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Recon Snorkel Survey of the Middle Sacramento River
RM 180 to 230

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Abstract

The distribution and abundance of winter-run juvenile Chinook salmon (*Onchorhynchus tshawytscha*) were the subject of a recon snorkeling survey of the middle reach of the lower Sacramento River (RM 180-230) in the late summer and fall of years 2004-2006. Nine surveys were conducted with a team of divers. Surveys were conducted at river flows from 7,000 cfs to 13,300 cfs (Hamilton City gage). Water temperatures ranged from 13 to 17ºC with higher temperatures in late summer surveys at lower sites. Densities of juvenile winter-run Chinook salmon reached 0.5 per square feet of area surveyed. Densities were greatest along river margins in shallow water (less than 2 to 3 ft depth), low to moderate velocities (0.5-2.25 ft/s), sand and silt substrate, and moderate to high amounts of cover. Salmon were not observed in shallow, warm, near zero velocity backwater habitats including mouths of small tributary streams. Winter-run juvenile Chinook salmon rear in the middle Sacramento River at the lowest water surface elevations of the year, thus the focus of the protection and enhancement of their habitat should be on that river stage and flow.

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Introduction

Winter-run Chinook salmon(*Onchorhynchus tshawytscha*) in the Sacramento River (winter-run) once sustained runs of over 50,000 adults but numbered fewer than 200 spawners by 1994. The decline brought about their listing as endangered in 1989 under the California Endangered Species Act and in 1994 under the federal Endangered Species Act. After a decade of many recovery actions the run size reached 15,000 in 2005, but numbers have yet proven sustainable under the criteria of the recovery plan. One of the criteria of the Winter-Run Recovery Plan (NMFS 1997) is to "improve understanding of the life history and habitat requirements of winter-run".

One part of the winter-run's life history and habitat requirements that is relatively unknown is that related to juvenile-rearing in the middle Sacramento River downstream of the Red Bluff to Redding (RM 250-300) spawning reach. Winter-run spawn in the upper reach above Red Bluff from late-April through mid-August with a peak in May-June (CDFG 1993). The area in question is approximately RM 150-250, where after hatching a portion of the fry and fingerling winter-run rear through the late summer and fall before migrating to the lower river and estuary. This part of the river is the reach where flood bypass weirs to the Sutter Bypass are located; however, juvenile winter-run generally are not susceptible to diversion into the Sutter Bypass because there are generally low river flows in late summer and fall[1].

The middle river is also home to the Sacramento River Bank Protection Project (SRBPP) of the Sacramento River Flood Control Project (SRFCP), which is a cooperative effort of the federal and state government to provide flood protection to north-central California. The SRBPP is responsible for maintaining riverbanks and levees constructed along portions of the river bank from about RM 220 near Corning to the mouth at RM 0 in the Delta. The Sacramento River Flood Control Project consists of about 1,300 miles of levees, overflow weirs, pumping plants, and bypass channels on the Sacramento River and adjacent sloughs and streams from RM 0 at Collinsville to RM 194 near Chico (U.S. Army Corps of Engineers 1993). Bank protection and levee construction in the middle river have greatly altered the natural meander process of the river and the associated natural habitat maintenance and forming processes of the river that provide for the rearing habitat of the juvenile salmon. On August 23, 2001 and September 27, 2001, the U.S. Fish and Wildlife Service (F&WS) and the National Marine Fisheries Service, respectively, issued their final Biological Opinions on the flood control project that identified the SRBPP as jeopardizing the existence of 5 fish species including the winter-run. The SRBPP and interagency working groups continue to reconcile needs for continued flood control and bank protection with impacts to fish as prescribed by the Biological Opinions.

The upper and middle Sacramento River from Redding (RM 300) downstream to Verona at the mouth of the Feather River (RM 80) are also part of the State of California's SB 1086 Program that calls for state management to protect, restore, and enhance the fish

[1] The authors did observe juvenile winter-run stranded below the weirs in early December 1998 during a late fall flood episode.

and riparian habitat of the Sacramento River. The 1086 Program includes planning efforts to describe actions that will help restore the salmon runs and protect and restore riparian habitat. The Sacramento River Conservation Area Forum (SRCAF) continues to implement the 1086 Program under the CA Department of Water Resources, Northern District. Although their main focus is on the natural-bank meander reach upstream of the levee reach, the SRCAF continues planning efforts on the levee reach from Chico to Verona.

The fish habitat of the middle river has also been affected by the Shasta Dam-Keswick Dam complex (RM 300) and Red Bluff Diversion Dam (RM 250) of the Central Valley Project (CVP). Streamflow, sediment, and water quality have been greatly altered by the CVP dams and diversions, which has contributed to loss and degradation of fish habitat of the middle river. Large water diversions of the CVP occur below Red Bluff at the Tehama Colusa Canal (RM 243) and Glen Colusa Irrigation District (GCID) Canal (RM 206) and affect river flow in the middle river. Many tributaries from Redding to Verona also affect the middle river. The federal Central Valley Project Improvement Act of 1994 (CVPIA) includes provisions for studying and restoring habitat along the middle river and its tributaries.

The CVPIA Anadromous Fish Restoration Program (AFRP), the CALFED's Ecosystem Restoration Program (ERP), and Sacramento and San Joaquin River Basins Comprehensive Study (Comprehensive Study) have sustained interest in habitat restoration of the middle river floodplain habitats. The Comprehensive Study involves the US Army Corps of Engineers and the State Reclamation Board including the California Department of Water Resources' Flood Management Division. Responsibility for fish and riparian losses of the river are estimated to be 75 percent federal and 25 percent state and local (Resources Agency 1989).

The AFRP and CALFED programs have purchased miles of river shoreline and floodplain properties along the middle river and with partners such as the Nature Conservancy have begun restoration. Their goal is to restore a continuous 100-mile stretch of riparian habitat along the river between Red Bluff and Colusa. The Nature Conservancy, the U.S. Fish and Wildlife Service, the California Department of Fish and Game, and the California Wildlife Conservation Board have acquired 14,000 acres along the river. Three thousand acres have been restored thus far to native riparian forest.

Under the AFRP program over the past decade, the US Fish and Wildlife Service and CA Department of Fish and Game have been studying the middle river to determine the importance of the middle river to rearing salmon. They have employed screw traps at Red Bluff, the GCID Canal diversion, and Knights Landing along the middle reach, as well as various surveys on middle-river tributaries.

Results of the screw trap surveys indicate the middle river is important to juvenile winter-run for downstream passage and rearing. With winter-run spawning in the upper reach above Red Bluff from late-April through mid-August, fry emergence occurs from mid-June through mid-October. Movement of juvenile salmon in the fry stage (30-50mm in length) past Red Bluff begins in late July and peaks in September. Emigration past the

GCID diversion at Hamilton City (RM 206) occurs from mid-July through April. The juvenile (fry, fingerlings 50-75mm, and smolts 75+mm) winter-run spread through the middle river between October and March. Based on surveys in the spawning reach above Red Bluff, juvenile winter-run are thought to seek out calm, shallow waters characterized by fine sediments and bank cover including such habitat as eddies, back-waters, and off-channel habitats (e.g., sloughs and oxbows). Submerged and overhead cover provide shade and protection from predation. Riparian vegetation along the river banks provides substrate and nutrients for aquatic and terrestrial invertebrates that are important food for juvenile salmon.

The Nature Conservancy and California State University Chico have also surveyed portions of the middle river and its off-channel habitats (Limm and Marchetti 2003). They found the off-channel habitats to have abundant food and warmer waters that could lead to higher growth rates and survival of juvenile salmon. Their studies focused on the February through April period when spring and fall-run salmon juvenile rearing predominates in the middle river. They found off-channel habitats and lower non-natal tributaries to have more optimal rearing conditions (water temperature, cover, food, and low predation) than the main river.

No recent surveys of winter-run have occurred below GCID (RM 206), and little is known about the distribution and habitat use of winter-run within the middle river. Earlier studies have shown that juvenile salmon avoid rocked banks. The USFWS conducted a study to assess the relationship of juvenile Chinook salmon to the construction of rock revetment type bank protection between Chico Landing and Red Bluff (Michny and Hampton 1984). They found that piscivorous predators such as Sacramento pikeminnow (*Ptychocheilus grandis*) and prickly sculpin (*Cottus asper*) were more abundant at rocked sites than at naturally eroding bank sites with riparian vegetation. Conversely, juvenile salmon were found more frequently in areas adjacent to riparian bank habitat than at rocked sites. The authors concluded that riparian habitat provides overhead and submerged cover, an important refuge for juvenile Chinook from predators.

In 2004 the USFWS and US Army Corps of Engineers under the direction of the SRBPP, AFRP, and CVPIA programs commissioned the Fishery Foundation of California to conduct a recon snorkel survey with funding from the FWS of the distribution and habitat use patterns of juvenile winter-run salmon in the middle river from late summer to early winter.

A total of nine snorkel surveys in the middle river were conducted by FFC in the fall of 2004, 2005, and 2006 to determine use by and habitat used by juvenile winter-run. The surveys were to provide information on juvenile salmonid and other fish rearing within the reach and contribute to the understanding of fish use of specific habitats modified by flood control activities such as rocked streambanks. Results of the recon snorkel surveys are presented in this report.

Methods

Survey Design

The nine total 2004-2006 snorkel surveys were conducted from late summer into the fall. Snorkeling observations were conducted at specific locations along the middle river from RM 180 to 230 (from near Corning south to Ordbend) (Figure 1). One or two team of divers, with two to three divers, conducted the surveys from a jet boat or four-wheel drive vehicle. Individual surveys were conducted over a period of two to four days.

Survey sites within locations were chosen to be representative of habitat of the middle river and to represent the broad array of physical habitat. Locations were chosen systematically to represent the longitudinal distribution of fish in the middle river through the survey period. Choice of sites and locations was influenced to some degree by accessibility and water clarity conditions (water clarity was greater in the upper portion of the survey reach).

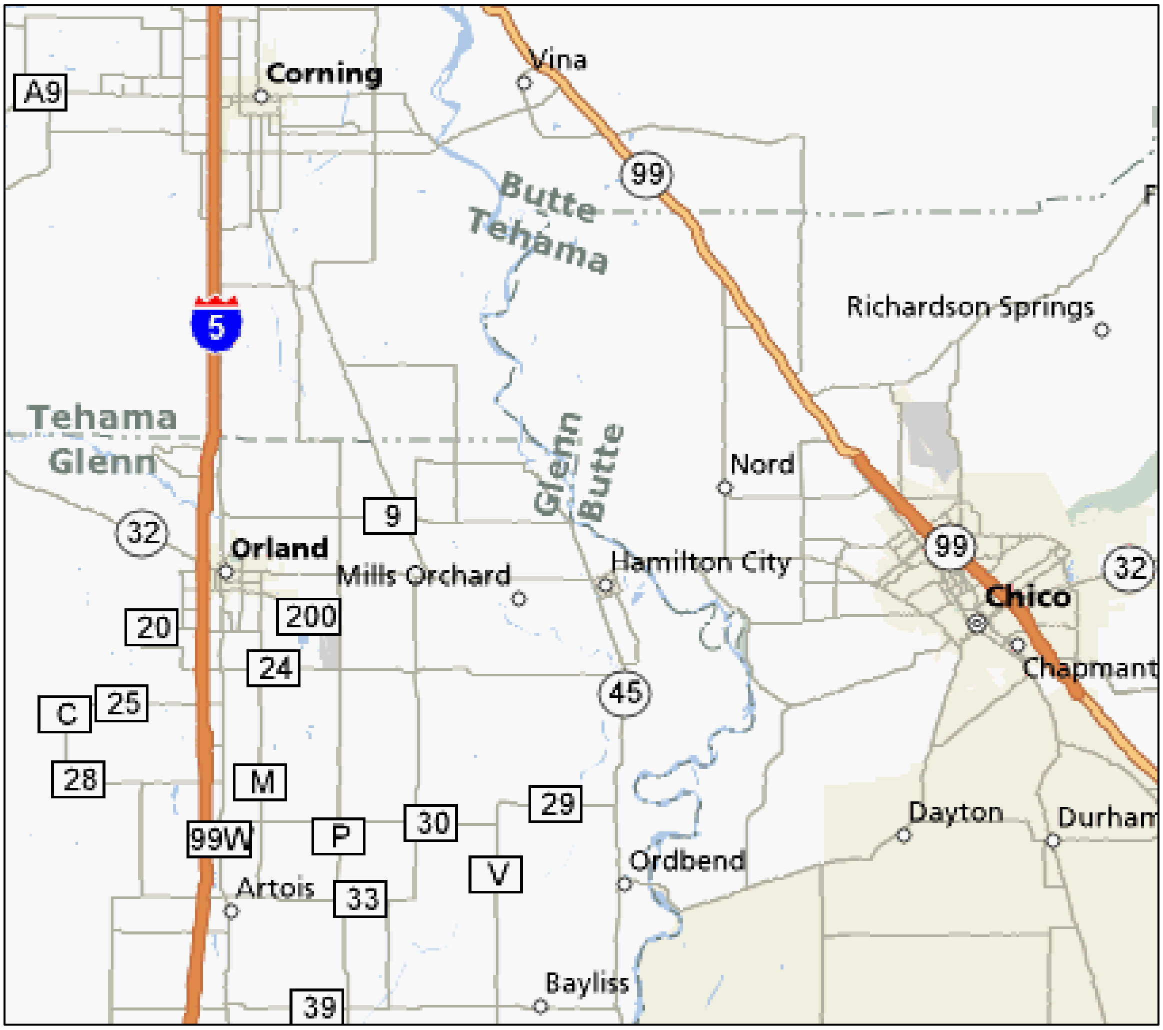

Figure 1. Survey area of lower Sacramento River from near Corning south to Ordbend.

At each of the sites the available habitat area was visually surveyed and representative habitat polygons designated as sampling units. Units varied in size from 50 to 300 feet in length and 6 to 20 feet in width. Dimensions differed as a function of homogeneity of the habitat within the unit. For example, mainstem center units were generally 100-300 feet in length and 10 to 20 feet wide because habitat varied little in large runs and pools of the main river channel. Shoreline and side channels units were smaller, varying in size from 50 to 200 feet in length and 6 to 10 feet in width, because variability of habitat was greater. The units were called polygons because of their varying two-dimensional shapes. In designating polygon/cell units we followed the general approach of Kocik and Ferreri (1988), McCain (1992), Thomas and Bovee (1993), and others, where cells were discrete functional habitat units having a consistent range of microhabitat variables (depth, velocity, substrate, and cover). The functional habitat unit concept allows a flexible approach to evaluating habitat and determining seasonal habitat use patterns at a scale that can be readily visualized and is intuitively understandable. For example, shallow shoreline riffle margins with uniform cover were one common type of cell; while mainstem runs with consistent depth and substrate were another. Other common types were backwater and riffle/pool margins with and without cover, and deep pool margins or riprap banks with and without cover. In most cases units had unique qualities with obvious differences from other units among and within sites, but units could usually be categorized into general types (e.g., shoreline, bar or bank, side channel, riffle, run, or pool, and with or without cover).

The number of sampling units chosen varied directly with the diversity of habitat at the site. For example, sites with islands and side channels were allocated more sampling units. Most units within a site had some unique habitat features or conditions that differentiated them from other units. Overall, we were able to sample only a representative portion of the types available at any one site and then only a minimum of one or two units per type.

Sampling units were chosen from the available array of riffles, pools, runs/glides, banks, bars, side channels, and backwaters following mesohabitat classification systems in the standard literature (Bisson et al. 1981). At each site, sampling units were designated from as many mesohabitat types as possible. Given the high variability in habitat available among possible river sites and within each site, the final survey array has some degree of randomness despite being discretely chosen. We had hoped to choose units at random from among habitat types; however, no map of habitat at the unit level was available for the river from which to choose sites or units in a random or systematic fashion.

Not all sampling units were sampled in each survey for a variety of reasons. In some cases under the varying river flows it was not possible to survey all units at all flows. In some cases when a designated unit could not be surveyed other units were added or substituted. Generally, for each sampling period, surveys were conducted at most of the designated sampling units at each regular sampling site and location.

Sampling Technique

Snorkeling was conducted similar to other published snorkel surveys (Edmundson et al 1968; Hankin and Reeves 1988; McCain 1992; Jackson 1992; Dolloff et al. 1996; Cavallo et al. 2003). One snorkeler generally sampled each unit[2]. For nearshore units, the diver proceeded upstream against the current. In eddies, the diver proceeded against the current. In faster water the diver often had to pull along the shoreline using rocks and brush to hold or gain position. Deeper and center stream units were sampled by the diver proceeding downstream with the current. Swimming with the current in deeper water brought about less avoidance than appeared to be the case when swimming downstream in shallow water. It also appeared to be effective (at least in terms of approaching large wary fish) because of the general high rate of speed and relatively little need to swim and disturb the water being surveyed when moving over the deeper waters of the main

[2] At times a second diver followed the data collector for the purposes of observing, training, or quality assurance checking.

channel of the river. In units deeper than six feet, we were generally unable to observe fish near the bottom because of poor water clarity.

Fish were identified and counted by size group as the diver proceeded up or down the sampling unit. A typical approach was to move upstream along shore either six feet from shore (velocity permitting) or directly along shore viewing upstream and offshore – observing, identifying, counting, and sizing fish as proceeding. Care was taken to observe and count fish just once by passing fish and allowing them to escape downstream of the diver. Some counts were made as fish escaped past the diver, but generally divers were able to observe fish under normal behavior conditions before fish were passed or escaped downstream past the diver. Generally fish escaped when approached by passing inshore or offshore past the diver and going downstream. Some fish especially large fish escaped by heading offshore to deeper water. Others, especially schools of pikeminnow and juvenile salmon, escaped upstream, and for these the divers attempted to ensure they were not counted twice. Sampling units within a site in shallow waters along shorelines were sampled sequentially from downstream to upstream units to minimize disturbance of fish from one unit to the next unit.

Data Collection

Divers recorded their observations on PVC slates attached to their forearms. Numbers of fish were recorded by species and size group as the diver proceeded through the sampling unit. Individual concentrations of fish were recorded along with habitat conditions associated with the concentration and the sampling unit.

Habitat conditions of the sampling unit and individual fish concentration were recorded included depth, velocity, substrate, and cover. Depth was recorded in feet and was either a range or a discrete depth. Velocity was likewise recorded as a range or discrete velocity.

Substrate was recorded by major and minor type using codes defined specific for divers observing substrate (Table 1).

Table 1. Substrate size categories.

Substrate Category	Description
1	silt – fine grain generally individual particles below a micron.
2	sand – fine grain of a millimeter or less.
3	gravel – from several mm pea gravel size to near cobble size of 6 inches.
4	cobble – 6 to 12 inches diameter stones
5	boulder – rocks larger than 12 inches in diameter to six feet in diameter.
6	bedrock –rock or claystone, or fragments greater than 6 ft in diameter.

Cover was recorded in three categories:

1. Size of cover: 1 < 6in diameter; 2 = 6-12 diameter; 3 > 12 inch
2. Type: 1 = instream; 2 = overhead; 3 = both; 4 = flooded terrestrial vegetation
3. Quantity/quality: 0 = 0%; 1=25%; 2 = 50%; 3 = 75%; 4 = 100%. The amount is defined as the degree of dependence of the fish on the cover in combination with the extent of instream and overhead cover.

The cover variable used in data analyses was the sum of the values for the three types. A total of 11 was possible and represented large dense cover in flooded benches along the river. We considered a total of 1 to 3 as low cover, 4 to 6 as moderate cover, and 7 to 11 as high cover.

Slope was recorded as shallow (less than 10 degrees), moderate, or steep (greater than 45 degrees).

Lengths of fish observed were estimated for fish over 20 mm. Divers were trained on scale models as size is distorted underwater. Fish lengths were recorded in nine categories:

mm group	**code**	**mm group**	**code**
20-39	1	200-299	6
40-59	2	300-400	7
60-79	3	400-600	8
80-99	4	>600	9
100-199	5		

Fish were identified to species following keys in Moyle (2002). Other than salmon, pikeminnow, and Sacramento suckers (*Catostomus occidentalis*) were the most common species encountered. The three species were generally readily differentiated based on size, shape, color, and behavior. Larger predatory fish including largemouth bass (*Micropterus salmoides*), smallmouth bass(*Micropterus dolomieu*), and striped bass (*Morone saxatilis*) were observed in low numbers, but were not effectively sampled by snorkeling because these fish were wary and not readily observed with the detectable range being less than six feet.

Temperature was recorded with hand-held thermometers at each site. Generally, temperature varied among locations but not among or within sites sampled in a specific location.

Flow data were obtained from the California Data Exchange Center (CDEC) via the Internet.

Data Processing and Analysis

Data were transferred from slates to standard field “write-in-the-rain” data sheets. From data sheets, data were transferred directly to MS Excel spreadsheets. All tables and charts were developed in MS Excel spreadsheets.

Analyses were accomplished with MS Excel data analysis routines or WinStat Excel macros available from WinStat.com. Fish numbers per unit area sampled were the dependent variable used in analyses. In some analyses the log of the number was used to “linearlize” the data. Independent variables included river mile, water temperature, and site specific variables such as depth, slope, substrate, velocity, bank type, and cover.

Results

Snorkel surveys were conducted from late August to mid November 2004 -2006 conditions permitting. Nine surveys were conducted over the three years (Table 2).

Table 2. Snorkel survey sampling periods by survey number - 2004-2006.

2004	2005	2006
1. October 7-8	2. September 15	6. August 22
	3. September 22	7. September 12
	4. October 19	8. September 28
	5. November 17	9. October 12

River Flows

The flows during the 2004, 2005, and 2006 surveys were seasonally normal with 7,000 to 8,000 cfs in the fall, after summer base flows in the 10,000-14,000 cfs range (Table 3).

Table 3. River flow (cfs) by survey number.

2004	2005	2006
1. 7,200	2. 9,000	6. 13,300
	3. 8,000	7. 10,800
	4. 7,600	8. 8,400
	5. 7,000	9. 7,300

2004 Survey

The October 7 and 8, 2004 survey was conducted at 15 sampling units at five sites from Woodson Bridge (RM 219) downstream to Jacinto Bend (RM 182). Water temperature at Woodson Bridge was 15.5ºC (Table 4), which was about 0.5ºC higher than the temperature from the upstream Bend gage (CDEC data). Water temperature at the lower four locations was about 1.5-2.5ºC higher. Densities of winter-run juveniles (fry and fingerlings) observed at Woodson Bridge were approximately 0.01 to 0.05 per ft^2 (Table 4). Densities were slightly lower at Pine Creek (RM 194) and Chico Landing (RM 192), and much lower at Ord Bend (RM 184) and Jacinto Bend (RM 182).

September 15, 2005 Survey

The September 15, 2005 survey was conducted at 12 sampling units at four sites from Woodson Bridge (RM 219) downstream to Ord Bend (RM 184). Water temperature at Woodson Bridge was 13ºC (Table 5). Water temperature at the lower three locations was about 1-2ºC higher. Densities of winter-run juveniles (fry and fingerlings) observed at Woodson Bridge were approximately 0.01 to 0.03 per ft^2 (Table 5). Densities were lower at Pine Creek (RM 194) and Chico Landing (RM 192), and much lower at Ord Bend (RM 184).

September 22, 2005 Survey

The September 22, 2005 survey was conducted at 31 sampling units at seven sites from Woodson Bridge (RM 219) downstream to Jacinto Bend (RM 182). Water temperature at Woodson Bridge was 14ºC (Table 6). Water temperature at the lower locations was 1.0-1.5ºC higher. Densities of winter-run juveniles (fry and fingerlings) observed at Woodson Bridge were 0.01 to 0.14 per ft^2 (Table 6). Density was relatively high at RM 214 at 0.04 to 0.28 per ft2. Densities were lower downstream with 0.00 at Jacinto Bend (RM 182).

October 13, 2005 Survey

The October 13, 2005 survey was conducted at 15 sampling units at four sites from Woodson Bridge (RM 219) downstream to GCID (RM 206). Water temperature was 13ºC at all units (Table 7). Densities of winter-run juveniles (fry and fingerlings) observed at Woodson Bridge were approximately 0.01 to 0.03 per ft^2 (Table 7). Densities were 0.06 to 0.49 at RM 214. Densities were lower downstream at RM 206 and 211.

October 19, 2005 Survey

The October 19, 2005 survey was conducted at 27 sampling units at seven sites from Woodson Bridge (RM 219) downstream to Ord Bend (RM 184). Water temperature was 13ºC at the upper sites and 14ºC at the lower units (Table 8). Densities of winter-run juveniles (fry and fingerlings) observed at Woodson Bridge were approximately 0.003 to 0.014 per ft^2 (Table 8). Densities were 0.09 to 0.40 at RM 214. Densities were lower downstream at RM 211 and 206, and increased again from RM 194 to 196.

November 17, 2005 Survey

The November 17, 2005 survey was conducted at 33 sampling units at seven sites from Woodson Bridge (RM 219) downstream to Ord Bend (RM 184). Water temperature was 12ºC at all sites (Table 9). Densities of winter-run juveniles (fry and fingerlings) observed at Woodson Bridge were 0.00 per ft^2 (Table 9). Densities reached only 0.02 at RM 214. Densities were near zero downstream.

August 22, 2006 Survey

The August 22, 200 survey was conducted at 4 sampling units at two sites from Woodson Bridge (RM 219) and at RM 194. Water temperature was 13.5ºC at Woodson Bridge and

15 at RM 194 (Table 10). Winter-run juveniles (fry and fingerlings) were observed at one Woodson Bridge site (density of 0.01 per ft^2 - Table 10).

September 12, 2006 Survey

The September 12, 2006 survey was conducted at 31 sampling units at eight sites from Woodson Bridge (RM 219) downstream to Ord Bend (RM 184). Water temperature was 14.5-16.5ºC with cooler temperatures at upstream sites (Table 11). Densities of winter-run juveniles (fry and fingerlings) observed at Woodson Bridge were 0.00-0.01 per ft^2 (Table 11). Densities were 0.00-0.02 at RM 214. Densities reached as high as 0.03 at some units downstream.

September 28, 2006 Survey

The September 28, 2006 survey was conducted at 17 sampling units at six sites from RM 220 downstream to RM 186 (Table 12). Water temperature was 15ºC. Densities of winter-run juveniles (fry and fingerlings) observed at RM 200 near Woodson Bridge were 0.00 per ft^2 (Table 11). Densities reached as high as 0.12 per ft^2 at RM 195 and 0.06 per ft^2 at RM 186.

October 12, 2006 Survey

The October 12, 2006 survey was conducted at 18 sampling units at seven sites from RM 230 downstream to RM 222 (Table 13). Water temperature was 13.0-13.5ºC at the upper sites and 14-15ºC at the lower sites. Densities of winter-run juveniles (fry and fingerlings) observed at the upper sites near RM 230 were relatively high at 0.07-0.43 per ft^2 (Table 13). Densities reached as high as 0.20-0.29 per ft^2 at RM 222.

Density by Survey Date

Density of young winter-run salmon reached a peak of near 0.5 per ft^2 at some sampling units in October of both 2005 and 2006 (Figures 2 and 3). The relationship with date was positive and statistically significant ($p=0.005$) in 2006.

Density by Water Temperature

Density of young winter-run salmon was significantly negatively related ($p=0.02$) to water temperature in September 2005 (Figure 4), the period of sampling when water temperature over the survey reach had the greatest range (13.0-15.5ºC). Peak densities occurred at 13-14ºC. In September 2006 peak densities occurred at 14.5-15.5ºC (Figure 5).

Density by Water Depth

Density of young winter-run salmon was significantly greater for surveyed units with water depths less than 2 ft ($p=0.03$) in October 2005. In late September and early October 2006 the density of salmon was significantly greater at depths less than 2.5 ft.

Density by Water Velocity

Density of young winter-run salmon was lowest a near zero velocity (0.0-0.25 ft/s) and highest at category 1 velocity (0.5-1.25 ft/sec) (Figures 8 and 9). The difference in density between category 1 and category 2 (1.5-2.25 ft/s) was significant only in 2006.

Density by Substrate

Density of young winter-run salmon was two to three times greater for substrate categories 1 and 2 (silt and sand) than larger sized substrate (categories >2); however the difference was not statistically significant (Figures 10 and 11).

Density by Cover

Density of young winter-run salmon was generally highest in moderate to high cover amounts (> than 3) (Figures 12 and 13); however the difference was not statistically significant.

Density by Multivariate Dataset

It is obvious that the variables measured were not independent and a multivariate analysis was unable to detect multivariate features in the dataset. For example, water temperature was generally higher with distance downstream. Substrates were generally smallest in low velocity shallow water. The three highest covers units in 2006 were in waters three feet deep or greater and in velocity category 2 and few salmon were observed, which is consistent with lower densities in deeper, faster water.

Other Species

Other than juvenile salmon, only juvenile pikeminnow were commonly observed, often in large numbers especially in warmer backwater habitats. Larger predators such as smallmouth bass, largemouth bass, striped bass, and adult pikeminnow were observed in low numbers. It was obvious that with the low visibility that detection of these larger fish was very difficult as they actively avoided the divers.

Discussion

The goal of this recon survey was to determine the distribution of juvenile winter-run salmon in the fall in the middle portion of the lower Sacramento River (RM 180-230). From our observations it was obvious that fry and fingerling winter-run are abundant from late summer through the fall in this reach of the river. From our observations it appears that density peaks in October and then may decline in November. The observed decline in the fall may be a function of actual reduced numbers or a function of reduced visibility due to seasonal rains. Density is highest early in the fall in the upper cooler portion of the reach, but generally young salmon spread throughout the reach with cooler fall water temperatures.

Unlike Limm and Marchetti (2003) who found juvenile spring and fall-run salmon abundant in off-channel habitats of the river in spring, we found such areas (e.g., mouth of Pine Creek) to be too warm[3] in the fall with very low velocity, and frequented by an abundance of predators such as largemouth or smallmouth bass, and sub-adult pikeminnow. After initial recon of these off-channel habitats we did not include them in the survey because of their obvious poor habitat conditions. Zero velocity units along river margin were included in the survey and no salmon were observed in these units, only large numbers of juvenile cyprinids (mostly pikeminnow). The advantages of off-channel habitats in winter and spring are not apparent in the fall.

Generally, juvenile winter-run salmon were confined to shallow (<2.5 ft) margin habitat with low to moderate velocity (0.5-2.25 ft/s). Such units generally had silt, sand, or sometimes gravel substrate. Highest densities were found in units with moderate to abundant cover. Such habitat makes up a very small percentage of the habitat of the middle river, which could be characterized as a large wide, shallow river in the upper portion and a narrower deeper rip rapped bank reach in the lower portion.

While it is difficult to make generalizations from our survey about habitat use by juvenile winter-run in the middle river given the small numbers of observations and lack of sampling effectively in all habitat types, we developed a number of hypotheses about habitat use that could be tested with a more comprehensive study. These hypotheses are consistent with our findings in a more comprehensive survey of the lower American River (Cannon and Kennedy 2003), as well as conclusions from the general literature (e.g., Everest and Chapman 1972; Bjornn and Reiser 1991).

1. Abundant shallow point bar habitat with minimal slope and cover is used little by young salmon probably because of very low velocity, warmer water, and lack of cover.
2. Abundant deep (> 3ft) bank habitat opposite point bars, whether rocked or natural with or without abundant large woody materials and other cover, and with higher velocities (>2 ft/s) is also used little by young salmon, probably because it is too deep and fast. The restoration area just upstream of the Woodson Bridge where pilings have been placed to capture large woody debris is just such a place. We observed few salmon and often large predatory fish at this site.
3. Abundant mid-river habitat even shallow with abundant large woody material was used little by young salmon, probably because with time the young salmon gravitate to the river margin habitats where there is a greater linear corridor of low velocity shallow habitat with more shade and cover.
4. While abundant rocked banks had deep, fast water with little cover and few young salmon, a conclusion consistent with Michny and Hampton (1984), some areas of rocked banks with shallow, low velocity units with current breaks and other cover had localized concentrations of juvenile salmon.

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[3] Generally temperatures were near or higher than 18ºC in off-channel habitats including mouths of valley tributary streams (e.g., Pine Creek). Chinook salmon young preference is 12-14ºC, (Brett 1952). Marine and Czech (2004) found that young salmon reared at 17–20ºC experienced similar growth, variable smoltification impairment, and higher predation vulnerability compared with young salmon reared at 13–16ºC.

5. Side channels, island shorelines, and localized main river shorelines with low-moderate velocity, shallow habitat, abundant vegetative shade and cover, and large woody debris often had concentrations of young salmon. Locations where willow-root banks were slightly undercut, especially when roots created current breaks, generally had higher densities of young salmon.

Perhaps most relevant to the middle river is the Beechie et al. (2005) study of large rivers in the Pacific Northwest. They found midchannel habitats too deep and fast for young salmon.
They also found that juvenile salmon preferred banks that had complex cover such as rootwads and wood debris jams. Like Limm and Marchetti (2003), they found high concentrations of young salmon in backwater units in winter (Figure 14). As we observed, they too found habitat selection of habitat types by juvenile salmon mirrored that in small streams with most fish occupying shallow (less than 3 ft deep) river margin areas with lower velocity (less than 2 ft/s) and greater cover.

The obvious implications of these hypotheses pertains to their use in protecting and enhancing important habitats for juvenile winter-run salmon rearing in the summer and fall in the middle reach of the lower Sacramento River. With generally low flow and warm conditions in the fall, the focus for improving rearing habitat in the middle river for juvenile winter-run salmon should be on the margins of the river under the lowest water surface elevations of the year. At Hamilton City in the middle of the reach this would be elevations 129-131 ft (occurs in flow range of 6,000-8,000 cfs at HMC gage) as compared to wetter winter water surface elevations 5 to 10 ft higher. Maximizing margin habitat at a water surface elevation of 130 ft would provide the greatest benefit for fall rearing winter-run as well as spring- and fall-run salmon in the winter and spring of drier years. Margin habitat of the main river and side channels with low velocity and abundant cover at elevation near 130 ft would provide optimal conditions for juvenile winter-run salmon. An abundance of side channels connected at this elevation and flow would be of obvious advantage. Habitat restoration at higher water surface elevations would provide fewer benefits for fall rearing winter-run or drier year spring- and fall-run salmon. Habitat restoration of off-channel habitats such as oxbows and backwaters would provide minimal benefit to winter-run salmon as these areas are too warm and benefit non-salmonids and non-native predatory fishes. Enhancements in deeper, faster main channel habitats would provide minimal benefit to juvenile winter-run salmon and would likely benefit predatory fish.

In addition to more comprehensive surveys of habitat use in the middle river, we recommend developing stream habitat maps under typical summer and fall flows to identify and quantify those habitats that need to be protected, as well as those that can be enhanced to provide additional benefit.

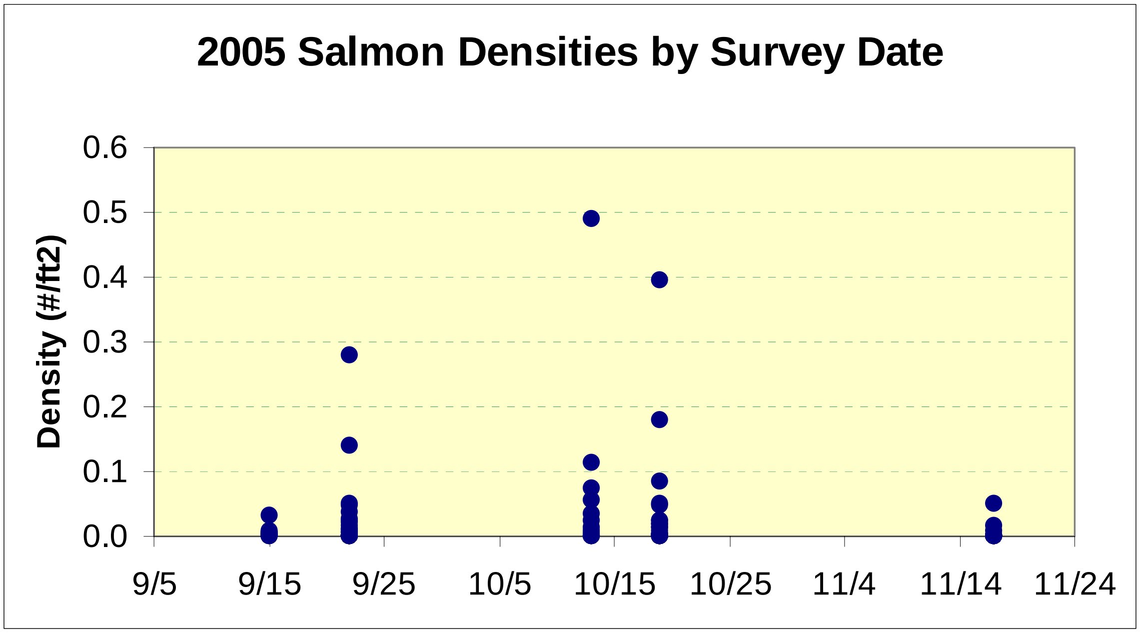

Figure 2. Density of juvenile winter-run salmon in fall 2005 surveys.

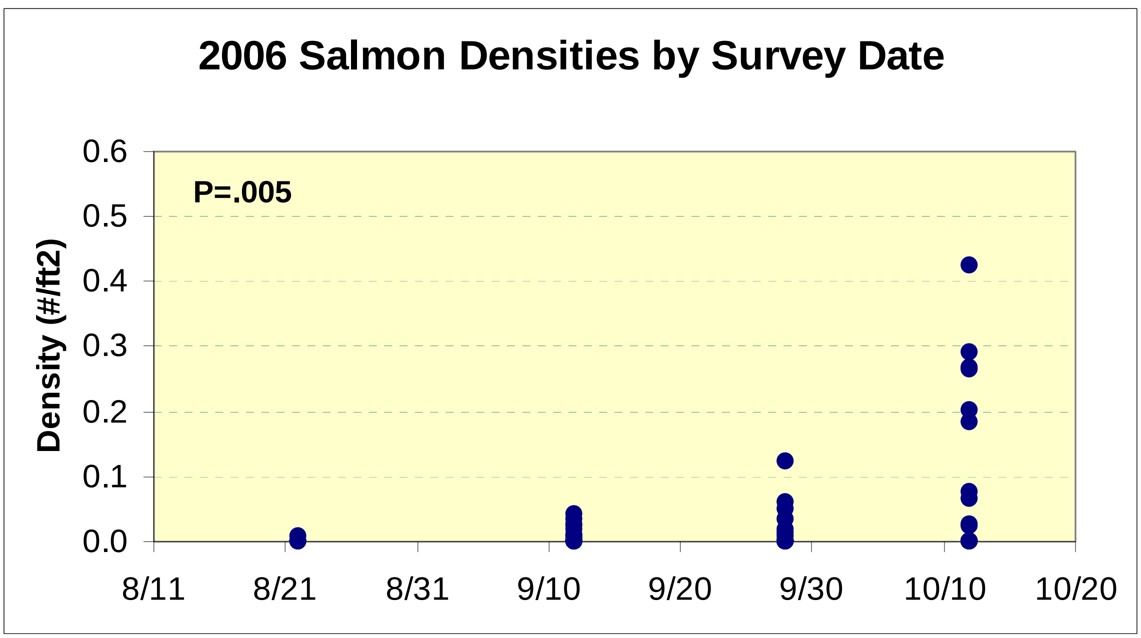

Figure 3. Density of juvenile winter-run salmon in fall 2006 surveys. The relationship between density and date was positive and statistically significant (p=0.005).

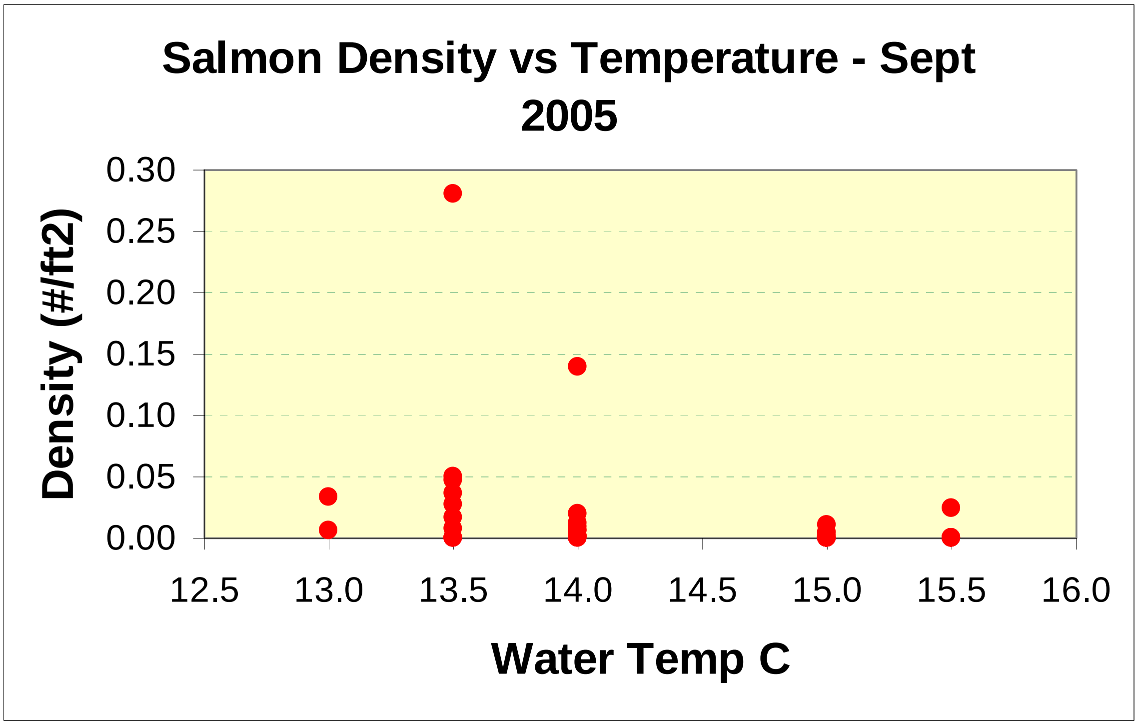

Figure 4. Density of juvenile winter-run salmon versus water temperature in units sampled in September 2005.

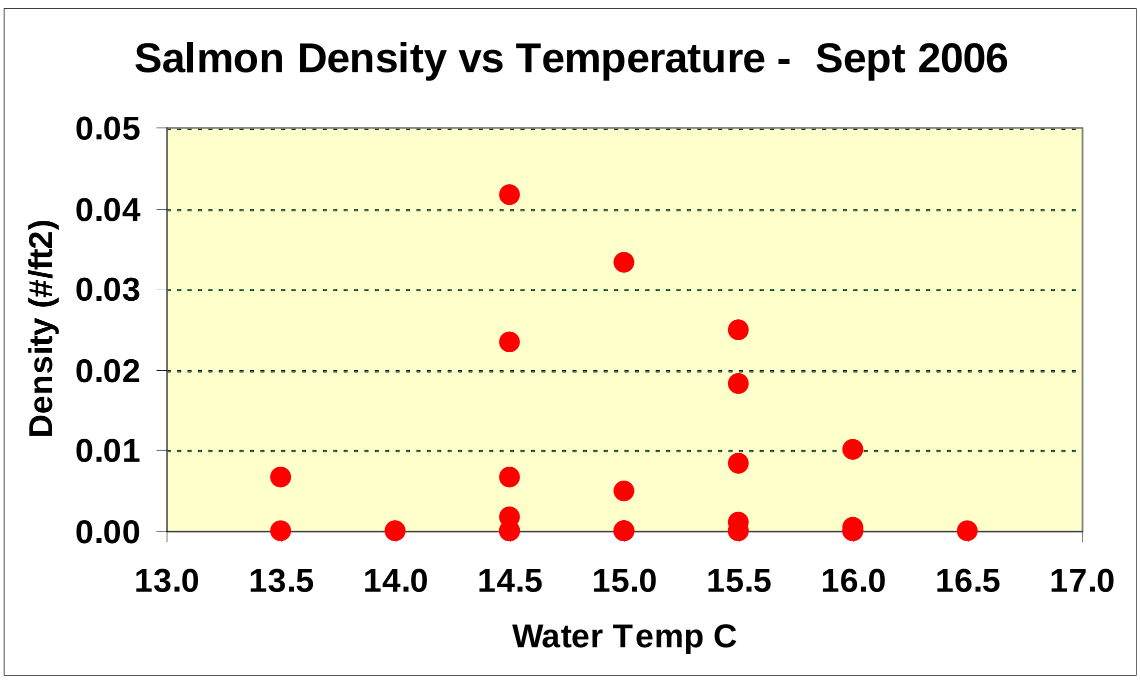

Figure 5. Density of juvenile winter-run salmon versus water temperature in units sampled in September 2006.

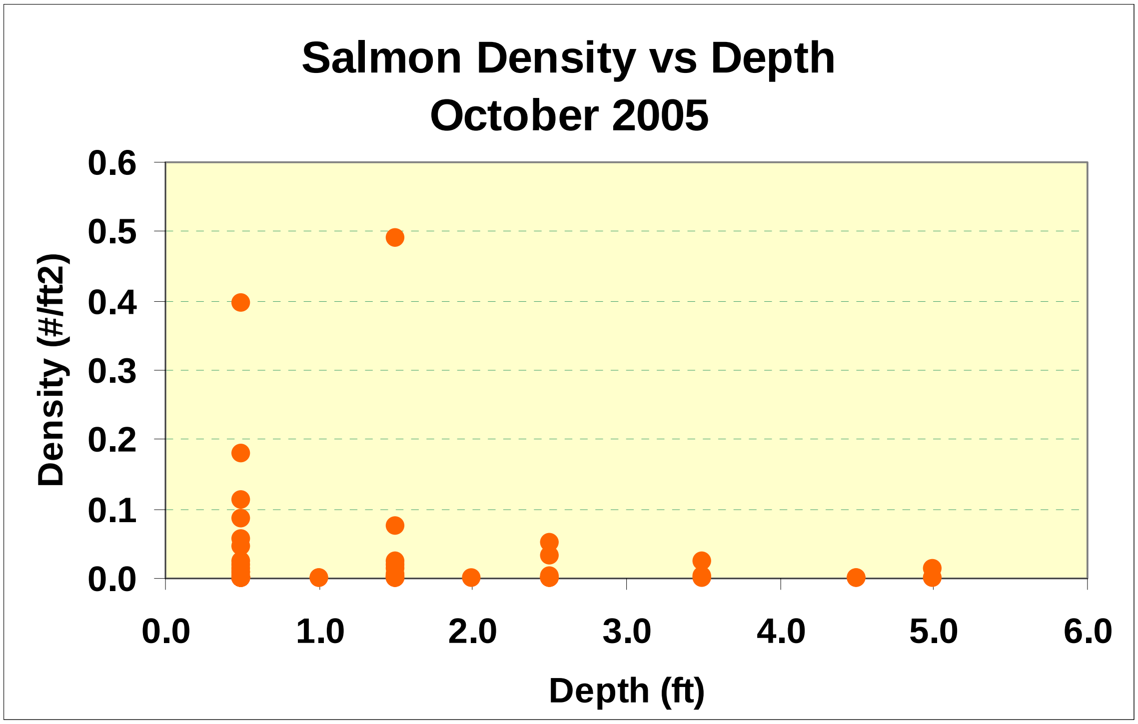

Figure 6. Density of juvenile winter-run salmon versus depth of units sampled in October 2005.

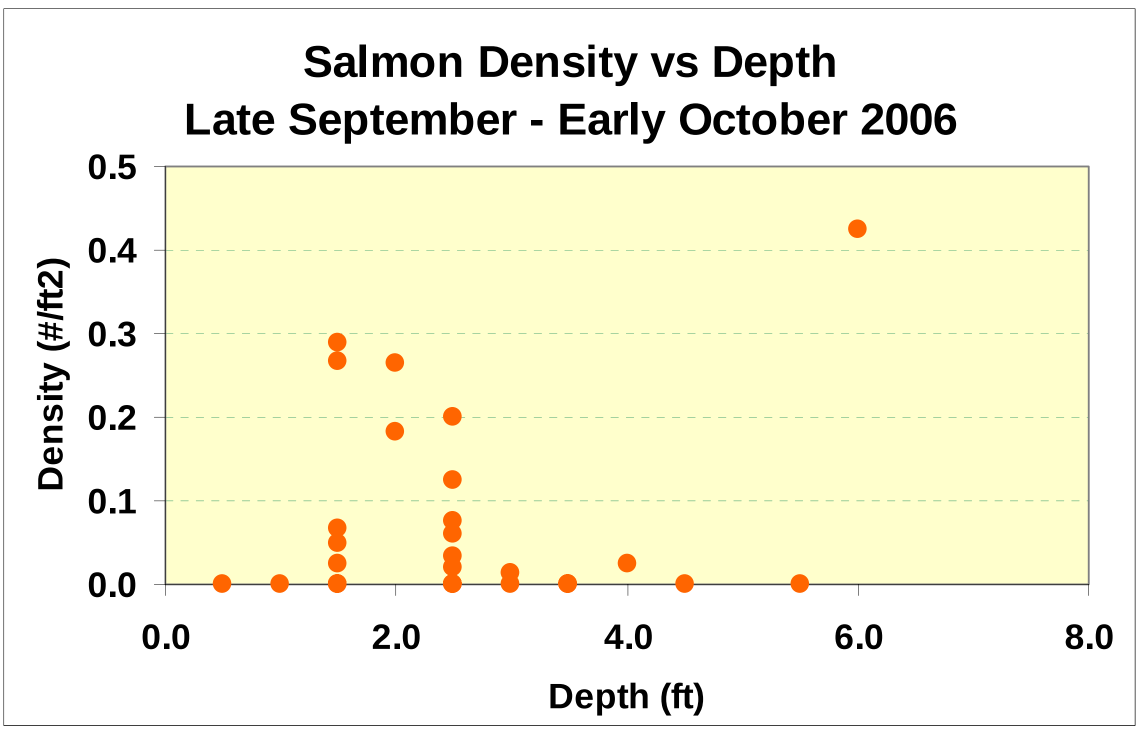

Figure 7. Density of juvenile winter-run salmon versus depth of units sampled in late September and early October 2006.

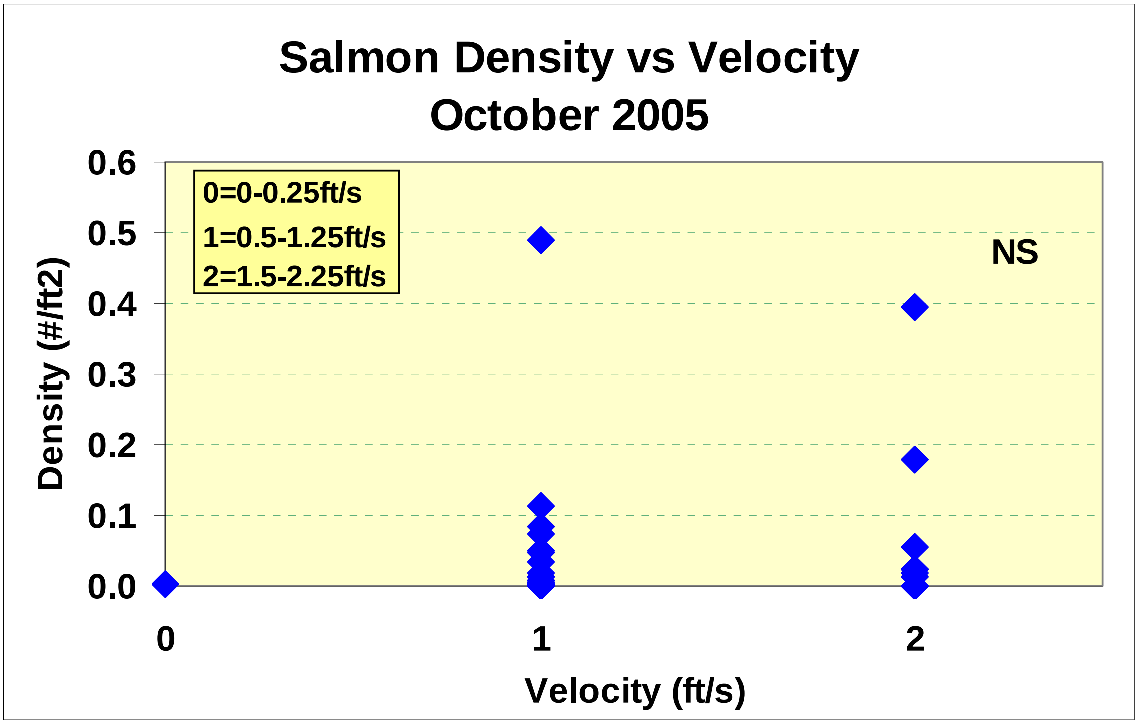

Figure 8. Density of juvenile winter-run salmon versus water velocity category of units sampled in October 2005.

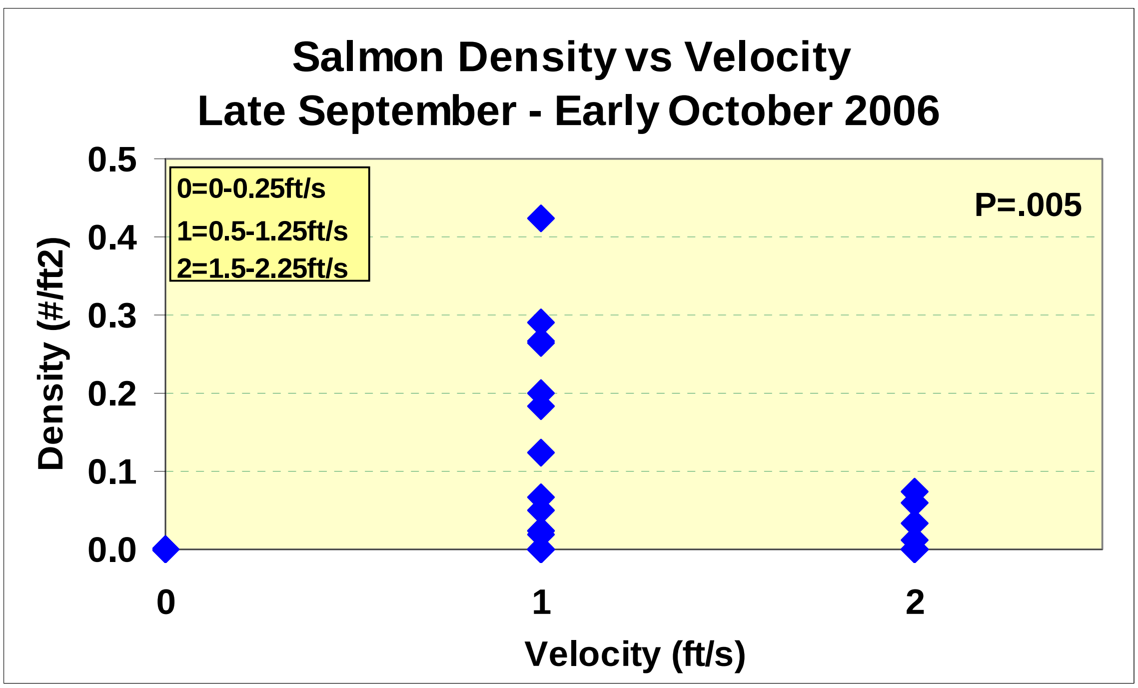

Figure 9. Density of juvenile winter-run salmon versus water velocity category of units sampled in late September and early October 2006.

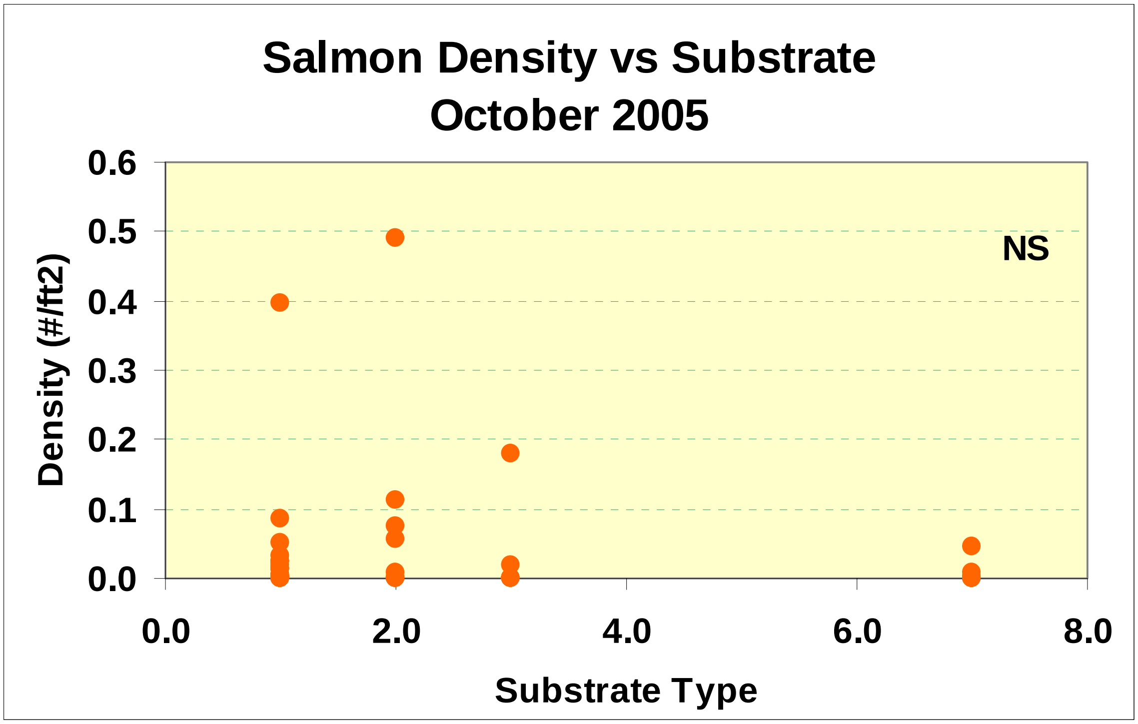

Figure 10. Density of juvenile winter-run salmon versus bottom substrate classification of units sampled in October 2005.

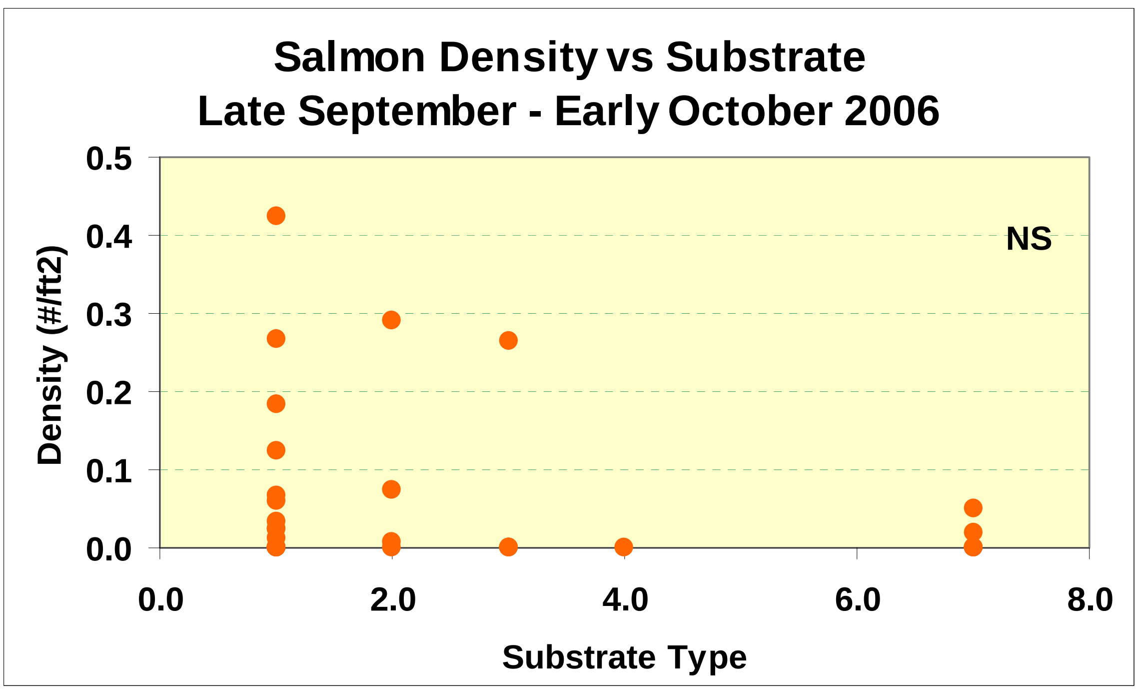

Figure 11. Density of juvenile winter-run salmon versus substrate classification of units sampled in late September and early October 2006.

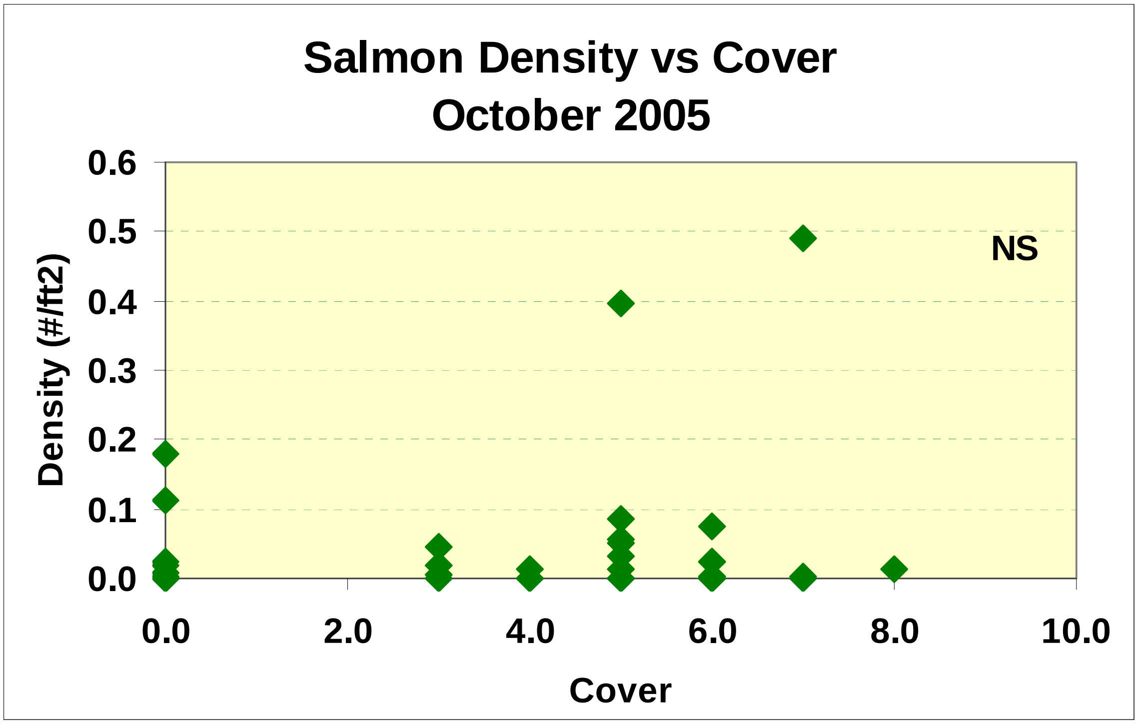

Figure 12. Density of juvenile winter-run salmon versus cover amount of units sampled in October 2005.

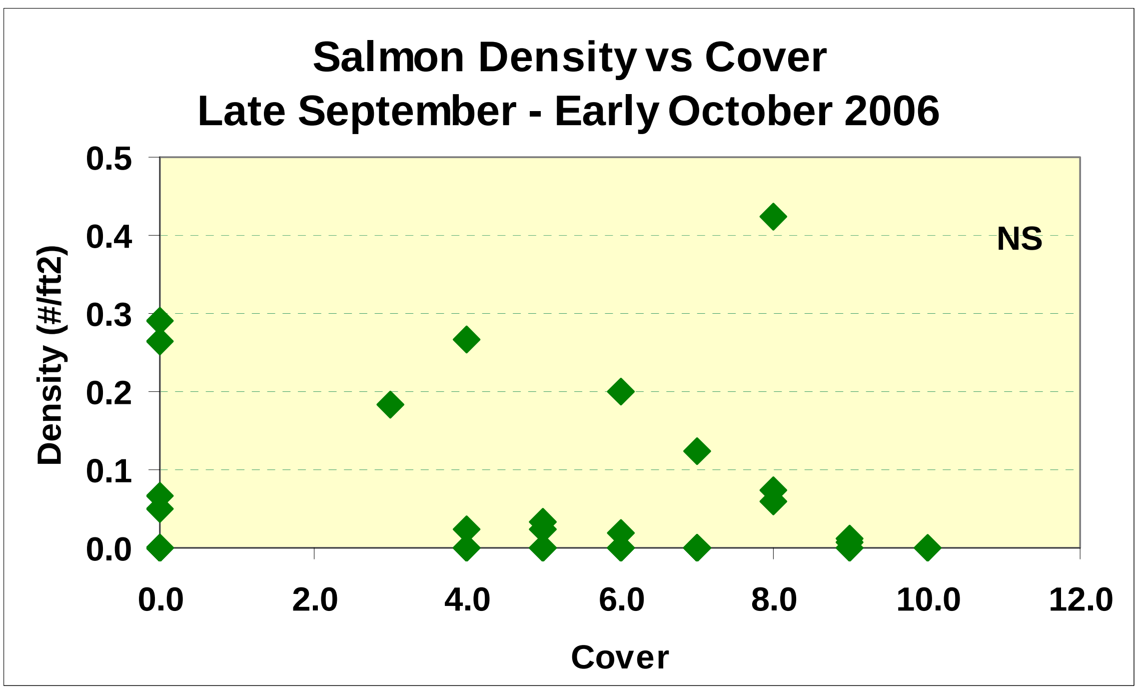

Figure 13. Density of juvenile winter-run salmon versus cover amount of units sampled in late September and early October 2006.

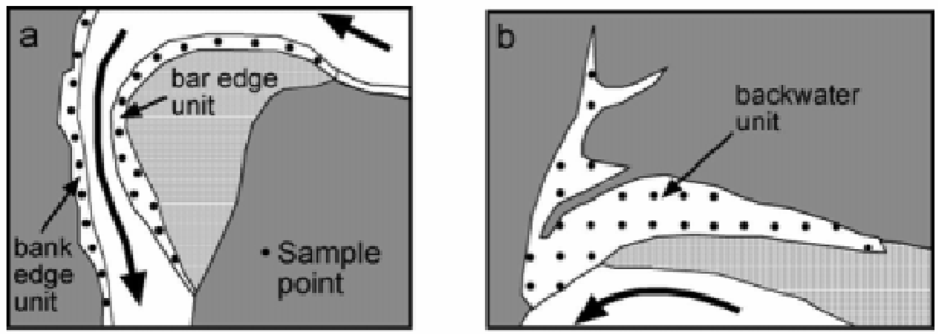

Figure 14. Beechie et al. 2005 defined bank, bar, and backwater types of river margin habitat. A side-channel would be similar to a backwater unit except it would be connected at its upper end to the main river. (Source: Beechie et al. 2005)

Table 4. 2004 October 7-8 survey results.

Date	Sample Unit	Winter-run Salmon	Water Temp ºC	Area Sampled (ft^2)	Density per ft^2
River Mile 219		WOODSON BRIDGE			
10/8/2004	1	10	15.5	2194	0.005
10/8/2004	2	90	15.5	2682	0.034
10/8/2004	3	146	15.5	3200	0.046
River Mile 196		PINE CREEK			
10/7/2004	1	122	17.5	975	0.125
10/7/2004	2	0	17.5	731	0.000
10/7/2004	3	25	17.5	731	0.034
10/7/2004	4	0	17.5	731	0.000
River Mile 194		CHICO LANDING			
10/8/2004	1	17	17.5	731	0.023
10/8/2004	2	5	17.5	1371	0.004
10/8/2004	3	5	17.5	365	0.014
River Mile 184		ORD BEND			
10/7/2004	1	2	17	457	0.004
10/7/2004	2	0	17	320	0.000
10/7/2004	3	0	17	137	0.000
River Mile 182		JACINTO BEND			
10/8/2004	1	2	18	1463	0.001
10/8/2004	2	1	18	731	0.001

Table 5. 2005 September 15 survey results.

Date	Sample Unit	Winter-run Salmon	Water Temp ºC	Area Sampled	Density per ft2
River Mile 219		WOODSON BRIDGE			
9/15/2005	1	10	13	1800	0.006
9/15/2005	2	98	13	3000	0.033
River Mile 196		PINE CREEK			
9/15/2005	1	0	14	1500	0.000
9/15/2005	2	16	14	800	0.020
River Mile 194		CHICO LANDING			
9/15/2005	1	6	14	3600	0.002
9/15/2005	2	6	14	900	0.006
9/15/2005	3	3	14	1800	0.002
9/15/2005	4	3	14	1500	0.002
River Mile 184		ORD BEND			
9/15/2005	1	0	15	4200	0.000
9/15/2005	2	0	15	1500	0.000
9/15/2005	3	5	15	4800	0.001
9/15/2005	4	0	15	1800	0.000

Table 6. 2005 September 22 survey results.

Date	Sample Unit	Winter-run Salmon	Water Temp ºC	Area Sampled	Density per 100m2
River Mile 219		WOODSON BRIDGE			
9/22/2005	1	11	14	1800	0.006
9/22/2005	2	35	14	3000	0.012
9/22/2005	3	125	14	900	0.139
9/22/2005	4	12	14	600	0.020
River Mile 214					
9/22/2005	1	350	13.5	1250	0.280
9/22/2005	2	100	13.5	2100	0.048
9/22/2005	3	109	13.5	3000	0.036
River Mile 211					
9/22/2005	1	45	13.5	2700	0.017
9/22/2005	2	1	13.5	2400	0.000
9/22/2005	3	0	13.5	2400	0.000
9/22/2005	4	0	13.5	400	0.000
River Mile 206		GCID			
9/22/2005	1	65	15.5	2400	0.027
9/22/2005	2	2	15.5	3600	0.001
9/22/2005	3	15	15.5	2000	0.008
9/22/2005	4	10	15.5	200	0.050
9/22/2005	5	0	15.5	160	0.000
9/22/2005	6	0	15.5	600	0.000
River Mile 196		PINE CREEK			
9/22/2005	1	0	15	1500	0.000
9/22/2005	2	0	15	2400	0.000
9/22/2005	3	9	15	1800	0.005
9/22/2005	4	9	15	900	0.010
River Mile 194		CHICO LANDING			
9/22/2005	1	0	15.5	3600	0.000
9/22/2005	2	0	15.5	900	0.000
9/22/2005	3	43	15.5	1800	0.024
9/22/2005	4	0	15.5	1500	0.000
9/22/2005	5	0	15.5	600	0.000
9/22/2005	6	0	15.5	500	0.000
9/22/2005	7	0	15.5	300	0.000
River Mile 182		JACINTO BEND			
9/22/2005	1	0	15	1200	0.000
9/22/2005	2	0	15	1200	0.000
9/22/2005	3	0	15	1200	0.000

Table 7. 2005 October 13 survey results.

Date	Sample Unit	Winter-run Salmon	Water Temp ºC	Area Sampled	Density per 100m2
River Mile 219		WOODSON BRIDGE			
10/13/2005	1	60	13	1800	0.033
10/13/2005	2	24	13	3000	0.008
10/13/2005	3	12	13	900	0.013
River Mile 214					
10/13/2005	1	613	13	1250	0.490
10/13/2005	2	186	13	3000	0.055
River Mile 211					
9/22/2005	1	0	13	2700	0.000
9/22/2005	2	0	13	2400	0.000
9/22/2005	3	0	13	2400	0.000
9/22/2005	4	30	13	400	0.075
River Mile 206		GCID			
9/22/2005	1	10	13	2400	0.004
9/22/2005	2	9	13	3600	0.003
9/22/2005	3	4	13	2000	0.002
9/22/2005	4	0	13	200	0.000
9/22/2005	5	0	13	160	0.000
9/22/2005	6	0	13	600	0.000

Table 8. 2005 October 19 survey results.

Date	Sample Unit	Winter-run Salmon	Water Temp ºC	Area Sampled	Density per 100m2
River Mile 219		WOODSON BRIDGE			
10/19/2005	1	25	13.5	1800	0.014
10/19/2005	2	38	13.5	3000	0.013
10/19/2005	3	3	13.5	900	0.003
10/19/2005	4	15	13.5	600	0.025
River Mile 214					
10/19/2005	1	495	13	1250	0.396
10/19/2005	2	255	13	3000	0.085
River Mile 211					
10/19/2005	1	0	13	2700	0.000
10/19/2005	2	0	13	2400	0.000
10/19/2005	3	0	13	2400	0.000
10/19/2005	4	0	13	400	0.000
River Mile 206		GCID			
10/19/2005	1	3	13	2400	0.001
10/19/2005	2	2	13	3600	0.001
10/19/2005	3	14	13	2000	0.007
10/19/2005	4	0	13	200	0.000
10/19/2005	5	0	13	160	0.000
10/19/2005	6	0	13	600	0.000
River Mile 196		PINE CREEK			
10/19/2005	1	75	13.5	1500	0.050
10/19/2005	2	83	13.5	1800	0.046
10/19/2005	3	0	14	900	0.000
River Mile 194		CHICO LANDING			
10/19/2005	1	85	13.5	3600	0.024
10/19/2005	2	3	13.5	900	0.003
10/19/2005	3	0	13.5	1800	0.000
10/19/2005	4	0	13.5	1500	0.000
River Mile 184		ORD BEND			
10/19/2005	1	0	13.5	4200	0.000
10/19/2005	2	0	13.5	1500	0.000
10/19/2005	3	87	13.5	4800	0.018
10/19/2005	4	2	13.5	1800	0.001

Table 9. 2005 November 17 survey results.

Date	Sample Unit	Winter-run Salmon	Water Temp ºC	Area Sampled	Density per 100m2
River Mile 219		WOODSON BRIDGE			
11/17/2005	1	0	12	1800	0.000
11/17/2005	2	1	12	3000	0.000
11/17/2005	3	0	12	900	0.000
11/17/2005	4	0	12	600	0.000
River Mile 214					
11/17/2005	1	20	12	1250	0.016
11/17/2005	2	0	12	600	0.000
11/17/2005	3	0	12	3000	0.000
River Mile 211					
11/17/2005	1	0	12	2700	0.000
11/17/2005	2	0	12	600	0.000
11/17/2005	3	0	12	2400	0.000
11/17/2005	4	0	12	2400	0.000
River Mile 206		GCID			
11/17/2005	1	0	12	2400	0.000
11/17/2005	2	0	12	3600	0.000
11/17/2005	3	15	12	2000	0.008
11/17/2005	4	10	12	200	0.050
11/17/2005	5	0	12	160	0.000
11/17/2005	6	0	12	600	0.000
River Mile 196		PINE CREEK			
11/17/2005	1	0	12	600	0.000
11/17/2005	2	0	12	1500	0.000
11/17/2005	3	0	12	2400	0.000
11/17/2005	4	1	12	1800	0.001
11/17/2005	5	0	12	900	0.000
River Mile 194		CHICO LANDING			
11/17/2005	1	0	12	3600	0.000
11/17/2005	2	0	12	900	0.000
11/17/2005	3	0	12	1800	0.000
11/17/2005	4	0	12	1500	0.000
11/17/2005	5	0	12	600	0.000
11/17/2005	6	0	12	600	0.000
11/17/2005	7	0	12	600	0.000
River Mile 184		ORD BEND			
11/17/2005	1	0	12	4200	0.000
11/17/2005	2	0	12	1500	0.000
11/17/2005	3	0	12	4800	0.000
11/17/2005	4	0	12	1800	0.000

Table 10. 2006 August 22 survey results.

Date	Sample Unit	Winter-run Salmon	Water Temp ºC	Area Sampled	Density per 100m2
River Mile 219		WOODSON BRIDGE			
8/22/2006	1	0	13.5	3000	0.000
8/22/2006	2	6	13.5	900	0.007
River Mile 194					
8/22/2006	1	0	15	3600	0.000
8/22/2006	2	0	15	900	0.000

Table 11. 2006 September 12 survey results.

Date	Sample Unit	Winter-run Salmon	Water Temp ºC	Area Sampled	Density per 100m2
River Mile 219		WOODSON BRIDGE			
9/12/2006	1	18	16	1800	0.010
9/12/2006	2	0	16	3000	0.000
9/12/2006	3	0	15	900	0.000
River Mile 214					
9/12/2006	1	0	15	1250	0.000
9/12/2006	2	3	15	600	0.005
9/12/2006	3	70	14.5	3000	0.023
River Mile 211					
9/12/2006	1	1	14.5	600	0.002
9/12/2006	2	0	14.5	600	0.000
9/12/2006	3	0	14.5	600	0.000
River Mile 209					
9/12/2006	1	0	15	600	0.000
9/12/2006	2	4	14.5	600	0.007
9/12/2006	3	25	14.5	600	0.042
9/12/2006	4	0	15	600	0.000
9/12/2006	5	0	15	600	0.000
9/12/2006	6	20	15	600	0.033
River Mile 206		GCID			
9/12/2006	1	0	14.5	2400	0.000
9/12/2006	2	0	14.5	3600	0.000
9/12/2006	3	0	14.5	2000	0.000
9/12/2006	4	0	14.5	200	0.000
9/12/2006	5	0	15.5	160	0.000
9/12/2006	6	0	14.5	600	0.000
River Mile 196		PINE CREEK			
9/12/2006	1	0	16.5	600	0.000
9/12/2006	2	0	15.5	1800	0.000
9/12/2006	3	11	15.5	600	0.018
River Mile 194		CHICO LANDING			
9/12/2006	1	0	16	3600	0.000
9/12/2006	2	1	15.5	900	0.001
9/12/2006	3	0	15.5	1800	0.000
9/12/2006	4	5	15.5	600	0.008
9/12/2006	5	15	15.5	600	0.025
River Mile 184		ORD BEND			
9/12/2006	1	0	16	4200	0.000
9/12/2006	2	2	16	4800	0.000

Table 12. 2006 September 28 survey results.

Date	Sample Unit	Winter-run Salmon	Water Temp ºC	Area Sampled	Density per 100m2
River Mile 200					
9/28/2006	1	0	15	600	0.000
9/28/2006	2	0	15	600	0.000
River Mile 196		PINE CREEK			
9/28/2006	1	5	15	600	0.008
9/28/2006	2	19	15	1000	0.019
9/28/2006	3	0	15	500	0.000
River Mile 195					
9/28/2006	1	62	15.5	500	0.124
River Mile 191					
9/28/2006	1	0	15	1750	0.000
9/28/2006	2	0	15	250	0.000
9/28/2006	3	0	15	600	0.000
9/28/2006	4	0	15	600	0.000
River Mile 188					
9/28/2006	1	0	15	350	0.000
9/28/2006	2	5	15	400	0.013
9/28/2006	3	0	15	750	0.000
River Mile 186					
9/28/2006	1	15	15	250	0.060
9/28/2006	2	0	15	500	0.000
9/28/2006	3	0	15	400	0.000
9/28/2006	4	0	15	300	0.000

Table 13. 2006 October 12 survey results.

Date	Sample Unit	Winter-run Salmon	Water Temp ºC	Area Sampled	Density per 100m2
River Mile 230					
10/12/2006	1	60	13.5	900	0.067
10/12/2006	2	190	13	720	0.264
River Mile 229					
10/12/2006	1	153	13	360	0.425
River Mile 228					
10/12/2006	1	150	15.5	1000	0.075
River Mile 225		PINE CREEK			
10/12/2006	1	160	15	600	0.267
10/12/2006	2	0	15	900	0.000
River Mile 224					
10/12/2006	1	110	15	600	0.183
10/12/2006	2	0	15	600	0.000
10/12/2006	3	0	15	600	0.000
10/12/2006	4	0	15	600	0.000
10/12/2006	3	0	15	600	0.000
10/12/2006	4	15	15	600	0.025
River Mile 222					
10/12/2006	1	0	15	400	0.000
10/12/2006	2	174	14	600	0.290
10/12/2006	3	22	14	900	0.024
River Mile 222					
10/12/2006	1	0	15	750	0.000
10/12/2006	2	201	15	1000	0.201
10/12/2006	3	0	15	600	0.000

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Attachments

A. Recovery Plan

- *To recover winter-run Chinook, primary consideration must be given to the main factors causing their decline and which impede their recovery, and **survival must be improved in every segment of their life history**.*
- ***Recovery actions need to cover the total sequence of habitats and life history stages**, rather than focusing on a single target for action, e.g., curtailing harvests, improving dam passage, or using hatchery production to augment natural production.*
- *The proposed recovery objectives and actions are directed at **restoring and maintaining the ecosystems** upon which winter-run Chinook depend.*
- *Measures are also needed to restore the overall ecosystem functions of the Sacramento River and Sacramento-San Joaquin Delta to more **closely emulate habitat conditions in which the population evolved**.*
- *Additional measures are needed to develop information which will enhance our ability to recover winter-run Chinook through **improved understanding of its habitat requirements** and life history.*
- *Improve **juvenile fish passage and survival** in the upper Sacramento River through the Delta.*
- *Improve **rearing** and migration habitat conditions within natural migratory pathways to the Pacific Ocean.*
- ***Protect and restore riparian** and tidal marsh habitat.*

Table V-2. Recovery Goals for the Sacramento River Winter-run Chinook.

Goal	Description
I	Protect and restore spawning and rearing habitat.
II	Improve survival of downstream migrants.
III	Improve adult upstream passage.
IV	Prevent extinction through artificial propagation.
V	Reduce harvest and incidental take in commercial and recreational fisheries.
VI	Reduce impacts of fish and wildlife management programs.
VII	Improve understanding of life history and habitat requirements