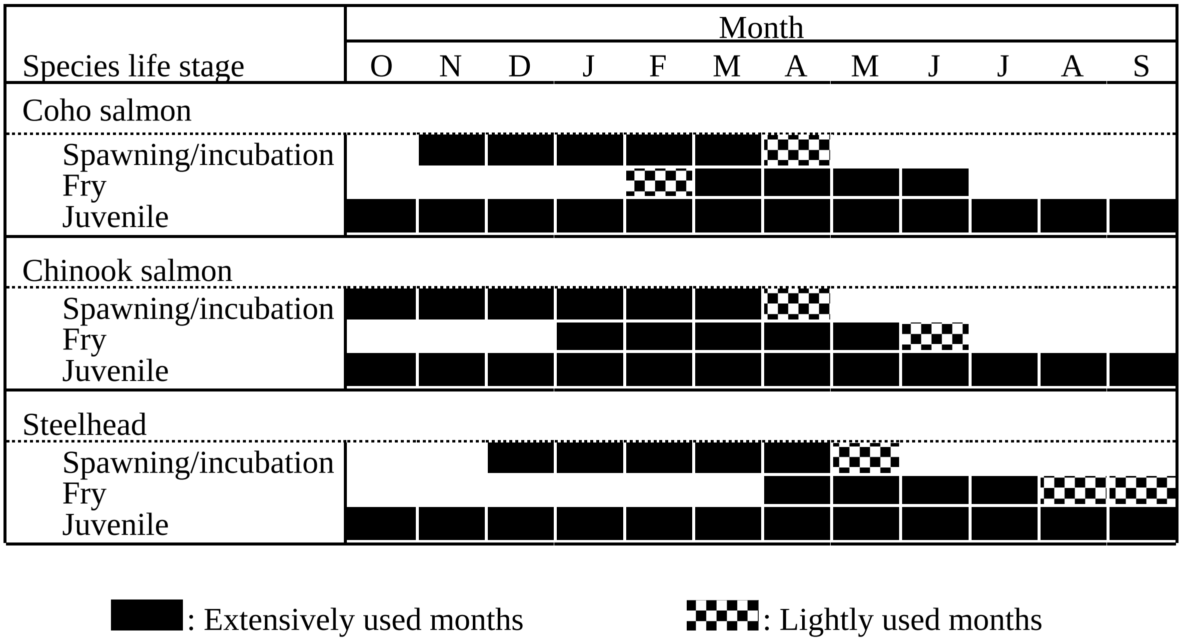

Figure 3. General timing of anadromous salmonid life stages within the Klamath River, California, Iron Gate Dam to Salmon River.

METHODS

FIELD METHODS

All sampling for this investigation was conducted within the 47-mile reach of the Klamath River from Iron Gate Dam downstream to the confluence with the Scott River. The reach was sampled for anadromous salmonid spawning, fry, and juvenile life stages at various times between spring of 1999 and fall of 2000.

All field methods, definitions, and schedules were developed with consultation and cooperation with the:

- CDFG
- U.S. Fish and Wildlife Service (USFWS)
- USGS
- U.S. Bureau of Reclamation
- USNMFS
- Klamath River Technical Working Group, which included the above agencies and the:
    - Hoopa Valley Tribe
    - Yurok Tribe
    - Karuk Tribe
    - U.S. Forest Service
    - Oregon Department of Fish and Wildlife
    - Del Norte County, California
    - Humboldt County, California
    - Siskiyou County, California
    - Trinity County, California

Mesohabitat Types

The study area's mesohabitat types were identified and partitioned into sub-mesohabitat types by the USFWS prior to the beginning of this investigation (Thomas A Shaw, USFWS, Arcata, California, personal communication). Mesohabitat types were numbered sequentially, beginning at Iron Gate Dam. Mesohabitat classification consisted of partitioning the river channel into three primary channel types (i.e., main, split, and side channel). These primary types were further subdivided into pool (P), low slope riffle (LS, gradient <0.3%), moderate slope riffle (MS, gradient 0.3-0.8%), and steep slope riffle (SS, gradient >0.8%) mesohabitat types. Data collected during our study were referenced to the habitat type and unit number to apportion sampling effort (Table 3).

Mesohabitat types were further partitioned into smaller habitat characteristic in an effort to more finely differentiate salmonid fry and juvenile habitat use characteristics. These sub-mesohabitat components were identified as Stream Margin Edge Types (SMET). These are:

1. Trees
2. Trees and emergent vegetation
3. Dense aggregates of willow and woody debris and blackberry
4. Emergent shrubs
5. Open areas
6. Sparse herbaceous vegetation
7. Dense herbaceous vegetation
8. Large substrate and rip-rap
9. Large substrate and rip-rap with vegetation
10. Eddy

SMET 6 (sparse herbaceous vegetation) is an area with obvious open spaces ($\geq$1-ft square) interspersed among clusters of vegetation. Dense herbaceous vegetation and dense aggregates of willows (SMETs 3 and 7) are vegetated areas with no obvious open spaces interspersed among the vegetation. Herbaceous vegetation includes grass, cattails, and bulrushes. Large substrate and rip-rap is defined as materials $\geq$24 inches.

These edge types were further divided into specific vegetative and substrate components. These specific components are:

Vegetative Components
1. Filamentous algae
2. Non-emergent rooted aquatic vegetation
3. Emergent rooted aquatic vegetation
4. Grass
5. Sedges
6. Cockle burrs
7. Grape vines
8. Willows
9. Berry vines
10. Trees (<4 inches dbh)
11. Trees (>4 inches dbh)
12. Root-wad
13. Aggregates of small vegetation (<4 inches)
14. Aggregates of large vegetation (>4 inches)
15. Duff, leaf litter, organic debris
16. Small woody debris (<0.3 x 12 ft)
17. Large woody debris (>0.3 x 12 ft)

Substrate Components	
18. Clay	--
19. Sand or silt/sand	<0.1 inches
20. Coarse sand	0.1-0.2 inches
21. Small gravel	0.2-1.0 inches
22. Medium gravel	1-2 inches
23. Large gravel	2-3 inches
24. Small cobble	3-6 inches
25. Medium cobble	6-9 inches
26. Large cobble	9-12 inches
27. Small boulder	12-24 inches
28. Medium boulder	24-48 inches
29. Large boulder	48 inches
30. Bedrock	--

Table 3. Summary of mesohabitat types in the Klamath River between Iron Gate Dam and Scott River, 1999-2000.

	Mesohabitat Type			
	Low slope riffle (LS)	Moderate slope riffle (MS)	Steep slope riffle (SS)	Pool (P)
River segment: Iron Gate Dam to Cottonwood Creek				
Number of mesohabitat units	32	29	1	26
Total length (ft) of mesohabitat type	18,537	10,683	230	15,579
Mesohabitat average length (ft)	579	368	230	599
River segment: Cottonwood Creek to Shasta River				
Number of mesohabitat units	21	17	6	20
Total length (ft) of mesohabitat type	10,392	6,315	2,371	11,516
Mesohabitat average length (ft)	495	3714	395	576
River segment: Shasta River to Beaver Creek				
Number of mesohabitat units	45	42	45	85
Total length (ft) of mesohabitat type	15,763	17,026	13,945	44,377
Mesohabitat average length (ft)	379	459	356	587
River segment: Beaver Creek to Horse Creek				
Number of mesohabitat units	64	45	5	66
Total length (ft) of mesohabitat type	27,684	17,082	1,170	34,857
Mesohabitat average length (ft)	433	380	234	528
River segment: Horse Creek to Scott River				
Number of mesohabitat units	17	16	3	25
Total length (ft) of mesohabitat type	7,170	6,253	963	12,435
Mesohabitat average length (ft)	422	391	321	497
River segments combined: Iron Gate to Scott River				
Total number of mesohabitat units	179	149	60	222
Total length (ft) of mesohabitat units	79,546	57,359	18,679	118,764
Mesohabitat unit average length (ft)	444	385	311	535

The first sampling period was from October 18 to 26, 1999. We measured environmental conditions at all redds that had actively spawning fish, and at all redds that appeared to be recently constructed. Prior to, and during this sample period, river flow was nearly constant at Iron Gate Dam (1,380 to 1,390 cfs), precipitation was negligible, and tributary contribution was low and consistent (see Appendices A-2 and A-3). Therefore, we assumed river conditions were consistent from initial construction activities to the time of redd observation for redds observed without actively spawning fish. Each redd examined during the first sample period was marked with a flagged rock placed near the redd to avoid repeated measurements during the later sample period.

River flow from Iron Gate Dam was increased to about 1,825 cfs (range 1,820-1,830 cfs) October 28, 1999, and held at that level through November 8, 1999. Flows and river conditions were allowed to stabilize for 4 to 5 days prior to conducting the second sampling. The second sampling period extended from November 2 to November 8, 1999. We examined all redds observed, but measured conditions only for redds where female salmon were observed defending or digging the redds, or that were clearly constructed during the higher flow condition.

Redds were identified by the presence of actively spawning fish, the presence of substrate that was still "clean" due to spawning activities, or the redds' pit-tail spill configuration. When redds were located without obviously actively spawning fish, observers noted whether adult female salmon could be seen nearby, and observed the fish to determine if it was actively preparing the redd.

Sampling crews consisted of two, two-person teams using catarafts to navigate the river. Each team was comprised of a biologist and a technician. During sampling, one survey team floated downstream along one side of the river, while the other team simultaneously floated downstream on the opposite side of the river. The river was sampled from river margin to river margin as the teams proceeded down-river. The teams surveyed 3 to 10 river miles per day.

Above-water direct observation techniques were used to locate chinook salmon redds within most areas of the study reach. Above-water observers used polarized glasses and stood on a viewing platform mounted on top of each cataraft to aid in locating redds. In deeper areas, above-water observations were augmented with underwater direct and indirect observations. Underwater direct observations techniques consisted of use of snorkel or SCUBA equipment. Observation techniques consisted of entering the river upstream of the area to be sampled, floating through the area, marking located redds, and then returning to collect the necessary information.

Underwater indirect observations were conducted by using two, wide-angle Fisheye brand underwater cameras for videography observations (Figure 4). The two cameras were mounted on a 15-lb lead weight. One camera faced downstream, and the other 90 degrees to the current. The weighted cameras were raised and lowered from the front of a cataraft by cable and custom downrigger (Figure 5). The amount of suspension cable used provided water depth data. Each camera was linked to a black-and-white DC-powered monitor with a 7-inch screen. A biologist viewed the video images in a custom viewing compartment mounted on the cataraft. When fish or redds were observed, the cataraft was stopped, and the necessary information was measured and recorded. Most observations were made using above-water observation techniques.

We used horizontal Secchi disk transparency as an index of visibility. Horizontal, rather than vertical, Secchi disk visibility is a more realistic measurement of the range and limits of underwater and near-surface observation techniques, as it provides a better measure of actual visibility. Light striking entrained air, suspended particles, and other components in the water reflects differently if viewed from within the water or at a low angle, rather than if viewed from directly above. Secchi disk visibility distance was measured from an underwater observer's eye to the disk, at the point where the disk became invisible. During the first sample period, horizontal Secchi disk distance ranged from 7 to 13 ft, water temperature from 54° to 61°F, and weather was mostly clear. During the second sampling period, horizontal Secchi disk distance ranged from 7 to 12 ft, water temperature from 52 to 55° F. Weather conditions often included overcast skies or light rain.

Figure 4. Underwater Fish Eye videography cameras, direct current black and white video monitors, Swoffer water velocity meter, and down-rigger bomb used to search deepwater during the Klamath River habitat suitability investigation, 1999-2000.

Figure 5. Inflatable cataraft and equipment used to search deepwater during the Klamath River anadromous salmonid habitat suitability investigation, 1999-2000.

Data recorded for each redd observed are:

- Mesohabitat number and type.
- SMET and location.
- Total water depth; measured with a graduated rod to the nearest 0.1 ft, to the immediate left and right of the pit in areas with undisturbed substrate. Water depth measurements from the left and right side of the spawning pit were averaged to approximate the water depth conditions characterizing the streambed at the pit site prior to redd construction.
- Average velocity of the water column; measured to the nearest 0.01 ft/sec with a Swoffer model 2100 or 3000 water velocity meter, to the immediate left and right of the pit in areas with undisturbed substrate. Standard USGS protocol was followed for water velocity measurements. Water velocity measurements from the left and right side of the spawning pit were averaged to approximate the water velocity conditions characterizing the streambed at the pit site prior to redd construction. Water column average velocity is referred to as average water velocity in this report.
- Fish focal point water velocity; measured to the nearest 0.01 ft/sec with a Swoffer Model 2100 or 3000 water velocity meter, on the centerline of the redd, immediately upstream of the pit and 0.4 ft above the undisturbed streambed. Fish focal point water velocity is the water velocity at an observed fish's position, or at a predetermined (i.e., 0.4 ft above the undisturbed substrate) when a fish is not observed actively preparing a redd.
- Dominant and sub-dominant substrate particle sizes comprising, and surrounding the redd were visually estimated. Substrate particle size categories are:

Code	Component	Size range	Code	Component	Size range
1.	Organic debris	- - -	8.	Small cobble	3-6 inches
2.	Clay	- - -	9.	Medium cobble	6-9 inches
3.	Sand and/or silt	<0.1 inches	10.	Large cobble	9-12 inches
4.	Coarse sand	0.1-0.2 inches	11.	Small boulder	12-24 inches
5.	Small gravel	0.2-1 inches	12.	Medium boulder	24-48 inches
6.	Medium gravel	1-2 inches	13.	Large boulder	>48 inches
7.	Large gravel	2-3 inches	14.	Bedrock	- - -

- Percent fines; visual estimate of the percent of the streambed surface in and around the redd comprised of fines (<0.025 inches diameter).
- Distance (to the nearest 0.5 ft) to nearest escape cover and feature creating the escape cover; escape cover is defined as a structural or vegetative feature that an adult chinook salmon could use for concealment.
- Distance (to the nearest 0.5 ft) to water's edge.
- Length (to the nearest 0.5 ft) of the redd (from upstream end of the pit to downstream end of the redd's tail spill).
- Presence or absence of an actively spawning female salmon on or near the redd.

All data collected during the first sampling period were from redds observed via direct above-water observation. During the second sampling period, our methods were identical to the first period, except that we also used underwater videography, and occasionally face plate and snorkel or SCUBA gear, to search for redds in water too deep for observations from the surface (e.g., >6 ft deep). USFWS and Tribal crews conducted redd counts during our November sampling effort, and we focused on some of their observed spawning locations in an effort to observe spawning chinook in deeper water. We deployed our SCUBA observers and videography gear in several places identified by these crews. We also made similar observation efforts in several other deep pool tail-out areas, where redds were abundant in shallower water.

Fry Chinook Salmon

For this investigation, chinook salmon < 2.2 inches FL were defined as fry, and chinook ≥2.2 inches FL were defined as juveniles. These categories conformed with those used by other Klamath River fishery investigations.

We conducted a pilot study during spring 1999 to test the feasibility of using face plates and snorkels to make direct underwater observations of fry and juvenile chinook salmon within the study reach. High river flows and poor water visibility that accompanied these flows prevented effective data collection. River flows at Iron Gate Dam ranged from 2,090 to 4,790 cfs (a median of 3,440 cfs) during May 1999. Horizontal Secchi disk distances as little as about 6 inches often occurred, and seldom exceeded 3 ft. We concluded from these observations that there was little likelihood of obtaining sufficient fry chinook observations via direct underwater observation to develop HSC. Therefore, it was necessary to explore alternate techniques.

An alternate technique was developed and agreed upon during a December 14, 1999 interagency meeting, and was implemented in 2000. The alternative technique consisted of evaluating the suitability of using fry chinook salmon habitat use data previously collected by electrofishing to develop HSC, if the information proved unbiased and representative. The electrofishing data were collected by the USFWS in 1998 and 1999.

Evaluations included comparison of underwater direct and indirect observation data we were able to collect with the USFWS' electrofishing techniques and data (Thomas A. Shaw, USFWS, Arcata, California, personal communication). In addition, we used our underwater videography equipment and techniques to search for fry salmonids in deep and/or open water areas not accessible to electrofishing to include these components in our evaluations.

The plan had four basic elements:

1. Conduct a controlled comparison of direct underwater observation and electrofishing data to test for differences and similarities due to sampling technique.
2. Test the effectiveness of use of underwater videography to observe young salmonids.
3. Use underwater videography to search for fry in deeper and open water areas not accessible to wading and electrofishing during USFWS's sampling.
4. Use underwater videography and direct observation techniques to collect HSC data for juvenile chinook salmon; the USFWS electrofishing data included few observations of juvenile salmon (i.e., young salmon >2.2 inches).

We sampled for fry and juvenile chinook salmon at select mesohabitats within the study reach from April 6 to May 12, 2000. These mesohabitats were known to be used by fry chinook salmon, and included a range of SMETs (USFWS, Arcata California, unpublished data). Flows at Iron Gate Dam during this period ranged from 2,220 to 3,770 cfs. Horizontal Secchi disk readings ranged from 3.8 to 6.2 ft. These flow and visibility conditions were substantially improvments over those of 1999, and facilitated our underwater observations and videography techniques and results.

We tested use of underwater videography to observe salmonid fry April 6-9, 2000. We made a series of observations in areas known to have chinook fry present at the Salmon Hole and R-Ranch (RM 189.5 and 187) in LS, MS, and P mesohabitat types, and a variety of SMETs. First, an underwater observer located a group of fry chinook, and then maintained a position close enough to watch the fish, but far enough to avoid disturbing the fish or causing them to flee. In water shallow enough to wade, the group of fish was then approached by a second person wading from the bank using a video camera mounted on a hand-held, 12-ft boom. In deeper water, the group of fish was approached by a two-person team on a cataraft using the previously described video camera/downrigger apparatus. To evaluate use of the video equipment, we asked (Q), and conducted preliminary sampling to answer (A) the following questions:

1. Q: Do salmon fry leave the area before they can be observed in the video monitor?
   A: No.
2. Q: At what distance from the camera do fry begin to displace?
   A: 0.0 to 5.9 inches.
3. Q: When fry displace, how much time passes before they resume positions in front of the camera?
   A: Usually 10 seconds or less.
4. Q: After a fry's position is marked with a float and weight, how much time passes before all fry return to the marked position?
   A: Average = 10 seconds; range = 8 seconds to 7 minutes; n = 11.
5. Q: With a video camera in place underwater, and fry holding position near it, how closely could an underwater observer approach without causing fry to displace?
   A: To within 1 ft; close enough for positive species identification.

These trials confirmed that: underwater video cameras deployed by a person from the bank or by a team using a cataraft, did not displace fry any more than did an underwater observer; that direct underwater observation was a viable method to observe chinook salmon fry in their natural habitats given adequate flow and visibility characteristics; and that a waiting period of 10 minutes was sufficient to allow chinook fry to return to positions after these positions were marked with floats and weights.

Once the viability of underwater videography and direct observation was confirmed, we applied these techniques to three aspects of the fry and juvenile salmon HSC work:

1. Comparison of direct observation and electrofishing HSC.
2. Open-water search for fry salmonids.
3. Collection of independent HSC data for juvenile salmonids.

<u>*Comparison of direct observations and electrofishing results*</u>: During and after efforts to locate fry and juvenile salmonids in deep water, we also collected information in shallower areas that were being sampled via electrofishing for the concurrent USFWS salmonid density study. Our objective in this phase of the investigation was to compare microhabitat use characteristics derived from direct underwater observations to those derived from electrofishing within selected sites.

Underwater observers accompanied, and worked closely with, the USFWS's electrofishing teams during this phase of the investigation.

This effort consisted of an underwater observer observing and marking fish positions; allowing the sample area to rest for at least 10 minutes; and the electrofishing team then conducting its usual sampling and data collection within the same area. Microhabitat conditions for fish observed by each technique were measured, and the results compared.

We sampled the USFWS's established fry chinook monitoring sites, described by ten SMETs located within P, LS, and, MS. Of USFWS's approximately 70 total sites, a subset of 23 sites was selected based on the importance to the USFWS's monitoring effort, the likelihood of the site to hold fry under the existing flow conditions, and the opportunity for maximizing the amount of information obtained. The 23 sample sites included 14 mesohabitat units and 9 SMETs (Table 4).

Table 4. Mesohabitat types and stream margin edge types (SMET) sampled for fry chinook salmon in the Klamath River between Iron Gate Dam and Scott River, 1999-2000.

Mesohabitat type	Mesohabitat unit number	SMET sampled	SMET code	Description
	11	5	1.	Trees >4" (diameter at water surface)
Low slope riffle (LS)	17	1	2.	Trees and emergent vegetation
	22	4,5	3.	Dense aggregates of plant material
	174	8,6	4.	Emergent shrubs
	26	6	5.	Open areas
Moderate slope riffle (MS)	6	9	6.	Sparse herbaceous vegetation
	81	9	7.	Dense herbaceous vegetation
	485	7	8.	Large substrate or rip-rap
	25	1	9.	Large substrate or rip-rap w/vegetation
	21	2	10.	Eddy
	5	4		
Pool (P)	306	6,3,4,6,3		
	307	9		
	308	9		
Total number of units sampled	14	20		

The following protocol was followed at each selected site:

1. The observer entered the water about 10-20 ft downstream of the site, and moved slowly in an upstream direction through the site, observing salmonids and determining their positions before they were disturbed by any human activity.
2. Location markers (4-oz weights with line and float attached) were placed at the following fish positions: the first location where an undisturbed chinook fry (1 or more) was observed, the next two locations where a group (3 or more) of chinook fry was observed, and any

location where undisturbed coho or steelhead fry or juveniles were observed. When three chinook positions were marked in only the first half of the site, as many as 3 more chinook positions were marked in the remainder of the site to better characterize the range of conditions used within the site. This sampling scheme was patterned after that of the USFWS and Tribal fry anadromous salmonid study.

3. Where large groups (20+) of fry were distributed over an area greater than a foot wide that encompassed different water depths and velocities, they were recorded and marked as at least two smaller groups to characterize the different habitats in which they resided and potentially different sizes of fish within the group.
4. To reduce the bias for the electrofishing crew to concentrate on markers, the underwater observer also placed a variable number (0 to 2) of decoy markers at each site.
5. Every attempt, such as moving around rather than through fish positions, was made by the underwater observer to avoid herding fry within, or out of the site.
6. Attempts were also made to view the full range of water depths present in each site.
7. Fish marker number, species of fish, number of fish, estimated size (to the nearest 0.04 inch) of fish, and focal depth of fish (to the nearest 0.4-inch) was recorded for each observation.
8. Once underwater observation was completed (10-30 minutes per site), the observer swam beyond the site and exited the water in the least disturbing way possible.
9. After at least a 10-minute waiting period, the USFWS crew began electrofishing. The crew placed fish location markers per the USFW protocol (Thomas A Shaw, USFWS, Arcata, California, personal communication). The electrofishing team was careful to avoid disturbing previously placed markers. During electrofishing activities, the underwater observer gave no information to the USFWS crew concerning the number and location of fish observed.
10. After each electrofishing session, the USFWS crew measured habitat characteristics at all underwater observation and electrofishing markers, to ensure consistency.
11. Ambient weather and cloud cover, mesohabitat number and fry site, water temperature, horizontal Secchi disk distance, and observation start and end times were recorded.
12. HSC characteristics recorded for each marked fish location are:
    a. Mesohabitat number and type.
    b. Fry site number and SMET.
    c. Fish species, number, and size range (if marked by an underwater observer).
    d. Water depth and average velocity.
    e. Water velocity and/or overhead cover type used. Collectively, these cover types are referred to as functional cover to differentiate from escape cover. Functional cover refers to cover components (e.g., water velocity shelter) that influence a fish's daily activities (feeding, resting, etc.), and to which fish may select or orientate. Cover components to which a fish may flee when threatened (i.e., fright response) are defined as escape cover (defined below). Four functional cover types generally are considered during PHABSIM analyses. These are object, overhead, and combinations of object and overhead cover. Data were collected for these four functional cover types during the initial phases of this investigation. However, data from this and other Klamath River investigations being conducted indicated that overhead cover should be partitioned into in- and out-of-water overhead cover, and combinations of object cover and in-and out-of-water overhead cover. Thus, six functional cover types were considered during the latter phases of this investigation.

The four functional cover types considered during the initial phases of this investigation are defined as:

Code	Type	Description
1.	No cover: No object or overhead cover is directly affecting a fish's position or habitat station.	
2.	Object cover: A substrate component, vegetative component, or structure feature creates a break (i.e., reduction) in water velocity, to which the fish being sampled occupies or orients. Such water velocity reductions must occur at, and directly influence, the fish's position for object cover to be considered present. Object cover 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 object cover as they are considered channel morphometry features rather than discrete objects.	
3.	Overhead cover: Any substrate, structural, or vegetative component or feature located within the water, or out of the water, but within 18 inches of the water surface, that affords fish being sampled concealment or camouflage from predation, sunlight, or other factor that may influence a fishes daily activities (i.e., non-fright response). For overhead cover to be considered present, the 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). Overhead cover components include crevices among cobbles and boulders, ledges, aquatic vegetation, overhanging branches of riparian vegetation, organic debris, etc.	
4.	Object and overhead cover: Combinations of object and overhead cover (cover types 2 and 3, above, respectively).	

Partitioning overhead cover into in- and out-of-water components resulted in six functional cover types being considered. These are defined as:

Code	Type	Description
1.	No cover: No object or overhead cover is directly affecting a fish's position or habitat station.	
2.	Object cover: A substrate component, vegetative component, or structure feature creates a break (i.e., reduction) in water velocity, to which the fish being sampled occupies or orients. Such water velocity reductions must occur at, and directly influence, the fish's position for object cover to be considered present. Object cover 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 object cover as they are considered channel morphometry features rather than discrete objects.	
3.	In-water overhead cover: Any substrate, structural, vegetative component, or feature located within the water that could afford fish being sampled concealment or camouflage from predation, sunlight, or other factors 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 or observation station must be directly beneath the cover component (i.e., horizontal distance from the fish's 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.

4. Out-of-water overhead cover: Any substrate, structural, or vegetative component or feature located out of the water, but within 18 inches of the water surface, that affords the fish being sampled concealment or camouflage from predation, sunlight, or other factors that may influence a fishes daily activities (i.e., non-fright response). For overhead cover to be considered present, an observed fish, or station, must be directly beneath the cover component (i.e., horizontal distance from the fish position to this cover type is 0.0 ft). 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 from the water surface are considered canopy.
5. Object and in-water overhead cover: Combinations of object and in-water overhead cover (cover types 2 and 3, above, respectively).
6. Object and out-of-water overhead cover: Combinations of object cover and out-of-water overhead cover (cover types 2 and 4 above, respectively).

f. Escape cover: Any substrate, structural, or vegetative component or feature located within the water, or out of the water, but within 18 inches of the water surface, that an observed fish seeks out, or may seek out, for concealment, hiding, etc. in response to fright or threat. Distance from the observed fish to the nearest escape cover was recorded (typically to the nearest 0.1 ft up to 10 ft, then to the nearest 0.5 ft thereafter). This cover type is used for short-term fright response concealment, and is not used on a routine basis for daily activities (e.g., 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. Out-of-water escape 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 from the water surface are considered canopy. In the event in-water and out-of-water escape cover are present equal distance form an observed fish, in-water escape cover is generally given priority consideration.
g. Type of and estimated distance to object, in-water, and out-of-water cover types for observations where a specific cover type being used. Distances <10 ft were measured to the nearest 0.5 ft. Distances >10 ft were estimated to the nearest 1.0 ft.
h. Distance (estimated to the nearest 0.5 ft) to nearest water's edge.
i. Water velocity shear zone presence and distance from the observed fish. A shear zone is defined as a zone of noticeable and rapid difference in water velocities.
j. Dominant and subdominant substrate particle sizes
k. Embeddedness of the substrate.
l. Direction of water flow.

Search for fry chinook salmon in open water: Because the USFWS's electrofishing method for collecting fry chinook salmon data was concentrated in shallower, wadeable areas along the river's margin, the validity of using the electrofishing data for development of HSC hinged partly on the question of whether fry were using only those areas, or, were also in open water habitats beyond the river margins. We used underwater videography to search for fry in areas of the river and waterway outside of the immediate river margin area. Sampling was conducted from April 9 to 14, 2000. We considered using free diving or SCUBA as well, but the river conditions were too deep, fast, and turbid to safely and efficiently implement these sampling methods.

We sampled five pools, six LS riffles, and four MS riffles during six days of sampling. All sample sites were in mesohabitat units associated with USFWS fry sampling sites and concentrated in the vicinity of Salmon Hole (RM 189.5), R-Ranch (RM 187), Tree of Heaven (RM 170.5), Beaver Creek (RM 158), and Blue Heron (RM 138.4) (Figure 2). Five to ten, 30-ft-long longitudinal transects were sampled in each of the habitat units, except unit 20.1. Unit 20.1 is a very short unit, and two transects were used to sample the unit. Transects were staggered across the river, throughout the unit to sample any areas where fry could possibly hold positions (especially within 20 ft of the bank, and in velocity breaks behind points, snags, and boulders). At each transect, the raft was anchored at the upstream end, the cameras were lowered within view of the bottom, and then the bottom and vicinity were viewed for 30 ft in a downstream direction as the raft's anchor line was slowly fed out.

In addition to sampling discrete longitudinal transects, we occasionally sampled off-transect "fry habitat" areas within the body of the river for fry chinook salmon. This sampling was conducted to verify the longitudinal transects represented the river.

Wherever salmonids were observed holding position, the raft was stopped and microhabitat conditions were measured and characterized from the raft or by wading. We measured the same HSC characteristics described above.

Very few chinook salmon fry were observed in deep water (e.g., >3 to 4 ft), or not associated with the river margin during this phase of the investigation. Therefore, no further effort was warranted, nor made, to sample that portion of the waterway not associated with the river's margin.

Juvenile Chinook Salmon

For this investigation, young chinook salmon $\geq$2.2 inches FL were defined as juveniles. This classification is consistent with that of other Klamath River investigations.

Search for juvenile chinook salmon in open water: We searched for juvenile chinook salmon in open water, away from the river's margin, May 7, 2000. We used the same cataraft-mounted underwater videography techniques and equipment used in our April open-water fry searches. We concentrated efforts in a pool and riffle near the Salmon Hole, where previous experience indicated substantial numbers of juvenile chinook could be expected. In contrast to the April searches for fry (where few were observed), juvenile chinook were commonly present 10 to 30 ft from the bank and in water deeper than 3 ft.

HSC data collection for juvenile chinook salmon: We used underwater direct or indirect techniques (i.e., the raft-mounted underwater videography equipment) to observe juvenile chinook salmon in habitats where electrofishing was difficult or impossible. We sampled the study reach from May 8 to 12, 2000 to locate and characterize habitat components used by juvenile chinook. We used a stratified-random-sampling design to spread our effort over the study reach and among mesohabitat types. Within each of three segments (i.e., Iron Gate Dam to Cottonwood Creek, Cottonwood Creek to Beaver Creek, and Beaver Creek to Scott River) we randomly selected a starting number and a direction (upstream or downstream). We sampled the first of each mesohabitat type corresponding to these criteria. For example, in the middle segment, the random start number corresponded to mesohabitat unit 218, and the selected direction was downstream. We then sampled mesohabitats 218 (an SS) and 219, 226, and 228 (the nearest P, LS, and MS, respectively) in the specified direction. Exceptions to this selection rule occurred in the first segment to avoid an uncharacteristic pool and to add the only SS in the segment; and in the middle segment to also sample a large back eddy. We sampled five habitat units in each segment, plus the additional back eddy in the middle segment.

Within each sampled unit, we randomly selected a side of the river to sample, and then selected three, 30-ft-long sites along the bank. The three sites were selected to represent the greatest diversity in SMETs possible. Within each 30-ft site, an underwater observer sampled near the bank, in the shallow and slow water velocity areas. A cataraft and videography equipment were used to sample the water areas of the river. Underwater observers worked upstream along the bank, marking the position of each undisturbed salmonid or group of salmonids, noting fish species, size, and fish focal depth (i.e., the distance from the fish to the water surface). The videography team then searched longitudinal 30-ft transects from the cataraft. The initial longitudinal transect was near the upstream end of the sample area, and about 10 ft into the waterway from the river's margin. The start of the next transect was 10 to 15 ft further into the waterway. This process was repeated until juvenile salmonids were no longer observed or water velocity (i.e., >5 ft/s) significantly affected raft control and videography observation.

At each observation point, we measured habitat characteristics following the protocol of the USFWS (see fry chinook section, above). We also included measurements of fish focal point water velocities, that the USFWS crew was not able to measure for fish sampled via electrofishing. We sampled 48 transects and 8 different SMET types within 16 mesohabitat units, and collected 95 observations of juvenile chinook salmon and 27 observations of steelhead fry and juveniles. Many of the 95 HSC observations of juvenile chinook included more than one fish. We tallied the total number of juveniles seen, and the effort per SMET type, in order to determine possible relationships between juvenile numbers and SMET type.

Cover measurements for juvenile chinook salmon: Juvenile chinook salmon use of functional cover and the proximity of the nearest escape cover to fish observed were recorded. For functional cover types, the primary data collected were presence-absence. Information recorded for nearest escape cover observations included the fish's distance from the nearest escape cover, whether the escape cover was in or out of the water, and the specific type of escape cover (e.g., cobbles, boulders, willows, grass, etc.).

Juvenile Steelhead

During the fall of 2000 (October 30 to November 3), we repeated our stratified random sampling and direct underwater observation methods used on juvenile chinook salmon to collect habitat use information for juvenile steelhead. We also partitioned steelhead observations into the SMET categories developed during the fry chinook salmon HSC phase of this investigation. We sampled in five river segments (Iron Gate Dam to Cottonwood Creek, Cottonwood Creek to Shasta River, Shasta River to Beaver Creek, Beaver Creek to Horse Creek, and Horse Creek to Scott River) and randomly selected five mesohabitat units from within each. At each selected unit, we randomly selected a side of the river to sample, then selected three transects from 30 to 150 ft long along the bank to represent the greatest diversity of SMETs possible. One or two underwater observers worked upstream along each transect and marked the positions of any undisturbed salmonids. At each observation point, we measured habitat characteristics following the protocol of the USFWS, except that we also included measurements of fish focal point water velocity. Flows at Iron Gate Dam averaged 1,332 cfs (ranging from 1,330 to 1340 cfs) during this period (Appendix A-2).

We were able to make only 37 observations of juvenile steelhead during this effort. These fish represented four age classes. We also collected information for juvenile steelhead observed during collection of HSC data for juvenile chinook (May 2000). We collected data on 29 observations of steelhead during May 2000; these observations consisted of nine fry, 14 juveniles (2-6 inches), and six larger (>6 inches) fish. These observations are too few to warrant HSC construction, but enough to be valuable additions to a larger Klamath River data set. Insufficient funds were available to extend juvenile steelhead sampling efforts to other times of the year.

Coho Salmon

The only coho salmon seen during this investigation were four observations (totaling six fish) made in April 2000. These observations were made during the course of the fry chinook salmon investigations, and are too few to develop HSC. Microhabitat information was collected by the USFWS, but is not included in this report.

DATA ANALYSIS

Spawning Chinook Salmon

Number of data sets: We intended to collect data at three different river discharges in order to compare water depth and velocity and other microhabitat use distributions, and to develop HSC from data for more than one river flow. We were able to collect data at a low flow, and at a slightly higher flow. We were unable to collect data at a third, higher flow. We collected an adequate sample size during the lower of the two flows sampled, and a limited sample size at the slightly higher flow. Unfortunately, by the time the slightly higher releases from Iron Gate Dam had stabilized (November 1, 1999), the spawning season was nearing its end, and few fresh fish were moving into the study area to spawn, and we observed few new fish or redds at the “mid-flow.” Insufficient time and water were available to attain a third sample at a higher flow.

In an effort to augment our 1999 data, we requested flows again be released in fall 2000, but drought conditions within the Klamath River Basin precluded the requested releases. Thus, no additional data were collected on spawning chinook at higher flows.

The 1999 data were compiled into summary histograms to compare observations made at the two flow levels, and to provide a frame of reference for further stages of data treatment. Histograms of key variables (e.g., water depth and velocity, dominant substrate, mesohabitat type, and percent fines) were constructed using the smallest practical bin size for each variable. In addition to plotting the observation data separately for the two data sets, we compared the sample means for several different parameters with a two-sample t-test. We examined and compared average water depth and average velocity, fish focal point water velocity, and distance to water's edge for the two samples.

In order to combine two data sets in a such a way that each set has an equal influence on resultant HSC, each data set should include about the same number of observations. Unfortunately, this was not the case with our two samples. Two procedures were considered to address this problem. The first consisted of randomly drawing a smaller sample of observations from the first data set. This approach would have resulted in elimination of a substantial number of observations and the analyses being based on two small samples. The second approach consisted of multiplying the second sample's observations (i.e., the smaller sample) by a constant to attain a total sample size equal to that of the first sample. The second approach was selected. This approach is advantageous in that it includes all observation data.

Development of HSC: Nonparametric tolerance limits (NPTL) were used to develop HSC for water depth and average water velocity, fish focal point water velocity, distance to in-water escape cover, distance to wetted margin, and percent fines in redds. Dominant and subdominant substrate and in-water escape cover specific components are discontinuous distributions, and, consequently, HSC for these factors were developed by normalizing the respective frequency of use distributions. We developed individual rather than bivariate dominant/subdominant HSC to allow greater flexibility in HSC use.

Use of NPTL for HSC development was first suggested by Gosse (1982), and expanded by Bovee (1986). NPTL has several advantages over curve-smoothing techniques:

1. The method does not require any sort of assumption about the distribution of data points. Jackson (1992) found, for example, that distributions for juvenile chinook were non-normal for almost every parameter analyzed.
2. Outliers have little effect on the final curve; they are taken into account, but their magnitude does not disproportionately influence adjacent values.
3. Gaps in the histogram do not lead to bimodalities in the final curve.
4. The assignment of confidence intervals is straightforward.

The steps in developing NPTL curves were summarized by Slauson (1986). They are given below as adapted for the Klamath study:

1. Fish observation data were partitioned into bins (e.g., average water velocities were partitioned into 0.2 ft/sec bins).

2. Cumulative distribution frequencies were calculated in ascending and descending directions.
3. Two-tailed tolerance intervals were chosen to encompass the central 95%, 90%, 75%, and 50% of the sample.
4. Suitability index (SI) value assigned to each percentage of coverage was SI = 2(1-P). Thus, the central 50% of observations were assigned SI = 1.0, the 75% interval SI = 0.5, the 90% interval SI = 0.2, and the 95% interval SI = 0.1.
5. The confidence level was set at 0.9.
6. The tolerance interval values for the total sample size (n) were taken (or interpolated) from the table in Somerville (1958) . These values are the numbers to exclude from the tails (half from each tail) of the distribution. For example, for n = 200, the values are 91, 42, 15, and 6. Thus, the central 50%, where SI = 1.0, would be the central 108 observations, because 91/2 = 46 observations would be excluded from each tail.

Fry Chinook Salmon

The objective of the fry observations was to compare measurements made via underwater direct observation with those obtained by the USFWS using electrofishing, rather than to actually develop HSC. Data collected by the two methods were compared using an unpaired t-test of the means, and a Kolmogorov-Smirnoff test of the overall distributions. Tests were performed for the following characteristics: water depth and average velocity, distance to bank, and distance to in-water escape cover. Too few fry were observed away from the river margins to allow statistical treatment.

Juvenile Chinook Salmon

Analytical methods for juvenile HSC development were similar to those used for spawning fish. We constructed histograms for total water depth and average velocity, focal depth, focal water velocity, distance to water’s edge, distance to in-water escape cover, and distance to shear zone. We then constructed two-tailed NPTL HSC for total water depth, fish focal depth, distance to water’s edge, and distance to shear zone. We constructed one-tailed NPTL for juvenile chinook average and focal point water velocities, as the one-tailed HSC, rather than the two-tailed, more closely resembled the field data.

One-tailed NPTL computational procedures were similar to the two-tailed NPTL procedures. The one-tailed tolerance intervals were also based on 95%, 90%, 75%, and 50% of the sample. The one-tailed intervals, however, started on the left of the frequency distributions, and the SI value assigned to each percentage ranged from 1.00 for the left 50% interval to 0.10 for the 95% interval.

We used the normalized frequency of use distribution approach to develop HSC for juvenile chinook distance to in-water overhead/escape cover. When compared with the NPTL approach, the frequency of use HSC more closely followed the field data.

The distribution of juvenile chinook among SMET types was analyzed by chi-square goodness of fit for more than two categories (Zar 1984). We tested the null hypothesis that the number of juvenile chinook was distributed in proportion to the sampling effort among SMETs; that is, that juvenile chinook salmon were evenly distributed among SMETs.

RESULTS

SPAWNING CHINOOK SALMON

We examined 290 chinook salmon redds for microhabitat conditions during fall 1999. Most observations (256) were collected during the first sampling period. Only 34 redds were observed during the second sampling period. River flow at Iron Gate Dam was about 1,385 cfs during the first sampling period, and about 1,825 cfs during the second period.

The observed redds were much more abundant in the upper sections of the river (Figure 6)[1]. About 36% of the redds observed during the first sampling period were distributed within the first 4 miles downstream of Iron Gate Dam, and more that 70% of the observed redds were within 20 miles of the dam. The upstream distribution of the new redds observed during the higher river flow was even more pronounced. Twenty-nine (85%) of the 34 redds observed during the second sampling period were within 6 miles of Iron Gate Dam. Even though they were not abundant relative to upstream areas, redds were observed throughout the 47-mile study reach during each sampling period. The observed redd distribution was not unexpected, and is consistent with results of previous surveys (USFWS, Arcata, California, 1993-1999, unpublished data). These USFWS surveys indicate about half the redds in this section of the river generally occur within the first 15 miles downstream of Iron Gate Dam.

Redds observed were almost exclusively (about 87% of the total observations) located in P or LS mesohabitats habitats (Figure 7). Few spawning observations were made in MS mesohabitat. No redds were observed in SS habitat. Mesohabitat selection and redd distribution were similar between the two flow periods. The concentration of redds in lower-gradient mesohabitats was expected, given the combination and general suitability of water velocities and gravel-cobble substrate found in these mesohabitats.

Redd Hydraulic Habitat Variables

Water depth: Water depths at the 256 redds observed at the 1,385 cfs release from Iron Gate Dam ranged from 0.6 to 5.2 ft, and averaged 2.3 ft (Table 5). At the 1,825 cfs release, redd water depths at redds observed ranged from 0.9 to 6.0 ft, and averaged 2.4 ft. Although water depths measured at the two river flows were slightly different, the difference was not statistically significant (one-tailed t-test, $p = 0.24$). Water depths of redds observed at the two flows are compared in Table 5 and Figure 8.

Average Water Velocity: Average water velocities of the 256 redds measured at 1,385 cfs, averaged ranged from 0.83 to 5.63 ft/sec, and averaged 2.56 ft/sec. Water velocities at redds observed at the 1,825 cfs river flow were slightly faster than those observed at the lower flow. These observed water velocities averaged 2.75 ft/sec, and ranged from 1.55 to 3.83 ft/sec. The difference between average water velocities was not significant (one-tailed t-test, $p = 0.07$). Water velocity observations at the two flows are compared in Table 5 and Figure 9.

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1. Figures 6 through 40 are presented at the end of the Results section.

Table 5. Chinook salmon redd characteristics measured at two flows in the Klamath River between Iron Gate Dam and Scott River, October and November 1999.

	Statistic	Water depth (ft)	Average water velocity (ft/sec)	Fish focal point water velocity (ft/sec)	Dominant Substrate[1]	Sub-dominant Substrate[1]	Percent fines within redds	Distance from redd to nearest water's edge (ft)
Iron Gate Dam release = 1,385 cfs (Sample size = 256)	maximum	5.1	5.63	4.24	7	11	40	110
	minimum	0.6	0.83	0.21	4	2	0	4
	average	2.3	2.56	1.84	NA	NA	13	26
	median	2.3	2.56	1.79	6	6	10	19
	std. dev.	0.9	0.72	0.69	NA	NA	7	21
Iron Gate Dam release = 1,825 cfs (Sample size: 34)	maximum	6.0	3.83	3.95	6	7	30	45
	minimum	0.9	1.55	0.81	4	4	5	3
	average	2.4	2.75	1.95	NA	NA	12	17
	median	2.1	2.98	1.87	6	5	10	13
	std. dev.	1.3	0.68	0.77	NA	NA	7	12
All data (Sample size = 290)	maximum	6.0	5.63	4.24	7	11	40	110
	minimum	0.6	0.83	0.21	4	2	0	3
	mean	2.3	2.58	1.90	NA	NA	12	25
	median	2.3	2.58	1.82	6	6	10	18
	std. dev.	0.9	0.72	0.70	NA	NA	7	20

1.

Code	Substrate	Code	Substrate	Code	Substrate
1.	Clay	6.	Medium Gravel (1.0 – 2.0 inches)	9.	Large Cobble (9.0 – 12.0 inches)
2.	Sand and or Silt (<0.1 inches)	5.	Large Gravel (2.0 – 3.0 inches)	10.	Small Boulder (12.0 – 24.0 inches)
3.	Coarse Sand (0.1 – 0.2 inches)	7.	Small Cobble (3.0 – 6.0 inches)	11.	Medium Boulder (24.0 – 48.0 inches)
4.	Small Gravel (0.2 – 0.1 inches)	8.	Medium Cobble (6.0 – 9.0 inches)	12.	Large Boulder (>48.0 inches)
				13.	Bedrock

Fish Focal Point Water Velocity: Fish focal point water velocity (measured immediately upstream of the redd's pit, and 0.4 ft above the substrate) of redds observed at the lower river flow ranged from 0.21 to 4.24 ft/sec. These velocities averaged 1.84 ft/sec. At the 1,825 cfs flow, the average focal point velocity was 1.95 ft/sec, with a range of 0.81 to 3.95 ft/sec. As for water depths and average velocities, focal point velocities observed at the lower river flow were slightly less than those observed at the higher river flow. The difference between fish focal point water velocities is not significant (one-tailed t-test, $p = 0.19$). Fish focal point water velocity observations at the two flows are compared in Table 5 and Figure 10.

Substrate components: Dominant substrate at almost all (about 99%) redds was either medium gravel, large gravel, or small cobble (substrates 1-2, 2-3, and 3-6 inches diameter, respectively; (Table 6; Figure 11). Small gravel (0.2 to 1.0 inches) was the dominant substrate in the remainder. As with dominant substrate, medium/large gravel and small cobble were the most common sub-dominant substrates in the 290 redds observed. Substrate smaller than medium gravel, or larger than small cobble, were the sub-dominant substrates in 23 of the 290 (7.9%) redds observed. Small gravel (0.2-1.0 inches) was the sub-dominant substrate in 12 of the 23 redds.

Use of substrate components between the two river flows was similar, except that no redds were observed with small cobble as the dominant substrate for observations made at the higher flow (Figure 12). Conversely, small cobble was the dominant substrate for about one-third of the observations made at the lower flow.

Percent fines occurring in redds observed at the 1,385 cfs flow averaged 12%, and ranged from 0 to 40% (Figure 13). Results from the higher flow were similar; percent fines averaged 12%, with a range of 5-30%. Over 80% of the observations ranged from 5 to 15% fines.

Other Redd Variable

Distance to Water's Edge: Nearly two-thirds of the redds were found within 25 ft of the water's edge (Figure 14). Since the average width of LS and P mesohabitats in the main channels of the Klamath are 136 and 129 ft, respectively, on average, two-thirds of the redds occur in a little over one-third of the channel width. The average distance from redds to water's edge for redds observed at 1,385 and 1,825 cfs was 26 and 16 ft, respectively, suggesting fish may tend to spawn closer to shore at the higher flow. This difference was significant (two-tailed t-test, $p = 0.008$)

FRY CHINOOK SALMON

Comparison of Direct Underwater Observation and Electrofishing Observations

We collected data for 88 direct and 70 electrofishing observations of fry chinook salmon in nine SMETs (Table 7). Data sets within most SMETs were too small for individual comparisons. Therefore, we pooled the information for all SMETs for an overall comparison.

Distributions of water depth, water velocity, and distance to water's edge for observations made by the two techniques are plotted in Figures 15, 16, and 17, respectively. The differences between distributions were minor.

Table 6. Dominant and sub-dominant substrates used by spawning chinook salmon in the Klamath River between Iron Gate Dam and Scott River, fall 1999.

		Observed use	
Code	Substrate category	Dominant substrate	Subdominant Substrate
1	Clay	0	0
2	Sand or silt/sand (<0.1 inches)	0	1
3	Coarse sand (0.1-0.2 inches)	0	2
4	Small gravel (0.2-1.0 inches)	4	12
5	Medium gravel (1-2 inches)	92	74
6	Large gravel (2-3 inches)	113	145
7	Small cobble (3-6 inches)	81	48
8	Medium cobble (6-9 inches)	0	7
9	Large cobble (9-12 inches)	0	0
10	Small boulder (12-24 inches)	0	0
11	Medium boulder (24-48 inches)	0	1
12	Large boulder (48 inches)	0	0
13	Bedrock	0	0

The means for water depth and velocity and distance to water's edge were slightly lower for direct observations than for those obtained from electrofishing (Table 8). A two-tailed t-test indicated the differences between the means for depth, velocity, and distance to water's edge were not significant (p values of 0.06, 0.08, and 0.06, respectively).

A second analysis for differences between the two methods was made with the Kolmogorov-Smirnov test. The Kolmogorov-Smirnov test compares the cumulative distribution of the data, rather than just the means. The data (which were first normalized to account for unequal sample size) are plotted in Figures 18, 19, and 20, respectively. The key statistic is the point where the two cumulative distributions show the maximum difference. The maximum differences for water depth, water velocity, and distance to water's edge were 0.14, 0.18, and 0.11, respectively. These differences were not statistically significant ($0.05<p<0.10$).

Distance to Stream Banks and Use of Open Water

The results of surveying 127 longitudinal open-water transects via the cataraft-mounted videography equipment indicate that fry typically occur in shallow water near the river's margin, rather than in deeper water away from the margin. No fry chinook were observed at the vast majority (123 of 127) of open-water transects sampled from April 9 to 14, 2000. This was true even for transects within 15 ft of the river's margin, and sometimes even when hundreds of fry were seen closer to the bank in the nearby, adjacent shallows. These data strongly indicate that few fry used deep water habitats, and that they seldom occurred more than about 10 ft from the water's edge.

Table 7. Distribution of fry chinook salmon observed by direct underwater or electrofishing techniques among stream margin edge types (SMET) in the Klamath River between Iron Gate Dam and Scott River, 2000.

	Number[1] of fry chinook salmon observed				
SMET[2]	Direct underwater observation	Electrofishing observation	SMET[2]	Direct underwater observation	Electrofishing observation
1	13	12	6	19	16
2	10	10	7	1	1
3	5	5	8	3	0
4	9	4	9	24	18
5	4	4	10	0	0

1. Total sample sizes: Direct underwater observation: 88; Electrofishing observation: 70
2.

SMET	Description	SMET	Description
1	Trees >4 inches diameter at water surface	6	Sparse herbaceous vegetation
2	Trees and emergent vegetation	7	Dense herbaceous vegetation
3	Dense aggregates of plant material	8	Large substrate or rip-rap
4	Emergent shrubs	9	Large substrate or rip-rap with vegetation
5	Open areas	10	Eddy

JUVENILE CHINOOK SALMON

We searched for juvenile chinook salmon in 15 habitat units representing all four mesohabitat types and eight of the 10 possible SMETs. We measured habitat use at 94 locations where juvenile chinook were observed. Twenty-one of these observations were made with the cataraft and videography equipment, and the remainder via direct underwater observation. These 94 observations consisted of 392 individual fish.

Mesohabitats and SMETs

Mesohabitats: Equal areas of four mesohabitat types in each of three segments were sampled. Juvenile chinook were encountered in all four mesohabitat types sampled (Figure 21). Observations of one or more fish were made most commonly in MS mesohabitats, but the overall distribution of observations and total numbers of fish was relatively even, indicating no strong preference for mesohabitat type.

SMET: Eight different SMET types were sampled for presence of juvenile chinook salmon. The number of units (30-ft bank lengths) sampled of each type was not equal, and ranged from 1 to 12 units (Figure 22). A total of 48 units was sampled. Altogether, 392 juvenile chinook salmon were observed among these units. We corrected for the number of sites sampled per SMET type to 1account for unequal sampling effort, and to gain insight into comparable use of SMET types. SMETs 7 (dense herbaceous vegetation - 16.3 fish/unit) and 10 (eddy - 16 fish/unit) had the most number of observations per unit sampled. SMETs 2 (trees and emergent vegetation - 8 fish/unit), 4 (emergent shrubs - 7.2 fish/unit), and 6 (sparse herbaceous vegetation - 5.9 fish/unit) were intermediate in use. SMETs 8 (large substrate or rip rap - 1 fish/unit) and 3 (dense aggregates - 4 fish/unit) had the least. SMETs 1 (trees >4 inches in diameter) and 9 (large substrate or rip-rap and vegetation) were not encountered in this part of the study.

Chi-square analysis showed juvenile chinook salmon were distributed evenly among SMET types ($X^2 = 126$, df = 7, $p<0.001$). Juvenile chinook were more abundant than expected in SMETs 5, 7, and 10, and less abundant than expected in SMETs 3, 6, and 8 (Figure 23).

Habitat Variables

Total Water Depth: Juvenile chinook salmon were observed in locations with water depths ranging from 0.7 to 7.0 ft; the average depth was 2.9 ft (Table 9). More than 60% of the observations were at water depths ranging from 0.8 to 3.0 ft. The histogram of water depth frequencies is shown in Figure 24.

Table 8. Comparison of habitat use statistics for fry chinook salmon observed by direct underwater or electrofishing observation in the Klamath River between Iron Gate Dam and Scott River.

	Statistic	Water Depth (ft)	Average water velocity (ft/sec)	Dominant substrate[1]	Sub-dominant substrate[1]	Cover type[1]	Distance to instream cover (ft)	Distance to water's edge (ft)
Direct underwater observations (Sample size = 88)	maximum	3.9	1.89	31	31	30	7	17
	minimum	0.3	0.00	2	15	0	0	0
	mean	1.2	0.49	20	21	--	1	5
	std. dev.	0.6	0.47	--	--	--	1	4
	variance	0.4	0.22	--	--	--	1	12
Electrofishing observations (Sample size = 70)	maximum	3.1	2.71	31	28	30	7	17
	minimum	0.6	0.00	15	15	0	0	1
	mean	1.4	0.65	21	20	--	1	6
	std. dev.	0.6	0.59	--	--	--	1	4
	variance	0.3	0.34	--	--	--	2	15

1.

Code	Vegetation/Substrate Cover	Code	Vegetation/Substrate Cover
1	Filamentous algae	17	Large woody debris (>4 inches x 12 ft)
2	Non-emergent rooted aquatic	18	Clay
3	Emergent rooted aquatic	19	Sand and or Silt (<0.1 inches)
4	Grass	20	Coarse Sand (0.1 – 0.2 inches)
5	Sedges	21	Small Gravel (0.2 – 0.1 inches)
6	Cockle burrs	22	Medium Gravel (1.0 – 2.0 inches)
7	Grape vines	23	Large Gravel (2.0 – 3.0 inches)
8	Willows	24	Very Large Gravel (3.0 – 4.0 inches)
9	Berry vines	25	Small Cobble (4.0 – 6.0 inches)
10	Trees < 4 inches dbh	26	Medium Cobble (6.0 – 9.0 inches)
11	Trees >4 inches dbh	27	Large Cobble (9.0 – 12.0 inches)
12	Rootwad	28	Small Boulder (12.0 – 24.0 inches)
13	Aggregates of small vegetation (<4 inches)	29	Medium Boulder (24.0 – 48.0 inches)
14	Aggregates of large vegetation (>4 inches)	30	Large Boulder (>48.0 inches)
15	Duff, leaf litter, organic debris	31	Bedrock
16	Small woody debris (< 4 inches x 12 ft)		

Fish Focal Point Water Depth: The depth (from the water surface to the fish) at which the fish were observed ranged from 0.2 to 5.3 ft, and averaged 1.43 ft (Figure 25). More than 70% of the observations had focal depth less than about 1.7 ft. Only 7% of the observations had focal depths greater than about 3 ft. Focal depth as a percentage of total depth is plotted in Figure 26.

Average Water Velocity: The water column velocity at the location where juvenile chinook salmon were observed averaged 1.03 ft/sec, and ranged from 0.00 to 3.82 ft/sec (Figure 27). Over half of the fish were observed with water column velocities <1 ft/sec, and 80% of the observations were made at velocities <2 ft/sec. Only one fish was observed at a velocity faster than 3.4 ft/sec.

Fish Focal Point Water Velocity: Water velocities at the fish focal point generally were slightly less than average water column velocities. Focal point velocities ranged from 0.00 to 3.35 ft/sec, and averaged 0.88 ft/sec (Figure 28). Similar to column velocity, more than 50% of the observations were at velocities <1 ft/sec, and 86% at velocities <2 ft/sec.

Substrate: Almost all substrate types were used by juvenile chinook salmon, but the numbers of observations tended to decrease with increasing substrate size (Figure 29). Juvenile chinook were most commonly observed in areas with sand and coarse sand substrates. This may indicate a real habitat preference for finer substrates. Or, this could be an artifact of use of low water velocity; that is, juvenile chinook are associated with slow water velocities, and finer substrate materials commonly associated with such water velocities in streams and rivers.

Functional Cover: Juvenile chinook were often observed not actively using any type of functional cover. Of 392 juvenile chinook observed, 220 (56%) were using no cover (Figure 30). Object cover was the second most frequently used cover type of the six functional cover types considered. Object cover alone was used by 27% of all chinook juveniles. However, if all object cover use observations (i.e., fish observed using object cover individually and in combination with in-water or out-of water overhead cover) are considered, then object cover was used by 39% of all fish.

Juvenile chinook infrequently used in-water overhead cover. When considered as an individual cover type, 16 of the fish observed were using in-water overhead cover. Twenty-one fish were observed using combinations of object cover and in-water overhead cover.

Only three juvenile chinook salmon were observed using out-of-water overhead/escape cover as an individual cover type. Use of this cover type was somewhat greater if its use in combination with object cover is considered (Figure 31). In that case, 26 fish were observed using object cover and out-of-water cover.

In-Water Escape Cover Specific Components: In addition to preferring to be near in-water escape cover, juvenile chinook salmon also demonstrated notable affinity for specific escape cover types. Vegetative in-water escape cover was the nearest cover type for nearly all (92.7%) of the juvenile chinook observed using, or near in-water overhead/escape cover (Figure 32). In-water escape cover was not recorded for 38 of the 392 total fish observed. When considering all juvenile chinook observed, 88.7% of the 392 fish were associated with vegetative in-water escape cover. Hard substrate elements were the nearest escape cover for only 26 (about 7.3%) of the 354 fish observed associated with in-water escape cover.

Table 9. Habitat use statistics for juvenile chinook salmon observed in the Klamath River, between Iron Gate Dam and Scott River, May 8-12, 2000.

Statistic	Sample size	Maximum	Minimum	Average	Median	Standard deviation
Iron Gate Dam release (cfs)	NA	3,020	2,940	2,980	2,990	34
Water depth (ft)	392	7.0	0.7	2.9	2.8	1.4
Water velocity (ft/sec)	392	3.82	0.00	0.91	0.66	0.76
Fish focal point water depth (ft)[1]	392	5.3	0.2	1.6	1.2	1.0
Fish focal point water velocity (ft)	392	3.35	0.00	0.78	0.54	0.63
Distance from nearest water's edge(ft)	392	46	2	15	15	10
Distance from shear zone (ft)	392	50	0	13	8	14
Dominant substrate	392	bedrock	fine sand	NA	NA	NA
Subdominant substrate	392	bedrock	fine sand	NA	NA	NA

1. Fish focal point water depth is the water surface to fish distance.

Non-emergent and emergent rooted aquatic vegetation and young willows were the most commonly used, or nearest, in-water specific escape cover types. Individually, 36.2, 20.6, and 31.9% of the 354 in-water escape cover observations were within or near these escape cover components, respectively. Collectively, these observations account for nearly 89% (314 of the 354 fish) of the total observations. Medium sized boulders (24-48 inches) were the most commonly used hard substrate escape cover type.

Distance to In-Water Escape Cover: In-water escape cover was noted at, or relatively near, 358 of the 392 juvenile chinook salmon observed (Figure 33). Nine percent of the fish observed were actively using escape cover. Including the fish actively using overhead cover, over 40% were within 1.0 ft of in-water escape cover, and 89% were within 2 ft of in-water escape cover.

Distance to Shear Zone: The shear zone allows fish to rest or hold in low velocity water, while staying in proximity to faster water velocity zones that transports food items. About 40% of the juvenile chinook in this study were found within 3 ft of a shear zone; the median value was 9 ft (Figure 34). The observations made beyond this median value could be considered unaffected by the shear zone due to fish size and swimming ability.

Distance to Water's Edge: About 30% of juvenile chinook salmon observed were within 8 ft of the river's margin (i.e., bank) (Figure 35). The median distance was 15 ft. Nearly all fish were within 30 ft of the water's edge. The bimodal frequency distribution may be due to the use of two different sampling techniques, electrofishing along the river's margin, and underwater videography in deeper and/or swifter areas.

HABITAT SUITABILITY CRITERIA

Spawning Chinook Salmon

Since spawning chinook salmon habitat use data were collected at two different flows (1,385 and 1,825 cfs) and sample sizes were unequal (256 versus 34), the second data set was expanded (i.e., each observation multiplied by 7) before proceeding with HSC construction. The purpose of this procedure was to construct frequency of observation distributions that weighted the two flow conditions and observation data approximately equally.

Total Water Depth: The total water depth NPTL HSC for spawning chinook salmon indicates spawning salmon do not use water < 0.6 ft deep. Suitability increases rapidly for depths between 0.6 and 1.5 ft deep. Depth suitability is 1.00 at 1.5 ft (Table 10, Figure 36). The NPTL of the habitat use observations suggests suitability remains at 1.00 for depths ranging from 1.5 to 3.1 ft, and then decreases to zero at 6.0 ft deep. However, since we were unable to sample flows that inundated substantial areas with suitable spawning substrate to depths of 6 ft or more, the decrease in suitability for depths greater than about 3 ft may be an artifact of limited sampling and habitat availability. Therefore, we maintained the suitability at 1.00 from 1.5 to 6.0 ft.

Average Water Velocity: The suitability of average water velocities ranging from 0.0 to 0.9 ft/sec is 0.00 (Figure 37). Suitability then increases to 0.20 at 1.5 ft/sec, and reaches 1.00 at 2.1 ft/sec. Water velocity suitability remains at 1.00 until 3.3 ft/sec, then rapidly decreases to 0.10 at 3.9 ft/sec. Velocities faster than about 5.6 ft/sec are not suitable for spawning chinook salmon.

Fish Focal Point Water Velocity: The NPTL HSC for fish focal point water velocity at redds indicates use of slower water velocities in comparison to water column average velocities. The suitability of focal point velocities ranging from 0.0 to 0.6 ft/sec is 0.00 (Figure 38). Focal velocity suitability then rapidly increases, reaching 1.00 at 1.3 ft/sec. It begins to decrease at 2.4 ft/sec, reaching 0.00 at 4.3 ft/sec.

Dominant and Sub-Dominant Substrate: Substrate components ranging from small gravel (0.1-1.0 inches) to small cobble (6-9 inches) were the only dominant substrates (Figure 39). Large gravel (2-3 inches) suitability is 1.00, and medium gravel (1.0-2.0 inches) and medium cobble suitabilities are 0.80 and 0.72, respectively. Small gravel was infrequently dominant, its HSC is 0.04.

Sub-dominant substrate HSC demonstrated characteristics similar to dominant substrate HSC, with combinations of medium gravel to small cobble being most commonly used by the spawning salmon. Sub-dominant substrate observations confirm the value of large gravel to spawning salmon. As with dominant substrate, large gravel has a suitability of 1.00. Medium gravel and small cobble suitabilities are 0.51 and 0.33 respectively. Some sub-dominant substrates outside of the small gravel to small cobble range were observed, but have HSC near zero.

Percent Fines in the Redds: The percent fines NPTL HSC shown in Figure 40 indicates that 0-15% fines in the redds have a suitability of 1.00 for spawning chinook salmon. There is a sharp decline in suitability beyond 15%. The suitability of 20% fines is 0.50, and for fines beyond 40% is 0.00.

Juvenile Chinook Salmon

All observations of juvenile chinook salmon habitat were made within a narrow flow range (2,940 to 3,020 cfs). Therefore, juvenile chinook data were pooled to construct HSC.

Table 10. Habitat suitability criteria (HSC) for spawning chinook salmon in the Klamath River, California, Iron Gate Dam to Scott River.

Water depth (ft)	HSC	Average water velocity (ft/sec)	HSC	Fish focal point water velocity (ft/sec)	HSC	Dominant substrate[1]	HSC	Sub-dominant substrate[1]	HSC	Percent fines	HSC
0.0	0.00	0.0	0.00	0.0	0.00	1	0.00	1	0.00	0	1.00
0.5	0.00	0.9	0.00	0.4	0.00	2	0.00	2	0.01	15	1.00
0.6	0.10	1.5	0.20	0.7	0.10	3	0.00	3	0.01	20	0.50
0.9	0.20	1.7	0.50	0.9	0.20	4	0.04	4	0.08	30	0.20
1.1	0.50	2.1	1.00	1.1	0.50	5	0.81	5	0.51	40	0.00
1.5	1.00	3.3	1.00	1.3	1.00	6	1.00	6	1.00	50	0.00
3.1	1.00	3.5	0.50	2.3	1.00	7	0.72	7	0..33	60	0.00
3.9	1.00	3.7	0.20	2.9	0.50	8	0.00	8	0.05	70	0.00
5.1	1.00	3.9	0.10	3.1	0.20	9	0.00	9	0.00	80	0.00
5.3	1.00	5.6	0.00	3.9	0.10	10	0.00	10	0.00	90	0.00
6.0	1.00	6.0	0.0	4.3	0.00	11	0.00	11	0.01	100	0.00
--	--	--	--	6.0	0.00	12	0.00	12	0.00	0.00	0.00
--	--	--	--	--	--	13	0.00	13	0.00	--	--

1.

Code	Substrate	Code	Substrate	Code	Substrate
1.	Clay	5.	Medium gravel (1.0 – 2.0 inches)	9.	Large cobble (9.0 – 12.0 inches)
2.	Sand and or silt (<0.1 inches)	6.	Large gravel (2.0 – 3.0 inches)	10.	Small boulder (12.0 – 24.0 inches)
3.	Coarse sand (0.1 – 0.2 inches)	7.	Small cobble (3.0 – 6.0 inches)	11.	Medium boulder (24.0 – 48.0 inches)
4.	Small gravel (0.2 – 1.0 inches)	8.	Medium cobble (6.0 – 9.0 inches)	12.	Large boulder (>48.0 inches)
				13.	Bedrock

Total water depth: The juvenile chinook salmon total water depth NPTL HSC indicates no use of water < 0.6 ft deep (Table 11; Figure 41). Water depth is most suitable (i.e., an index of 1.00) between 1.6 and 4.0 ft deep. Suitability declines to 0.20 at 5.6 ft, and to 0.00 at 7 ft.

Average Water Velocity: Suitability for average water velocity with one-tailed NPTL is 1.00 from 0.0 to 0.6 ft/sec (Figure 42). Suitability is 0.50 at 1.6 ft/sec, then declines to 0.10 at 2.6 ft/sec, and 0.00 at 3.8 ft/sec.

Fish Focal Point Water Velocity: The HSC for fish focal point water velocity with one-tailed NPTL is similar to that for the average water velocity. Focal point water velocity suitability is 1.00 from 0.0 to 0.6 ft/sec (Figure 43). It is 0.50 at 1.4 ft/sec, and declines to 0.10 at 2.2 ft/sec, and to 0.00 at 3.4 ft/sec.

Functional Cover: No cover and object cover suitabilities for the four functional cover types (i.e., observations of use of in-water or out-of-water overhead cover are combined into a single overhead cover category) are 1.00 and 0.48, respectively (Figure 44). The suitability of overhead cover alone is 0.09, and for overhead cover in combination with object cover HSC is 0.21.

When considering the six individual functional cover types (i.e., partitioning overhead cover into in-and out-of-water categories), no cover and object cover suitabilities continue to be 1.00 and 0.48, respectively (Figure 45). Individual in-water and out-of-water overhead and overhead cover in combination with object cover suitabilities range from only 0.01 to 0.12.

Distance to In-Water Escape Cover: The normalized frequency of use HSC for distance to in-water escape cover is 0.15 for 0 ft, and 0.95 and 1.00 for 1 and 2 ft, respectively (Figure 46). Suitabilities for 3 to more than 5 ft from escape cover range from 0.14 (3 ft) to 0.04 (>5 ft). The vast majority (89%) of the juvenile chinook salmon observed during this investigation were within 2 ft of in-water escape cover. The young fish, however, appear to prefer to be near, rather than actually within or under in-water escape cover.

In-Water Escape Cover Specific Components: Juvenile chinook salmon were notably associated with vegetative in-water escape cover types. Considered as a whole, suitability of vegetative in-water escape cover is 1.00. Suitability of hard substrate escape cover, on the other hand, is only 0.08. This relationship is reflected in the suitabilities of the in-water escape cover specific components. Non-emergent rooted aquatic vegetation has an in-water escape cover suitability of 1.00 (Figure 47). Young willows have a 0.88 suitability, rooted emergent vegetation suitability is 0.57. Sedges suitability is 0.05. Medium boulders (24-48 inches) are the most frequently nearest hard substrate escape cover (HSC = 0.14). Suitabilities of other hard substrate components range from 0.00 to 0.05.

Dominant and Sub-Dominant Substrate: Juvenile chinook salmon were observed over nearly all substrate types. Most, however, were associated with the smaller substrates. Sand was the most frequently observed dominant substrate, and has a suitability of 1.00 (Figure 48). Coarse sand, on the other hand, has a suitability of only 0.13. Dominant substrate suitability then consistently increases until reaching 0.39 for very large gravel (3-4 inches), then has variable, but lower, suitability thereafter. Suitabilities for larger substrate elements (i.e., components greater than 24 inches) range from 0.05 to 0.16.

Distance to Water's Edge: The NPTL HSC for juvenile chinook salmon distance to water's edge ranges from 0.00 at 0 ft to 1.00 at 7 ft. It remains at 1.00 until the distance from water's edge reaches 20 ft, then declines to 0 at 55 ft (Figure 49). About 30% of juvenile chinook salmon observed were within 8 ft of the river's margin (i.e., bank) (Figure 35). The median distance was 15 ft. Nearly all fish were within 30 ft of the water's edge.

Other Species and Life Stages

Although fry chinook salmon HSC were to be developed during this investigation, sampling conditions (poor water visibility) prevented collection of sufficient fry observations to develop site-specific HSC. We were able to make limited fry observations to verify that chinook salmon fry habitat use information (as collected by the USFWS using electrofishing) was suitable for developing fry HSC. A manuscript more fully describing electrofishing techniques, analytical methods, and resultant HSC is in preparation.

We did not encounter sufficient numbers of steelhead trout and coho salmon to allow construction of site-specific HSC. Only 67 observations of steelhead, representing four age classes, were made in all field efforts combined. These observations were comprised of 53 fry and 37 juvenile steelhead. We made four observations (six fish total) of fry coho salmon.

We also observed juvenile steelhead in the open-water transects, but along only two transects in one pool. These observations were within 10 ft of the water's edge.

Table 11. Habitat suitability criteria (HSC) for juvenile chinook salmon in the Klamath River, California, Iron Gate Dam to Scott River.

Water depth (ft)	HSC	Average water velocity (ft/sec)	HSC	Fish focal point water velocity (ft/sec)	HSC	Four functional cover types[1]	HSC	Six functional cover types[2]	HSC	Distance to water's edge (ft)	HSC	Distance to in-water escape cover (ft)	HSC
0.0	0.00	0.0	1.00	0.0	1.00	1	1.00	1	1.00	0	0.0	0.0	0.15
0.6	0.00	0.6	1.00	0.6	1.00	2	0.48	2	0.48	3	0.2	1.0	0.95
0.8	0.10	1.6	0.50	1.4	0.50	3	0.09	3	0.07	5	0.5	2.0	1.00
1.0	0.20	2.4	0.20	1.8	0.20	4	0.21	4	0.01	7	1.0	3.0	0.14
1.2	0.50	2.6	0.10	2.2	0.10			5	0.10	20	1.0	4.0	0.08
1.6	1.00	3.4	0.02	2.6	0.02			6	0.12	30	0.5	5.0	0.04
4.0	1.00	3.8	0.00	3.4	0.00					40	0.2	>5.0	0.01
4.8	0.50									50	0.1		
5.6	0.20									55	0.0		
5.8	0.10												
7.0	0.00												

1. Four functional cover type codes
   1. No cover
   2. Object cover
   3. Overhead cover
   4. Object and overhead cover

2. Six functional cover type codes
   1. No cover
   2. Object cover
   3. In-water overhead cover
   4. Out-of-water overhead cover
   5. Object cover and in-water overhead cover
   6. Object cover and out-of-water overhead cover

Table 11 (Continued). Habitat suitability criteria (HSC) for juvenile chinook salmon in the Klamath River, California, Iron Gate Dam to Scott River.

In-water escape cover specific component[3]	HSC	In-water escape cover specific component[3]	HSC	Dominant substrate[4]	HSC	Sub-dominant substrate[4]	HSC
1	0.00	16	0.02	1	0.00	1	0.00
2	1.00	17	0.00	2	1.00	2	0.24
3	0.57	18	0.00	3	0.13	3	1.00
4	0.00	19	0.00	4	0.13	4	0.74
5	0.05	20	0.00	5	0.30	5	0.22
6	0.00	21	0.00	6	0.32	6	0.81
7	0.00	22	0.00	7	0.93	7	0.25
8	0.88	23	0.00	8	0.24	8	0.42
9	0.00	24	0.00	9	0.32	9	0.22
10	0.00	25	0.01	10	0.00	10	0.08
11	0.00	26	0.02	11	0.00	11	0.01
12	0.00	27	0.00	12	0.05	12	0.05
13	0.00	28	0.00	13	0.12	13	0.05
14	0.00	29	0.14	14	0.16	14	0.12
15	0.05	30	0.04	15	0.02	15	0.03
		31	0.00				

3. Escape cover codes

1. Filamentous algae
2. Non-emergent rooted aquatic vegetation
3. Emergent rooted aquatic vegetation
4. Grass
5. Sedges
6. Cockle burrs
7. Grape vines
8. Willows
9. Berry vines
10. Trees (<4 inches dbh)
11. Trees (>4 inches dbh)
12. Root-wad
13. Aggregates of small vegetation (<4 inches)
14. Aggregates of large vegetation (>4 inches)
15. Duff, leaf litter, organic debris
16. Small woody debris (<0.3 x 12 ft)
17. Large woody debris (>0.3 x 12 ft)
18. Clay
19. Sand or silt/sand (<0.1 inches)
20. Coarse sand (0.1-0.2 inches)
21. Small gravel (0.2-1.0 inches)
22. Medium gravel (1-2 inches)
23. Large gravel (2-3 inches)
24. Very large gravel (3-4 inches)
25. Small cobble (4-6 inches)
26. Medium cobble (6-9 inches)
27. Large cobble (9-12 inches)
28. Small boulder (12-24 inches)
29. Medium boulder (24-48 inches)
30. Large boulder (>48 inches)
31. Bedrock

4. Substrate codes

1. Clay
2. Sand or silt/sand (<0.1 inches)
3. Coarse sand (0.1-0.2 inches)
4. Small gravel (0.2-1.0 inches)
5. Medium gravel (1-2 inches)
6. Large gravel (2-3 inches)
7. Very large gravel (3-4 inches)
8. Small cobble (3-6 inches)
9. Medium cobble (6-9 inches)
10. Large cobble (9-12 inches)
11. Small boulder (12-24 inches)
12. Medium boulder (24-48 inches)
13. Large boulder (>48 inches)
14. Bedrock
15. Roots

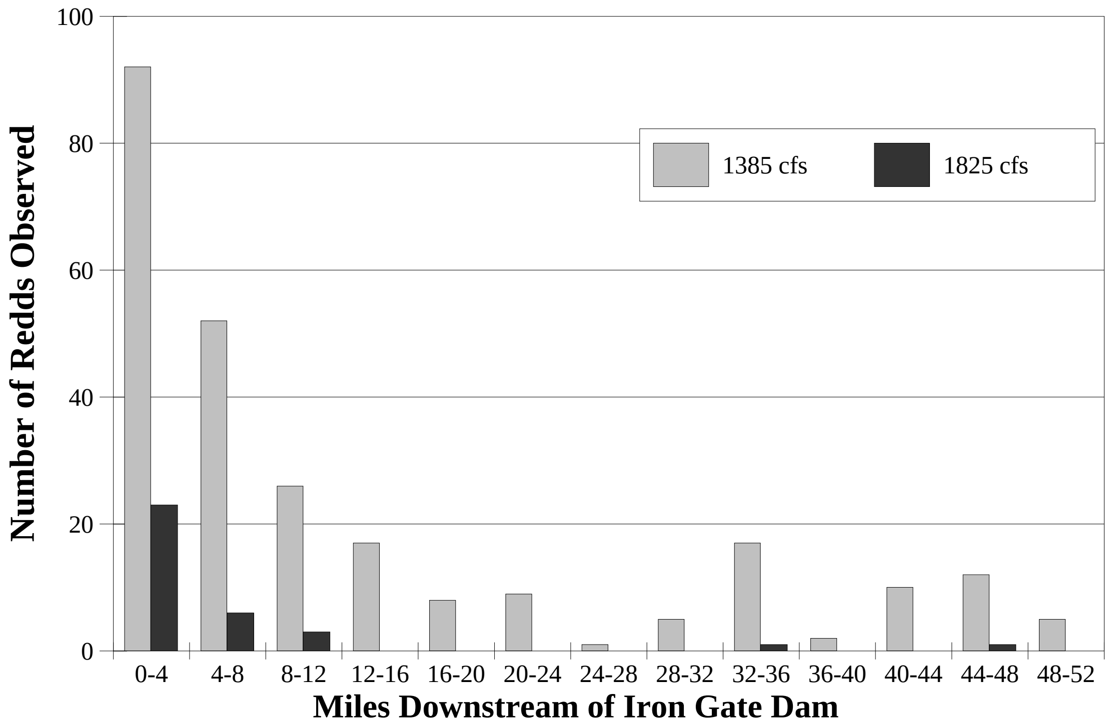


Figure 6. Number of chinook salmon redds observed in the Klamath River between Iron Gate Dam and the Scott River, fall 1999.

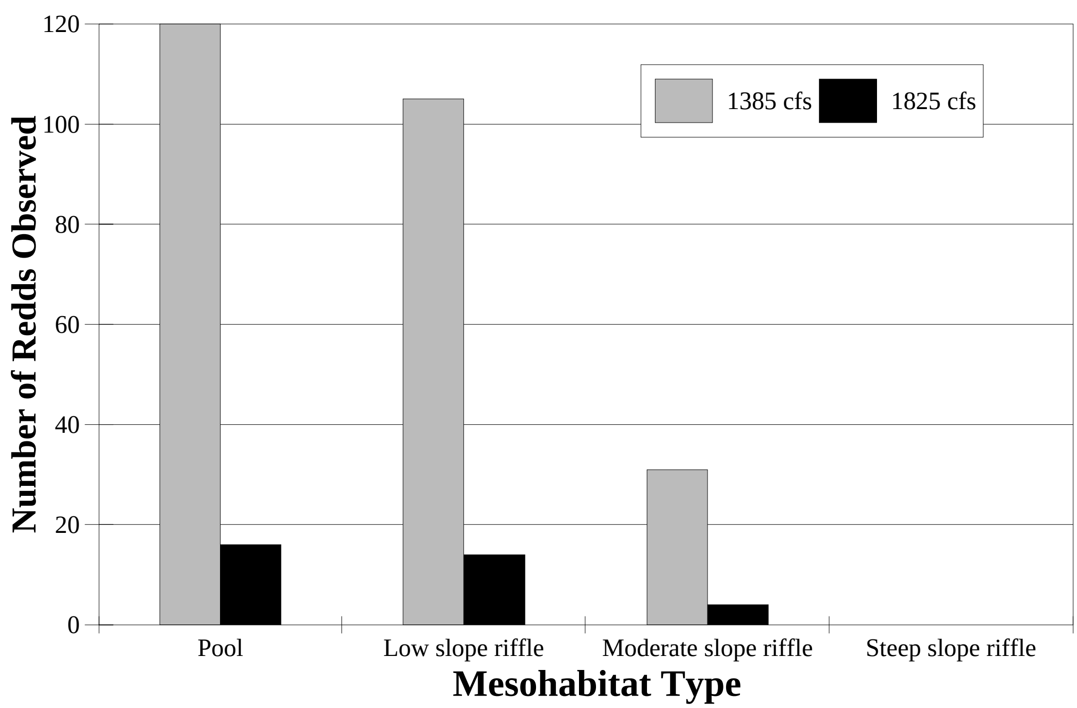


Figure 7. Distribution of chinook salmon redds by mesohabitat type and river flow in the Klamath River between Iron Gate Dam and Scott River, fall 1999.

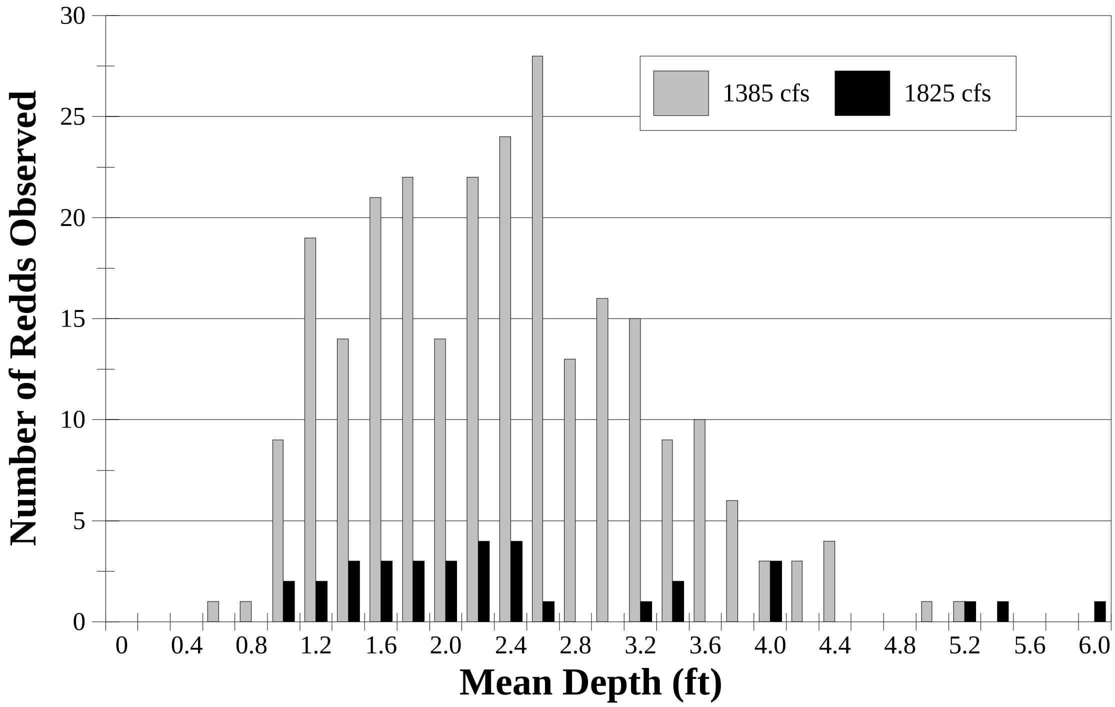


Figure 8. Total water depth at chinook salmon redds measured at two river flows in the Klamath River between Iron Gate Dam and Scott River, fall 1999.

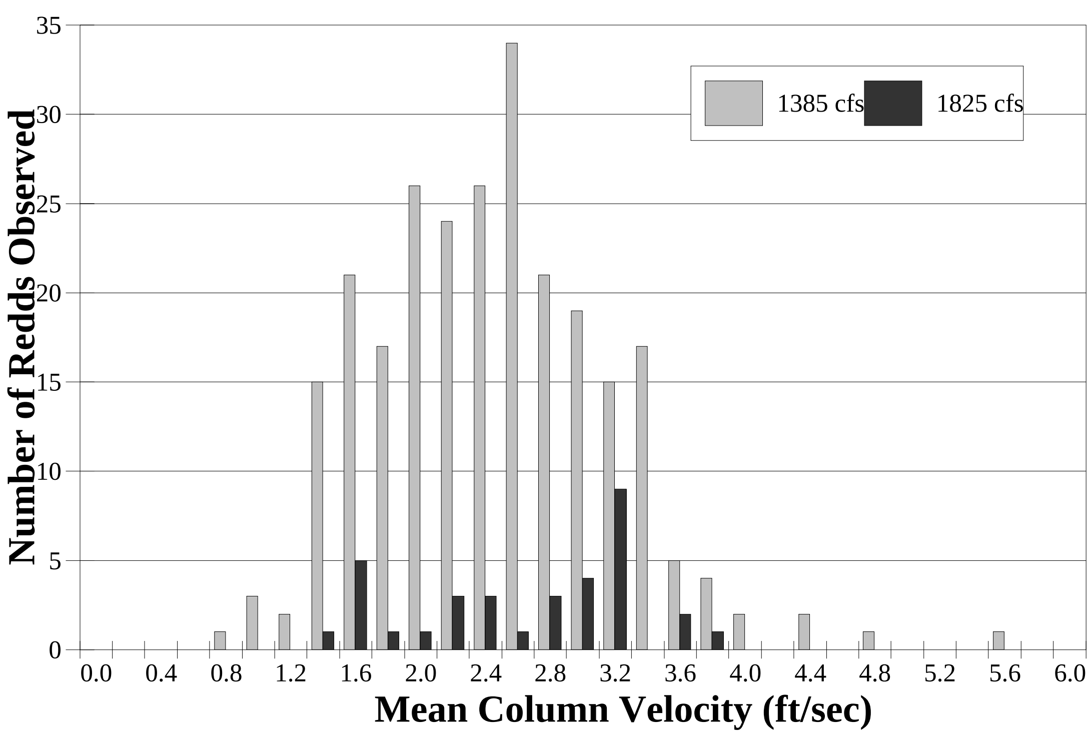


Figure 9. Frequency distribution for average water velocities measured at chinook salmon redds observed at two river flows in the Klamath River between Iron Gate Dam and Scott River, fall 1999.

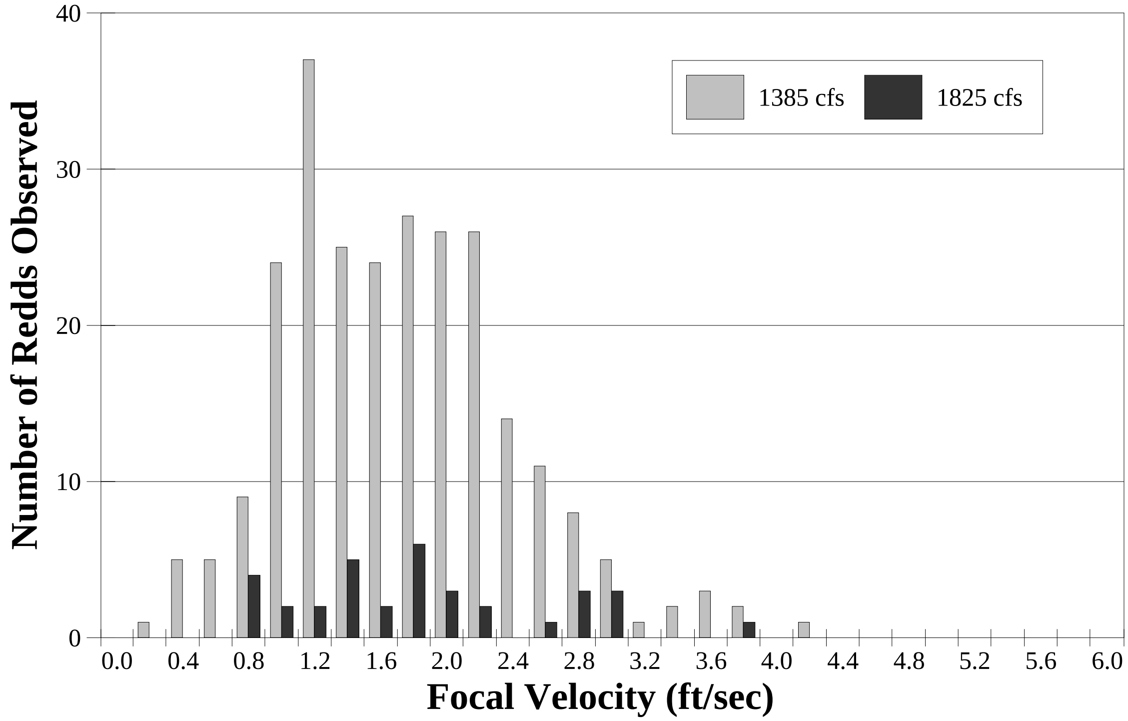
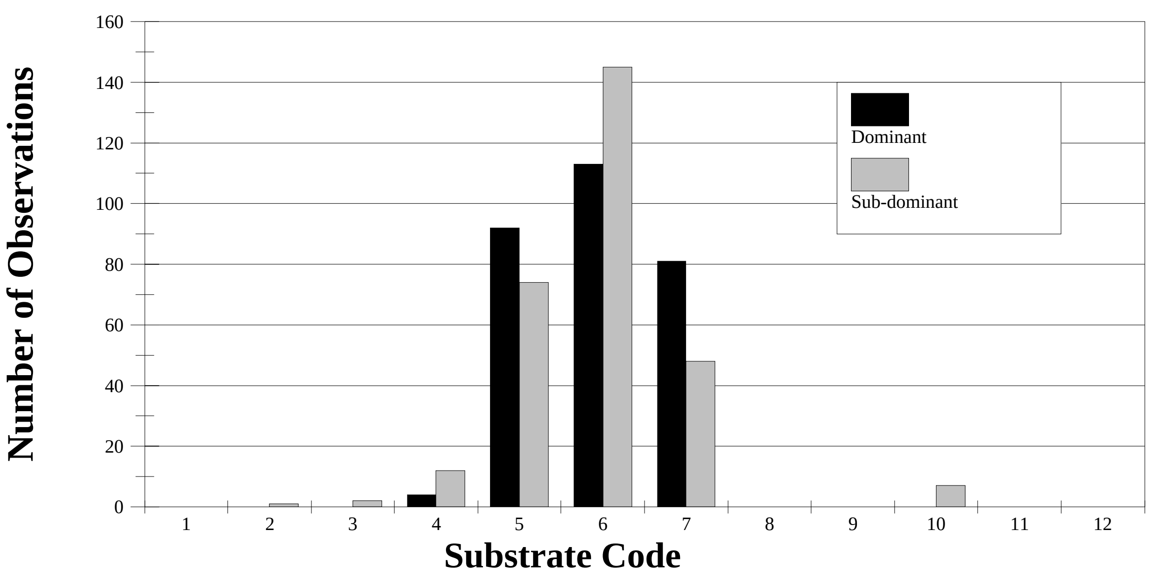
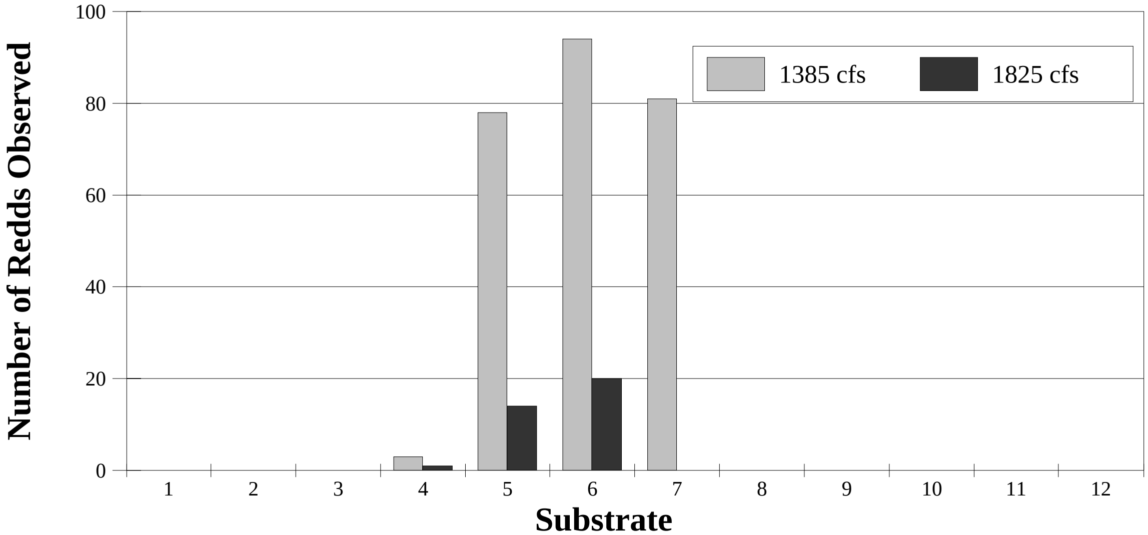


Figure 10. Fish focal point water velocity at chinook salmon redds measured at two river flows in the Klamath River between Iron Gate Dam and Scott River, fall 1999.



Substrate codes		
1. Clay	5. Medium gravel: 1-2 inches	9. Large cobble: 9-12 inches
2. Sand/silt: < 0.1 inches	6. Large gravel: 2-3 inches	10. Small boulder: 12-24 inches
3. Coarse sand: 0.1-0.2 inches	7. Small cobble: 3-6 inches	11. Medium boulder: 24-48
4. Small gravel 0.2-1.0 inches	8. Medium cobble: 6-9 inches	12. Large boulder: >48 inches

Figure 11. Dominant and sub-dominant substrate at chinook salmon redds in the Klamath River between Iron Gate Dam and Scott River, fall 1999.



Substrate type		
1. Clay	5. Medium gravel: 1-2 inches	9. Large cobble: 9-12 inches
2. Sand/silt: < 0.1 inches	6. Large gravel: 2-3 inches	10. Small boulder: 12-24 inches
3. Coarse sand: 0.1-0.2 inches	7. Small cobble: 3-6 inches	11. Medium boulder: 24-48 inches
4. Small gravel: 0.2-1.0 inches	8. Medium cobble: 6-9 inches	12. Large boulder: >48 inches

Figure 12. Dominant substrate at chinook salmon redds observed in the Klamath River between Iron Gate Dam and Scott River at 1,385 or 1,825 cfs releases from Iron Gate Dam, fall 1999.

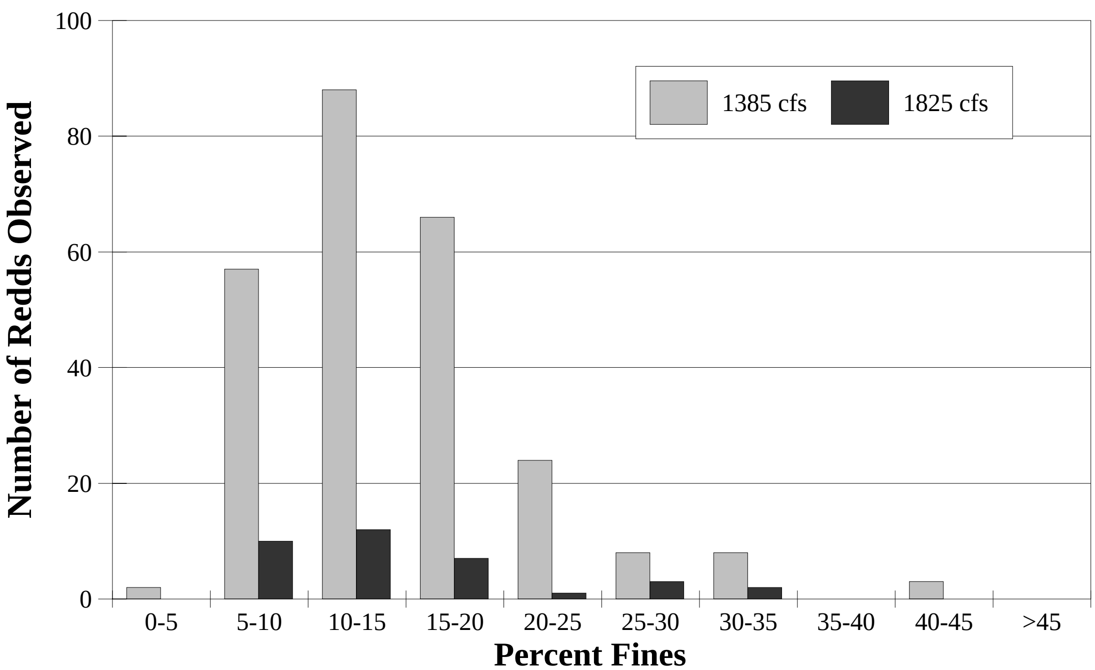


Figure 13. Percent fines at chinook salmon redds measured at two flows in the Klamath River between Iron Gate Dam and Scott River, fall 1999.

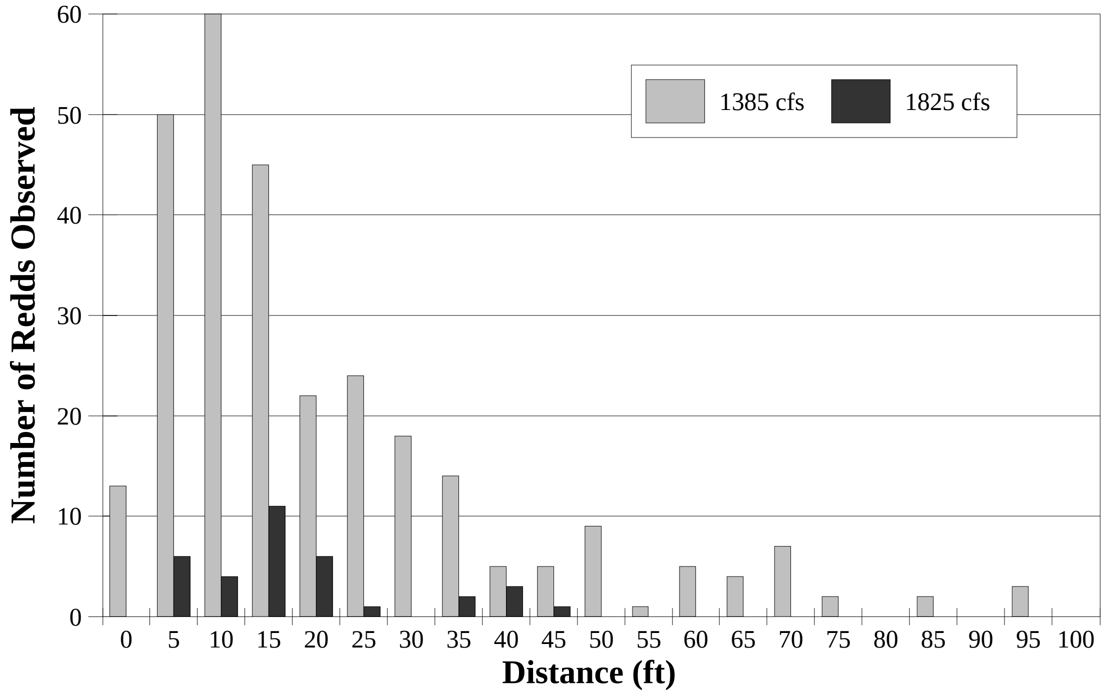


Figure 14. Distance to water's edge from chinook salmon redds measured at two flows in the Klamath River between Iron Gate Dam and Scott River, fall 1999.

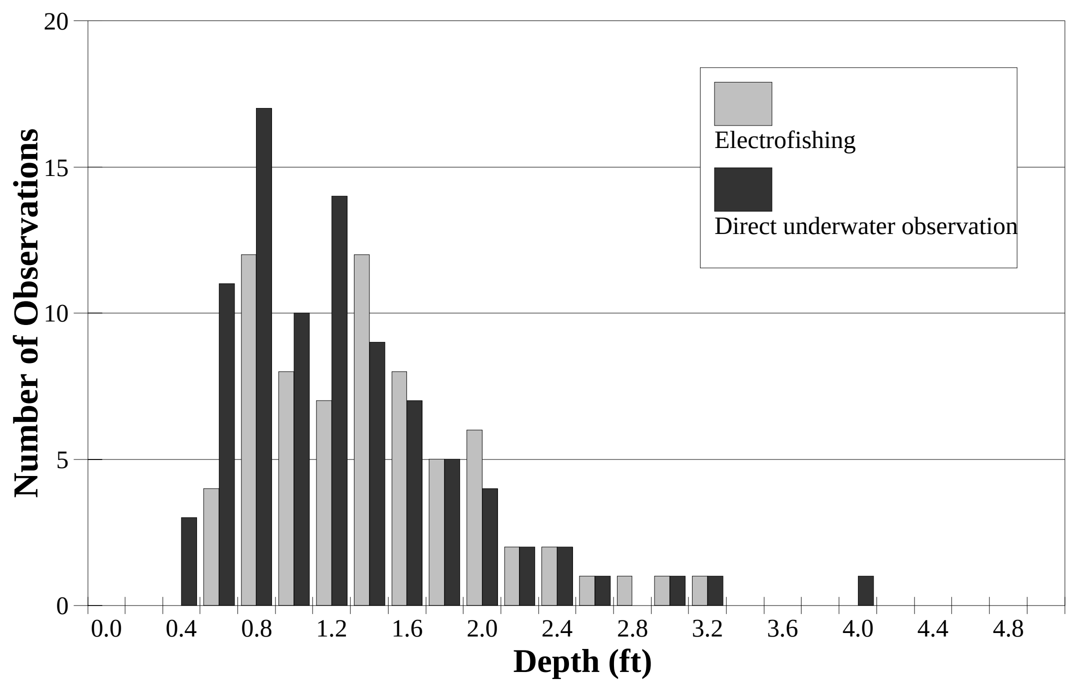


Figure 15. Frequency distribution of total water depths for fry chinook salmon sampled by direct underwater observation or electrofishing techniques in the Klamath River between Iron Gate Dam and Scott River, spring 2000.

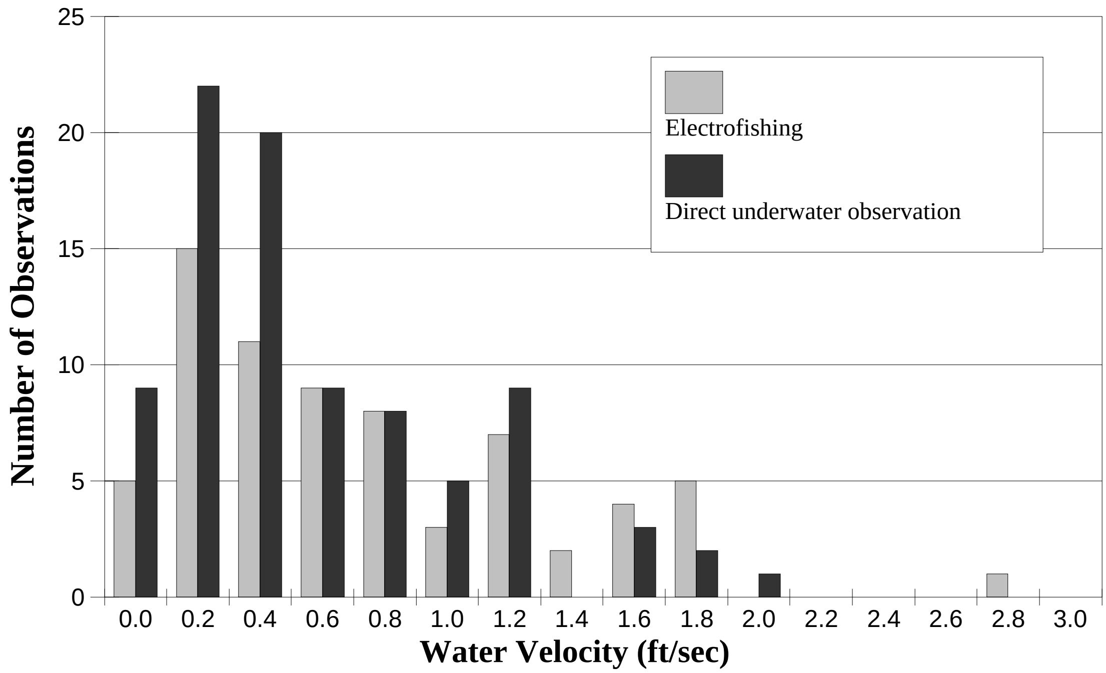


Figure 16. Frequency distribution of average water velocities for fry chinook salmon sampled by direct underwater observation or electrofishing techniques in the Klamath River between Iron Gate Dam and Scott River, spring 2000.

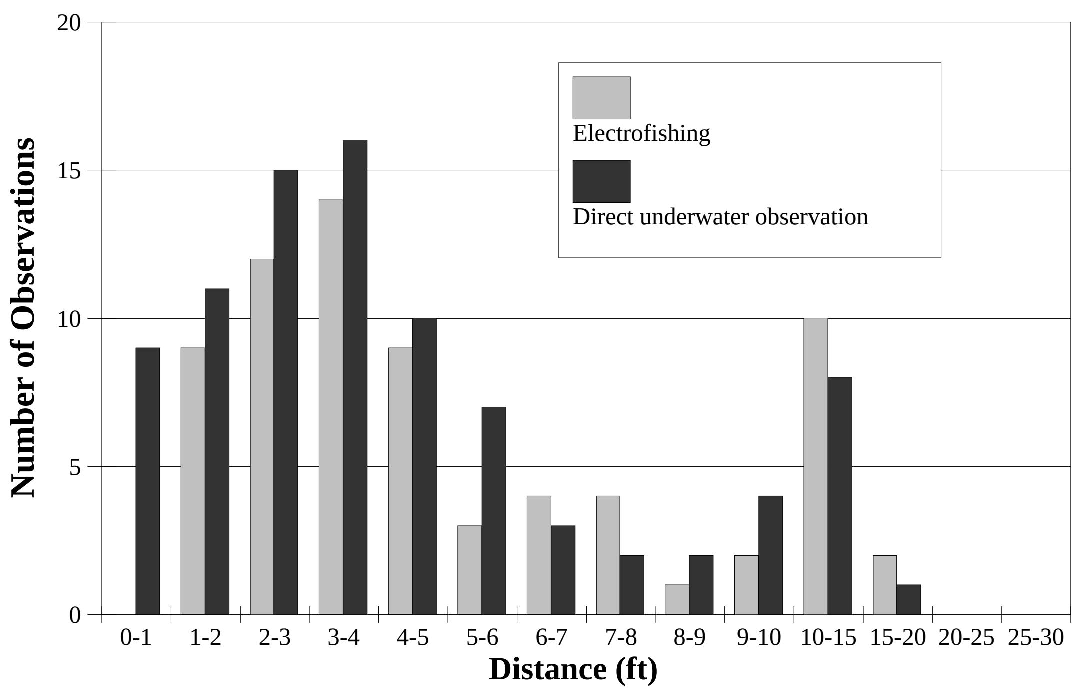


Figure 17. Distance to water's edge for fry chinook salmon sampled by direct underwater observation or electrofishing techniques in the Klamath River between Iron Gate Dam and Scott River, spring 2000.

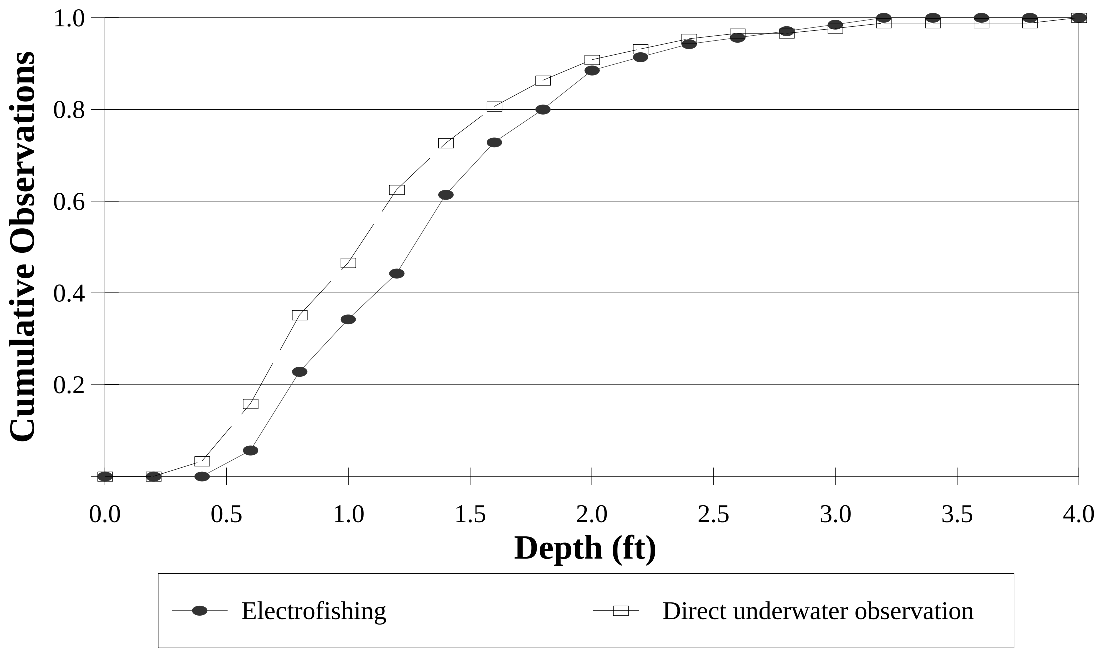


Figure 18. Cumulative distribution of total water depths for fry chinook salmon sampled by direct underwater observation or electrofishing techniques in the Klamath River between Iron Gate Dam and Scott River, spring 2000.

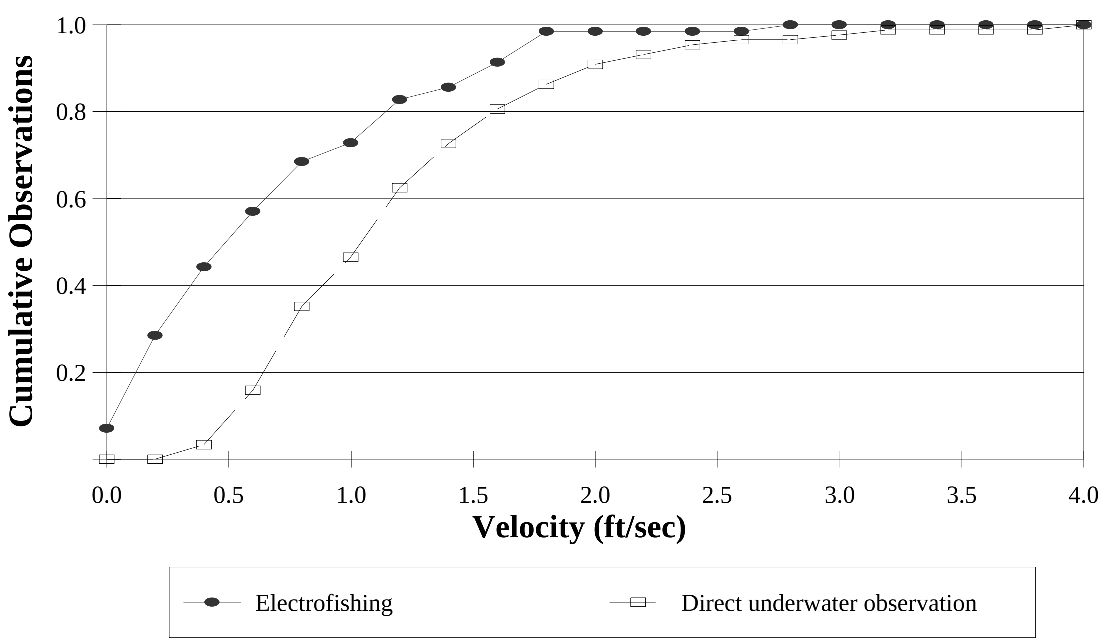


Figure 19. Cumulative distribution of average water velocities for fry chinook salmon sampled by direct underwater observation or electrofishing techniques in the Klamath River between Iron Gate Dam and Scott River, spring 2000.

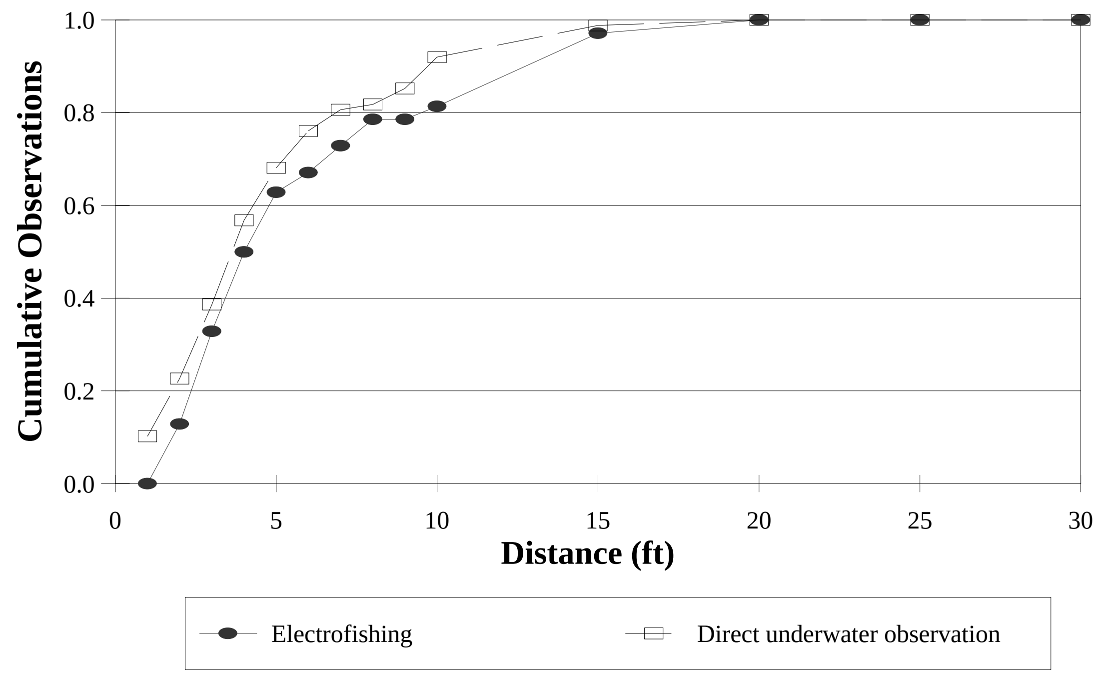


Figure 20. Cumulative distribution of distance to water's edge for fry chinook salmon sampled by direct underwater observation or electrofishing techniques in the Klamath River between Iron Gate Dam and Scott River, spring 2000.

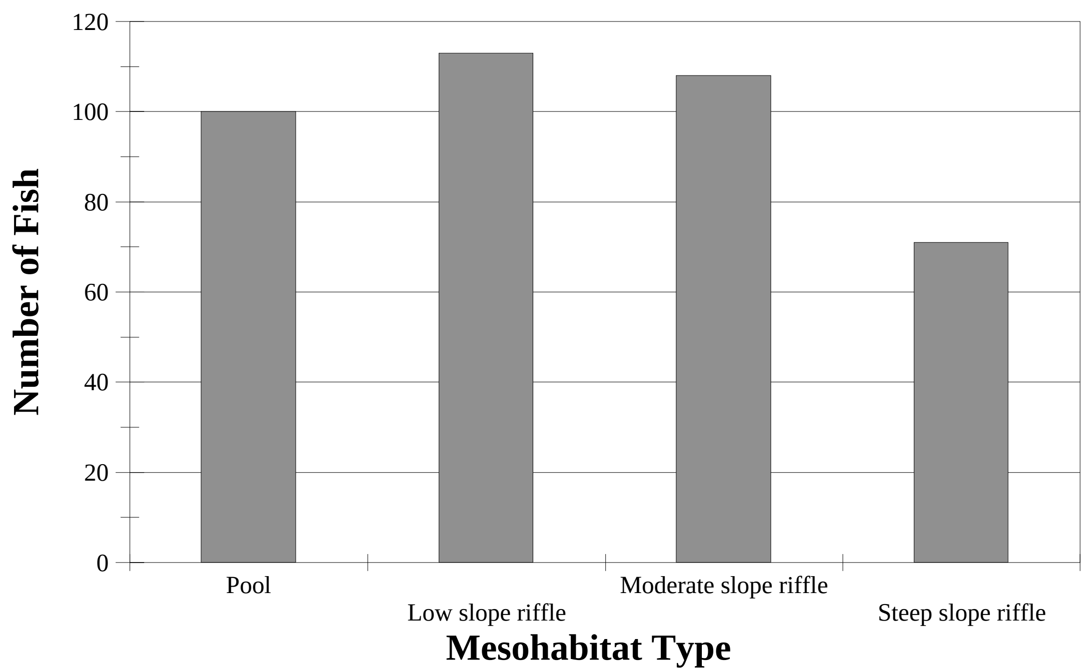
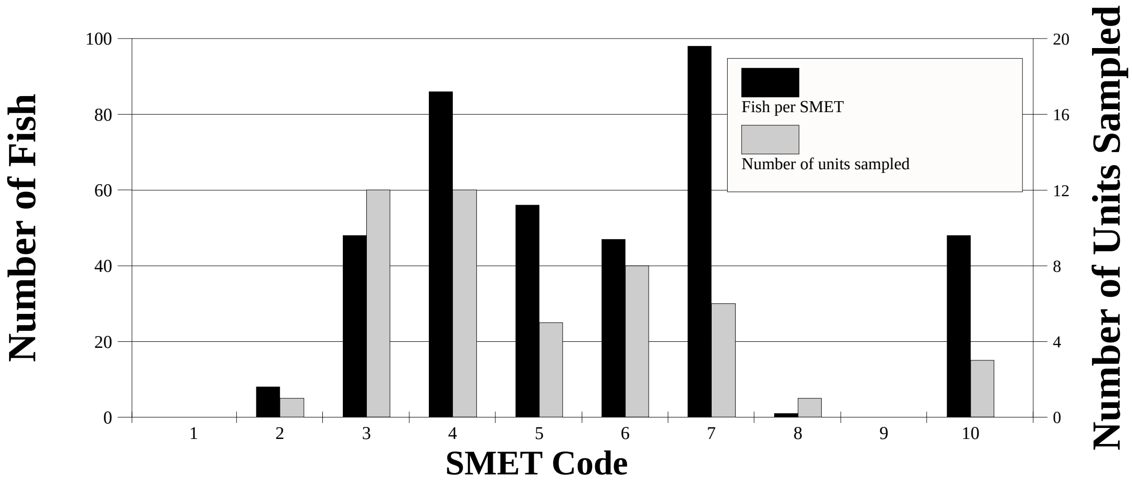
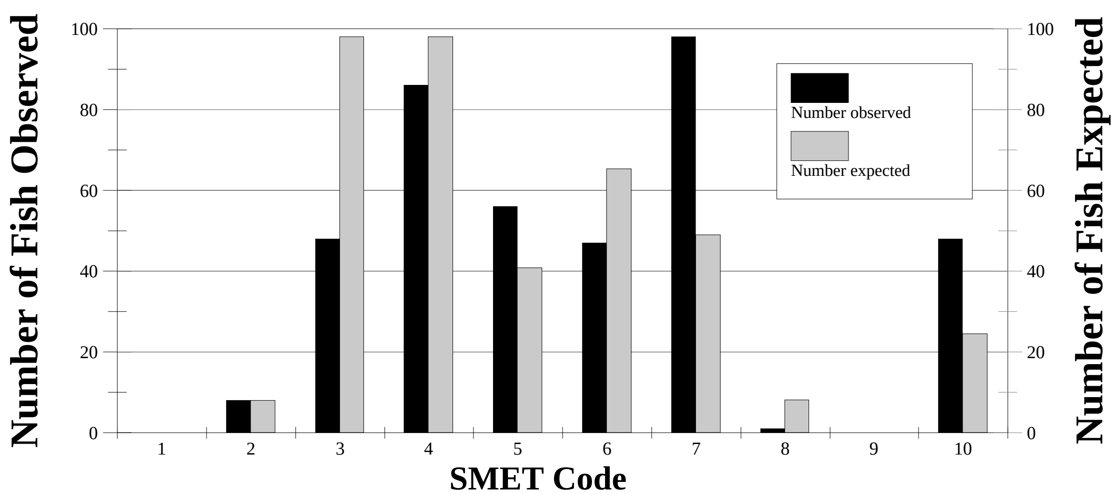


Figure 21. Distribution of juvenile chinook salmon by mesohabitat type in the Klamath River between Iron Gate Dam and Scott River, spring 2000.



Stream Margin Edge Codes		
1. Trees	4. Emergent shrubs	8. Large substrate and
2. Trees and emergent vegetation	5. Open areas	9. Large substrate and riprap with vegetation
3. Dense aggregates of willow, woody debris, and blackberry	6. Sparse herbaceous vegetation	
	7. Dense herbaceous vegetation	10. Eddy

Figure 22. Distribution of juvenile chinook salmon and sampling effort (i.e., number of units sampled) by stream margin edge type (SMET) in the Klamath River between Iron Gate Dam and Scott River, spring 2000. SMETs 1 and 9 were not observed during this portion of the investigation.



Stream Margin Edge Type Codes		
1. Trees	4. Emergent shrubs	8. Large substrate and riprap
2. Trees and emergent vegetation	5. Open areas	9. Large substrate and riprap with vegetation
3. Dense aggregates of willow, woody debris, and blackberry	6. Sparse herbaceous vegetation	
	7. Dense herbaceous vegetation	10. Eddy

Figure 23. Observed and expected numbers of juvenile chinook salmon by stream margin edge type (SMET) in the Klamath River between Iron Gate Dam and Scott River, spring 2000. SMETs 1 and 9 were not observed during this portion of the investigation.

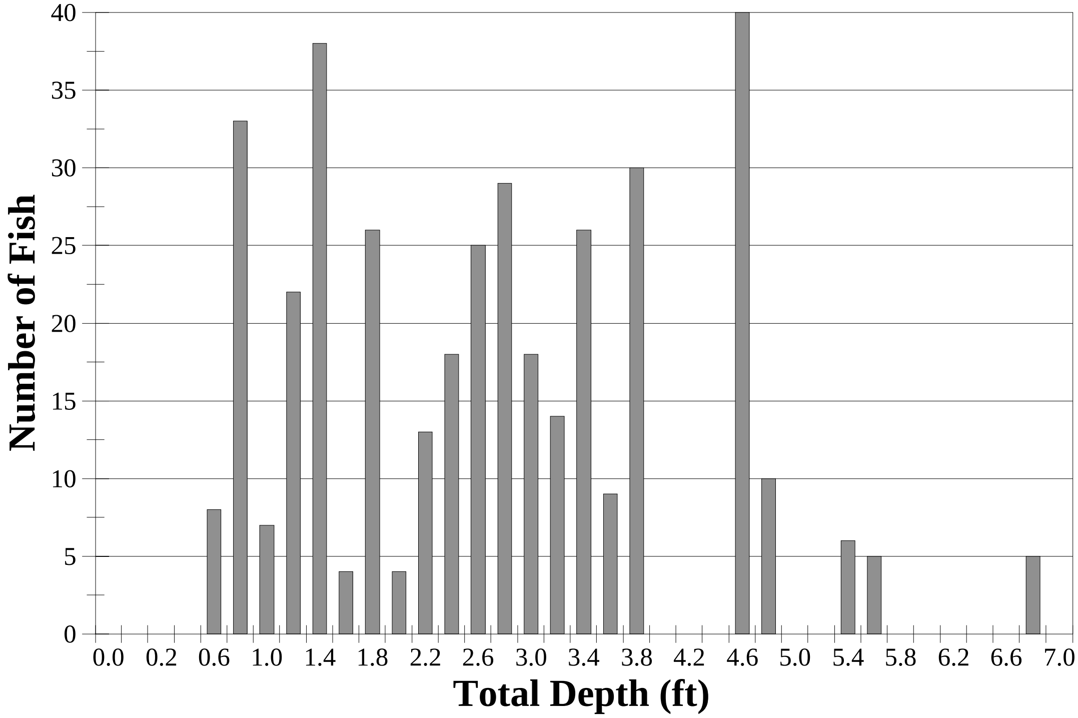


Figure 24. Total water depth frequency distribution for juvenile chinook salmon observed in the Klamath River between Iron Gate Dam and Scott River, spring 2000.

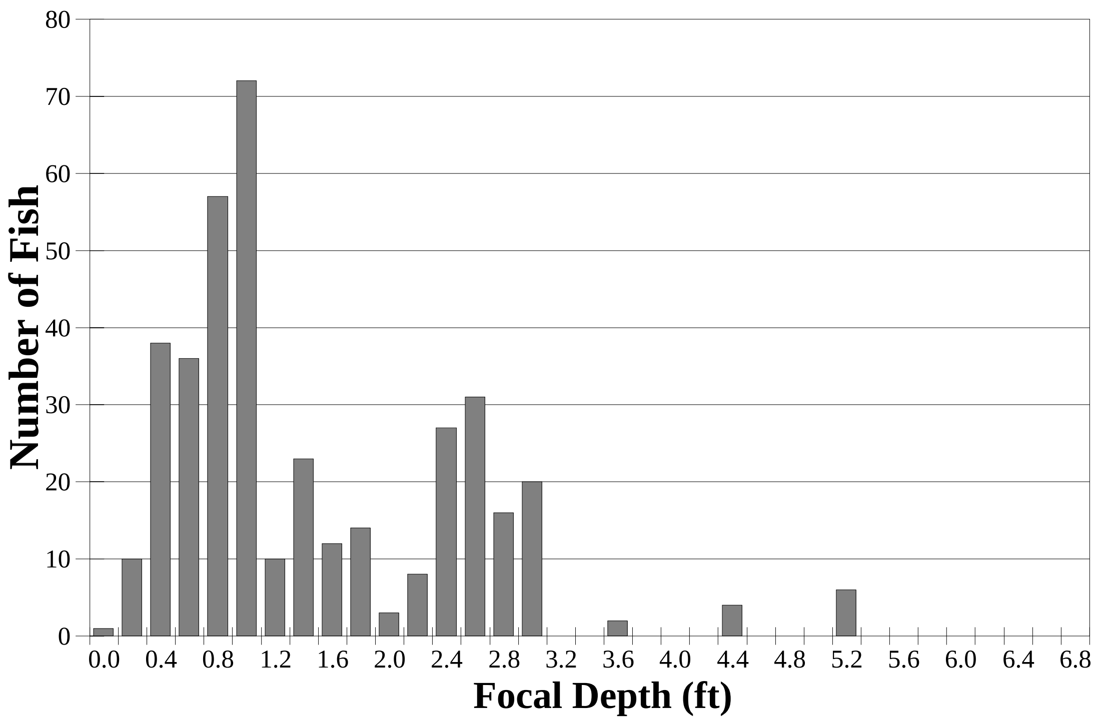


Figure 25. Fish focal point water depth frequency distribution for juvenile chinook salmon observed in the Klamath River between Iron Gate Dam and Scott River, spring 2000.

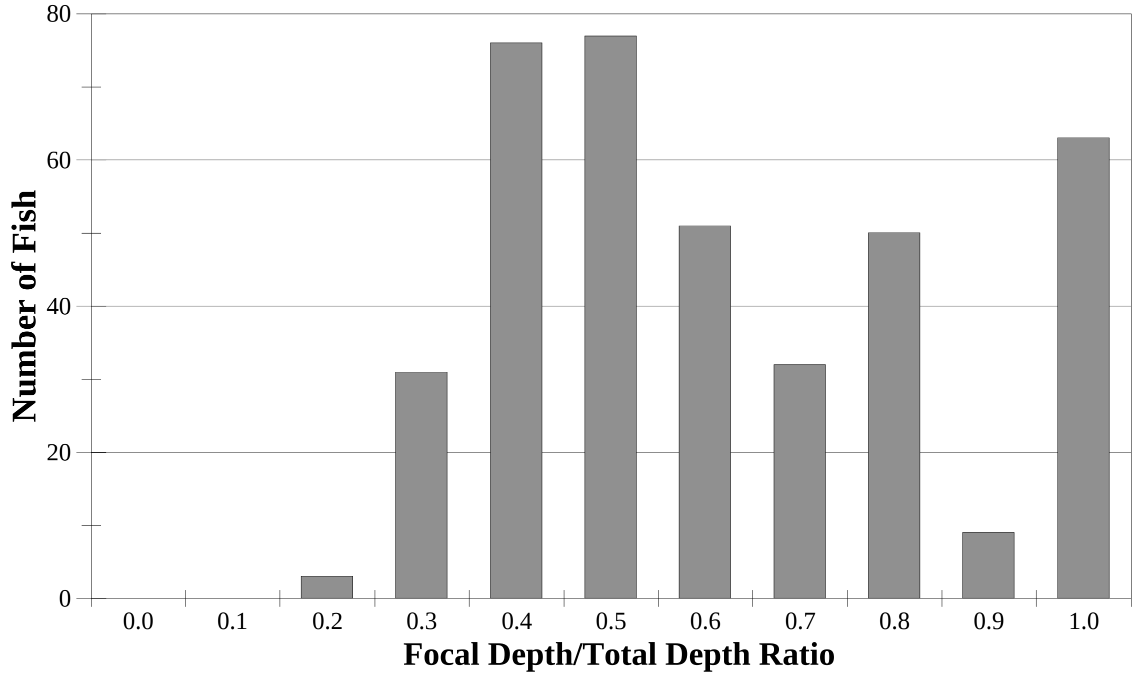


Figure 26. Ratio of fish focal-point water depth/total water depth for juvenile chinook salmon in the Klamath River between Iron Gate Dam and Scott River, spring 2000. A ratio of 0.0 means the fish is at the water surface; a 1.0 ratio means the fish is on the bottom.

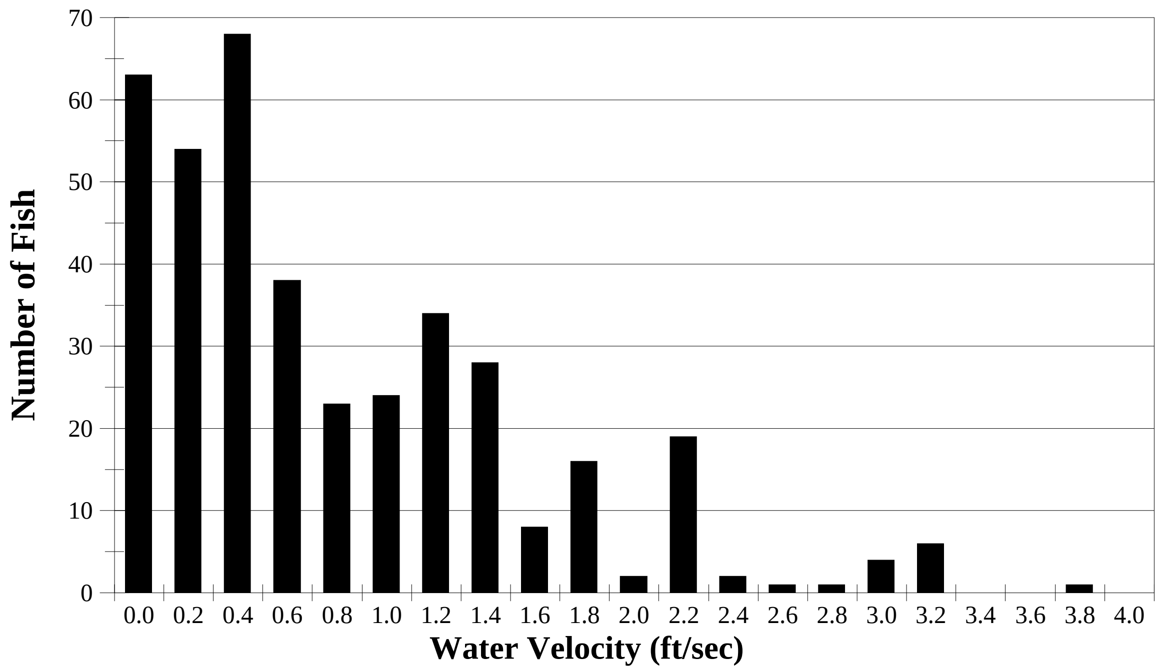


Figure 27. Frequency distribution for average water velocities used by juvenile chinook salmon observed in the Klamath River between Iron Gate Dam and Scott River, spring 2000.

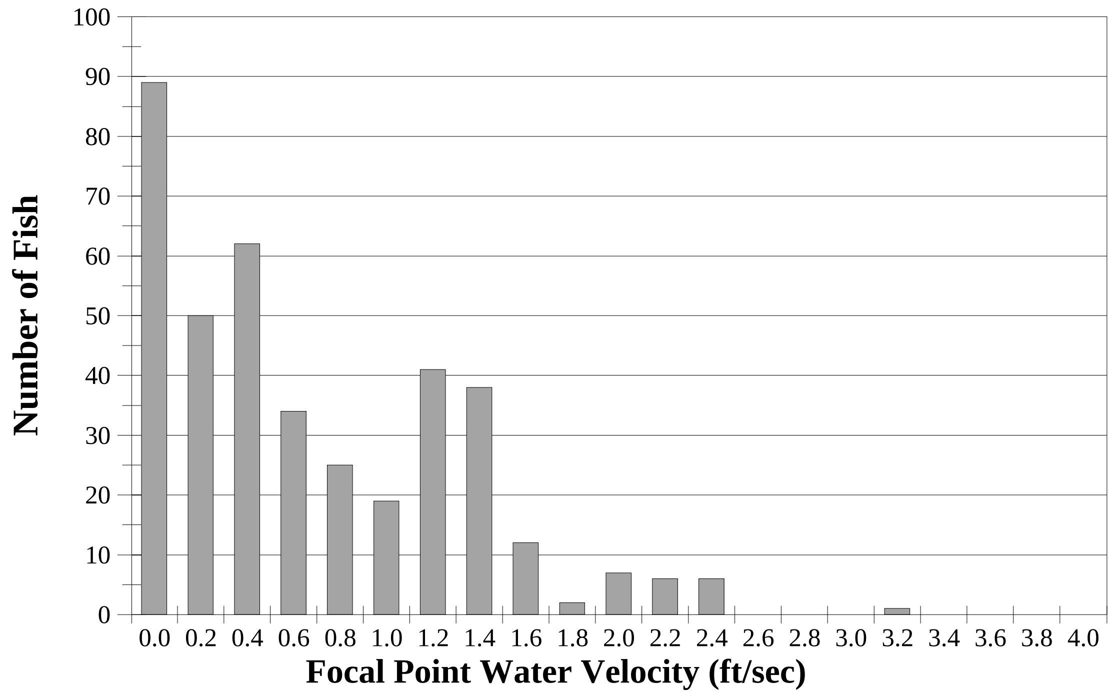
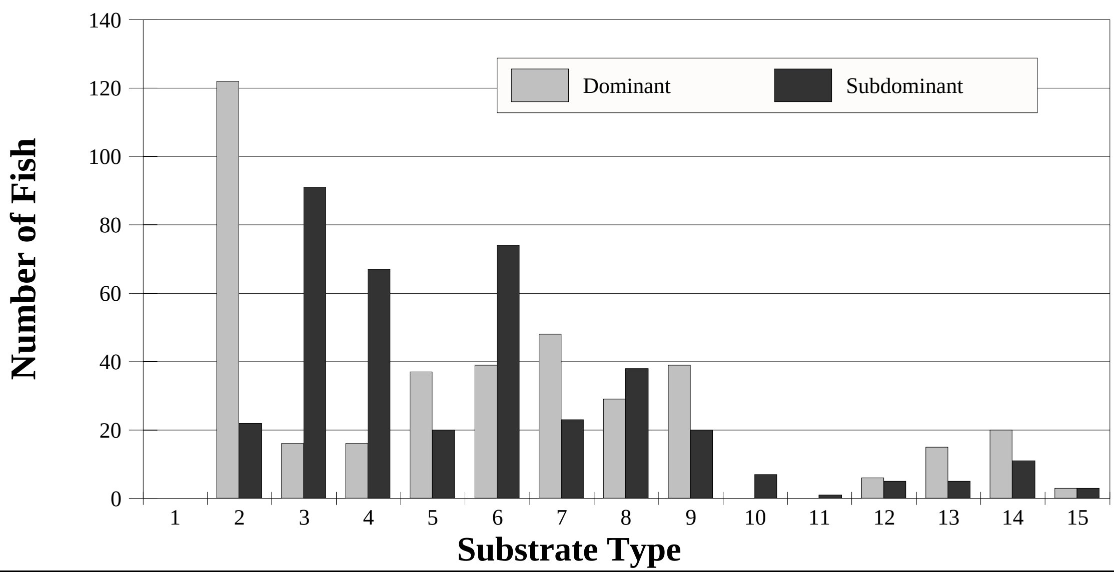
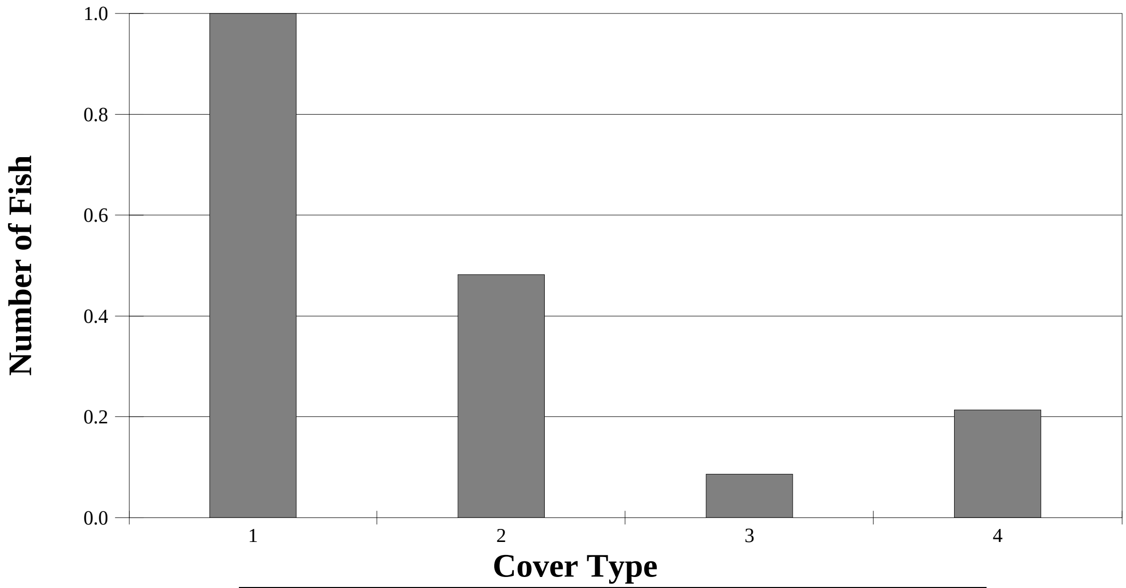


Figure 28. Frequency distribution for fish focal point water velocity used by juvenile chinook salmon in the Klamath River between Iron Gate Dam and Scott River, spring 2000.



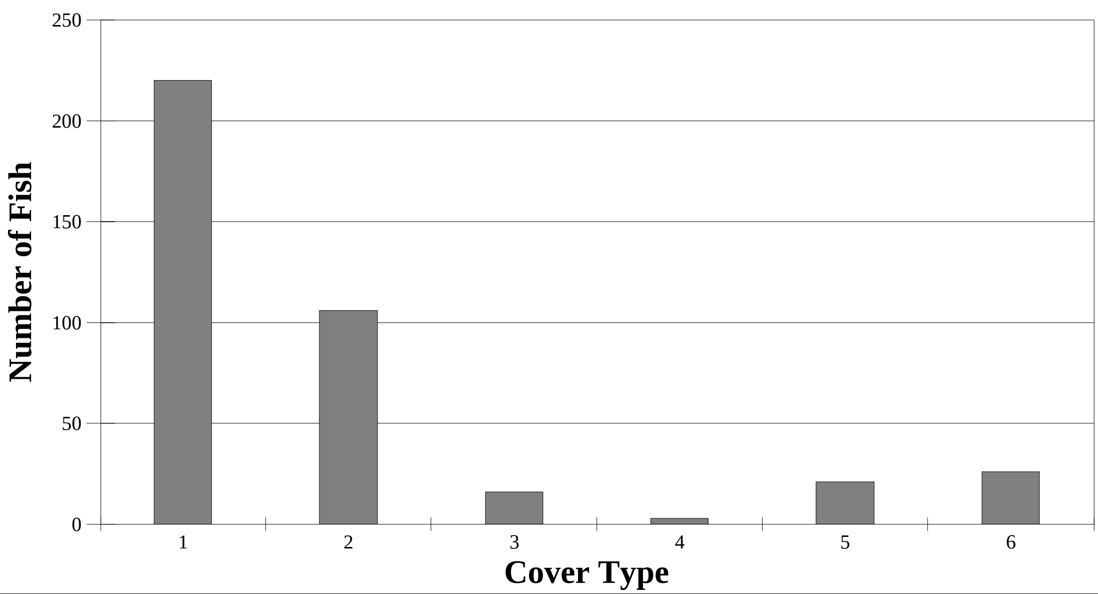
1. Clay	- - -	6. Large gravel:	2-3 inches	11. Small boulder:	12-24 inches
2. Sand and/or silt:	<0.1 inches	7. Very large gravel:	3-4 inches	12. Medium boulder:	24-48 inches
3. Coarse sand:	0.1-0.2 inches	8. Small cobble:	4-6 inches	13. Large boulder:	>48 inches
4. Small gravel:	0.2-1 inches	9. Medium cobble:	6-9 inches	14. Bedrock:	- - -
5. Medium gravel:	1-2 inches	10. Large cobble:	9-12 inches	15. Roots:	- - -

Figure 29. Frequency distribution for substrate types used by juvenile chinook salmon observed in the Klamath River between Iron Gate Dam and Scott River, spring 2000.



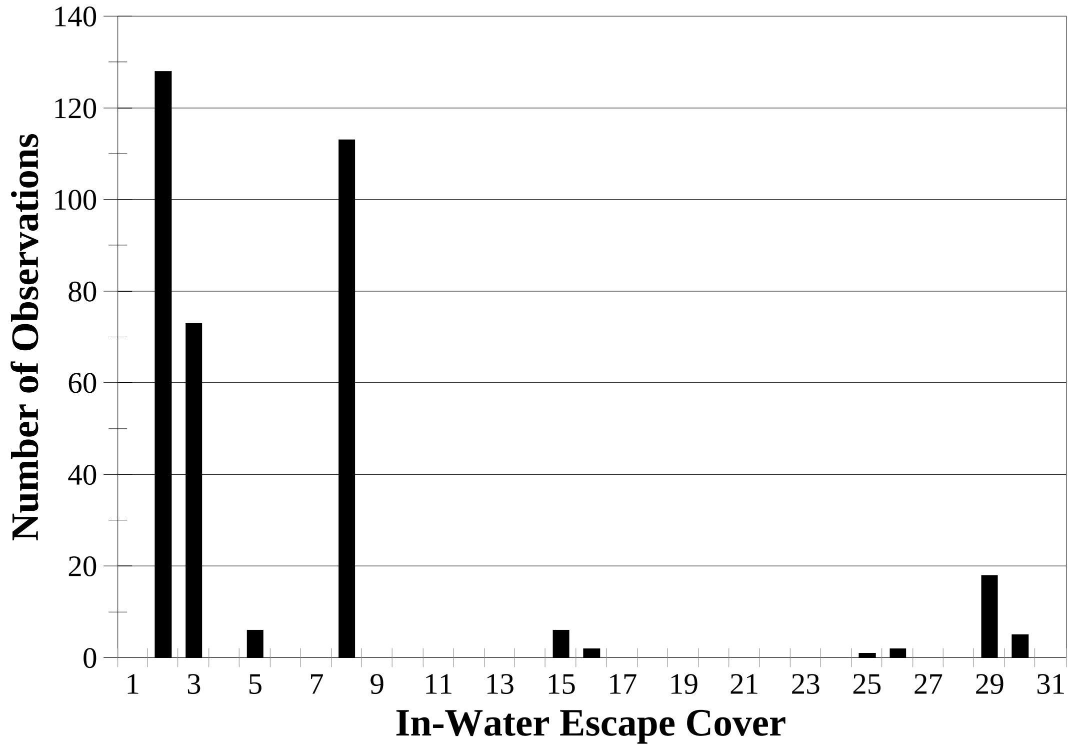
Cover type codes	
1. No cover	3. Overhead cover
2. Object cover	4. Object and overhead cover

Figure 30. Frequency distribution for four functional cover types used by juvenile chinook salmon observed in the Klamath River between Iron Gate Dam and Scott River, spring 2000.



Cover type codes		
1. No cover	3. In-water overhead cover	5. Object and in-water overhead cover
2. Object cover	4. Out-of-water overhead cover	6. Object and out-of-water overhead cover

Figure 31. Frequency distribution for six functional cover types used by juvenile chinook salmon observed in the Klamath River between Iron Gate Dam and Scott River, spring 2000.



Code	Vegetation
1.	Filamentous algae
2.	Non-emergent rooted aquatic vegetation
3.	Emergent rooted aquatic vegetation
4.	Grass
5.	Sedges
6.	Cockle burrs
7.	Grape vines
8.	Willows
9.	Berry vines
10.	Trees (<4 inches dbh)
11.	Trees (>4 inches dbh)
12.	Root-wad
13.	Aggregates of small vegetation (<4 inches)
14.	Aggregates of large vegetation (>4 inches)
15.	Duff, leaf litter, organic debris
16.	Small woody debris (<0.3 x 12 ft)
17.	Large woody debris (>0.3 x 12 ft)

Code	Substrate
18.	Clay
19.	Sand or silt/sand (<0.1 inches)
20.	Coarse sand (0.1-0.2 inches)
21.	Small gravel (0.2-1.0 inches)
22.	Medium gravel (1-2 inches)
23.	Large gravel (2-3 inches)
24.	Very large gravel (3-4 inches)
25.	Small cobble (4-6 inches)
26.	Medium cobble (6-9 inches)
27.	Large cobble (9-12 inches)
28.	Small boulder (12-24 inches)
29.	Medium boulder (24-48 inches)
30.	Large boulder (>48 inches)
31.	Bedrock

Figure 32. Frequency distribution of nearest in-water escape cover for juvenile chinook salmon observed in the Klamath River between Iron Gate Dam and Scott River, spring 2000.

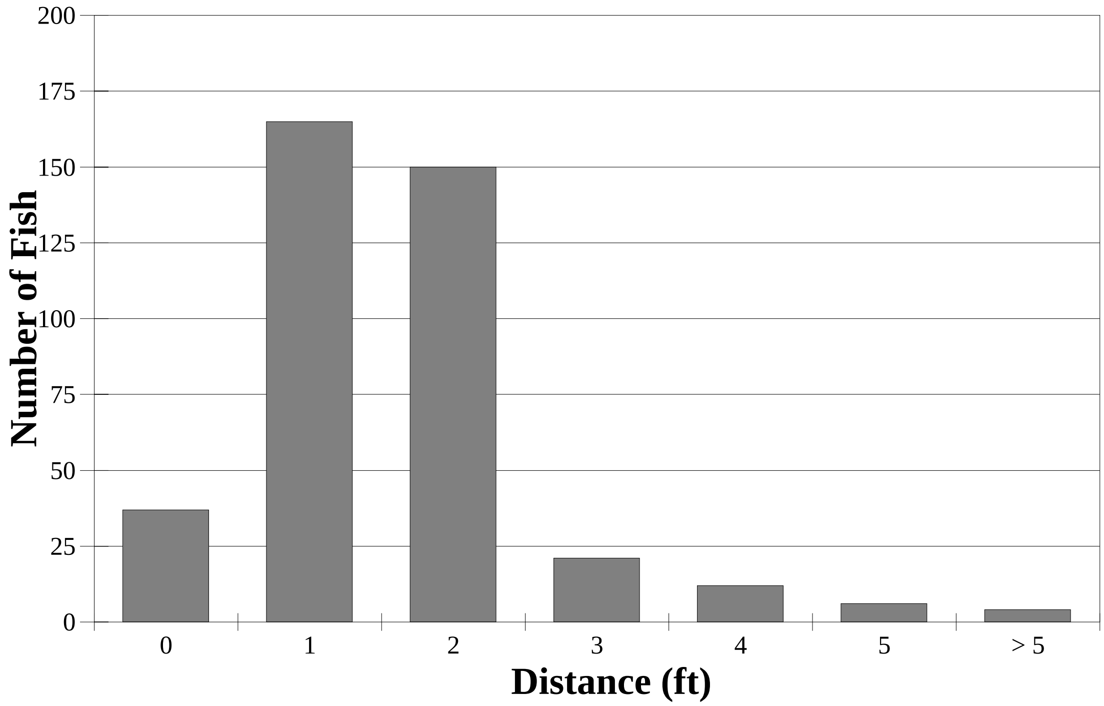


Figure 33. Frequency distribution of distance to in-water escape cover for juvenile chinook salmon observed in the Klamath River between Iron Gate Dam and Scott River, spring 2000.

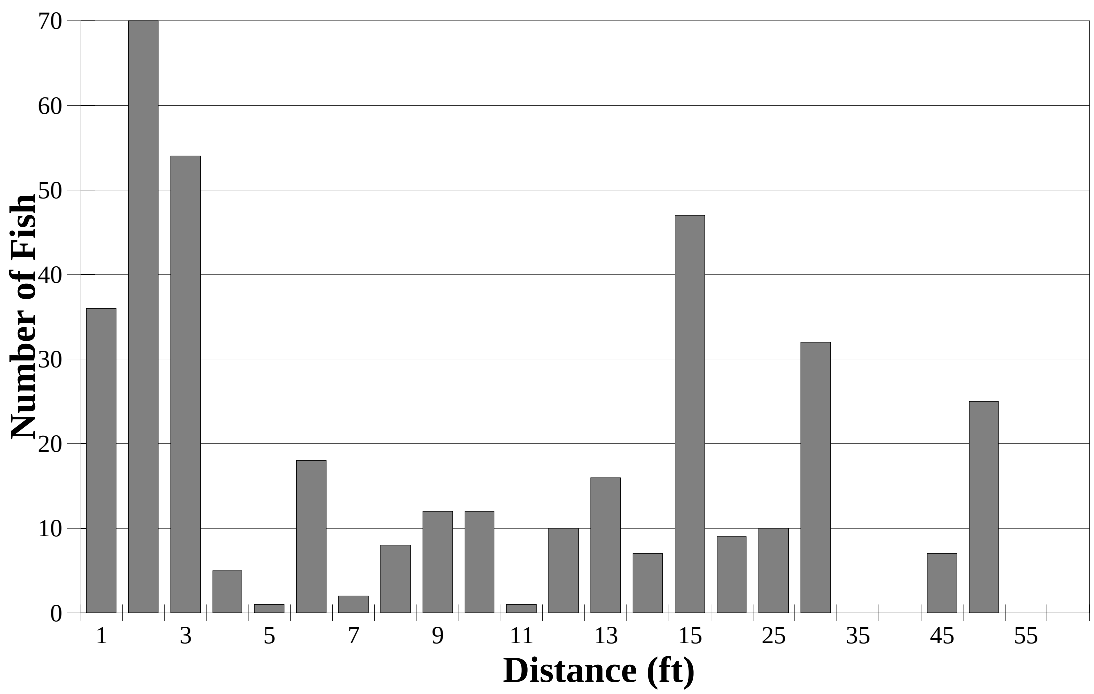


Figure 34. Frequency distribution of distance to a water velocity shear zone for juvenile chinook salmon observed in the Klamath River between Iron Gate Dam and Scott River, spring 2000.

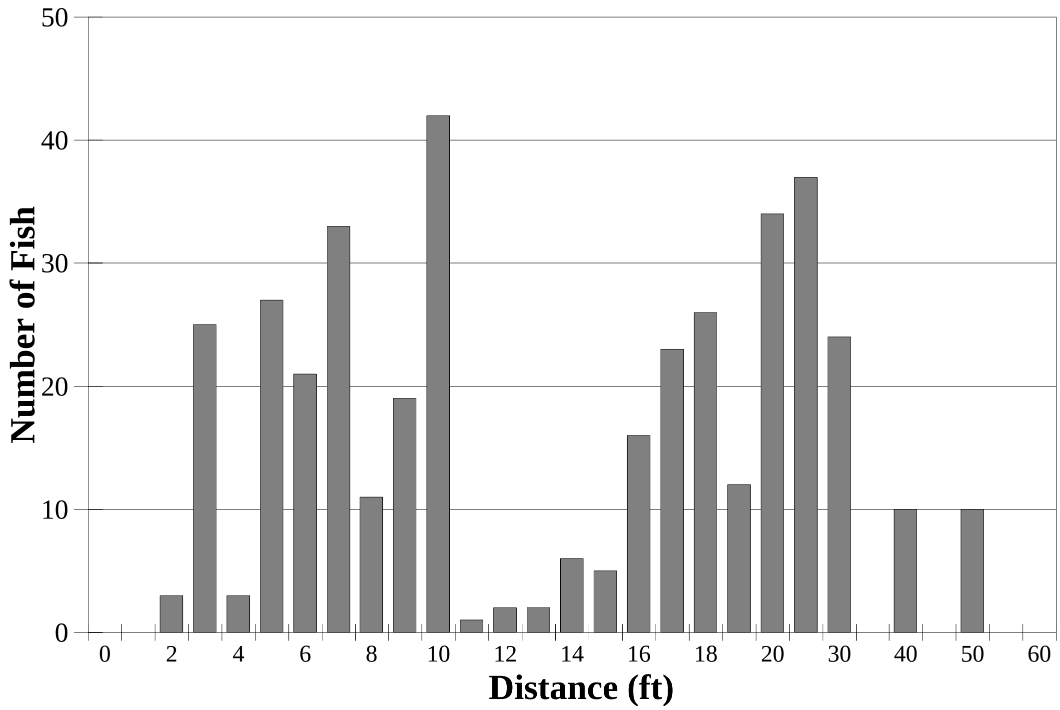


Figure 35. Frequency distribution of distance to water's edge for juvenile chinook salmon observed in the Klamath River between Iron Gate Dam and Scott River, spring 2000.

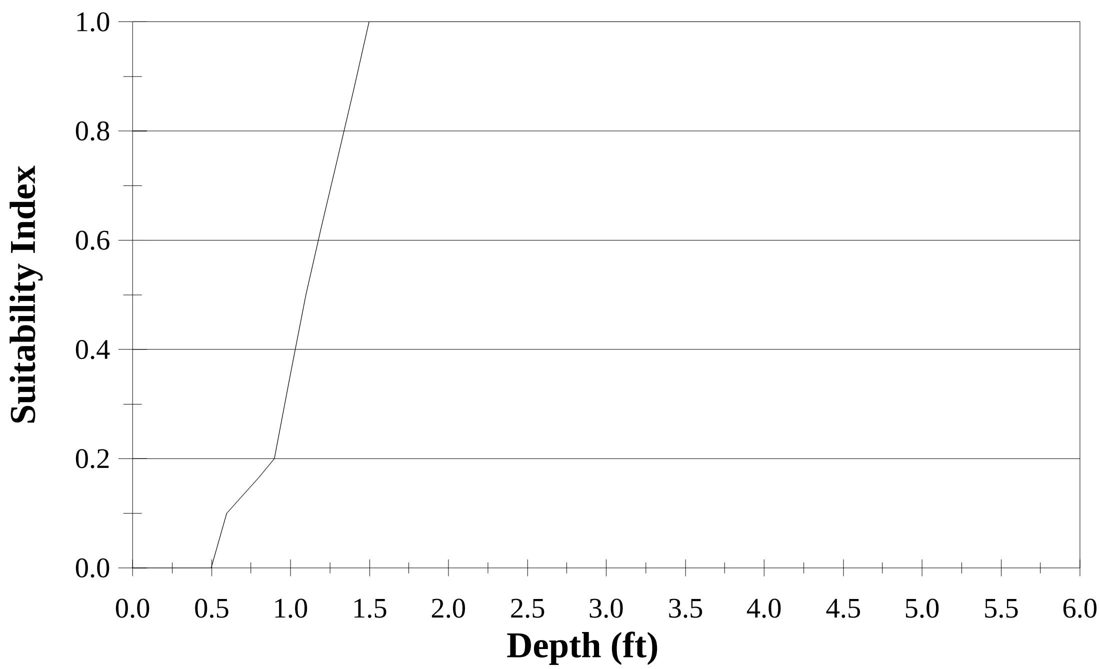


Figure 36. Total water depth habitat suitability criteria for spawning chinook salmon in the Klamath River between Iron Gate Dam and Scott River.

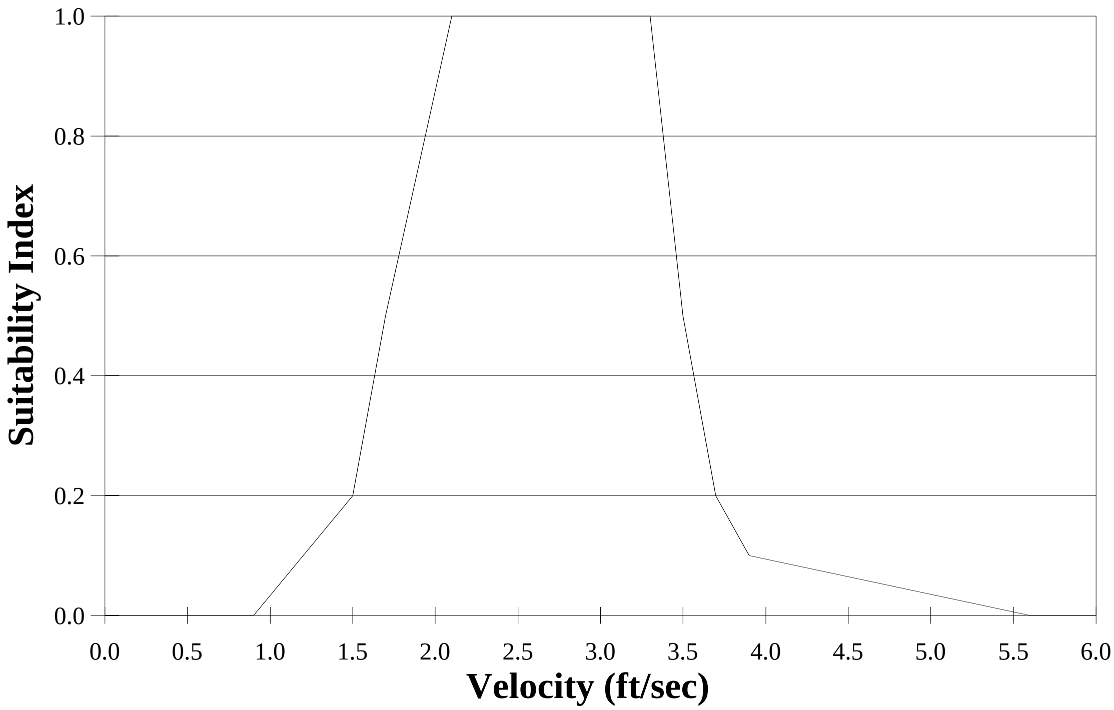


Figure 37. Average water velocity habitat suitability criteria for spawning chinook salmon in the Klamath River between Iron Gate Dam and Scott River.

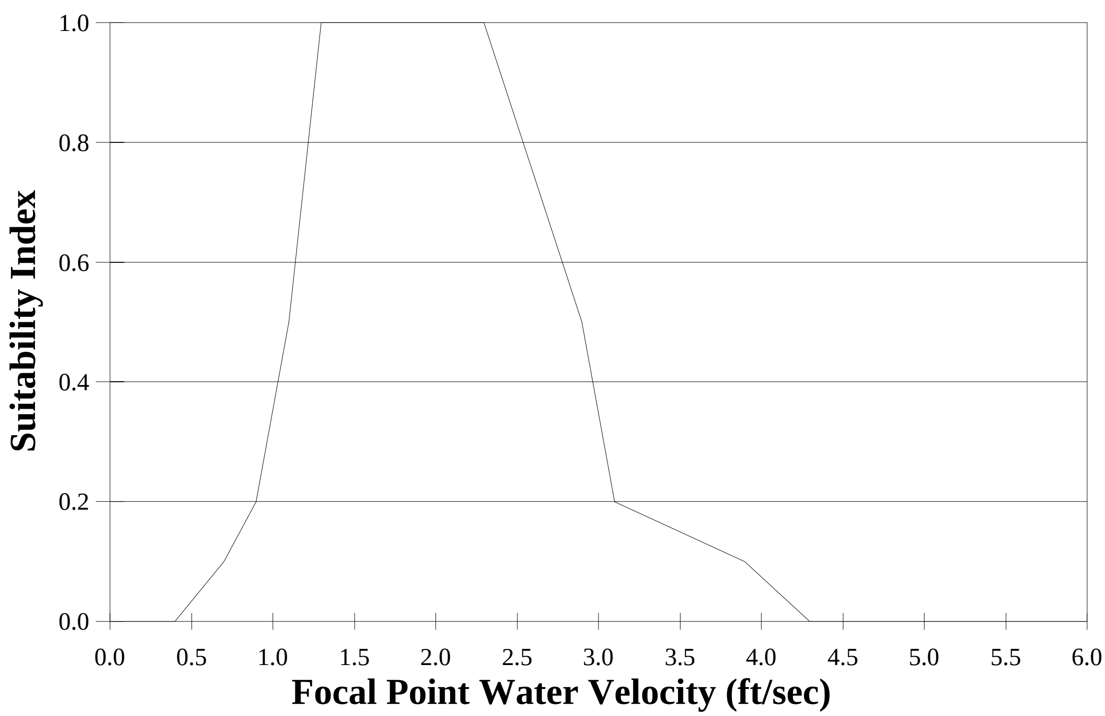


Figure 38. Fish focal point water velocity habitat suitability criteria for spawning chinook salmon in the Klamath River between Iron Gate Dam and Scott River.

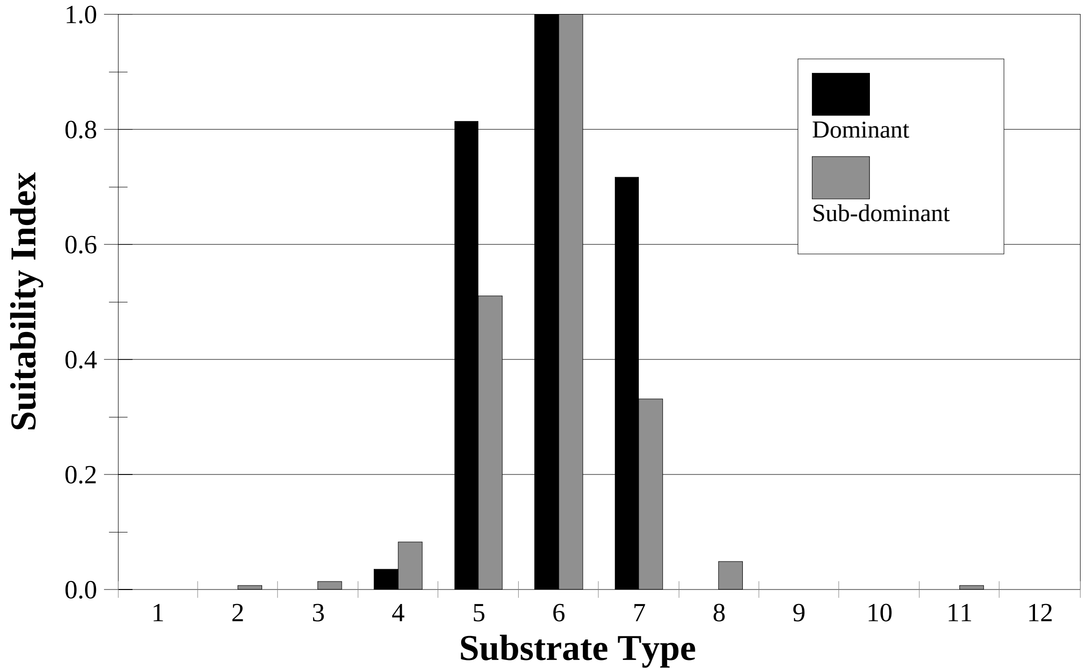


Figure 39. Dominant and sub-dominant substrate habitat suitability criteria for spawning chinook salmon in the Klamath River between Iron Gate Dam and Scott River

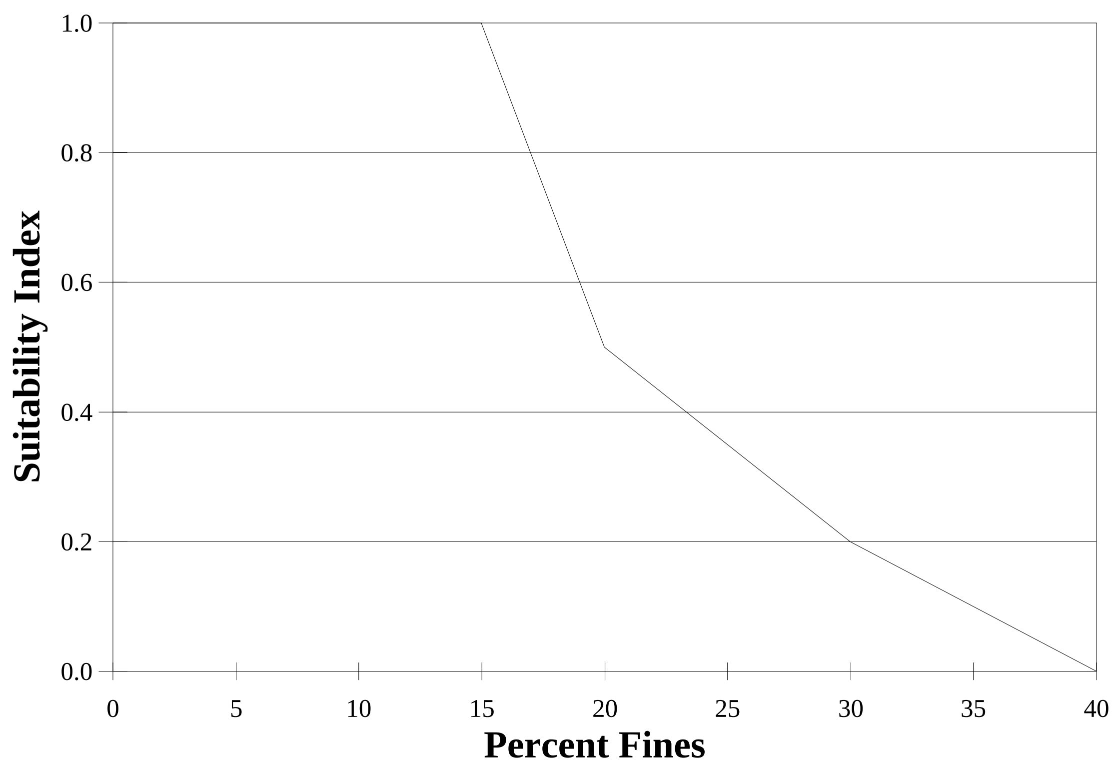


Figure 40. Habitat suitability criteria for percent fines in redds for spawning chinook salmon in the Klamath River between Iron Gate Dam and Scott River.

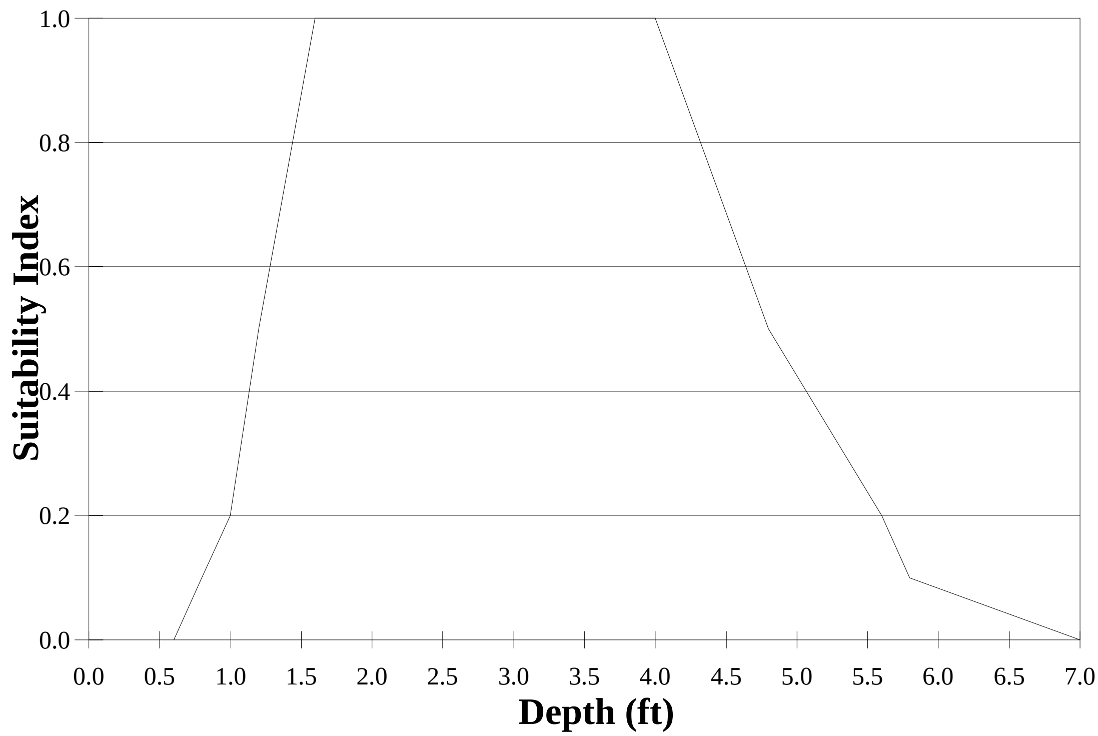


Figure 41. Total water depth habitat suitability criteria for juvenile chinook salmon in the Klamath River between Iron Gate Dam and Scott River.

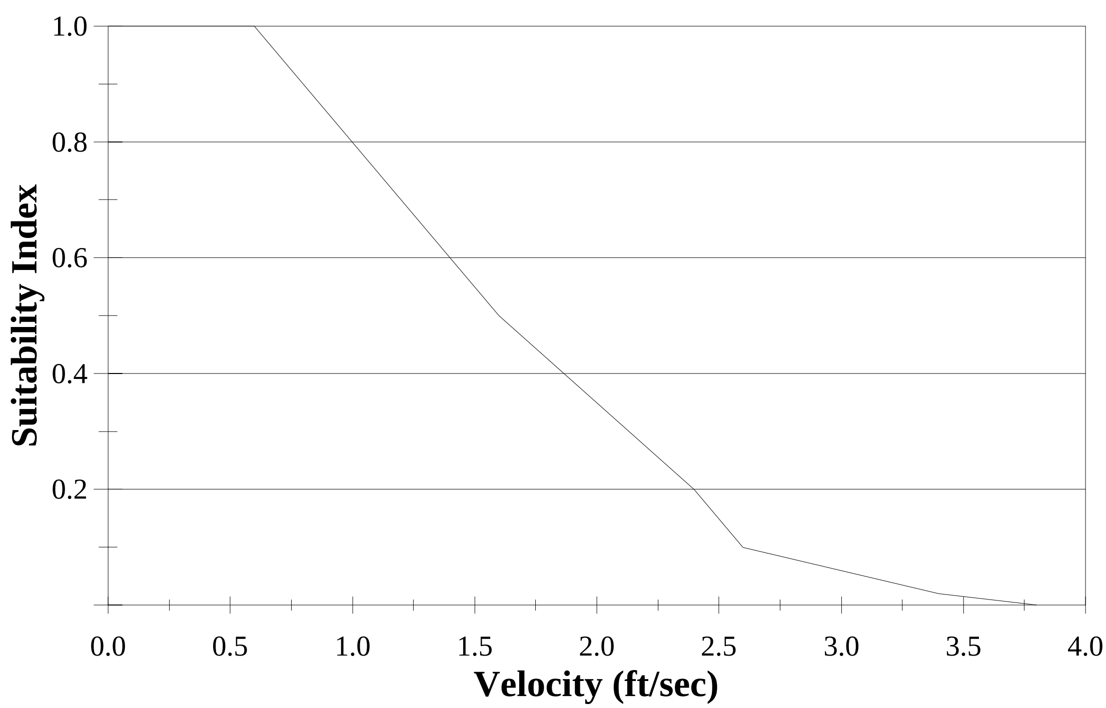


Figure 42. Average water velocity habitat suitability criteria for juvenile chinook salmon in the Klamath River between Iron Gate Dam and Scott River

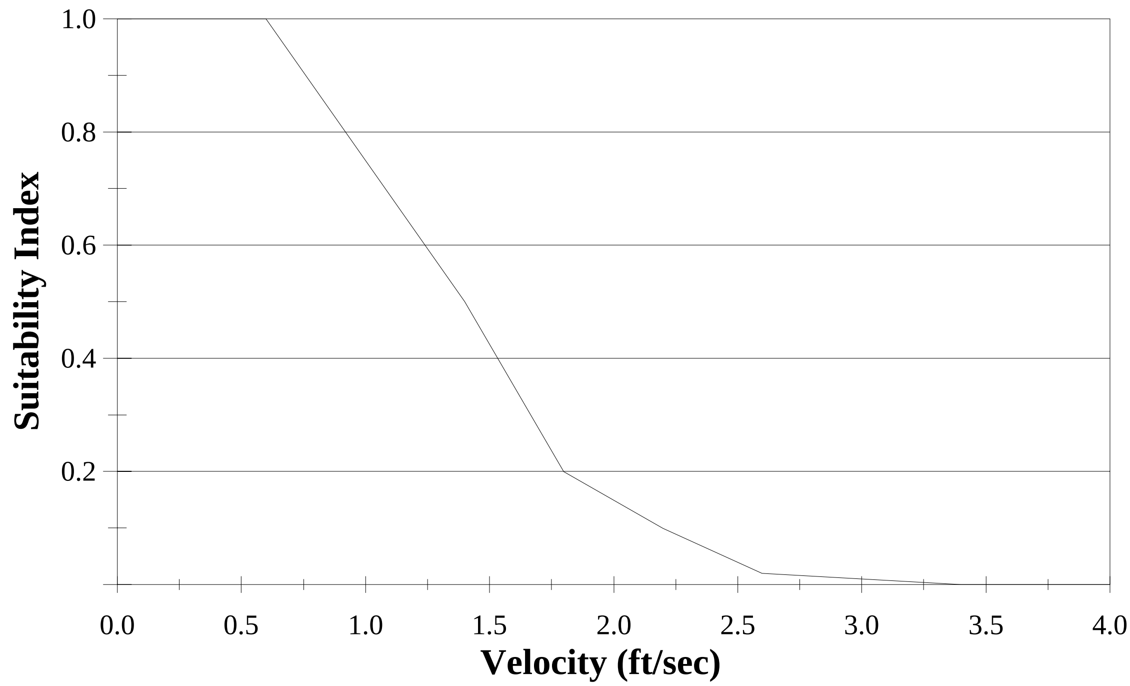
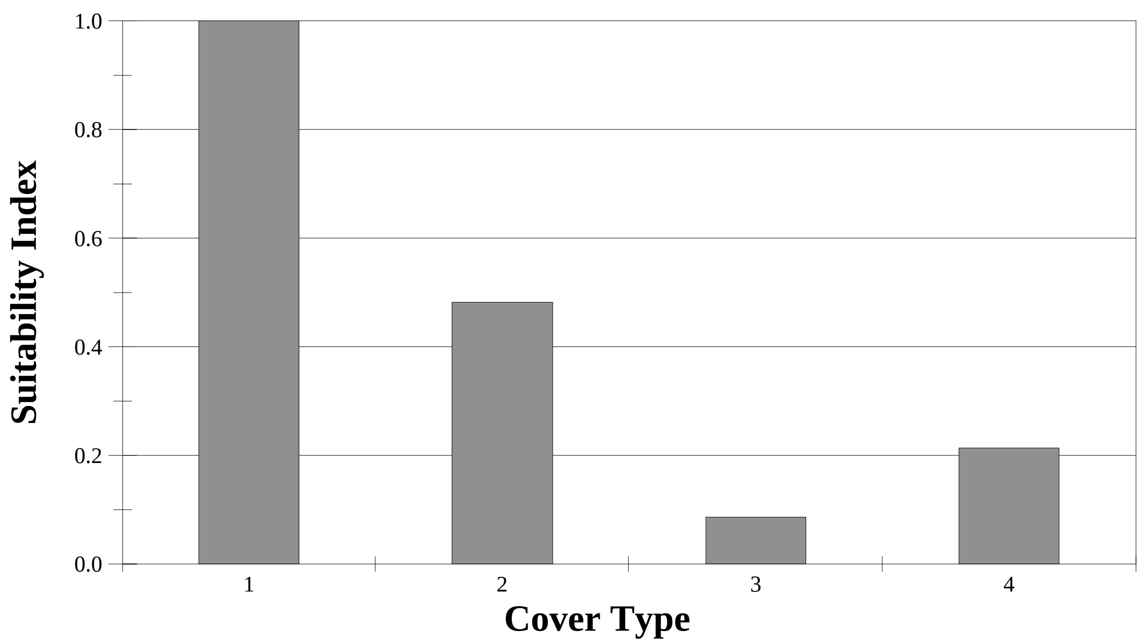
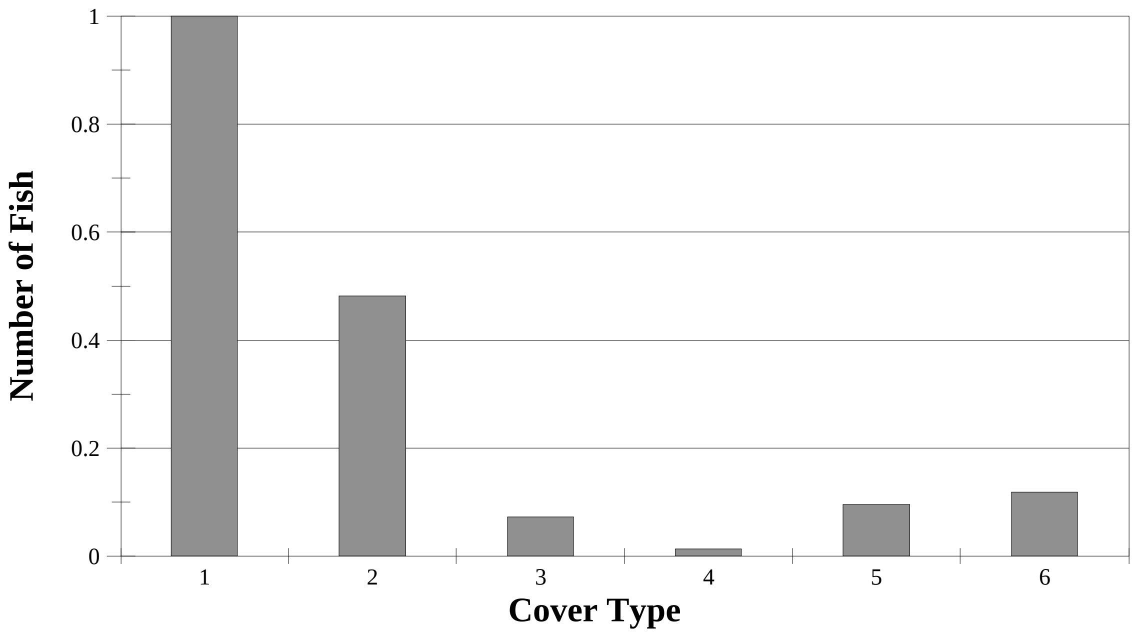


Figure 43. Fish focal point water velocity habitat suitability criteria for juvenile chinook salmon in the Klamath River between Iron Gate Dam and Scott River



Cover type codes	
1. No cover	3. Overhead cover
2. Object cover	4. Object and overhead cover

Figure 44. Habitat suitability for four functional cover types for juvenile chinook salmon in the Klamath River between Iron Gate Dam and Scott River.



Cover type codes		
1. No cover	3. In-water overhead cover	5. Object and in-water overhead
2. Object cover	4. Out-of-water overhead	6. Object and out-of-water cover

Figure 45. Habitat suitability for six functional cover types for juvenile chinook salmon in the Klamath River between Iron Gate Dam and Scott River.

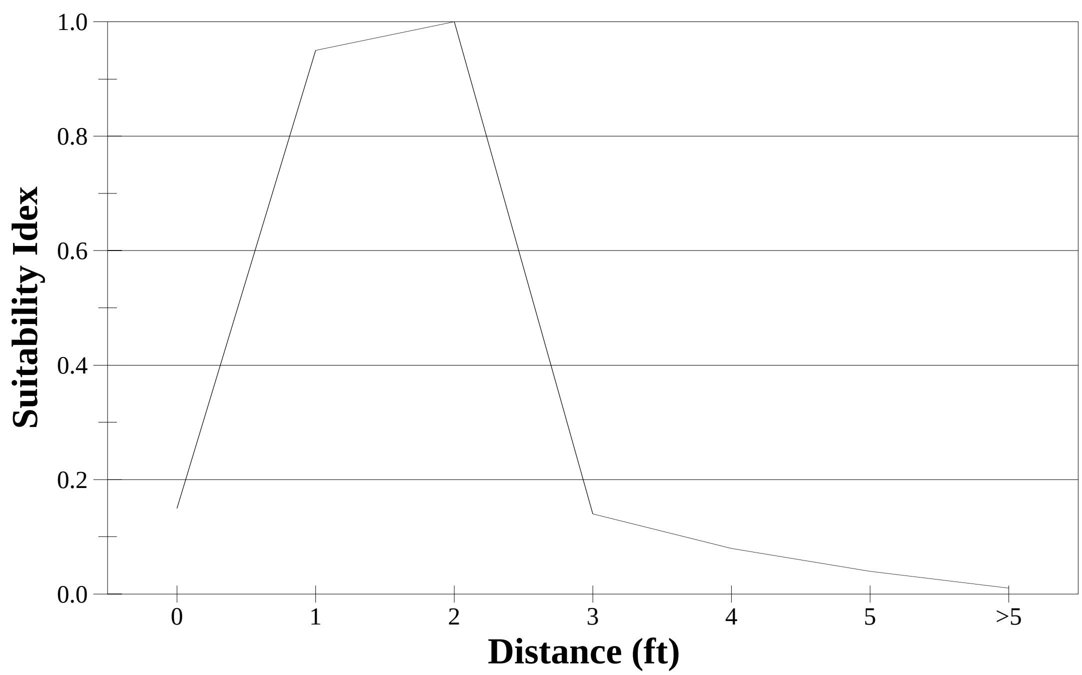
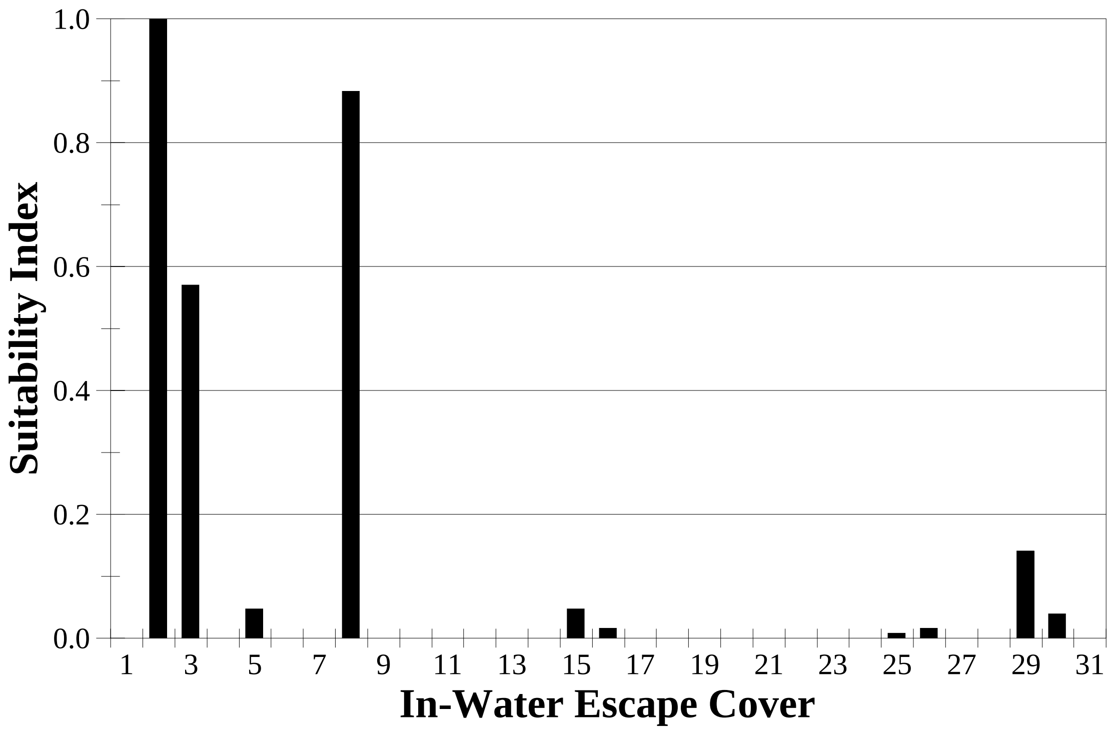


Figure 46. Habitat suitability criteria for distance to in-water escape cover for juvenile chinook salmon in the Klamath River between Iron Gate Dam and Scott River.



Code	Vegetation
1.	Filamentous algae
2.	Non-emergent rooted aquatic vegetation
3.	Emergent rooted aquatic vegetation
4.	Grass
5.	Sedges
6.	Cockle burrs
7.	Grape vines
8.	Willows
9.	Berry vines
10.	Trees (<4 inches dbh)
11.	Trees (>4 inches dbh)
12.	Root-wad
13.	Aggregates of small vegetation (<4 inches)
14.	Aggregates of large vegetation (>4 inches)
15.	Duff, leaf litter, organic debris

Code	Substrate
16.	Small woody debris (<0.3 x 12 ft)
17.	Large woody debris (>0.3 x 12 ft)
18.	Clay
19.	Sand or silt/sand (<0.1 inches)
20.	Coarse sand (0.1-0.2 inches)
21.	Small gravel (0.2-1.0 inches)
22.	Medium gravel (1-2 inches)
23.	Large gravel (2-3 inches)
24.	Very large gravel (3-4 inches)
25.	Small cobble (3-6 inches)
26.	Medium cobble (6-9 inches)
27.	Large cobble (9-12 inches)
28.	Small boulder (12-24 inches)
29.	Medium boulder (24-48 inches)
30.	Large boulder (>48 inches)
31.	Bedrock

Figure 47. Habitat suitability criteria for specific components of in-water escape cover for juvenile chinook salmon in the Klamath River between Iron Gate Dam and Scott River.

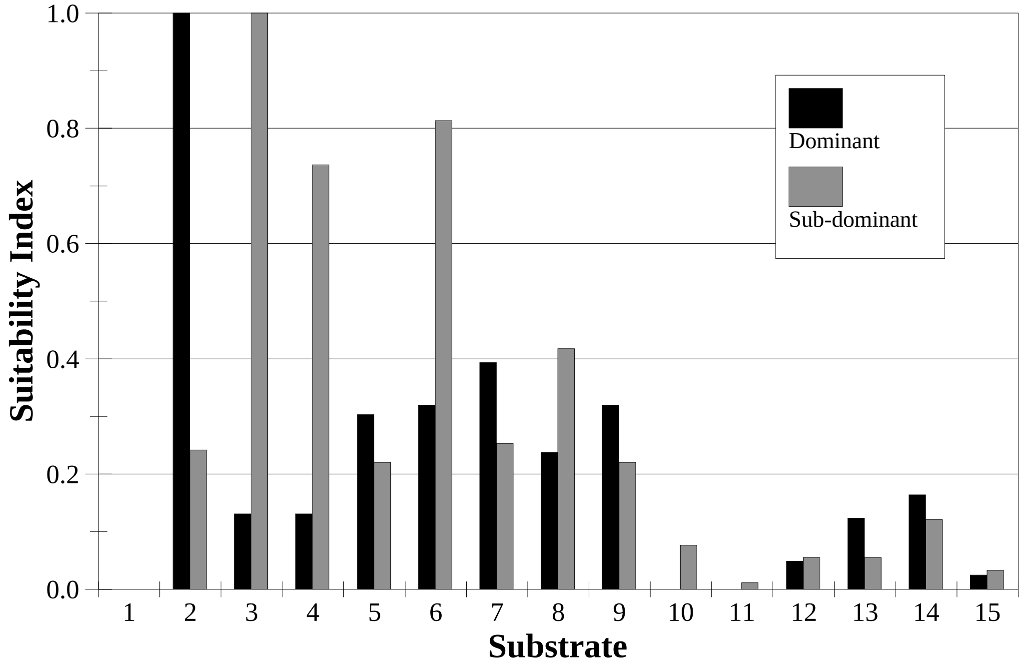


Figure 48. Dominant and sub-dominant substrate habitat suitability criteria for juvenile chinook salmon in the Klamath River between Iron Gate Dam and Scott River.

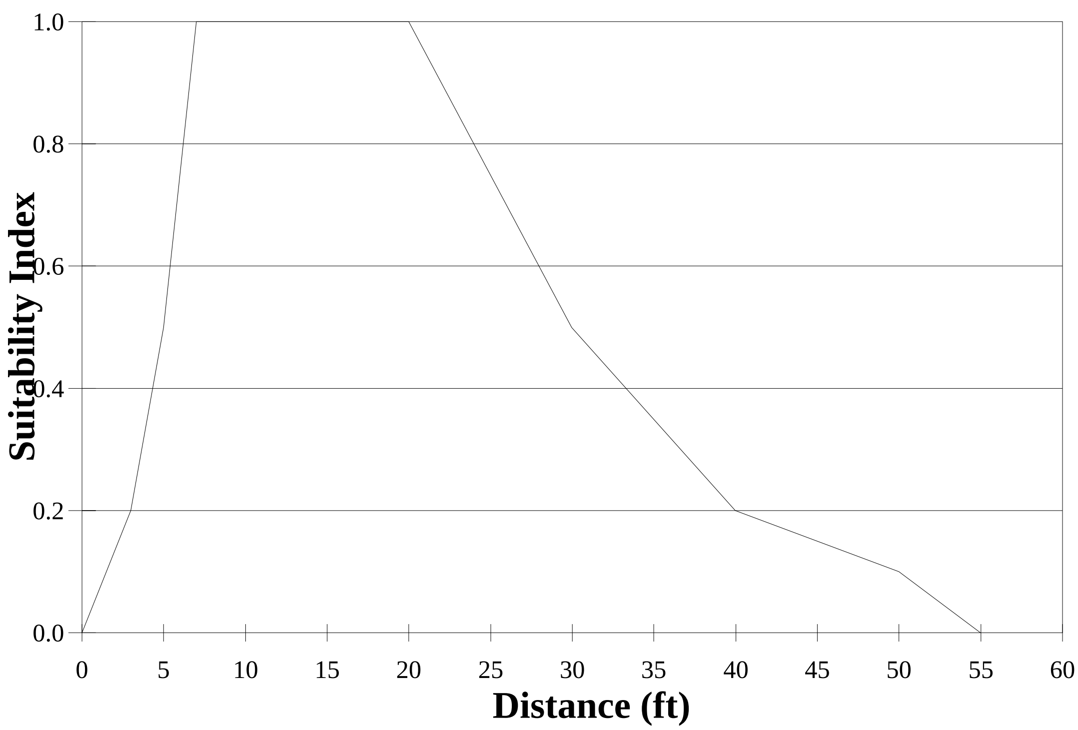


Figure 49. Distance to water's edge habitat suitability criteria for juvenile chinook salmon in the Klamath River between Iron Gate Dam and Scott River.

DISCUSSION AND CONCLUSIONS

SPAWNING CHINOOK SALMON

Chinook salmon site selection for redd construction was related to water depth, water velocity, and substrate conditions. Few chinook were observed spawning in water less than 0.5 ft deep. Once depth became usable, however, suitability rapidly increased to 1.00. Similarly, virtually no chinook salmon were observed spawning in average water velocities less than 0.8 ft/sec. Beyond 0.8 ft/sec, average water velocity suitability rapidly increased to 1.00. Water velocity suitability rapidly decreased to zero at velocities faster than about 3.2 ft/sec. Fish focal point water velocities as low as 0.2 ft/sec occurred at redds observed. However, the vast majority of the redds observed had fish focal point water velocities of at least 0.8 ft/sec. As with average water velocity, few redds exhibit focal point velocities faster than about 3.2 ft/sec. The dominant substrate in all redds observed ranged from small gravels (0.2-1.0 inches) to small cobble (4.0-6.0 inches).

We compared the Klamath River spawning chinook salmon water depth and velocity HSC to spawning chinook HSC from four other investigations (Beak Consultants 1985; Hardin-Davis, Incorporated et al. 1990; Raleigh et al. 1986; Washington Department of Fisheries 1990). The ascending limb of the Klamath River spawning chinook HSC indicates Klamath River chinook salmon have a higher minimum water depth threshold for spawning than do most chinook salmon literature criteria (Figure 50). The Klamath River depth suitability curve begins its rapid ascent to the 1.00 suitability at about the depth range at which Beak Consultants (1985), Hardin-Davis, Incorporated et al. (1990), and Washington Department of Fisheries (1990) curves begin their descents. We were unable to make meaningful comparisons for greater depths.

It is likely water depth alone does not preclude chinook salmon spawning, and, therefore, we prepared an open-ended (i.e., suitability is maintained at 1.0 once that value is attained) suitability curve for water depths to at least 6 ft. Others (e.g., Bovee 1978; Raleigh et al. 1986; Smith and Aceituno 1986) have prepared similar open-ended HSC for spawning salmonids. The rationale behind this assumption is that once suitable depth (i.e., an HSC of 1.0) is attained, water velocity and substrate are more influential in redd site selection. We expended considerable effort during searching for redds in deep water areas with suitable water velocities and substrates. Unfortunately, at the flows we were able to attain for sampling, such areas between Iron Gate Dam and Scott River were limited. Therefore, it is unclear from this investigation how far spawning depth HSC should be maintained at 1.0 beyond 6 ft deep. Water depth may become less suitable at greater depths (e.g., 15-20 ft), but this threshold was not defined. Consequently, care should be taken evaluating spawning habitat for depths and flows substantially greater than those sampled.

The average water velocity suitability for Klamath River spawning chinook salmon is 1.0 from 2.1 to 3.3 ft/sec. The range of water depths with suitability >0.5 was 1.7 to 3.5 ft/sec. When compared with Beak Consultants (1985), Hardin-Davis, Incorporated et al. (1990), Raleigh et al. (1986), and Washington Department of Fisheries (1990) HSC, Klamath River chinook salmon appear to be selecting slightly higher minimum velocities, but similar maximum velocities (Figure 51). The Klamath River's 1.0 suitability range falls within the 1.0 ranges of the other four investigations.

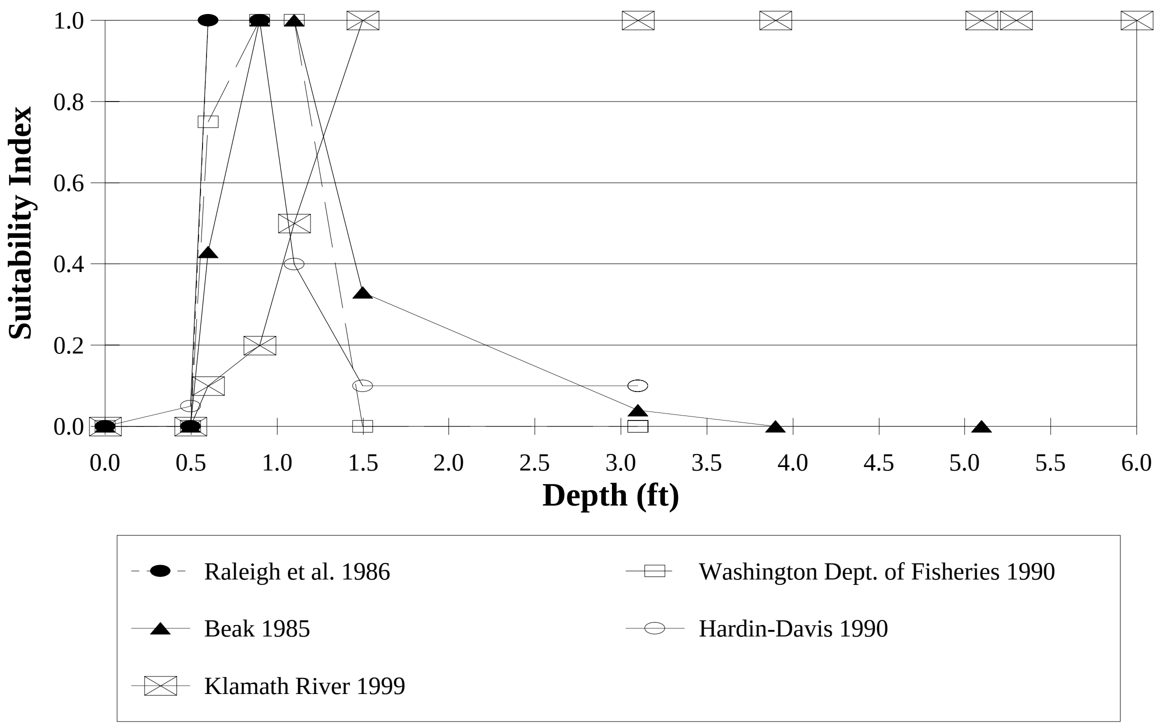


Figure 50. Comparison of Klamath River, Iron Gate Dam to Scott River, spawning chinook salmon total water depth habitat suitability criteria and criteria from four other investigations.

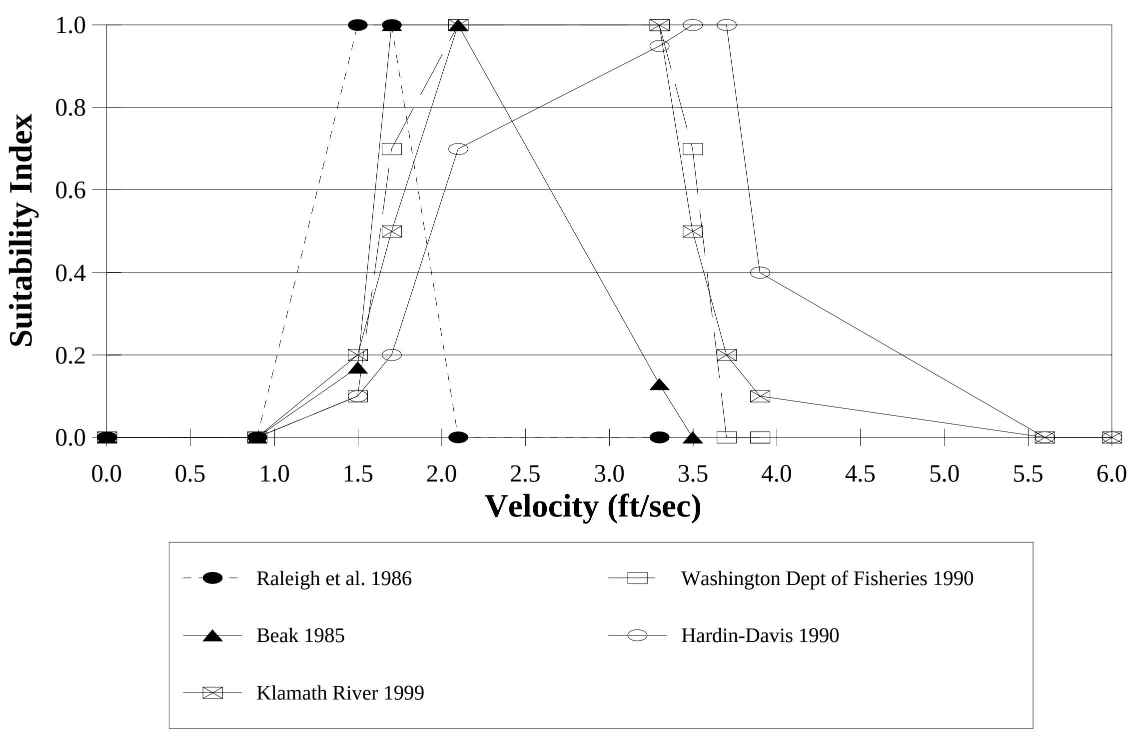


Figure 51. Comparison of Klamath River, Iron Gate Dam to Scott River, spawning chinook salmon average water velocity habitat suitability criteria and criteria from four other investigations.

The fish focal point water velocity HSC for spawning Klamath River chinook salmon peaks at velocities from 1.3 to 2.3 ft/sec. HSC from the literature are not available for comparison to this parameter. Our fish focal velocity HSC would be useful in investigations within our study area if additional velocities, at this specific depth, (0.4 ft from the bottom) were measured or predicted in PHABSIM. These HSC could also be useful in investigations outside the study area, providing appropriate steps are taken to validate their transferability and use.

Overall, the water depth and velocity HSC developed during our investigation indicate Klamath River spawning chinook salmon use deeper water, but similar average water velocities compared to that of chinook salmon in other systems. Thus, use of our site-specific criteria in Klamath River studies would be expected to yield somewhat different results with the PHABSIM model than when literature-based criteria were used. The resultant differences would be dependent upon each river's hydraulic and physical characteristics.

Large gravel (2.0-3.0 inches) was the most suitable substrate (an HSC of 1.0) for spawning chinook salmon. Medium gravel (1.0-2.0 inches) and small cobble (3.0-6.0 inches) had suitabilities of 0.8 and 0.72, respectively. Small gravel had a very low suitability (0.04). No other substrate components were used as dominant spawning substrate. Other than the dominant substrates used, few other substrate elements were used as subdominant components.

Redd site selection also appeared to be related to the distance to water's edge. Chinook salmon redds were absent immediately next to the bank, probably because that area would be less likely to have adequate depths and velocities, and because fish that built redds here might be more subject to predation. Redds also were scarce in the middle of the channel, perhaps due to inadequate water or substrate conditions, and/or to a greater potential for mid-channel scouring. Few redds were more than 50 ft from the river's margin. This may be because higher velocities (especially as flows increase) and larger substrates typically occur with increasing distances from the bank. Our data did not show a significant relationship between average water velocity at redds versus distance from water's edge ($r^2 = 0.03$). Similar information is not available in the literature, and, therefore, we were unable to make comparisons with chinook salmon spawning in other systems.

FRY CHINOOK SALMON

Our comparison and evaluation of fry chinook salmon direct underwater observations versus electrofishing observations verified the usefulness of electrofishing methods developed by the USFWS to sample fry chinook and their microhabitat. Habitat use information collected by the two methods, overall, was not significantly different.

Our deep-water fry search verified that fry chinook salmon are concentrated primarily along river margins. Thus, electrofishing as implemented in the manner employed by the USFWS appears to be an adequate surrogate for direct underwater observation techniques to develop HSC for fry chinook salmon in the Klamath River. Any deviation from the electrofishing techniques evaluated during our investigation would require independent evaluation and verification before such techniques could be relied upon to develop unbiased and reliable HSC.

JUVENILE CHINOOK SALMON

In addition to hydraulic microhabitat conditions (i.e., water depth and velocity), juvenile chinook salmon site selection is influenced by such factors as SMET, functional cover, proximity and type of in-water escape cover, and distance to water's edge. If a juvenile chinook salmon PHABSIM investigation is conducted within this study area, these factors should be incorporated into the calculations of weighted usable area.

Use of specific SMET by juvenile chinook in the Klamath River demonstrates edge types with young aquatic and/or inundated riparian vegetation are important habitats. Open areas also are used by many fish. Comparatively few juvenile chinook were observed using areas with large, mature trees and emergent vegetation (SMET 2) or large substrate/riprap (SMET 8), suggesting these SMETs are less important to young chinook than other SMETS. The low use of SMET 2 is particularly notable, given the high use of emergent vegetation alone (SMET 4). Areas with trees and large riprap with vegetation were not sampled. It is likely, however, that these areas also would not be as important to this life stage as other SMETs, given the low use of the combination of trees with emergent, and of large substrate/riprap.

The high abundance of juvenile chinook salmon in SMETs 3, 4, 6, and 7 (dense young willow, woody debris, and blackberry; emergent shrubs; and sparse and dense herbaceous vegetation) is similar to USFWS' observations of fry (i.e., fish less than 2.2 inches) in the Klamath river between Iron Gate Dam and Scott River. Large numbers of fry frequent these SMETs (Mr. Thomas Shaw, USFWS, Arcata, California, personal communication). The use of open areas (SMET 5) by juvenile chinook is in contrast to use of this SMET by fry chinook. Relatively few fry have been observed in this SMET (Mr. Thomas Shaw, USFWS, Arcata, California, personal communication).

Regardless of whether the four or six functional cover types are considered, microhabitat positions with no functional cover (i.e., no water velocity shelter and/or no overhead cover) specifically affecting the location, but with water depths ranging from about 1.5 to about 4.5 ft and average water velocities less than about 2 ft/s, appear to be most suitable for juvenile chinook salmon. Positions with such water depths and velocity shelters within faster velocity areas are also important conditions. Few observations were made of juveniles actively using in- or out-of-water overhead cover (alone or in tandem with velocity shelter), indicating this cover type may be of lower significance to a fish's "routine" activities.

Juvenile chinook observed during this investigation demonstrated a decided preference for being near in-water escape cover. Of the 392 juvenile chinook observations, 354 were using, or relatively near in-water escape cover. Escape cover was not sufficiently near to 38 observation to be considered present. These observations yield in-water and no in-water escape cover suitabilities of 1.00 and 0.11, respectively. Nearly 90% of the 354 fish observed near in-water escape cover were within 2 ft of this cover type. Juvenile chinook also appear to prefer to be near, rather actually within or under, escape cover, as only about 9% of the fish were actually actively using escape cover. On the other hand, only six of the 354 observations were farther than 5 ft from escape cover. It is likely this latter point is influenced by the river's channel types and abundance of in-water cover within the study, but the fact that many fish were observed in open water areas (SMET 5), and the association of these fish with in-water escape cover serves to confirm the importance of this cover type to juvenile chinook.

In addition to demonstrating a preference to being near, rather than within, in-water escape cover, juvenile chinook also demonstrated a decided selection of vegetative over hard substrate escape cover components. Of the 354 fish observed associated with in-water escape cover, vegetative in-water cover was the nearest cover for 326 fish, whereas 26 fish were near various hard substrate escape cover components. The respective HSC are 1.00 and 0.08.

As with general vegetative versus hard substrate escape cover, juvenile chinook also demonstrated a selection of specific escape cover components. The vast majority of the of the juveniles observed were in the proximity of non-emergent rooted aquatic plants, young willows, and emergent rooted aquatic vegetation (HSC = 1.00, 0.88, and 0.57, respectively. Other vegetative in-water cover components' HSC range from 0.0 to about 0.10. Hard substrates elements seldom were the nearest in-water escape cover component. Medium boulders (24- 48 inches; HSC = 0.14) were the most commonly occurring hard substrate. HSC for other hard substrate components range from 0.00 to about 0.05.

The Klamath River juvenile chinook salmon HSC were compared with juvenile fall chinook criteria presented in Hampton (1988), Jackson (low and high flow) (1992), and USFWS (1985) (Figures 52-53). Water depth comparisons indicate that, although there is some overlap, Klamath River juvenile chinook salmon typically use deeper water than this species life stage uses in other systems. Juvenile chinook salmon in the lower American River under high flow conditions is an exception. For average water velocity, the Klamath HSC peak extends to about the middle of the range of literature criteria. Juvenile chinook in the lower American River under high flow conditions however, tend to use higher water velocities. Our results were similar for average water velocity versus fish focal point water velocity. This suggest the observed fish were often at the point in the water column near the average water velocity. This is supported by Figure 26, which shows that many fish were found near the middle of the water column.

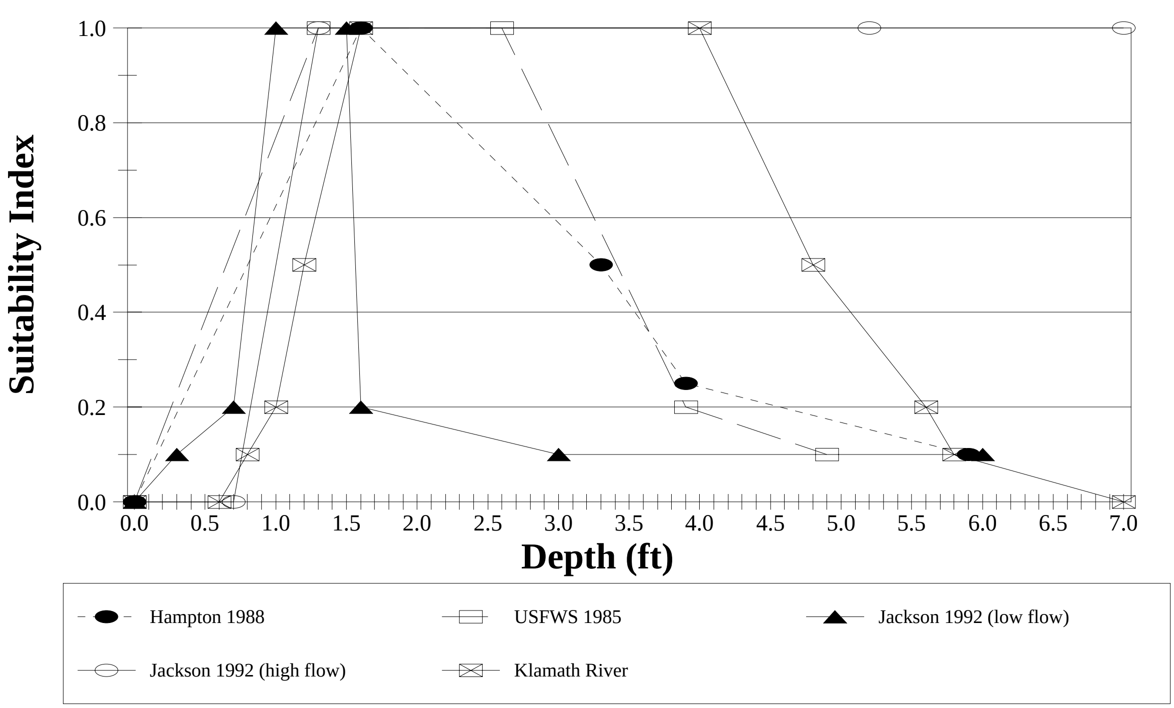


Figure 52. Comparison of Klamath River, Iron Gate Dam to Scott River, juvenile chinook salmon total water depth habitat suitability criteria and criteria from four other investigations

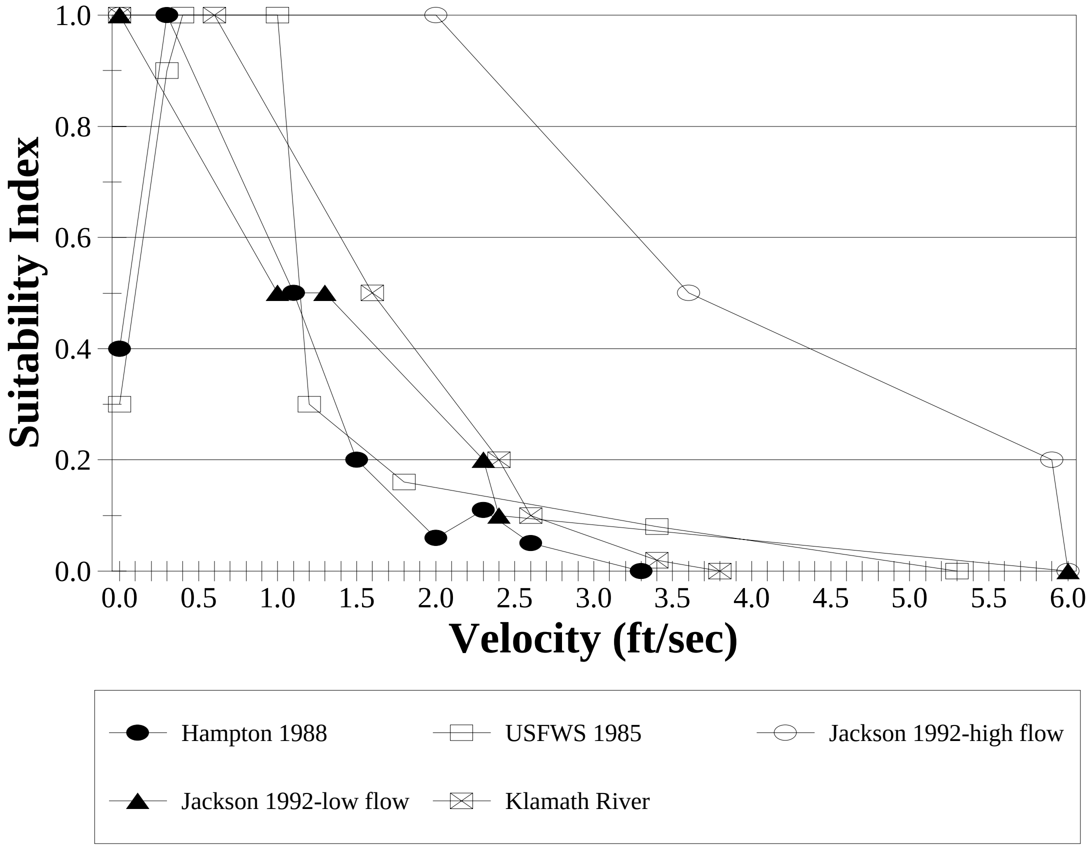


Figure 53. Comparison of Klamath River, Iron Gate Dam to Scott River, juvenile chinook salmon average water velocity habitat suitability criteria and criteria from four other investigations

ACKNOWLEDGMENTS

Many people contributed to the success of this project. The authors especially thank Tom Shaw, John Hamilton, Laurie Simons, and Gary Curtis (USFWS), Sam Williamson (USGS), and Mike Belchik (Yurok Tribe) for their many contributions. The field assistants, who performed admirably in challenging circumstances, include Nels Brownell, Michael Reber, and Karl Hartzell. Additional information, support, and assistance were provided by Mark Pisano and Mike Rode (CDFG), Mark Magneson, Charles Chamberlain, and Dennis Therry (USFWS), Jim Henriksen (USGS), and Linda Prendergast (PacifiCorp). Dave Calley provided valuable assistance with data analysis and report preparation.

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- Appendices -

Appendix A-1. Klamath River average monthly impaired flows at Iron Gate Dam, 1960-2000. Data recorded at U.S. Geological Survey Gage No. 11516530.

Month	Average monthly	Month	Average monthly	Month	Average monthly
Jan	3,087	May	2,181	Sep	1,299
Feb	3,234	Jun	1,141	Oct	1,640
Mar	3,733	Jul	791	Nov	2,114
Apr	3,111	Aug	893	Dec	2,738

Appendix A-2. Klamath River flow at Iron Gate Dam during anadromous salmonid habitat suitability criteria field observations, 1999-2000. Data recorded at U.S. Geological Survey Gage No. 11516530.

1999	Flow (cfs)	2000	Flow (cfs)	2000	Flow (cfs)
Oct 18-24	1,380	Apr 11	2,220	May 2	2,560
Oct 25-26	1,390	Apr 12	2,230	May 3-4	2,580
Nov 2-3	1,820	Apr 13	2,280	May 8	3,000
Nov 3-4	1,830	Apr 14	2,300	May 9	2,950
Nov 7-8	1,830	Apr 18	2,580	May 10	2,940
		Apr 19	2,500	May 11	3,020
		Apr 20	2,380	May 12	2,990
		Apr 25	3,770	Oct 30-31	1,330
		Apr 26	3,190	Nov 1-2	1,330
				Nov 3	1,340

Appendix A-3. Shasta River flow at Yreka, California, during Klamath River anadromous salmonid habitat suitability criteria field observations, 1999-2000.

1999	Flow (cfs)	1999	Flow (cfs)	2000	Flow (cfs)	2000	Flow (cfs)
Oct 18	134	Nov 2	182	Apr 11	108	May 2	165
Oct 19	136	Nov 3	190	Apr 12	98	May 3	183
Oct 20	142	Nov 4	194	Apr 13	184	May 4	175
Oct 21	156	Nov 7	183	Apr 14	258	May 8	173
Oct 22	159	Nov 8	188	Apr 18	309	May 9	174
Oct 23	166			Apr 19	394	May 10	154
Oct 24	159			Apr 20	347	May 11	144
Oct 28	158			Apr 25	200	May 12	151
Oct 26	152			Apr 26	183		

Appendix 4-A. Klamath River, California, stream margin edge types (SMET) examined for use by juvenile chinook salmon during the Iron Gate Dam to Scott River habitat suitability criteria investigation, 1999-2000.

Figure A-1. Klamath River SMET type 2 - trees and emergent vegetation.

Figure A-2. Klamath River SMET type 3 - dense aggregates of plant material.

Figure A-3. Klamath River SMET type 4 - emergent shrubs.

Figure A-4. Klamath River SMET type 5 - open areas.

Appendix 4-A (Continued). Klamath River, California, stream margin edge types (SMET) examined for use by juvenile chinook salmon during the Iron Gate Dam to Scott River habitat suitability criteria investigation, 1999-2000.

Figure A-5. Klamath River SMET type 6 - sparse herbaceous vegetation.

Figure A-6. Klamath River SMET type 7 - dense herbaceous vegetation.

Figure A-7. Klamath River SMET type 8 - large substrate or rip-rap.

Figure A-8. Klamath River SMET type 7 - dense herbaceous vegetation; and 10 - eddy.

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