State of California
The Resources Agency
Department of Water Resources

SP F-10 3A FINAL REPORT DISTRIBUTION AND HABITAT USE OF JUVENILE STEELHEAD AND OTHER FISHES OF THE LOWER FEATHER RIVER

Oroville Facilities Relicensing
FERC Project No. 2100

APRIL 2004

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REPORT SUMMARY

From 1999 to 2003, DWR conducted an intensive steelhead study in the Feather River below Oroville Dam. Investigations sought to describe characteristics of the wild steelhead population and identify factors potentially limiting steelhead success in the lower Feather River. Habitat, water temperature, flow conditions, predation, and food availability were all considered potentially important factors. To address these topics we applied multi-scale snorkeling surveys and seining. Results show that most steelhead spawning and early rearing occurs at the upstream end of the low flow channel (LFC), near the Feather River Hatchery. In-river spawning by hatchery steelhead in the vicinity of the Feather River Hatchery may explain this skewed distribution. Over time juvenile steelhead disperse to suitable habitats throughout the LFC, especially cover-rich side channels. Steelhead rearing in the downstream portion of the LFC appeared to grow faster, and were generally larger than fish further upstream. The abundance of steelhead less than 100 mm declined throughout the summer in each survey year. This may reflect the tendency of young-of-the-year steelhead to rapidly grow over 100 mm while rearing in the downstream portion of the LFC. However, larger juvenile steelhead (putative age-1+) or resident rainbow trout were relatively rare, suggesting few steelhead remain in the Feather River through their first year. Since LFC water temperatures and flow conditions appear suitable for steelhead, the apparently low production of juveniles suggests other limiting factors. For example, suitable mesohabitats, such as cover rich side channels, shallow channel margins and mid-channel bars seem to provide the best rearing habitat yet these habitats are currently relatively rare in the lower Feather River.

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1.0 INTRODUCTION

The rivers of California's Central Valley have been extensively dammed and modified to provide water storage, flood control and power generation (Mount 1995). Nearly all major, west slope tributaries are presently impounded by large dams located along the transition between the Central Valley and upland, foothill regions. The resulting alteration in flow regime, water temperature, and geomorphic process (Ward and Stanford 1983, Ligon et al. 1995) has had a large impact on downstream fish communities (Brown 2000, Brown and Ford 2002, Moyle 2002). Anadromous salmonids have been most severely affected. Chinook salmon *Oncorhynchus tshawytscha* and steelhead *Oncorhynchus mykiss*, which historically ranged far into watersheds of the Sierra Nevada (Yoshiyama et al. 1996), are now forced to complete their life history in habitat remaining below dams.

Despite these negative impacts, dams provide a potentially powerful tool for enhancing remaining stream ecosystems and fish communities. River flows and temperatures, for example, can be manipulated to create conditions more suitable for salmonid spawning and rearing. However, effective management of dam operations and implementation of any associated restoration activities requires a thorough understanding of how river conditions and habitats affect the distribution, abundance and behavior of downstream fish communities. Salmon have typically been the focus of such studies. However, this emphasis on salmon may be misplaced, since their freshwater life history phase is brief relative to steelhead, which spend several years in freshwater prior to migrating seaward (McEwan 1999). This extended residence means that habitat requirements for steelhead (e.g., river flows and temperatures) are more difficult to meet, particularly in summer months.

In California, relatively little effort has been devoted to the study of wild steelhead populations. Shapovalov and Taft's (1954) treatise on Waddell Creek is undoubtedly the most complete source of information, but since this study took place on a small, unregulated coastal river, it does not apply well to Central Valley rivers. Historic (1940-1960) adult steelhead harvest, migration timing and age composition make up the bulk of available information for Central Valley rivers (reviewed by McEwan 1999). Although largely unpublished, widespread rotary screw trap emigration monitoring in the Central Valley has provided some valuable data on the distribution and occurrence of steelhead smolts. However, we are unaware of any published study which addresses the abundance, distribution and rearing habitats of juvenile steelhead in a Central Valley river.

Typically, relationships between fish populations and habitat conditions have been conducted at fine spatial scales (Bayley and Li 1992). However, there is increasing evidence and sentiment among stream ecologists that better understanding of fish ecology and habitat relationships requires a multi-scale approach (see review by Fausch et al 2002). Central to this approach is the idea that the spatial arrangement and connectivity of critical habitats for each life history phase (spawning, rearing, feeding, refugia from stressors) strongly affects the persistence, abundance and productivity of fish populations (Schlosser 1991, 1995). A coarser spatial resolution may suggest patterns of population regulation that would not be apparent at finer spatial scales. Microhabitat data alone would likely miss these landscape scale population constraints, and might exaggerate the importance of other fine scale habitat variables. In our studies of the Feather River downstream of Oroville Dam, we implemented a multi-scale sampling program akin to those discussed by Fausch et al (2002). In this report we present data from three years of snorkeling and mark-recapture studies, focusing on juvenile steelhead, but including other species. Our purpose is to: (1) provide information on the seasonal distribution, relative abundance, growth, and habitat use of common Feather River fishes, particularly salmonids; and (2) identify river conditions, habitats, or ecological interactions which may limit the abundance of salmon and steelhead.

The Oroville Facilities on the Feather River is under review for re-licensing by the Federal Energy Regulatory Commission (FERC). The FERC re-licensing provides an opportunity to evaluate project effects on downstream fish communities and develop potential enhancement measures. Furthermore, the design of flow release structures from the Oroville Facilities provides a unique setting to evaluate the relative importance of habitat, temperature and flow regime on fishes. The findings may be especially pertinent as California considers and designs restoration activities for its regulated rivers.

1.1 BACKGROUND INFORMATION

1.1.1 Study Area

The Feather River drainage is located in the Central Valley of California, draining approximately 3,600 square-miles of the western slope of the Sierra Nevada (Figure 1.1.1-1). Where it leaves the foothills, the Feather River is impounded by Oroville Dam, completed in 1967. Lake Oroville has a capacity of about 3.5-million-acre-feet (maf) of water, and is the centerpiece of the State Water Project, the principal water storage and conveyance system operated by the State of California. Under normal operations, the majority of water released from Lake Oroville is directed into the Thermalito Complex. Except for local water diversions, the rest is returned to the Feather River through Thermalito Afterbay Outlet (TAO), then flows southward through the valley to the confluence with the Sacramento River at Verona. The remainder of releases from Lake Oroville, typically 600 cfs, runs through the historic river channel locally known as the low flow channel (LFC).

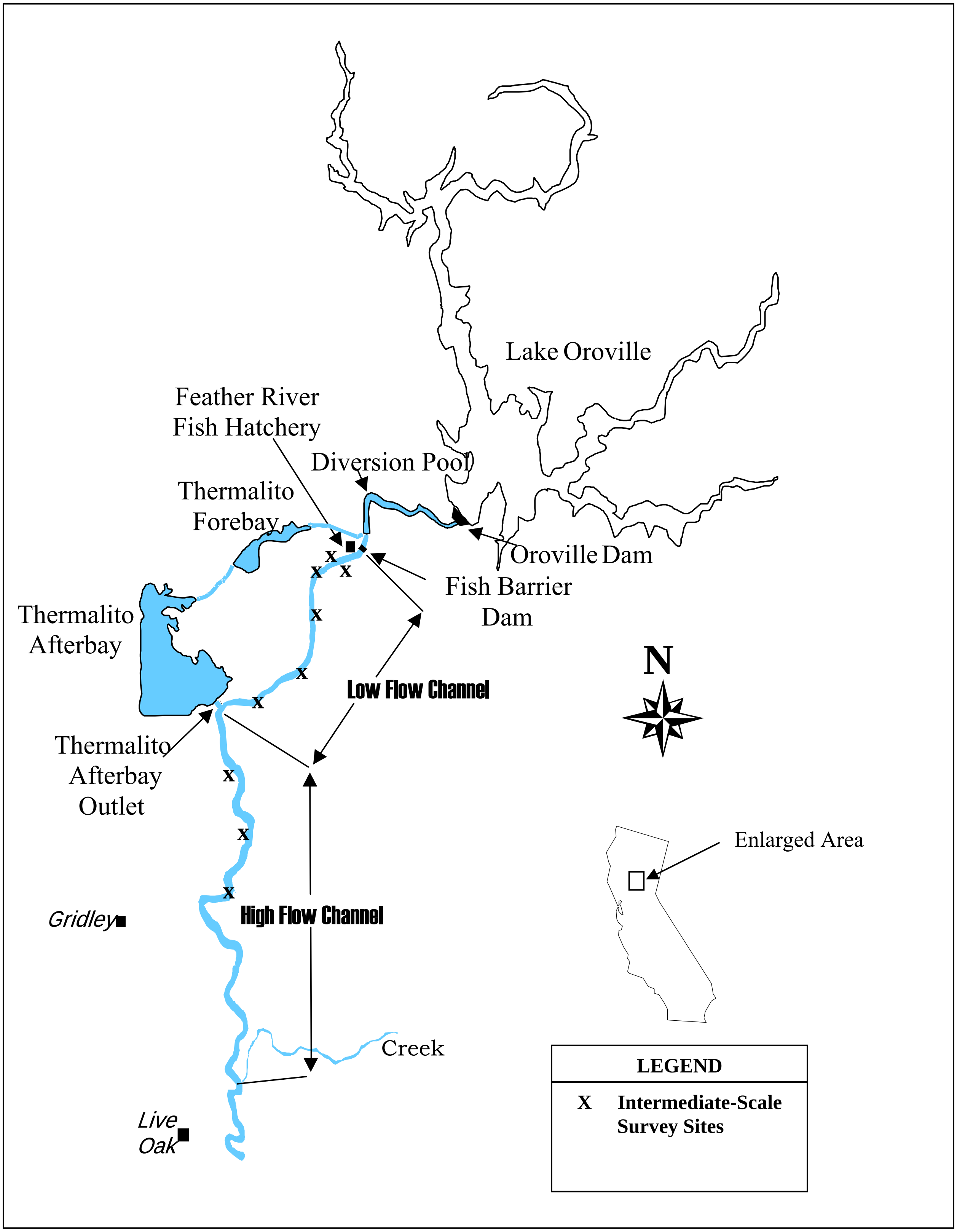

Figure 1.1.1-1. Snorkel Survey Area

Field activities occurred in a 23 mi river segment between the Fish Barrier Dam, which diverts salmon and steelhead into the Feather River Fish Hatchery, and Honcut Creek. This portion of the river is composed of two distinct river segments that differ in physical and environmental conditions. The LFC extends from the Fish Barrier Dam at river mile (RM) 67.1 to the TAO (RM 59.0). Flow regime in the LFC is stable, exceeding 600 cfs only during flood events. LFC temperature regime, channel morphology, and geomorphic process are strongly influenced by the proximity to Oroville Dam and the city of Oroville, which is separated from the river by flood control levees. In summer months, water temperatures in the LFC are cooler than those downstream, and generally do not exceed a mean daily maximum of 18.3°C at RM 62.0. The high flow channel (HFC), which extends from the TAO to Honcut Creek (RM 42.9), is subject to diverse thermal, hydrologic and geomorphic conditions. Because the HFC is further downstream, water temperatures are influenced less by dam releases and exhibit more diel and seasonal fluctuations. Flow regime in the HFC is more variable, driven by flood control and water storage operations at the Oroville Dam and Thermalito Complex. The river below Thermalito Outlet is generally less confined by levees, with a broader active channel and floodplain, than the LFC. However, both the LFC and HFC river segments are very low gradient.

1.2 DESCRIPTION OF FACILITIES

The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife.

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area (OWA), Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided on Figure 1.2-1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5 maf capacity storage reservoir with a surface area of 15,810 acres at its normal maximum operating level.

The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts (MW). The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Feather River just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 cfs and 5,610 cfs, respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam, four miles downstream of the Oroville Dam creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cubic feet per second (cfs) of water into the river.

The Power Canal is a 10,000-foot-long channel designed to convey generating flows of 16,900 cfs to the Thermalito Forebay and pump-back flows to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating Plant is designed to operate in tandem with the Hyatt Pumping-Generating Plant and has generating and pump-back flow capacities of 17,400 cfs and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000-foot-long earth-fill dam. The Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump-back operations, and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay outlet, and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead trout from the construction of Oroville Dam. The hatchery can accommodate 15,000 to 20,000 adult fish annually.

The Oroville Facilities support a wide variety of recreational opportunities. They include: boating (several types), fishing (several types), fully developed and primitive camping (including boat-in and floating sites), picnicking, swimming, horseback riding, hiking, off-road bicycle riding, wildlife watching, hunting, and visitor information sites with cultural and informational displays about the developed facilities and the natural environment. There are major recreation facilities at Loafer Creek, Bidwell Canyon, the Spillway, North and South Thermalito Forebay, and Lime Saddle. Lake Oroville has two full-service marinas, five car-top boat launch ramps, ten floating campsites, and seven dispersed floating toilets. There are also recreation facilities at the Visitor Center and the OWA.

The OWA comprises approximately 11,000-acres west of Oroville that is managed for wildlife habitat and recreational activities. It includes the Thermalito Afterbay and surrounding lands (approximately 6,000 acres) along with 5,000 acres adjoining the Feather River. The 5,000 acre area straddles 12 miles of the Feather River, which includes willow and cottonwood lined ponds, islands, and channels. Recreation areas include dispersed recreation (hunting, fishing, and bird watching), plus recreation at developed sites, including Monument Hill day use area, model airplane grounds, three boat launches on the Afterbay and two on the river, and two primitive camping areas. California Department of Fish and Game's (DFG) habitat enhancement program includes a wood duck nest-box program and dry land farming for nesting cover and improved wildlife forage. Limited gravel extraction also occurs in a number of locations.

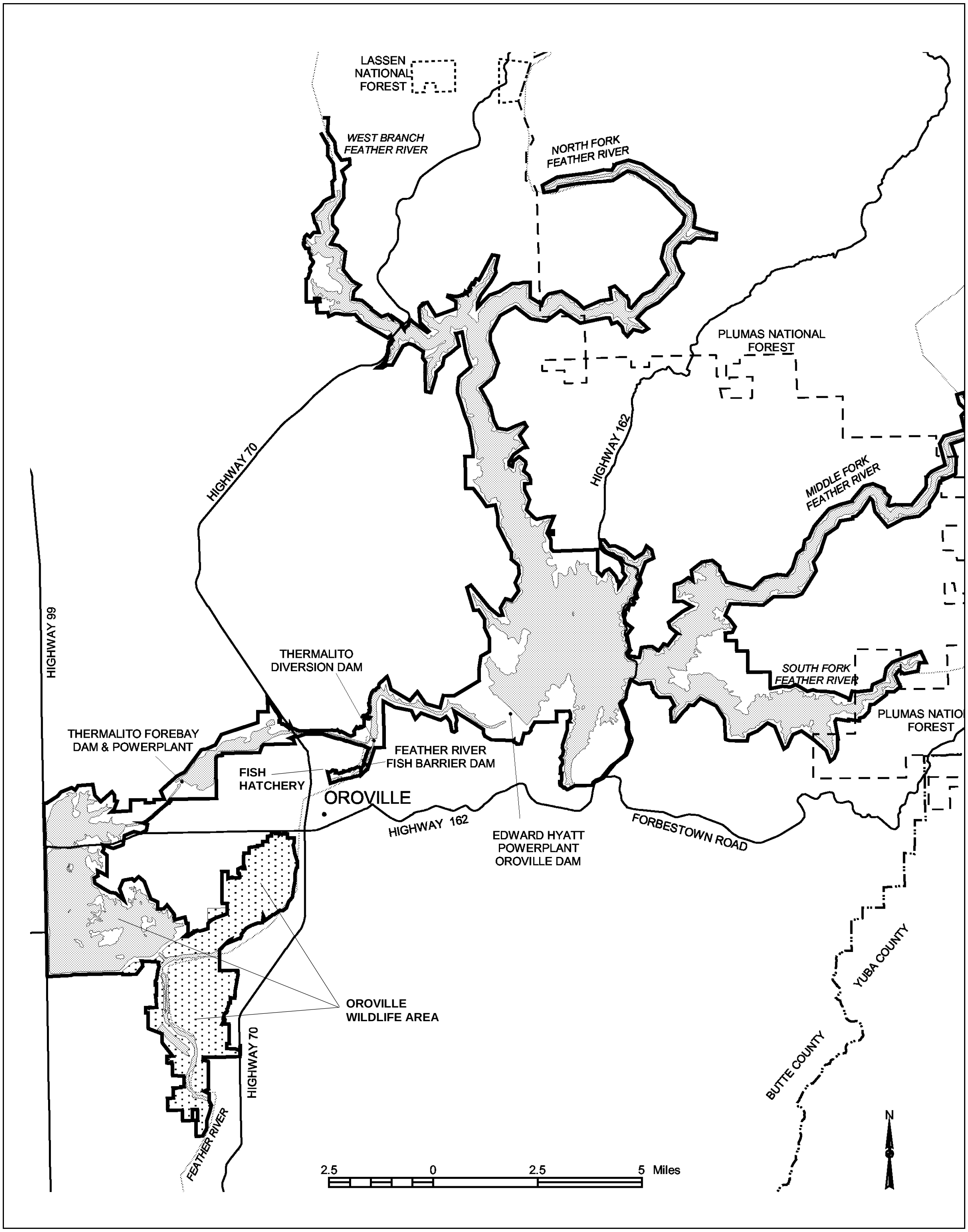

Figure 1.2-1. Oroville Facilities FERC Project Boundary

1.3 CURRENT OPERATIONAL CONSTRAINTS

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for project purposes. Meeting the water supply objectives of the SWP has always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning is conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000,000 acre-feet (af); however, this does not limit draw down of the reservoir below that level. If hydrology is drier than expected or requirements greater than expected, additional water would be released from Lake Oroville. The operations plan is updated regularly to reflect changes in hydrology and downstream operations. Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above mean sea level (msl) in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier years, the lake may be drawn down more and may not fill to the desired levels the following spring. Project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

1.3.1 Downstream Operation

An August 1983 agreement between DWR and DFG entitled, “Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife,” sets criteria and objectives for flow and temperatures in the low flow channel and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between the TAO and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass.

1.3.1.1 Instream Flow Requirements

The Oroville Facilities are operated to meet minimum flows in the Lower Feather River as established by the 1983 agreement (see above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March, and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942,000 af (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs from October to February, and 1,000 cfs for March. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

1.3.1.2 Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52°F for September, 51°F for October and November, 55°F for December through March, 51°F for April through May 15, 55°F for last half of May, 56°F for June 1-15, 60°F for June 16 through August 15, and 58°F for August 16-31. A temperature range of plus or minus 4°F is allowed for objectives, April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook. From May through August, they must be suitable for shad, striped bass, and other warmwater fish.

The National Marine Fisheries Service has also established an explicit criterion for steelhead trout and spring-run Chinook salmon. Memorialized in a biological opinion on the effects of the Central Valley Project and SWP on Central Valley spring-run Chinook and steelhead as a reasonable and prudent measure; DWR is required to control water temperature at Feather River mile 61.6 (Robinson’s Riffle in the low-flow channel) from June 1 through September 30. This measure requires water temperatures less than or equal to 65°F on a daily average. The requirement is not intended to preclude pump-back operations at the Oroville Facilities needed to assist the State of California with supplying energy during periods when the California ISO anticipates a Stage 2 or higher alert.

The hatchery and river water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. Under existing agreements, DWR provides water for the Feather River Service Area (FRSA) contractors. The contractors claim a need for warmer water during spring and summer for rice germination and growth (i.e., 65°F from approximately April through mid May, and 59°F during the remainder of the growing season). There is no obligation for DWR to meet the rice water temperature goals. However, to the extent practical, DWR does use its operational flexibility to accommodate the FRSA contractor’s temperature goals.

1.3.1.3 Water Diversions

Monthly irrigation diversions of up to 190,000 (July 2002) af are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1 maf. After meeting these local demands, flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

1.3.1.4 Water Quality

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from DWR's water rights permits. These standards are designed to meet several water quality objectives such as salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In particular, they protect a wide range of fish and wildlife including Chinook salmon, Delta smelt, striped bass, and the habitat of estuarine-dependent species.

1.3.2 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by the U.S. Army Corps of Engineers (USACE). Under these requirements, Lake Oroville is operated to maintain up to 750,000 af of storage space to allow for the capture of significant inflows. Flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by the USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with the USACE.

The flood control requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, the reservoir space can be used for storing water. From October through March, the maximum allowable storage limit (point at which specific flood release would have to be made) varies from about 2.8 to 3.2 maf to ensure adequate space in Lake Oroville to handle flood flows. The actual encroachment demarcation is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection. When the wetness index is high in the basin (i.e., wetness in the watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

2.0 METHODOLOGY

2.1 STUDY DESIGN

2.1.1 Field Sampling

Snorkel surveys were conducted at three spatial scales: broad 15.5 mi (25 km), intermediate 984-1640 ft (300-500 m), and fine 82 ft (25 m). Broad scale surveys covered the study area from the Fish Barrier Dam to Gridley Bridge (RM 50.8) and occurred only once per year. Broad scale surveys were completed annually in 1999, 2000, and 2001. The 1999 survey was conducted from 5/13 to 5/26; the 2000 survey from 6/5 to 6/20; and the 2001 survey from 5/1 to 5/10. These surveys provided a snapshot of overall abundance and distribution of fishes in the lower Feather River, and provided observations in areas or habitats not covered at smaller scales. Snorkel observations were generally made in a downstream direction, as currents were often strong. Three to six divers were distributed among three transects: left bank, right bank and center channel. Divers used plastic dive slates to mark information on individual fish or schools of fish located. Groups of similar sized fish that were observed in a one square meter or less area were treated as a single observation.

Data recorded included: the approximate fish size (mm fork length, hereafter FL), number of fish, substrate type, cover, and habitat type (hydrogeomorphic units). Fish identification and size estimation by divers was verified and calibrated by training with tethered fishes in a controlled setting, and also by oversight of experience divers. Size estimation was also aided by comparing observed fishes to nearby objects. These objects could then be measured using the scale provided on plastic writing slates. The classification system for substrate, cover and habitat are provided in Tables 2.1.1-1, 2.1.1-2 and 2.1.1-3, respectively. Effort at each sampling site was recorded in terms of the time sampled, area covered and the number of divers.

Intermediate-scale surveys occurred monthly from March through August 1999, 2000, and 2001. These surveys covered nine permanent sampling stations, six in the LFC and three in the HFC, each with at least one riffle-pool sequence. Observations of fish and habitat were performed as previously described for broad-scale surveys. Additionally, depth, velocity, substrate, cover and habitat types were measured in ten systematic transects at each station. This information was used to describe and quantify available habitat. The quantity and boundaries of hydrogeomorphic units (riffles, glides, pools and backwaters) for the entire study area were based on aerial photographs (1998) and on the ground observations. The linear extent of riffle, glide and pool habitat was measured from the resulting maps. A summary of the habitat characteristics of each site is in Table 2.1.1-4.

Table 2.1.1-1. Substrate classification system used to record dominant substrate type (adapted from Brusven 1977).

Code	Substrate Description
1	Fines – Small Gravel (0-50 mm) (0 – 2 in)
2	Small – Medium Gravel (50 – 150 mm) (2 – 6 in)
3	Medium – Large Cobble (150 – 300 mm) (6 – 12 in)
4	Boulder (> 300 mm) (> 12 in)

Table 2.1.1-2. Cover classification system.

Code	Cover description
None	No apparent cover
SIO	Small – Medium instream objects/woody debris (< 31 cm or 1 ft. diameter)
LIO	Large instream objects/woody debris (> 31 cm or 1 ft. diameter)
OvOb	Overhead objects
SAV	Submerged aquatic vegetation
UB	Undercut bank

Table 2.1.1-3. Hydrogeomorphic classification system.

Code	Hydrology Description
R	Riffle
G	Glide
P	Pool
W	Backwater

Table 2.1.1-4. Stream characteristics for each Intermediate-scale snorkel site. All stream measurements were completed in 1999. Under the cover categories, None represents No apparent cover, SIO represents Small Instream Objects, LIO represents Large Instream Objects, OvOb represents Overhead Objects, SAV represents Submerged Aquatic Vegetation, and UB represents Undercut Bank.

	Intermediate-scale snorkel sites								
Measurement	HD	HR	AuR	AIR	RR	ER	G95	GR	MR
River mile	66.5	66.6	66.5	63.5	61.5	60.2	57.3	54.8	52.3
Linear distance (m)	330	250	230	200	665	409	227	595	274
Habitat characteritics by site									
Hydrogeomorphic unit (%)									
Riffle	40	20	13	27	26	4	34	10	0
Glide	42	80	79	25	60	72	61	31	94
Pool	18	0	8	48	14	24	5	59	6
Cover (%)									
None	32	87	73	94	87	40	90	84	69
SIO	15	3	9	0	3	20	2	3	7
LIO	0	1	0	2	0	1	1	0	7
OvOb	51	7	17	3	8	23	3	13	14
SAV	1	0	0	2	3	15	3	0	4
UB	1	2	0	0	0	0	0	0	0
Velocity percentile (ft/s)									
25th	0.50	0.50	0.85	0.00	0.50	0.50	0.62	0.51	0.50
50th	1.09	1.00	1.80	0.50	1.22	1.18	2.20	1.95	1.94
75th	1.92	3.30	2.60	1.98	2.85	1.90	3.26	3.01	4.24
100th	3.77	12.50	4.39	3.57	11.70	4.23	6.54	6.54	7.73
Depth percentile (m)									
25th	0.18	0.40	0.49	0.35	0.42	0.32	0.39	0.64	0.52
50th	0.24	0.65	0.70	0.55	0.55	0.55	0.58	1.65	0.90
75th	0.30	1.00	0.90	0.77	0.85	0.75	0.79	2.50	1.50
100th	0.63	1.50	1.50	1.30	1.50	1.80	1.50	3.00	2.90

Fine-scale surveys were completed monthly from March through August 2001 and 2002 to provide replicated samples. Twenty-four sampling locations were selected at random and sampled each month, twelve each in the LFC and HFC. Each section covered an area 25 meters long and four meters wide and ran parallel to one river bank. Two divers surveyed the reach by working upstream and marking the number, species, size and position of all fishes observed. After the fish survey was complete, divers recorded water depth, average velocity, substrate, cover and habitat types at 36 points, each representing a one square meter cell within the reach. Fish observations were recorded by their association with these one square meter cells. Depth and focal velocity were also recorded for each fish observation. For all surveys, water temperatures were monitored continuously by a network of StowAway electronic thermistors.

Between June and August of 2002 and 2003, intensive seine and electrofish sampling was conducted at six sites in the LFC. This sampling was performed in association with a mark-recapture study of juvenile steelhead to document residence time, movements and growth rate. The sites sampled were (from upstream to downstream): Hatchery Ditch (RM 66.5), Auditorium Riffle (RM 66.4), Bedrock Riffle (RM 65.9), Matthews Riffle (RM 64.1), Aleck Riffle (RM 63.9) and Steep Riffle (RM 61.0). Electrofishing was conducted in shallow habitats particularly near shore. In offshore areas an electrofisher was used to herd fish into a seine. The combination of these methods was necessary because of swift currents and the inherent patchiness of suitable steelhead habitat. Effort was calculated as the number of fish captured per minute of electrofishing. All steelhead captured were weighed, measured (FL) and uniquely marked with a photonic color tagging gun. Steelhead recaptured with photonic color tags were recorded by tag code description. After measurement and marking, fish were returned to the river in the approximate location of their original capture.

2.1.2 Data analysis

We did not collect data to age steelhead, therefore we placed steelhead into size-classes: less than 100 mm FL (<100 mm) and greater than 100 mm FL (>100 mm). No size categories were used for Chinook salmon because nearly all were age-0. We did not distinguish between spring- and fall-run salmon because size differences between these two runs are generally small (Fisher and Greene 1994), especially on the Feather River, where there is little segregation of spawn timing. Non-salmonid fishes were grouped into three categories: native cyprinids, centrarchids and tule perch *Hysterocarpus traski*. Native cyprinids included Sacramento pikeminnow *Ptychocheilus grandis* and hardhead *Mylopharadon conocephalus*. Centrachids included largemouth bass *Micropterus salmoides*, smallmouth bass *Micropterus dolomieui*, and various sunfishes. These groupings were necessary because definitive species identification was difficult. Furthermore, these categories combined species of similar behavior, life history, and management significance (Moyle 2002). Tule perch were separated because they were relatively common, easily identified and could not be logically grouped with other fish species. Non-salmonids were not categorized by size because most individuals were juveniles or older. Fish species other than those listed above were occasionally observed, but were not included in this analysis; see Seesholtz et al (2004) for consideration of other species.

Broad-scale snorkeling results were summarized as the number of fish observed per river mile in each survey year. It was not necessary to standardize these observations because sampling effort was equally applied throughout the 16.2 river miles. Intermediate- scale observations were standardized by average number of fish observed per meter in each of the nine sampling reaches. Habitat use (cover, depth, velocity, etc.) was determined by calculating the percentage of all observations which occurred in a given habitat category. A modified chi square test goodness-of-fit test was used to determine if utilization of a habitat type was in proportion to the abundance of that habitat from the intermediate-scale snorkel sites. Ontogenetic shifts in habitat use by salmonids were evaluated with one-way analysis of variance on average FL across hydrogeomorphic and cover types. To assess size composition of the steelhead population, we assembled length frequency plots by month and seining site.

Stepwise binary logistic regression analysis (Legendre & Legendre 1998) was used to assess factors influencing the occurrence of steelhead and Chinook salmon. Fine scale survey results were analyzed at both the mesohabitat (100 m^2) and microhabitat (1 m^2) scale. Mesohabitat analysis was performed by treating the entire 25 m reach as a sample. Reach habitat variables where steelhead or salmon were present (logistic response variable) were compared to reaches where fish were absent (logistic reference variable). Since intermediate scale surveys covered only nine reaches, it was not worthwhile to explore mesohabitat associations for these data. Microhabitat analysis was performed similarly (from both fine and intermediate scale surveys), except that individual one square meter cells were considered rather than entire reaches. Reaches lacking salmon or steelhead observations were not included in the microhabitat analysis. This was necessary to prevent bias associated with inclusion of microhabitat availability data where no fish were present to select a microhabitat. Intermediate-scale microhabitat availability data were standardized by randomly selecting records from each reach relative to its size. Variables included for each scale of analysis are indicated in Table 2.1.2-1. Since this analysis was exploratory, rather than testing a priori hypotheses, we selected a relatively large critical (alpha) value of 0.1.

Table 2.1.2-1. Description of variables evaluated for binary logistic regression analysis of habitat use among salmon and steelhead.

Logistic Regression Variables	Variable Description	**Fine Scale** Mesohabiat	**Fine Scale** Microhabitat	**Intermediate Scale** Microhabitat
Depth			**x**	**x**
Velocity			**x**	**x**
OCOVA	Overhead Cover Absent	**x**	**x**	1
ICOVA	Instream Cover Absent	**x**	**x**	2
ICOVB	Small Instream Cover	**x**	**x**	
ICOVC	Large Instream Cover	**x**	**x**	
SURFTURB	Surface Turbulence	**x**	**x**	
SUBGRAV	Gravel Substrate		**x**	3
SUBSAND	Sand Substrate		**x**	3
DISTANCE	Distance from shore		**x**	
Pool				4
AVGVEL	Average Reach Velocity	**x**		
AVGDEPTH	Average Reach Depth	**x**		
Rivermile		**x**		
SideChannel		**x**		
Canopy		**x**		

1: relative to all types of overhead cover
2: relative to all types of instream cover
3: relative to cobble and larger substrates
4: relative to riffles and glides

3.0 STUDY RESULTS

3.1 Broad-scale snorkel survey

Distribution and abundance patterns for steelhead, Chinook salmon, native cyprinids, tule perch and non-native centrarchids (1999 – 2001) are summarized in Figures 3.1-1 through 3.1-3. In all years, nearly all observations steelhead less than 100 mm FL occurred in the LFC. Within the LFC, <100 mm steelhead distribution was strongly skewed upstream, with 91%, 77% and 84% of observations occurring in the first river mile in each successive survey year, respectively. Observations of <100 mm steelhead below the TAO accounted for 1% or less of all observations in each year (Figure 3.1-1). Abundance quickly decreased downstream of river mile 66, although abundance remained higher to mile 63 in 2001. A consistent cluster of observations is also evident upstream of the TAO (river mile 61 to 59). Similarly, steelhead greater than 100 mm FL were rare downstream of the TAO (<3% of total observations in all three years), but were much more broadly distributed in the LFC. Peaks in abundance occurred between river miles 66 and 63 and again in the area upstream of the TAO (Figure 3.1-1).

Age-0 Chinook salmon were the most abundant species observed in all three years (Figure 3.1-2). Nearly all observations (98%, 100% and 99%, respectively) were within the LFC. Although there was considerable interannual variation, young Chinook salmon were most common in the upper river miles and, in 2001, those just upstream of the TAO.

Cyprinid distribution and abundance varied greatly between years (Figure 3.1-2). Cyprinids were relatively common in the LFC, but, in contrast to steelhead and salmon, most were observed downstream of the TAO. Nearly all centrarchid observations were at the TAO or downstream (Figure 3.1-3). Centrarchids were particularly abundant in 2000. The majority of centrarchids observed were juveniles. Forty-two percent of *Lepomis spp*. and three percent of *Micropterus spp* were greater than 100 mm. Tule perch, a native freshwater embiotocid, were only observed in the HFC (Figure 3.1-3). Only in 2000 were they abundant.

Other species besides salmon, steelhead, cyprinids, centrarchids and tule perch were observed as part of broad scale snorkel surveys. Sacramento sucker *Catostomus occidentalis*, riffle sculpin *Cottus gulosus*, prickly sculpin *Cottus asper*, and carp *Cyprinus carpio* were very common in all parts of the survey area. However, these species were not enumerated because they were inefficiently sampled by snorkel survey methods. Species infrequently observed included wakasagi *Hypomesus nipponensis*, American shad *Alosa sapidissima*, and lamprey of the genus *Lamptera*. Seesholtz et al. (2004) contains more detailed information on these species in the Feather River.

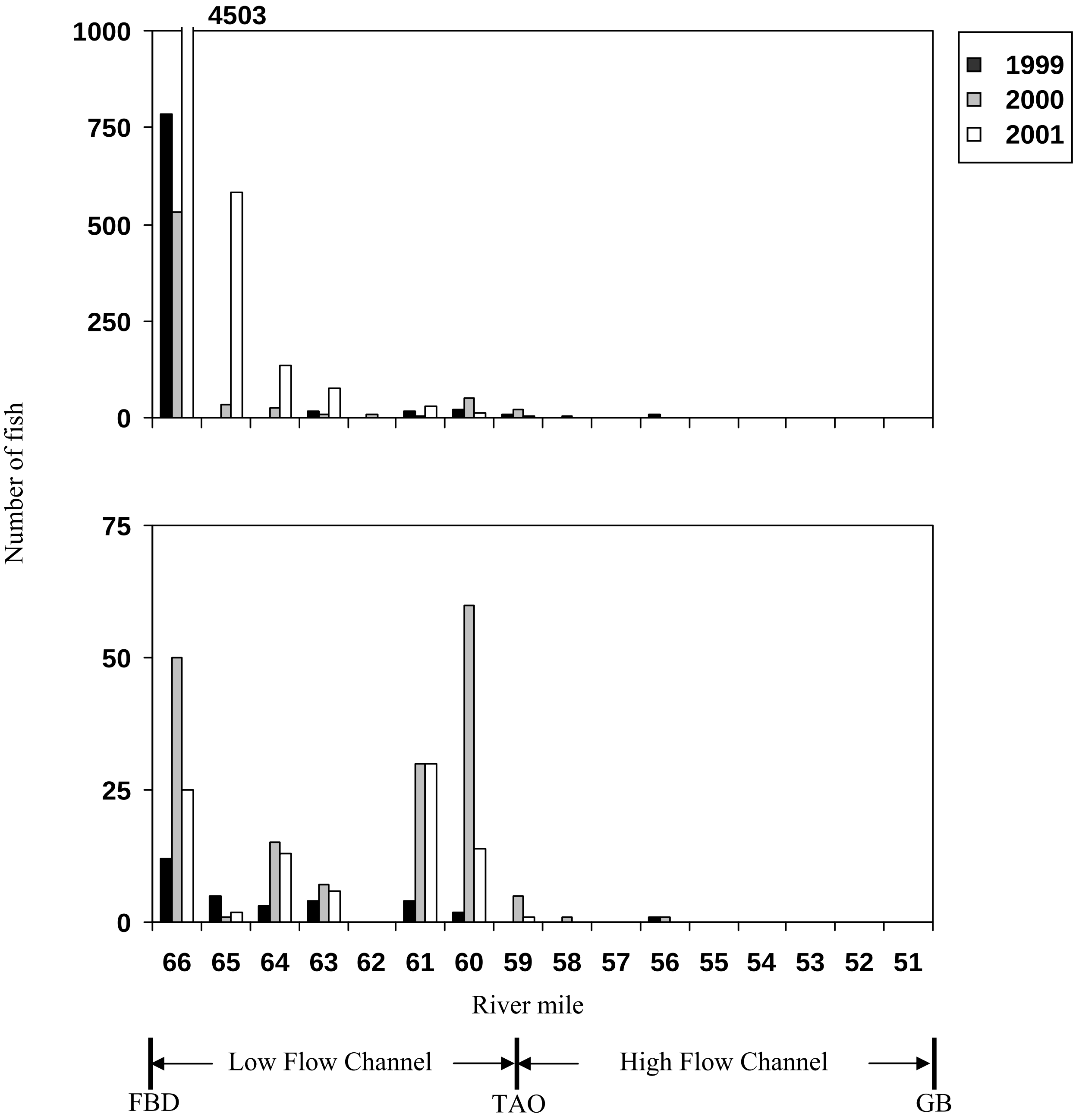

Figure 3.1-1. Number of <100 mm steelhead (top) and >100 mm steelhead (bottom) observed during 1999, 2000 and 2001 Broad-scale snorkel surveys. The Fish Barrier Dam (FBD), Thermalito-Afterbay Outlet (TAO), Gridley Bridge (GB), as well as the Low Flow Channel and High Flow Channel, are indicated under the appropriate river mile.

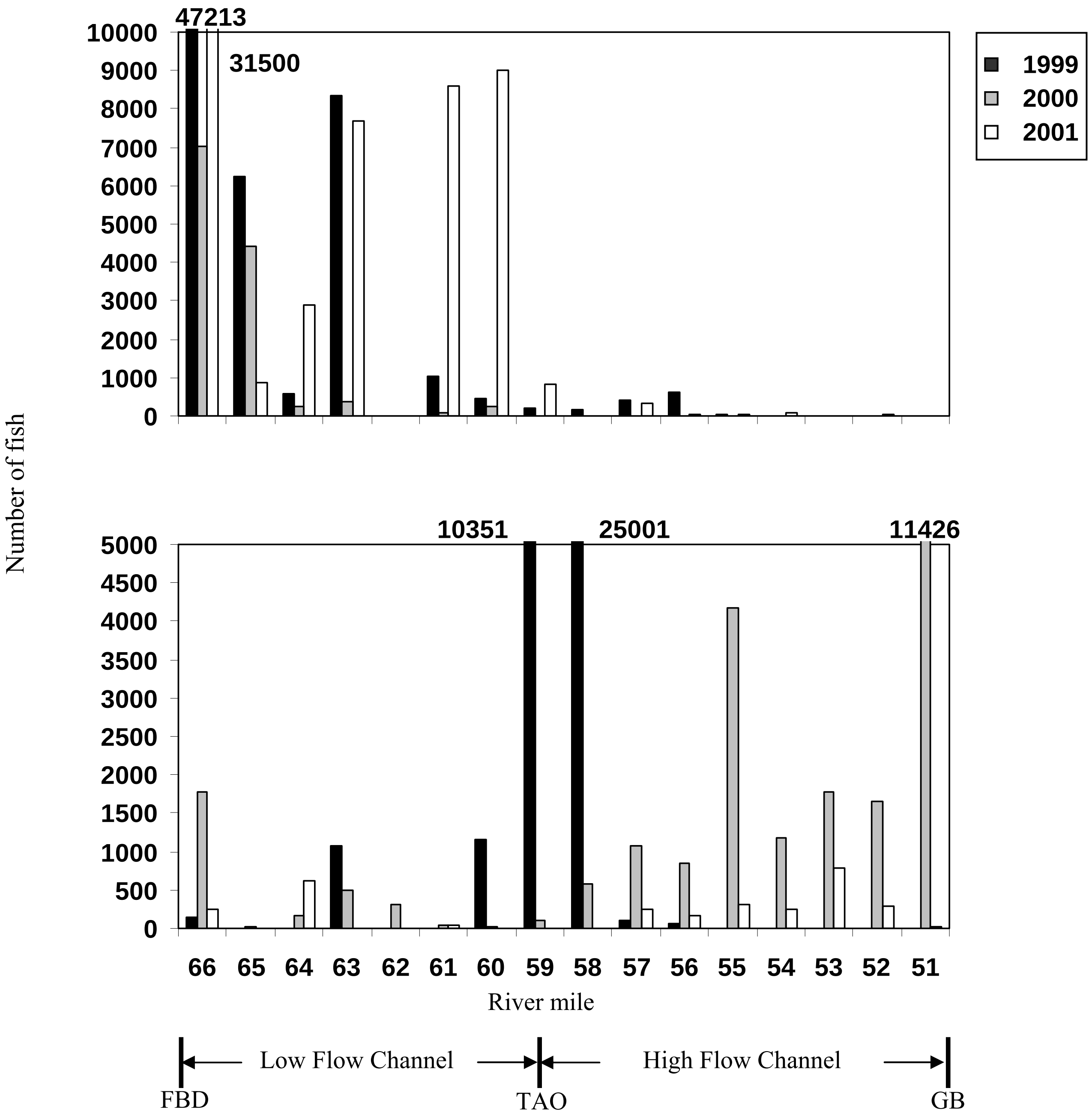

Figure 3.1-2. Number of Age-0 Chinook salmon (top) and juvenile/adult, native cyprinids (bottom) observed during 1999, 2000 and 2001 Broad-scale snorkel surveys. The Fish Barrier Dam (FBD), Thermalito-Afterbay Outlet (TAO), Gridley Bridge (GB), as well as the Low Flow Channel and High Flow Channel, are indicated under the appropriate river mile.

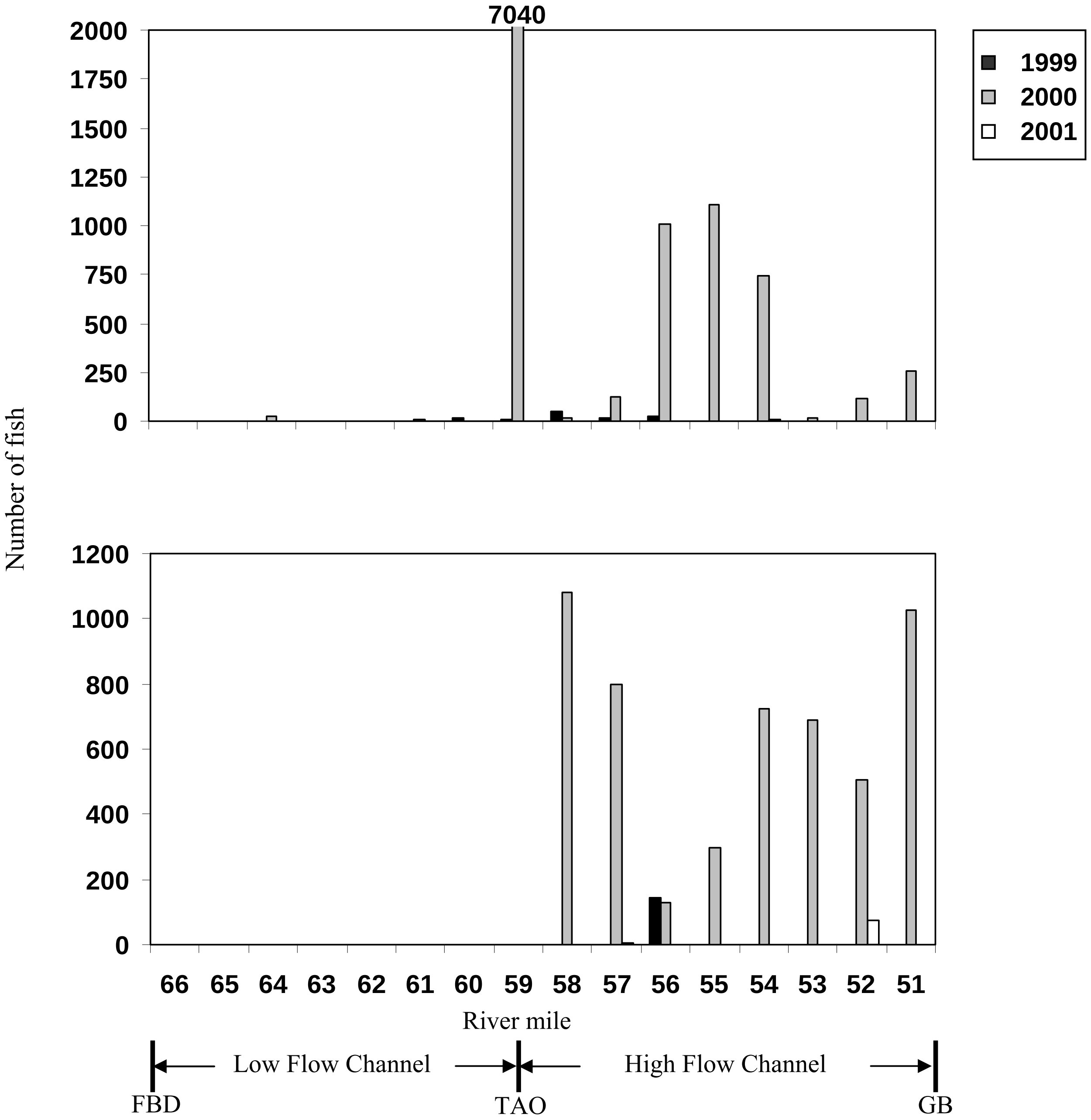

Figure 3.1-3. Number of juvenile/adult centrarchids (top) and juvenile/adult tule perch (bottom) observed during 1999, 2000 and 2001 Broad-scale snorkel surveys. The Fish Barrier Dam (FBD), Thermalito-Afterbay Outlet (TAO), Gridley Bridge (GB), as well as the Low Flow Channel and High Flow Channel, are indicated under the appropriate river mile.

Water temperatures recorded by electronic thermistors showed the expected seasonal and longitudinal trends (Figure 3.1-4). Temperatures were always coldest at the upstream end of the LFC and generally warmed from March through July. Monthly mean temperatures differed little between the downstream portion of the LFC and the HFC to Gridley Bridge, though there was some evidence of cooling downstream of the TAO in July and August.

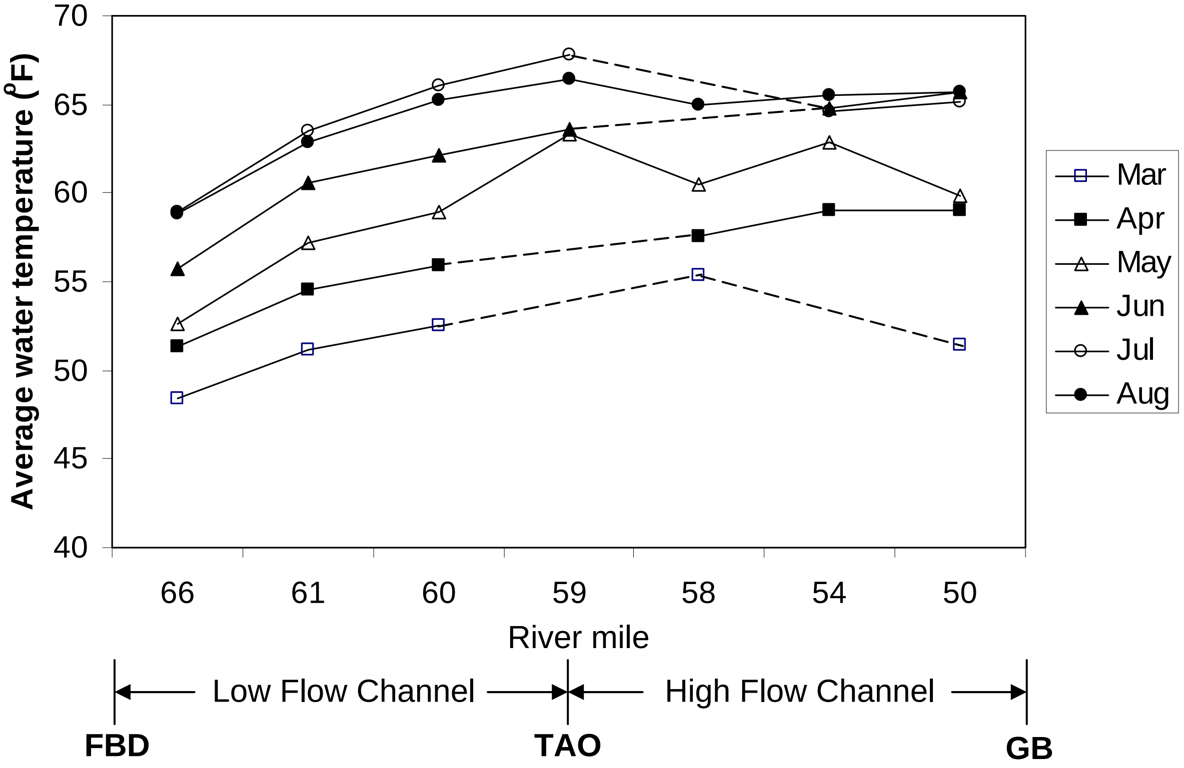

Figure 3.1-4. Average monthly temperature (°F) from continuous data loggers positioned throughout the lower Feather River (2001). Dashed lines represent missing data.

3.2 Intermediate-scale snorkel survey

Intermediate scale surveys were generally consistent with the broad scale results (Figures 3.2-1 through 3.2-6). In all months, Hatchery Ditch (HD) showed the highest abundance of age-0 steelhead (Figure 3.2-1). Abundance in Auditorium Riffle (AuR) was also relatively high. April was the month of peak abundance for all sites, except Aleck Riffle (AlR). By July, abundance was low in all survey reaches except HD. Steelhead less than 100 mm FL were never observed at HFC survey reaches G95, Goose Riffle (GR) or Macfarland Riffle (MR).

Comparatively, steelhead greater than 100 mm FL were more widely distributed in the LFC, but were observed commonly only later in the season (Figure 3.2-2). Abundance of >100 mm steelhead was generally low, but was highest at the downstream portion of the LFC, particularly Robinson Riffle (RR) and Eye Riffle (ER). Chinook salmon were extremely abundant and broadly distributed in March and April surveys (Figure 3.2-3). In later months, salmon were no longer observed in HFC sites. Abundance after April dropped dramatically at all sites.

Cyprinids were rarely or never observed at the upper three sites, HD, Hatchery Riffle (HR), and AuR, but were somewhat common at other LFC reaches (Figure 3.2-4). At the three HFC sites G95, GR, and MR, peak abundance was in July and August. Centrarchids were not abundant at any site, but peak observations occurred at ER in July (Figure 3.2-5). Generally, centrarchids were more common at HFC sites. Tule perch were observed consistently at one LFC site, ER, and all three HFC sites (Figure 3.2-6). Tule perch abundance seemed to increase further downstream. Peak numbers occurred at MR in May.

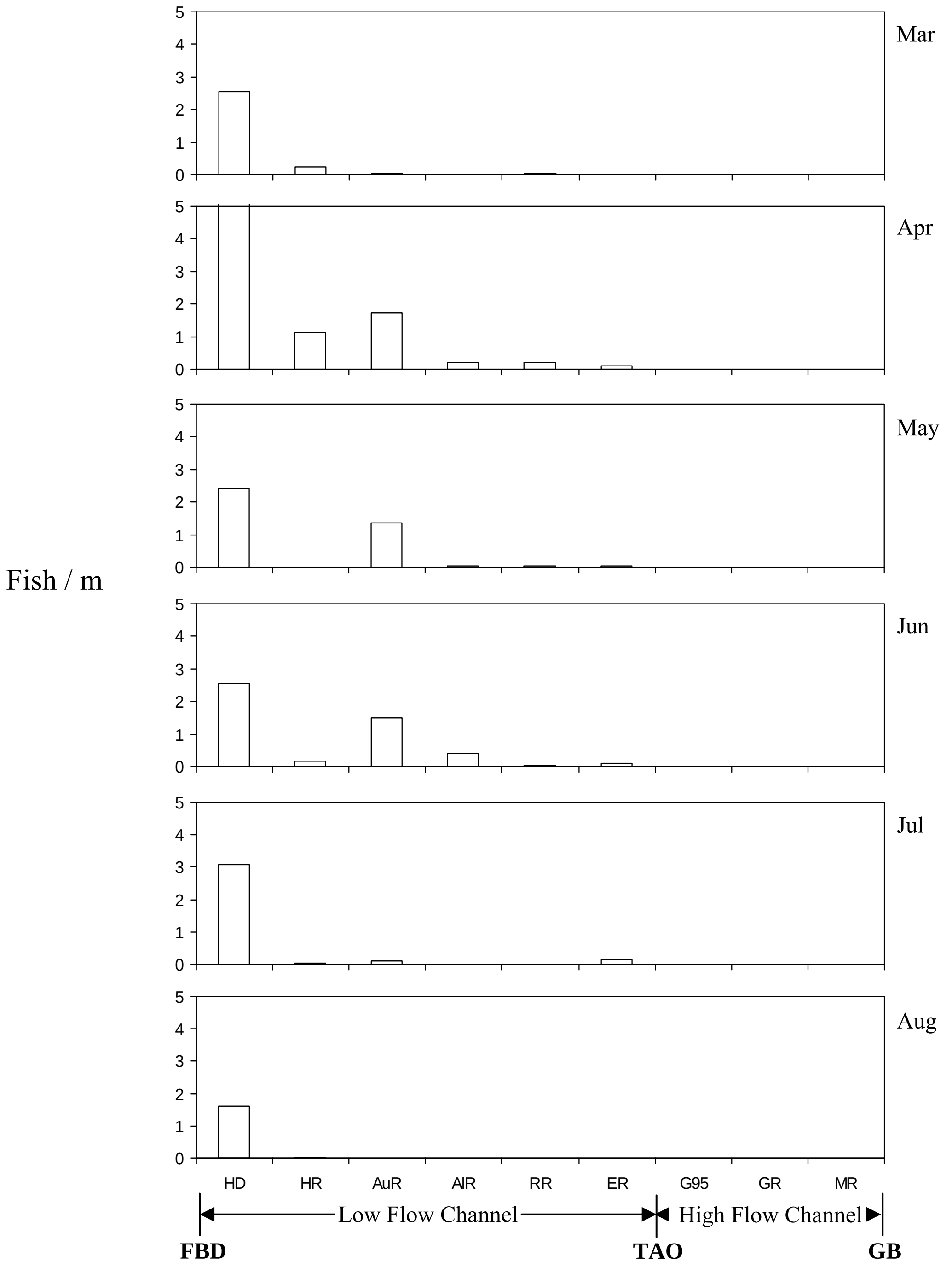

Figure 3.2-1. Seasonal abundance of <100 mm steelhead at nine intermediate scale snorkeling sites. Abundance is reported as the average number of fish observed per linear meter of river bank.

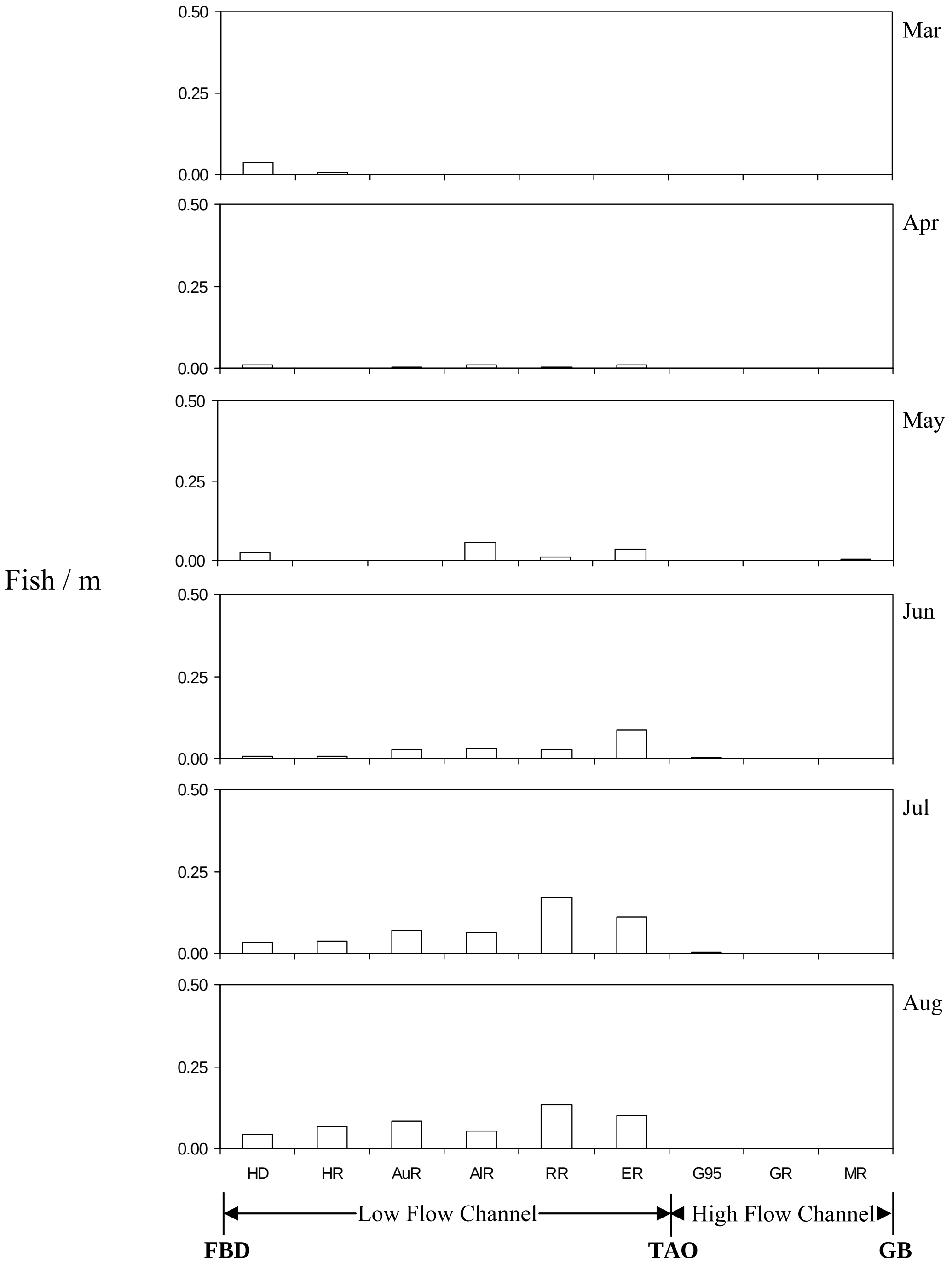

Figure 3.2-2. Seasonal abundance of >100 mm steelhead at nine intermediate scale sites. Abundance is reported as the average number of fish observed per linear meter of river bank.

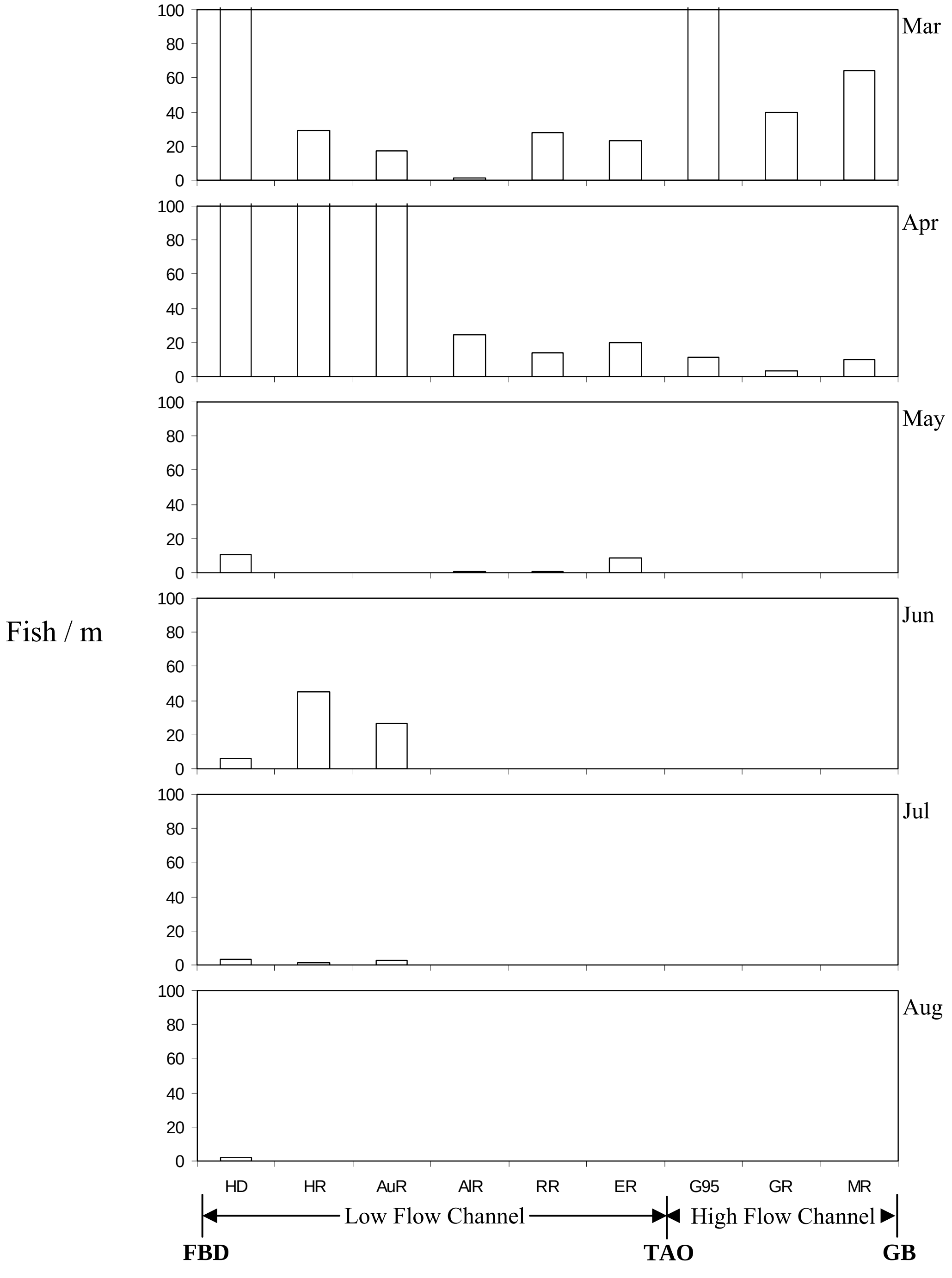

Figure 3.2-3. Seasonal abundance of age-0 Chinook salmon at nine intermediate scale sites. Abundance is reported as the average number of fish observed per linear meter of river bank.

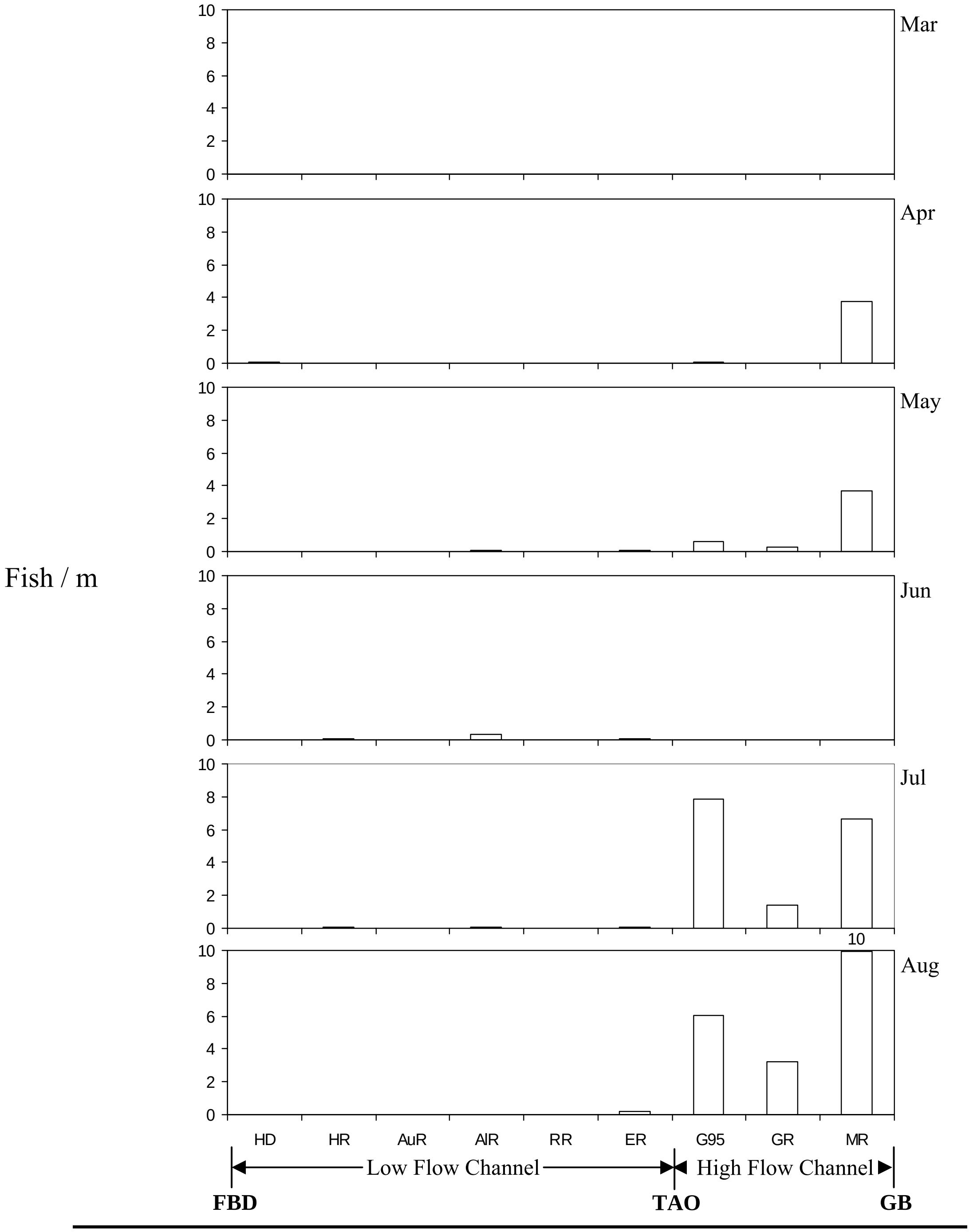

Figure 3.2-4. Seasonal abundance of native cyprinids at nine intermediate scale sites. Abundance is reported as the average number of fish observed per linear meter of river bank.

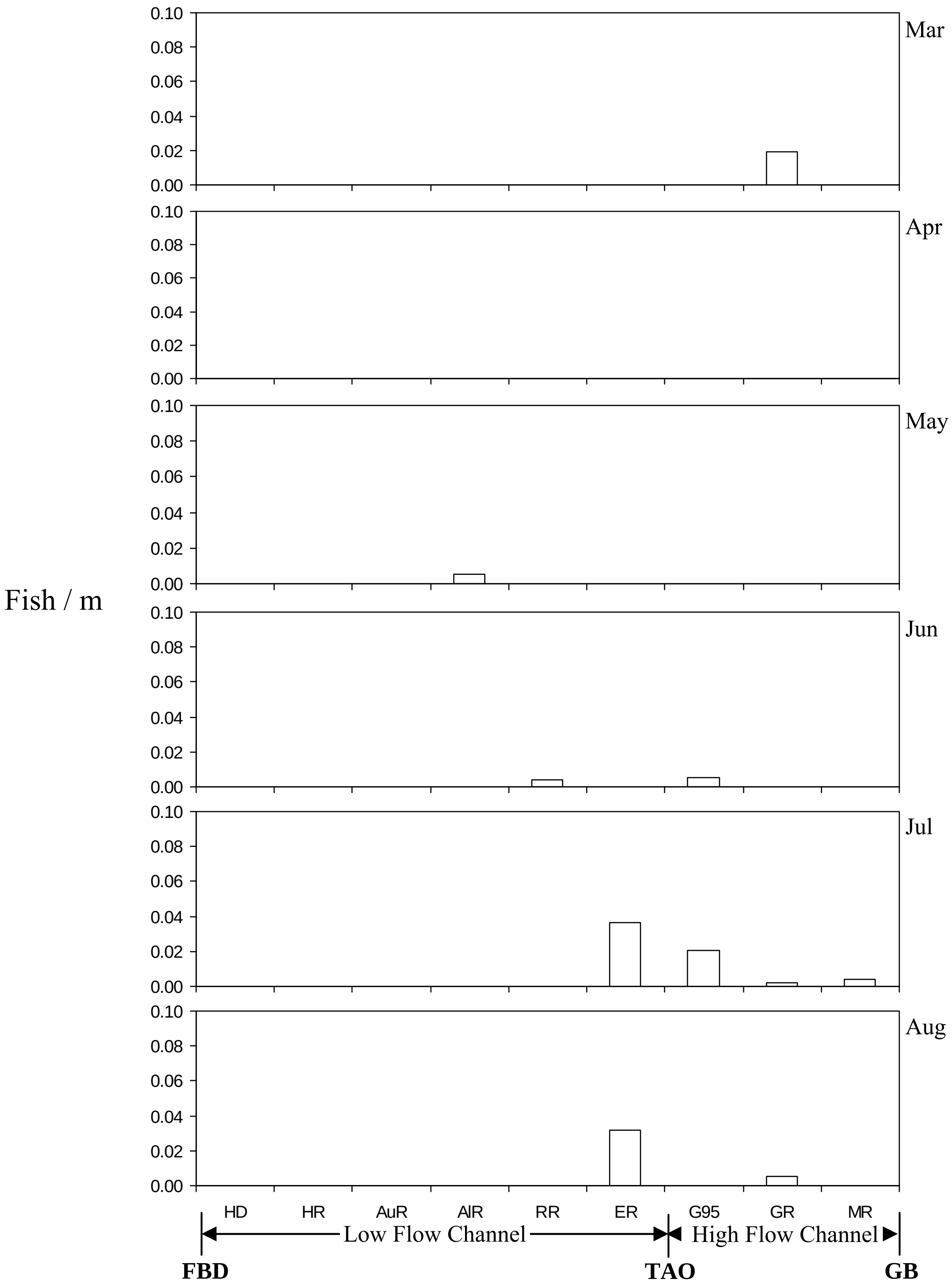

Figure 3.2-5. Seasonal abundance of centrarchids at nine intermediate scale sites. Abundance is reported as the average number of fish observed per linear meter of river bank.

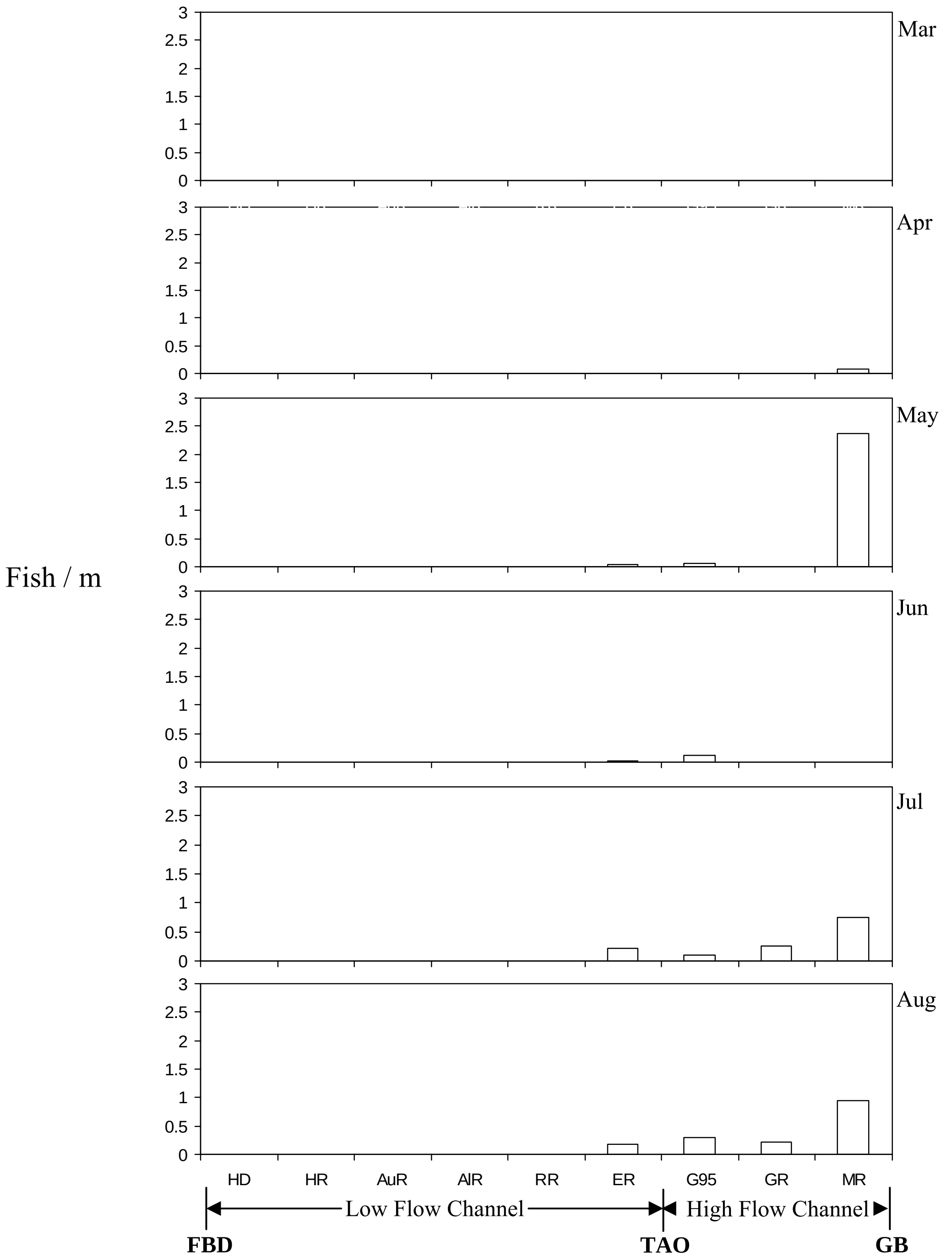

Figure 3.2-6. Seasonal abundance of tule perch at nine intermediate scale sites. Abundance is reported as the average number of fish observed per linear meter of river bank.

3.3 Habitat Utilization

Habitat use and availability for each group of fishes is summarized in Figure 3.3-1. Based on the availability of habitat types, Age-0 salmon and <100 mm steelhead were found more often in riffle and glide habitats than expected and less often in slow-moving waters like pools and backwaters ($\chi^2_{(0.05,\ 3)}$=79.345, p<<0.001 and $\chi^2_{(0.05,\ 3)}$=59.467, p<<0.001, respectively). Steelhead less than 100 mm FL were associated with all types of cover more often than expected and occurred substantially less often in the absence of cover ($\chi^2_{(0.05,\ 4)}$=1439.841, p<<0.001). Age-0 salmon were associated with cover types in proportion to availability ($\chi^2_{(0.05,\ 4)}$=7.763, p=0.1).

Habitat use also appeared to be somewhat dependent on fish size. Steelhead less than 100 mm FL became more common in riffle habitats and less common in pool and glides as fork length increased (Figure 3.3-2). Post-hoc comparisons indicated that mean FL for riffle habitats (M=57.17, SD=22.01) was significantly larger than glide (M=38.41, SD=15.44), pool (M=25.41, SD=3.63), and backwater habitats (M=25.80, SD=3.73). This trend was not as strong among Age-0 Chinook salmon. Although there was a statistically significant difference in mean FL between habitats ($F_{(3,\ 1922)}$=4.76, p=0.003), the actual difference was quite small.

A shift to faster moving habitats and open waters is also reflected in other measures of salmonid microhabitat use. For <100 mm steelhead, focal point velocity, water depth and distance from bank all increased with fork length (Figure 3.3-3). This trend was less clear among Chinook salmon, but velocity and depth did show a similar pattern of size dependence (Figure 3.3-4).

Cover use in juvenile salmonids also varied with fish size (Figure 3.3-5). Mean FL for <100 mm steelhead Post-hoc was (M=63.43, SD=22.98) was significantly larger in open areas than all other cover types, while mean FL for fish found in submerged aquatic vegetation was significantly lower (M=33.71, SD=12.87) than all other cover types. Cover use in Age-0 Chinook salmon was very similar to <100 mm steelhead. Again, mean FL was largest for observations in absence of stream cover (M=60.58, SD=25.70) and lowest for fish found in submerged aquatic vegetation was significantly lower (M=45.54 SD=11.55).

Habitat use varied substantially among non-salmonid fishes. Native cyprinds appeared to be extremely flexible in their selection of hydrogeomorphic units. Riffle and backwater habitats were used in greater proportion to availability, while glides and pools, were relatively under utilized ($\chi^2_{(0.05,\ 3)}$=14.438, p=0.004). The native tule perch were found more frequently in riffle and backwater habitats than expected ($\chi^2_{(0.05,}$

$_{3)}$=37.284, p<<0.001). Centrarchids were largely observed in backwater habitats, but also more frequently than might be expected in riffles and glides (too few observations for analysis).

Cover use among cyprinids was somewhat similar to that observed for steelhead. Use of small and large instream objects occurred in much greater proportion to availability ($\chi^2_{(0.05,\,3)}$=199.91, p<<0.001). Similarly, tule perch most often used small and large instream objects ($\chi^2_{(0.05,\,3)}$=437.23, p<<0.001). Centrarchids were rarely observed without some form of cover; submerged aquatic vegetation was most often used.

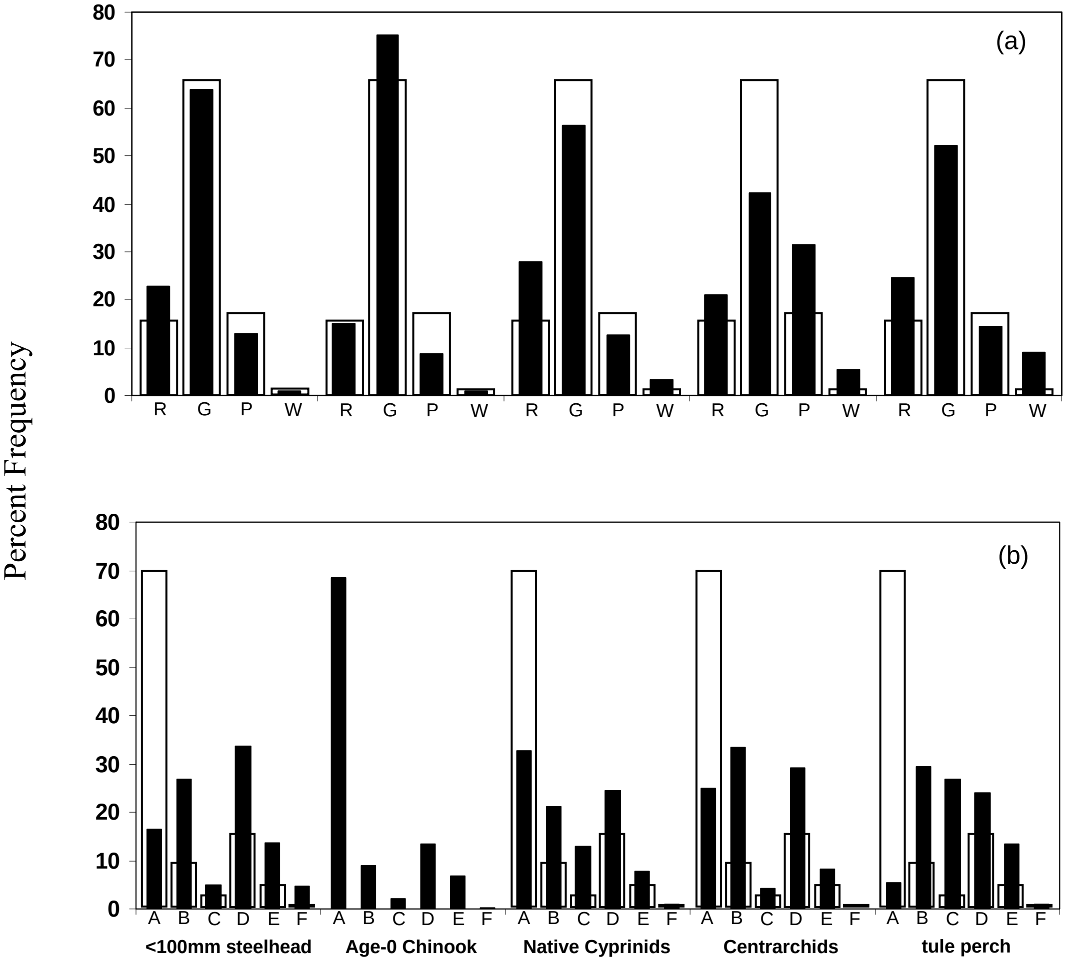

Figure 3.3-1. Percent Frequency of habitat use (black bars) for each fish group. The open bars indicate the percent frequency of available habitat. Hydrogeomorphic habitat type is summarized in (a), where R is riffle, G is glide, P is pool and W is backwater habitat. Cover types are depicted in (b), where A indicates absence of cover, B is small instream objects, C is large instream objects, D is overhead objects, E is submerged aquatic vegetation, and F is undercut bank. Data are taken from intermediate scale snorkel surveys.

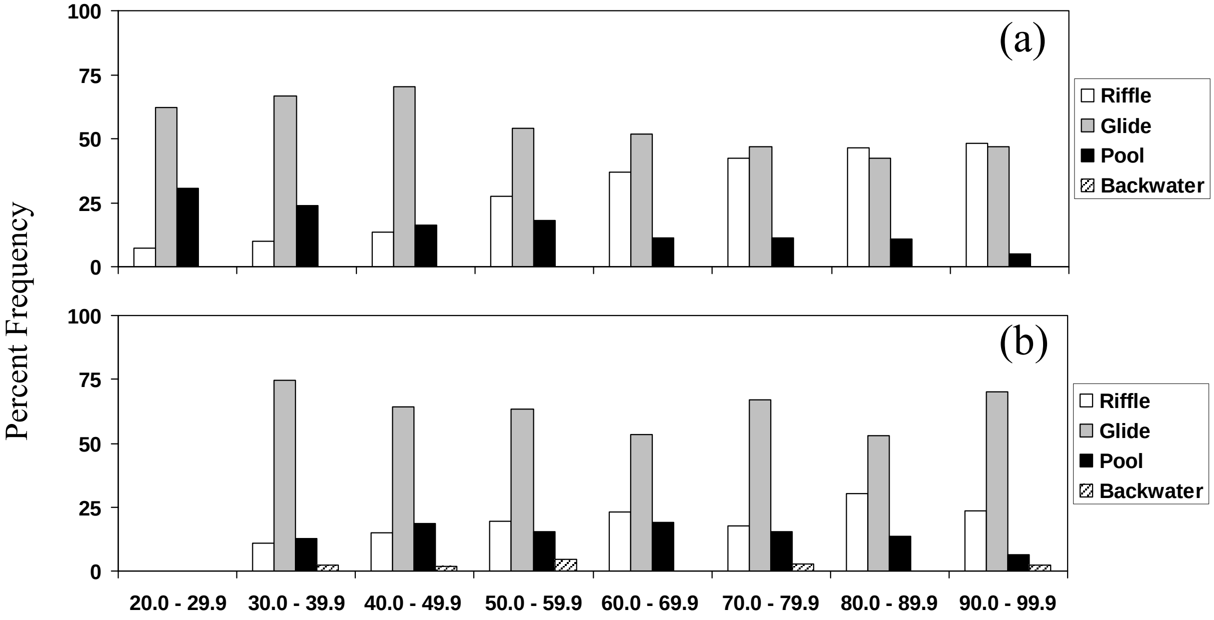

Figure 3.3-2. Hydrogeomorphic use by different size classes of (a) steelhead, and (b) Chinook salmon. There were no observations of Chinook salmon less than 30 mm.

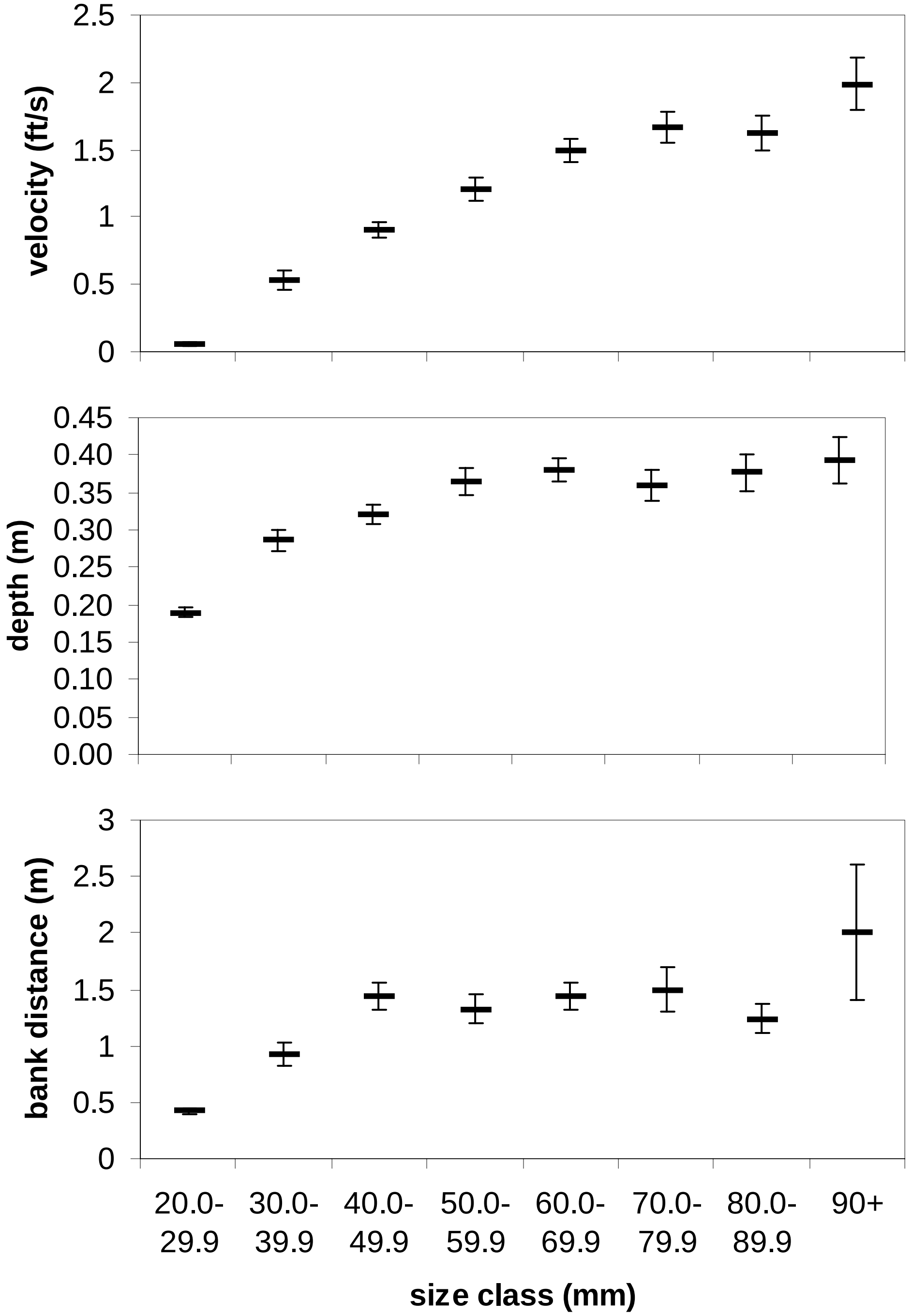

Figure 3.3-3. Average velocity, depth and distance from bank used by steelhead in various size classes. Errors bars represent standard deviation.

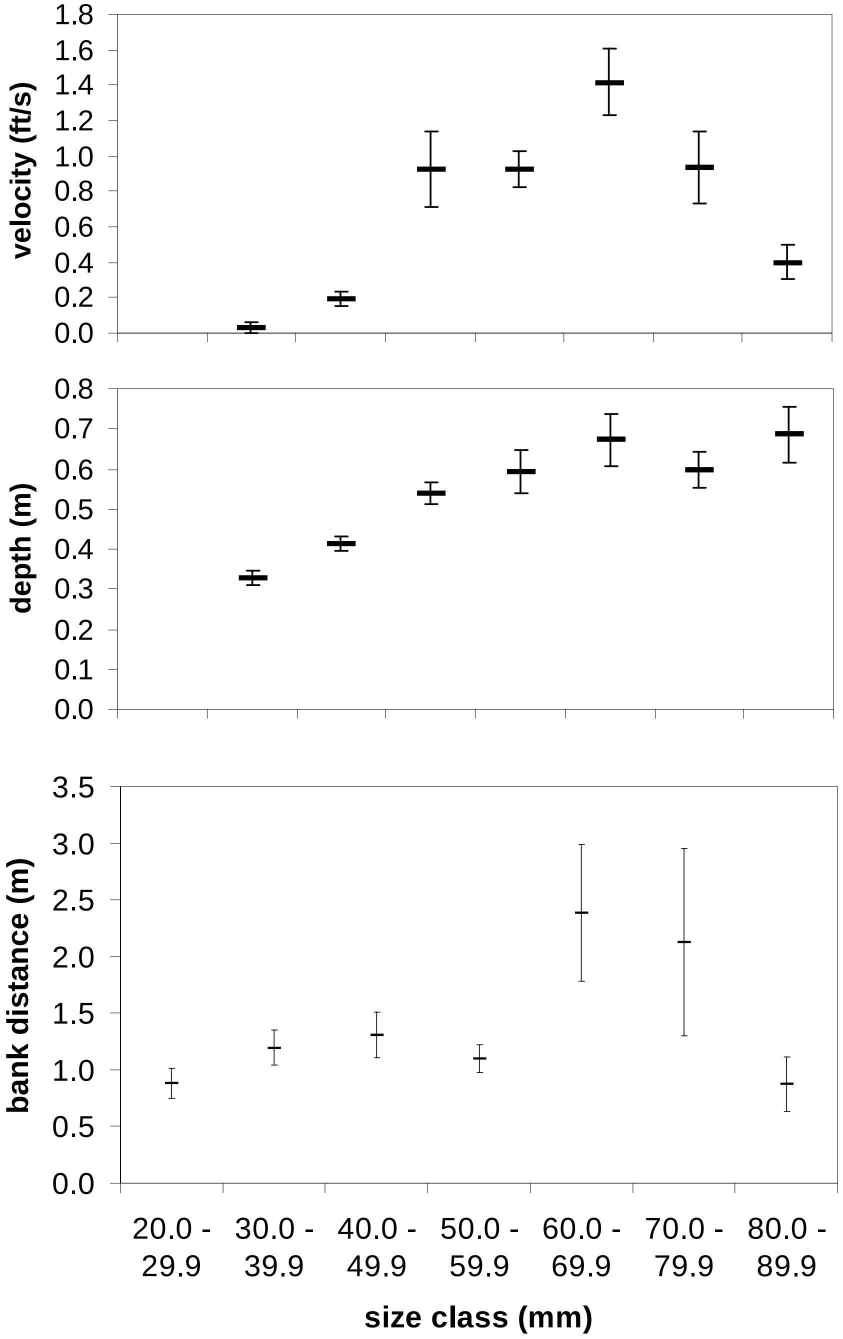

Figure 3.3-4. Average velocity, depth and distance from bank used by Chinook salmon in various size classes. Errors bars represent standard deviation.

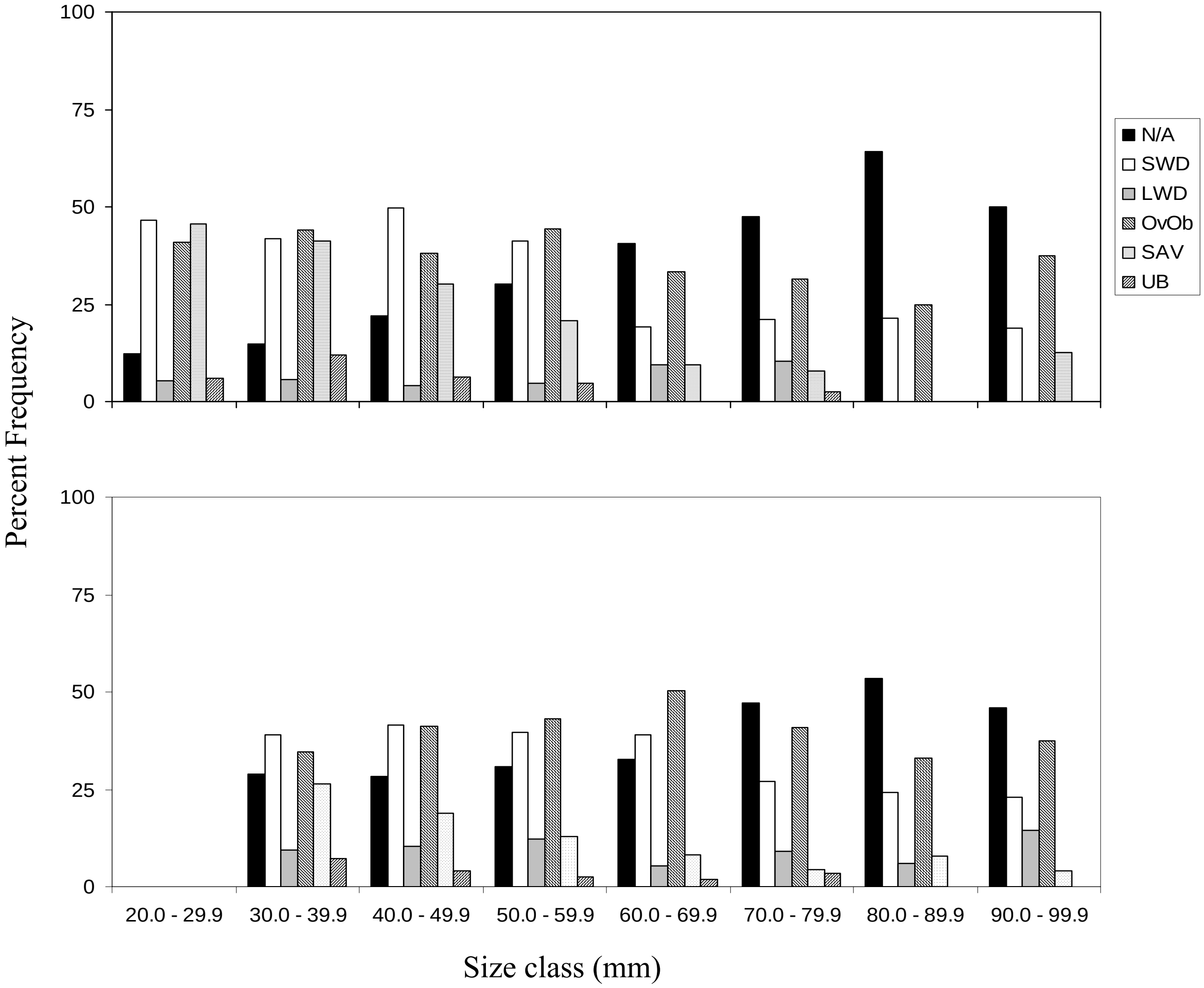

Figure 3.3-5. Cover use by different size classes of (top) steelhead and (bottom) Chinook salmon. The percent frequency of use was determined by dividing the number of observations associated with each habitat type by the total number of fish observations, such that the total percent use for all habitat types may exceed 100 %. N/A represents No Apparent cover, SWD represents Small Woody Debris, LWD represents Large Woody Debris, OvOb represents Overhead Objects, SAV represents Submerged Aquatic Vegetation, UB represents Undercut Bank.

3.4 Meso- and Microhabitat Preference

Logistic regression analysis of habitat preference among steelhead and salmon found that spatial scale and availability of habitat strongly affected the perceived importance of habitat variables. Mesoscale analysis for <100 mm steelhead found only two variables significantly influencing fish presence or absence: river mile and large instream objects (Table 3.4-1). Both variables were positively associated with the occurrence of age-0 steelhead at the mesohabitat scale (25 m reaches). Other variables that were analyzed but not found statistically significant are shown in Table 2.1.2-1. Microhabitat scale analysis based on intermediate scale snorkel surveys indicates five variables significantly affecting steelhead occurrence (Table 3.4-2). Water depth, current velocity, absence of overhead cover, absence of instream cover and gravel substrates were all found to be negatively associated with the occurrence of <100 mm steelhead. In other words, one square meter cells having higher values for these variables are less likely to contain steelhead. However, microhabitat analysis based on fine scale surveys indicates a smaller suite of important habitat variables: water depth, small instream objects, absence of overhead cover and distance from shore (Table 3.4-3). As with intermediate scale microhabitat selection, each of these variables is negatively associated with the occurrence of <100 mm steelhead.

Mesoscale analysis among steelhead larger than 100 mm was also of interest, but insufficient data were available to perform these analyses from fine-scale snorkeling surveys. However, intermediate-scale snorkel surveys provided a sufficient sample size (n=201) to analyze microhabitat selection. Six microhabitat variables were found statistically significant: water velocity, absence of overhead cover, pool, absence of instream cover, sand substrate, and gravel substrate (Table 3.4-4). All of these variables except water velocity and absence of instream cover were negatively associated with occurrence of age-1 or larger steelhead. Once again, results from microhabitat analysis with fine-scale snorkel data indicated fewer statistically significant habitat variables (Table 3.4-5). Water velocity, small instream objects, and large instream objects were positively associated with the presence of >100 mm steelhead.

River mile, average reach velocity, surface turbulence and small instream objects were significant predictors of age-0 Chinook salmon presence at the mesohabitat scale. (Table 3.4-6). River mile, surface turbulence, and small instream cover were all positively associated with the occurrence of Chinook salmon, while average reach velocity was negatively correlated. Intermediate scale microhabitat analysis indicated water depth, absence of overhead cover and gravel substrates were negatively correlated with the occurrence of age-0 Chinook salmon (Table 3.4-7). Only the pool hydrogeomorphic unit was positively associated with Chinook salmon. As with <100 mm steelhead, fine scale snorkel survey microhabitat analysis identified a shorter list of significant variables: absence of overhead cover and presence of small instream objects (Table 3.4-8). Lack of overhead cover was negatively correlated while presence of small instream cover was positively associated with age-0 Chinook observations.

Table 3.4-1. Binary logistic regression results for analysis of mesohabitat selection among age-0 sized steelhead. Data from fine scale snorkel surveys. Only variables with p-value <0.1 reported.

Category Choice	0 (reference)	140		
	1 (response)	49		
Parameter	Estimate	S.E.	t-ratio	p-value
Constant	-18.913	4.709	-4.64	0
ICOVC	0.5544	0.2221	2.5	0.013
RiverMile	0.22874	0.05578	4.1	0

Table 3.4-2. Binary logistic regression results for analysis of microhabitat selection among age-0 sized steelhead. Data from intermediate scale snorkel surveys. Only variables with p-value <0.1 reported.

Category Choice	0 (reference)	510		
	1 (response)	802		
Parameter	Estimate	S.E.	Z	p-value
Constant	5.890	0.390	15.087	0.000
Depth	-6.688	0.484	-13.812	0.000
Velocity	-0.167	0.084	-1.999	0.046
OCOVA*	-1.981	0.255	-7.764	0.000
ICOVA**	-0.806	0.223	-3.620	0.000
SUBGRAV***	-1.005	0.227	-4.437	0.000

*relative to any type of overhead cover
**relative to all types of instream cover
***relative to cobble and larger substrates

Table 3.4-3. Binary logistic regression results for analysis of microhabitat selection among age-0 sized steelhead. Data from fine scale snorkel surveys. Only variables with p-value <0.1 reported.

Category Choice	0 (reference)	1929		
	1 (response)	274		
Parameter	Estimate	S.E.	Z	p-value
Depth	-0.10358	0.004344	-2.38	0.017
ICOVB	0.014574	0.004798	3.04	0.002
OCOV0	-0.007424	0.002243	-3.31	0.001
Distance	-0.7793	0.09282	-8.4	0

Table 3.4-4. Stepwise binary logistic regression results for analysis of microhabitat selection among age-1 sized steelhead. Data from intermediate scale snorkel surveys. Only variables with p-value <0.1 reported.

Category Choice	0 (reference)	510		
	1 (response)	201		
Parameter	Estimate	S.E.	t-ratio	p-value
Constant	1.571	0.410	3.836	0.000
Velocity	0.162	0.074	2.197	0.028
OCOVA*	-3.520	0.457	-7.696	0.000
POOLS**	-1.509	0.434	-3.476	0.001
ICOVA***	1.397	0.467	2.989	0.003
SUBSAND****	-0.776	0.286	-2.714	0.007
SUBGRAV****	-1.154	0.219	-5.258	0

*relative to any type of overhead cover

**relative to riffles and glides

***relative to all types of instream cover

****relative to cobble and larger substrates

Table 3.4-5. Binary logistic regression results for analysis of microhabitat selection among age-1 sized steelhead. Data from fine scale snorkel surveys. Only variables with p-value <0.1 reported.

Category Choice	0 (reference)	345		
	1 (response)	20		
Parameter	Estimate	S.E.	Z	p-value
Constant	-5.86	3.192	-1.84	0.066
Velocity	0.6785	0.2927	2.32	0.02
ICOVB	0.05449	0.02723	2	0.045
ICOVC	0.07807	0.03724	2.1	0.036

Table 3.4-6. Binary logistic regression results for analysis of mesohabitat selection among juvenile Chinook salmon. Data from fine scale snorkel surveys. Only variables with p-value <0.1 reported.

Category Choice	0 (reference)	91		
	1 (response)	45		
Parameter	Estimate	S.E.	t-ratio	p-value
Constant	-12.521	4.354	-2.876	0.004
Rivermile	0.12	0.048	2.505	0.012
AVGVEL	-1.091	0.541	-2.017	0.044
SURFTURB	0.173	0.056	3.074	0.002
ICOVB	0.193	0.076	2.529	0.011

Table 3.4-7. Binary logistic regression results for analysis of microhabitat selection among juvenile Chinook salmon. Data from intermediate scale snorkel surveys. Only variables with p-value <0.1 reported.

Category Choice	0 (reference)	510		
	1 (response)	169		
Parameter	Estimate	S.E.	t-ratio	p-value
Constant	2.660	0.441	6.032	0.000
Depth	-3.270	0.498	-6.562	0.000
OCOVA*	-2.132	0.312	-6.825	0.000
Pool**	0.981	0.295	3.321	0.001
SUBGRAV***	-0.548	0.290	-1.889	0.059

*relative to all types of overhead cover

**relative to riffles and glides

***relative to cobble and larger substrates

Table 3.4-8. Binary logistic regression results for analysis of microhabitat selection among juvenile Chinook salmon. Data from fine scale snorkel surveys. Only variables with p-value <0.1 reported.

Category Choice	0 (reference)	1618		
	1 (response)	190		
Parameter	Estimate	S.E.	t-ratio	p-value
Constant	-2.663	0.753	-3.538	0.000
OCOVA	-0.009	0.006	2.153	0.000
ICOVB	0.031	0.003	-3.566	0.031

3.5 Steelhead mark recapture and size distribution

Over two seasons, a total of 1,065 steelhead were captured and marked. A majority of these were captured in Hatchery Ditch (n=455), but fairly large numbers were also captured at Steep Riffle (n=259), Aleck Riffle (n=142) and Matthews Riffle (n=94). Seventy-eight steelhead were captured at Auditorium Riffle and 27 were captured at Bedrock Riffle. Recapture rates were low, with only 8.4% (89) of fish recaptured at the site where they were originally marked and released. Hatchery Ditch and Aleck Riffle had the highest recovery rates, 12.1% (55) and 9.9% (14), respectively. Eight fish were recaptured downstream from where they were originally tagged. No tagged fish were recaptured upstream of their tagging site.

Fork lengths (FL) of captured fish differed considerably between sites (Figure 3.5-1). In general Average FL and FL standard deviation increased from upstream to downstream. In other words, fish captured downstream were generally larger and exhibited a wider range of sizes than upstream. The maximum growth rate for a steelhead between June and August was 1.65 mm/day, while the average was 0.67 (SD=0.05) mm/day. The mark recapture data also showed that young-of-the-year steelhead can reach lengths greater than 150 mm FL by August.

Using data from 2003 we compared the daily growth of steelhead marked and recaptured at the same site. Only Hatchery Ditch, Aleck Riffle and Steep Riffle had sufficient sample sizes (Figure 3.5-2). An analysis of variance showed a statistically significant difference in daily growth (by length and weight) between sites [$F_{(2, 64)}=11.69$, $p<<0.001$ and $F_{(2, 64)}=24.49$, $p<<0.001$), respectively]. Post-hoc comparisons revealed that daily growth was significantly lower at Hatchery Ditch (M=0.49, SD=0.62) than Aleck Riffle (M=1.13, SD=0.32) and Steep Riffle (M=1.27, SD=0.72). There was not a statistically significant difference between Aleck and Steep Riffle. The minimum period over which growth was measured was 13 days. The mean duration of growth for

Hatchery Ditch was 27.8 days (SD = 2.1), for Aleck Riffle was 24.3 days (SD = 3.8), and for Steep Riffle was 18.5 (SD = 1.2).

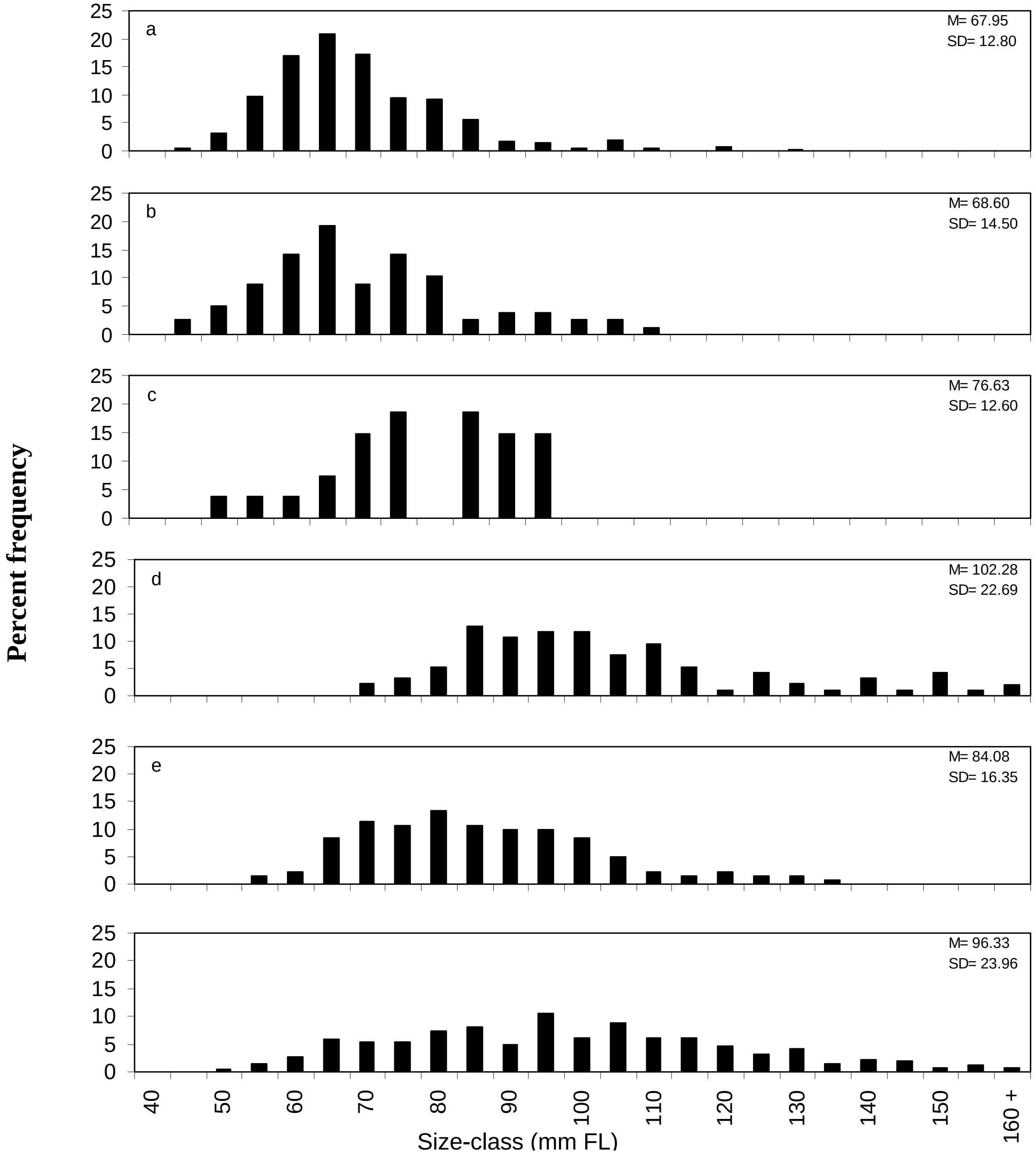

Figure 3.5-1. Length frequency distributions for steelhead captured during mark-recapture surveys. Figures are ordered from upstream to downstream: a) Hatchery Ditch, b) Auditorium Riffle, c) Bedrock Park, d) Matthews Riffle, e) Aleck Riffle, and f) Steep Riffle. Mean fork length and standard deviation listed in upper right corner.

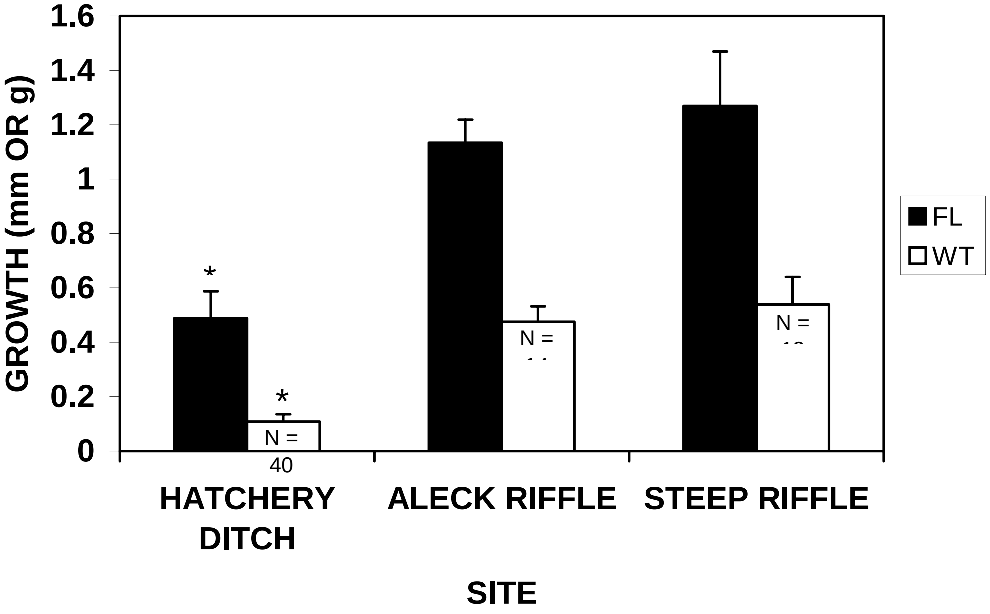

Figure 3.5-1. Mean growth of Age-0 steelhead marked and recaptured at the same location. (*) denotes statistically significant difference (alpha =0.05). Bars indicate S.E. of the mean. The minimum period over which growth was measured was 13 days.

4.0 DISCUSSION

The distribution and abundance of fishes in the lower Feather River appears to be strongly structured by environmental conditions operating at large spatial scales. Results from all three types of snorkel surveys suggest that river mile, and by implication, its correlates (water temperature, HFC or LFC, proximity to the FBD), explained much of the observed variation in fish distribution. The TAO causes a rapid transition in physical conditions that is mirrored clearly in the types and numbers of fish encountered both upstream (in the LFC) and downstream (in the HFC). Salmonids, particularly juvenile steelhead, were always more abundant in the LFC, while cyprinids, centrarchids and tule perch were always more abundant in the HFC. The existence of two distinct fish assemblages is consistent with the findings from seining and rotary screw trap sampling reported in Seesholtz et al (2004).

The scale at which organisms respond to available habitats is an important ecological issue (Wiens 1989, Poizat and Pont 1996), and strongly affects perceived distribution patterns and the importance of habitat variables. In our studies, all fish species showed an association with certain microhabitat characteristics. For example, centrarchids were most often found in backwaters near submerged aquatic vegetation. Steelhead less than 100 mm selected shallow, relatively slow moving waters with overhead and in-channel cover. However, these microhabitat types are common in the lower Feather River. That is, vegetated backwaters and shallow, shoreline glides are not unique to the river reaches where these species consistently occurred. Thus, the selection of small-scale habitat (i.e., microhabitat) appears to be strongly constrained by large-scale physical conditions such as river mile and water temperature.

The relative importance of various microhabitat variables changed substantially, depending on the scale at which availability was measured. Analysis from intermediate-scale snorkel surveys was based upon a 200 to 600 meter reach, which included at least one pool-riffle sequence, both river banks and everything in between. Fine-scale snorkel surveys were focused on areas thought to meet the minimum habitat criteria for <100 mm steelhead. Fine-scale reaches were selected among riffle-glides, based upon a much shorter reach (25 m), oriented along one bank and extended out only four meters. Because it treated a broad area as available habitat, the intermediate-scale microhabitat analysis identified many more variables as significantly affecting occurrence of <100 mm steelhead than did the fine-scale analysis. This result implies that <100 mm steelhead were highly specific in their microhabitat needs, because much of the area in the intermediate-scale analysis represented habitats that steelhead almost never used.

Proximity to river’s edge may be the strongest determinant of whether <100 mm steelhead used a given microhabitat cell. Steelhead less than 80 mm were almost always observed within two meters of shore (Figure 3.3-3). When this affinity for shoreline areas was taken into consideration (i.e., in the fine-scale analysis), only depth, overhead cover and distance from shore had statistically significant effects on microhabitat distribution. Similar results are apparent in comparing intermediate and fine scale based microhabitat selection among age-0 Chinook salmon.

The collective results of our multi-scale distribution analysis demonstrate some specificity in microhabitats among <100 mm steelhead and age-0 Chinook salmon. When viewed in isolation, these microhabitat requirements seemed amply available in the lower Feather River. However, when small-scale habitats were matched within large-scale requirements, the overall amount of suitable habitat shrank.

As an example, the scarcity of riffle/glide habitats in the lower Feather River constrains the amount of suitable smaller scale habitats. Glides were used by age-0 salmonids much more than pools or backwaters in intermediate-scale surveys (Figures 3.3-1 and 3.3-2). Similarly, pools and slow-moving waters were generally devoid of rearing salmonids in broad-scale surveys. This difference is striking because riffle/glide habitats are rare on the Feather River, being interspersed with much larger sections of slow moving, sometimes deep, pool habitats. However, hydrogeomorphic habitat selection was poorly represented in the statistical analyses, because most sampling was in riffle/glide areas thought to be potential salmonid rearing habitat.

The fact that large scale conditions appear to drive observed distribution and abundance patterns for lower Feather River fishes has important implications for the study and management of the river. Physical habitat simulation models (e.g. PHABSIM) are a common approach to studying instream flow needs in regulated rivers. These models are typically used with the assumption that fish habitat needs may be characterized by simple microhabitat variables such as depth, substrate, velocity and cover. However, our results suggest that focusing on small-scale habitat use and ignoring mesoscale and larger scale conditions would provide an inaccurate view of habitat suitability under different flow regimes. Thus, management actions emphasizing the effects of flow on simple microhabitat availability are unlikely to improve the productivity and success of wild salmonids in the lower Feather River. This view is supported by recent results from Feather River instream flow studies (DWR 2004) which yielded ambiguous and uninformative results for juvenile salmonid lifestages.

Preliminary work in the Feather River indicated that <100 mm steelhead were restricted to the upstream reaches of the Low Flow Channel (LFC). At the outset of our study, this restriction was attributed to any of several factors: selection of cold water, predator avoidance, and habitat preference. Our snorkeling studies confirm that the bulk of <100 mm steelhead occur at the upstream end of the LFC. However, neither water temperature, predation pressure nor habitat availability convincingly explain this pattern.

Water temperatures within the entire LFC are typically well within the thermal preference and tolerance range of steelhead (Myrick and Cech 2000). Furthermore, larger steelhead were typically more abundant at the downstream end of the LFC where water temperatures usually are higher in summer. We found little evidence of any effect of predation on the distribution of juvenile steelhead within the LFC. The most likely predators, Sacramento pikeminnow and Micropterus basses, were rare throughout the LFC. Also, changes in seasonal distribution of <100 mm steelhead were not consistent with an expected response to predation pressure. Recently emerged steelhead were restricted to the upstream end of the LFC from when surveys began in March. If this distribution were driven by predation pressure, we would expect to see a broad distribution early in the season that became more restricted as the season progressed. Predation may be a more significant factor for salmonids living in the HFC where predatory fishes were more common and where water temperatures were generally warmer.

Suitable microhabitat features (current velocities, depth, and cover) were not restricted to the upstream end of the LFC. Side channels, with abundant instream and overhead cover, were available at Hatchery Ditch, other locations in the LFC (Eye Riffle, Steep Riffle) and even some locations in the HFC. Although <100 mm steelhead densities were highest in Hatchery Ditch, overall abundance was generally high throughout the upper river mile of the LFC. In light of these facts, the availability of rearing habitat at the upstream end of the LFC does not seem to convincingly explain the observed distribution pattern.

Proximity to the Fish Barrier Dam (upstream migratory limit) and to the Feather River Fish Hatchery may provide a more complete explanation. Central Valley steelhead historically spawned as far upstream as they could physically reach (Yoshiyama et al. 1996). In a dammed river where the bulk of the historic migratory range is cut off, steelhead would be expected to swim up to the first artificial barrier before spawning. Our Feather River data from the period when steelhead fry emerge (March-April) suggest that spawning is largely restricted to the upper mile of the LFC (Figure 9). Results from redd surveys revealed that nearly half (48%) of all redds were constructed in the uppermost mile of river (between RM 66 and 67), between the Table Mountain Bicycle Bridge and Lower Auditorium Riffle (DWR 2003). This section of river maintained 36 redds per mile, over ten times greater than any other section of river. Hatchery Ditch alone had 26 redds constructed within it, five times more redds than were constructed in any other location. Age-0 steelhead surveys on the Yuba River (Kozlowski unpublished) and redd surveys on the American River (Hannon and Healey 2002) have also found highest densities at upstream sampling sites.

The Feather River Fish Hatchery, at the upstream end of the LFC, may exert a powerful influence on the spawning distribution of steelhead. Chemical or olfactory cues in effluent from the Hatchery may have a strong attraction for fish of hatchery origin. Hatchery Ditch, where much of the steelhead spawning occurs, is fed entirely by effluent from the hatchery settling pond. Mackey et al. (2001) found that hatchery steelhead in an Oregon river tended stay close to the hatchery, apparently as a result of chemical imprinting on the hatchery's water supply. It is possible that hatchery steelhead are spawning at the upstream end of the LFC for its proximity to the hatchery, rather that its overall habitat suitability.

On the lower Feather River, newly hatched steelhead were largely restricted to the upstream end of the LFC, but gradually dispersed downstream. Other studies have also found higher upstream densities of rearing steelhead (e.g. Roper et al. 1994). In these studies, unsuitably high water temperature in the lower reaches may have caused greater proportions of young steelhead to emigrate (Roper et al. 1994) or decreased their survival (Bisson and Davis 1976), resulting in lower observed steelhead densities. Juvenile steelhead typically move downstream in search suitable habitat and adequate food supplies (Peven et al. 1994). Roper et al. (1994) also found that age-1 and older steelhead were most abundant in middle reaches, while age-0 dominated areas further upstream.

Our studies indicated a substantial downstream migration of presumably age-0 steelhead (<100 mm). Those fish were on average larger than fish living upstream (Figure 3.5-2), and larger steelhead were generally more common, relative to smaller steelhead, in middle and downstream reaches of the LFC (Figures 3.1-1). The catch in rotary screw traps indicates that many young-of-the-year steelhead emigrate from the LFC shortly after emergence (Seesholtz et al 2004). The fate of these fish is unknown, but steelhead typically reside in-river for at least one year prior to smolting (McEwan 1999). Most of the apparent emigrants from the LFC are quite small, and therefore should be physiologically incapable of smoltification.

Our surveys found numerous <100 mm steelhead early in the season, but far fewer as the season progressed (Figure 3.2-1). Fish remaining in the upper reaches of the LFC appear to grow slowly relatively to those rearing downstream. Juvenile steelhead over 200 mm were scarce in our surveys, which suggests that few remain in the lower Feather River into their second year. Although steelhead this large are difficult to observe by snorkeling, they were also not observed by seining and electrofishing efforts. The Yuba River and Sacramento River (below Keswick Dam) support year-round populations of adult resident rainbow trout and/or steelhead. We saw little evidence for a similarly strong population in the Feather River. However, we detected an influx of 100 to 300 mm-long steelhead, more typical of pre-smolt juveniles, from June to August. These fish may primarily reside downstream of the TAO, where food and habitat are more abundant (Esteban 2002). In summer they may migrate into the LFC in search of cooler water. Many of the young-of-the-year steelhead which emigrate from the LFC (Seesholtz et al. 2004) may also adopt this strategy. Snorkel surveys could easily miss these individuals, given the river size below TAO, resulting low fish densities, poor visibility and greater observer avoidance among older steelhead.

However, our results from mark recapture surveys suggest that at least some of the larger steelhead observed in late summer may actually be rapid growing age-0 fish that selectively rear downstream. With aggressive seine and electrofishing tactics we were able to collect larger steelhead which were previously undetected from snorkel surveys. Many relatively large steelhead were collected in habitats such as shallow pocket water and swift currents with dense cover, that are particularly difficult to snorkel. Growth rates from recaptured young-of-the-year steelhead were fast enough for fish to attain lengths over 150 mm by the end of August. Additionally, the fastest growth rates occurred in the same downstream areas where we observed an increase of larger steelhead over the summer months.

Age-0 Chinook salmon were very abundant early in the season, but appeared to begin their downstream migration early, and were nearly absent from our surveys in summer (Figure 3.2-3). This observation is consistent with an ocean type life history and with the emigration pattern described by our rotary screw trap sampling (Seesholtz et al. 2004). A few age-0 salmon remained in the LFC through each summer of our survey. However, these individuals probably reflect normal behavioral variation rather than a distinct life history akin to some Chinook salmon races (e.g. spring-run).

In conclusion we found that the distribution and abundance of fishes in the lower Feather River is likely dictated by environmental conditions operating at large spatial scales. Along with containing colder summer water temperatures, the LFC is the upper extent of the river and is adjacent to the Feather River Fish Hatchery. Combined these attributes are attractive to salmonids and are ostensibly, why juvenile salmonids are practically exclusive to LFC. Summer water temperature in the HFC is generally warmer, which is more suitable for cyprinids, centrarchids, and other warm water fishes that dominate this section of the river. At the microhabitat level fish clearly demonstrate a preference for certain habitat types, however this does not apparently influence the overall distribution pattern of fishes in the lower Feather River. Essentially, microhabitats (velocity, depth, etc.) are typically not exclusive to any reach of the river and therefore do not determine the pattern observed distribution and abundance.

The spatial and temporal patterns of distribution and abundance we observed for steelhead are likely explained by the distribution of adult spawning and the apparent benefits of downstream rearing. For reasons discussed earlier adult steelhead prefer to spawn upstream and this tendency is mirrored by the skewed distribution of newly emerged steelhead. Our data suggests that many steelhead continue to rear upstream throughout the summer, but a substantial proportion appear to move downstream to rear. This observation is supported by the progressive increase in the abundance of larger steelhead downstream in later months. We also know from mark recapture data that growth is significantly greater downstream. Increased growth for these steelhead provides several selective advantages over slower growing cohorts. Larger salmonids are less susceptible to predation (Hunt 1969; Taylor and MacPhail 1985), are more likely to survive over winter (Hunt 1969; Quinn and Peterson 1996; Meyer and Griffith 1997), and are more adept at capturing prey more (Taylor and MacPhail 1985). Others have shown that smolt-to-adult survival is positively correlated to smolt size (Ward and Slaney 1993). We still have no concrete evidence that steelhead remain at least in the

LFC past their first winter. During our snorkel surveys in early spring virtually all observed steelhead are substantially less than 100 mm. The size distribution of steelhead from the mark recapture survey also suggests that steelhead emigrate by first winter. We are currently investigating new methods which will enable us to definitively determine the age structure of Feather River steelhead, as well as seasonal movement and migration patterns.

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