Fish Habitat Use Patterns in the Lower American River Based on Snorkel Surveys 2003-2005

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Abstract

The Fishery Foundation of California under grants from the U.S. Fish and Wildlife Service and the Sacramento Area Flood Control Agency (SAFCA) conducted snorkel surveys of the Lower American River (LAR) from late winter to early summer of 2003, 2004, and 2005. The purpose of the snorkel surveys was to monitor fish distribution within the LAR. The survey's objectives include (1) determine the distribution of juvenile salmonids and other fishes in the LAR; and (2) determine how fish use various river habitats. Ancillary objectives include relating the distribution, abundance, and habitat use patterns to flow, temperature, and other habitat conditions including the presence of other fish species. Information collected was to support determining optimal river flows for salmonid rearing and what habitats could be restored to increase salmonid production. Snorkeling was conducted at over 100 sampling units at 12 to 14 sites in the lower 23 miles of the American River below Nimbus Dam. Divers surveyed sampling units at sites approximately every other week during the survey periods when adequate visibility occurred. Salmon and steelhead trout fry were the dominant fish observed from February through April, while young Sacramento sucker, tule perch, and Sacramento pikeminnow dominated observations from May through August. Sacramento sucker, American shad, Sacramento pikeminnow, tule perch, and striped bass were the most abundant adult fish observed. Salmon young were initially very abundant in February, but density dropped sharply during the spring. Steelhead young were observed from April through September and densities observed declined sharply during the spring. The young of all the species observed showed a strong preference for stream margins with cover including vegetated benches constructed on rocked levee sites. Invasive Eurasian milfoil beds in channel margins and backwater areas provide extensive cover for young fish. Salmon young were observed abundant over a wider range of depths and velocities than steelhead, and were abundant over most of the 23 miles of the LAR. Steelhead young were most abundant near spawning areas in riffle and run margins with abundant cover of the upper portion of the LAR, especially in small stream type habitats of side channels. During the summer young steelhead concentrated in riffle habitats of the main river and side channels. Adult salmon, steelhead, pikeminnow, American shad, Sacramento sucker, Pacific lamprey, tule perch, bluegill, largemouth and smallmouth bass, and striped bass were observed in main channel glide and pool habitats. Adult sucker, pikeminnow, American shad, and striped bass appear to migrate into the LAR from the Delta in great numbers during the spring. Survey data should be useful in developing habitat suitability criteria for flow-habitat relationships for the LAR.

Keywords
American River, Chinook salmon, steelhead, native fishes, snorkel survey, habitat requirements.

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Introduction

The Fishery Foundation of California under grants from the U.S. Fish and Wildlife Service and Sacramento Area Flood Control Agency (SAFCA) conducted snorkel surveys of the Lower American River (LAR) from February 2003 through July 2005. The purpose of the snorkel surveys was to monitor fish populations within the LAR as part of a comprehensive assessment program to assess the biological results and effectiveness of actions under the Central Valley Project Improvement Act {Section 3406(b)}. The survey objectives include (1) determine how juvenile Chinook salmon and steelhead are distributed in time and space in the LAR from winter to summer; and (2) determine how juvenile salmonids and other fishes use various river habitats. Ancillary objectives include relating the distribution, abundance, and habitat use patterns of salmon and steelhead to flow, temperature, habitat conditions, and the presence of other fish species during the survey period.

The survey expanded upon other surveys of fish in the LAR by the California Department of Fish and Game (DFG) including those of Jackson (1992) and Snider and Titus (2000). Jackson conducted snorkel surveys of the LAR from 1989 to 1991. He focused on surveying differing macrohabitats[3] within the LAR. His objective was to determine habitat preferences of juvenile salmon. He concluded that microhabitat[4] use of each macrohabitat unit was unique because of the different morphology and habitat availability of each unit. He also found greater numbers of young salmon in spring of the year with higher average flow 105 m^3/s (3600 cfs) than lower average flow 9.9 m^3/s (340 cfs) because of the greater amount of suitable habitat at the higher flow. Snider and Titus conducted rotary screw trap and seine surveys over the past decade focusing on over-summer habitat of juvenile steelhead and factors related to emigration of young salmon from the LAR. They found that salmon catch peaked generally in February with most salmon emigrating from the LAR as fry and the index of their survival negatively related to January stream flow. They also found that steelhead over-summering is primarily limited by water temperature, which is indirectly related to reservoir releases. Based on these and other studies, there appears to be a general consensus that flow, flow-habitat availability, and water temperature are the limiting factors for salmon and steelhead smolt production in the LAR (Water Forum 2001, Jones and Stokes 2002).

Williams (2000) stated that these same findings verify that flows below those recommended by the Anadromous Fish Restoration Program (USFWS 1997) provide insufficient habitat for rearing young salmon and steelhead in the LAR, but that uncertainty remains as to what flows are adequate for optimal salmonid rearing and migration, as well as other aspects of the biology of salmon and steelhead in the LAR. Additional research has been prescribed for the LAR to better ascertain the relationships between physical habitat parameters and biological indices related to life history and in-river production of fall-run Chinook salmon and steelhead in the LAR (Water Forum 2001). Our 2003-2005 snorkel surveys were designed to address some of these uncertainties.

[3] Macrohabitat is generally referred to as the classification at the riffle, glide, and pool level.
[4] Microhabitat is generally referred to as the habitat associated with an individual fish including such parameters as the fish's focal point water velocity, depth, and substrate.

In addition to flow and temperature, the 2003-2005 snorkel surveys focused on physical habitat conditions and availability, building upon insights obtained from the earlier snorkel surveys of Jackson. Jackson found a strong association of juvenile salmon with stream cover and velocity shelters in his sampling units. The 2003-2005 surveys expanded upon the number as well as diversity of sampling units from Jackson's study. Our surveys also provided coverage of winter and summer conditions, whereas Jackson focused solely on spring conditions. Our surveys also provided more focus on young steelhead, as well as more coverage of juvenile salmon rearing habitat in the lower half of the LAR below Watt Avenue where the DFG rotary screw traps are located.

Our study focused on the mesohabitat level of stream habitat classification, rather than the more standard microhabitat and macrohabitat classifications that are more commonly described in the literature (e.g., Bjornn and Riser 1991; Beechie et al. 2005). Macrohabitat is generally referred to as the riffle and pool level of characterization. Macrohabitat in the LAR is a continuous progression of riffle, glide, and pool complexes (e.g., Nimbus Hatchery Pool). Microhabitat is the habitat condition at the location of individual fish (e.g., focal point velocity, depth of fish in water column, etc.). Mesohabitat are subunits of macrohabitats, such as a mid channel or bank-side run within a riffle complex, or an undercut bank under bank-side willows. Banks, bars, and backwaters are other characterization types of mesohabitats (Beechie et al. 2005). Classification by mesohabitat units overcomes the limitations of microhabitat analyses while still addressing macro factors that are determinants of fish choice of habitat (Orth 1987). Focusing on intermediate habitat units avoids scale problems with macrohabitat classification of stream habitat types generally identified for small streams (Nickelson et al. 1992, Bisson et al. 1982). It also avoids the "*macrohabitat analysis*" approach that is often used but fails to relate river or reach factors to production (Scarnecchia and Bergersen 1987). Mesohabitat units also avoids classification by individual fish typically termed "microhabitat analysis" (Moyle and Baltz 1985), although microhabitat factors still apply toward fish use of the mesohabitat units.

The mesohabitat approach is designed for use in flow-habitat studies and determining how flow regimes relate to production of salmon and steelhead. Microhabitat models contained within the Physical Habitat Simulation (PHABSIM) component of the Instream Flow Incremental Methodology (IFIM) (Bovee 1982) are generally used to quantify habitat availability over a range of stream flows for spawning and rearing salmonids. The mesohabitat approach can be related to flow and thus offer a potential alternative or supplement to traditional IFIM. Rubin et al. (1991) and Thomas and Bovee (1993) suggested the alternative of using 2-D surface-area cells for developing habitat suitability criteria instead of the standard IFIM procedure. By basing habitat suitability curves on cell data, no adjustment is needed for habitat availability. Beechie et al. (2005) and Hardy and Addley (2001) evaluated how velocity, depth, and cover influenced fish use of macrohabitat units by breaking up macrohabitat units into polygons and measuring velocity, substrate, depth, and cover. Beechie et al. did this by defining mesohabitat units of distinct type (e.g., bank, bar, and backwater). We carried this approach one step further by defining units based on unique characteristics of polygons within reaches that the fish appear to key on, which in most cases were conditions of depth, velocity, slope, substrate, and cover. Unlike Beechie et al., we were able to cover mid-river habitats, not just edge habitats, because the LAR is not so large as to preclude mid-river snorkeling.

Sampling habitat units and relating use patterns to environmental conditions that relate to flow in the units will provide information needed on the capacity of the LAR to produce young salmonids over a range of flow conditions. John Williams in the Fish Bulletin Paper in 2001 stated: *"More observations of habitat use like those of Jackson (1992) would be helpful, especially if they are directed toward developing a better understanding of the way juvenile Chinook use habitat rather than 'habitat suitability criteria' for PHABSIM studies"* (Williams 2001).

Though the snorkeling methods employed in the 2003-2005 surveys are standard, their application in an array of two-dimensional cells or polygon units each with narrow if not unique habitat conditions that are representative of habitats throughout the river is relatively new, especially in large rivers. Large rivers are generally sampled with electrofishing gear and then generally only along river margins (Beechie et al. 2005). If fish use can be related to habitat conditions in sampling units and habitat conditions in the sampling units can be related to flow, then the magnitude of streamflow can be related to the value of habitat. If habitat use can be translated into habitat value, then habitat use patterns may help in defining habitat restoration needs and alternatives. Williams (1999) related that defining habitat for such purposes has not been satisfactorily resolved, especially in large rivers such as the LAR.

Study Area

The 2003-2005 snorkel surveys were conducted at 14 locations within three reaches in the LAR (Figure 1) between the mouth at the Sacramento River and Nimbus Dam at river mile 23. These locations were designated to represent a wide array of habitat conditions as well as a

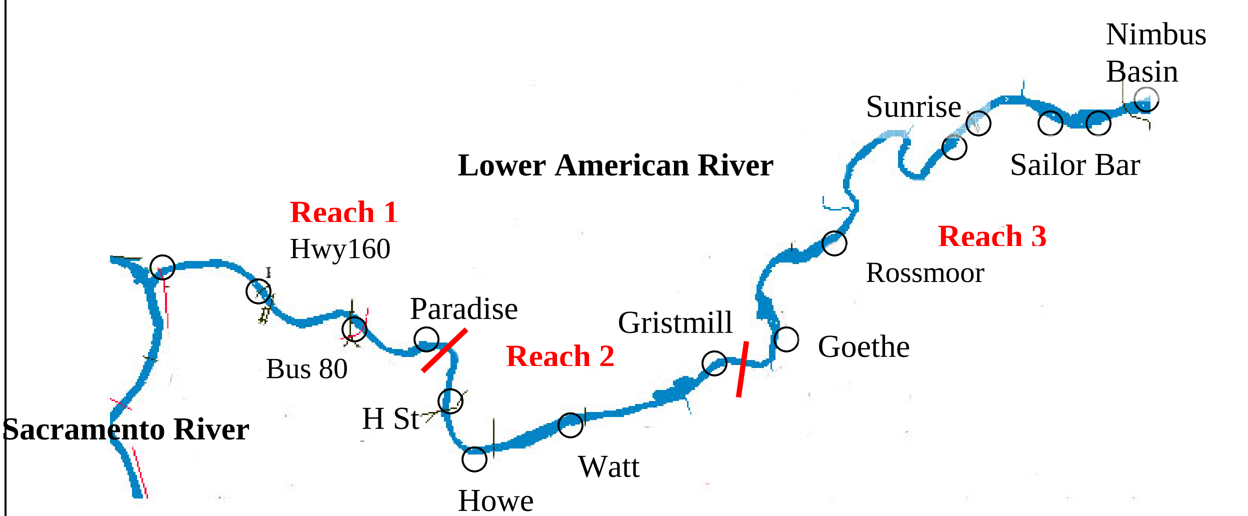


Figure 1. Sampling locations in Lower American River.

representative longitudinal picture of fish distribution in the LAR. All the locations are also readily accessible from the Lower American Parkway.

We divided the LAR into reaches based on geomorphology and hydraulic criteria per Snider et al. (1992). The upper river (Reach 3) was further divided into subreaches by bar complex simply because the parkway facilities are commonly referred to in this format.

Reach 1 - Lower Tidal River (RM 0-4.9) (Discovery, Hwy 160, Bus 80, Lower Paradise, Paradise Sites)

The lower-most reach of the LAR extends from the mouth at the Sacramento River upstream to Paradise Beach (River Park) at RM 4.9 (Figures 1 and 2). This is the approximate extent of the backwater effect of the Sacramento River on the LAR. The reach has a gradient of 0.03 percent with predominantly sandy and sandy-silt bank and bottom substrates, and is confined by flood-control levees. The reach is unique in that it has a fairly wide flood plain (about 2,000 to 3,000 feet between levees), with the river incised in a relatively narrow channel 500-ft in width along the south levee during all but flood flows. The floodplain is relatively high above the river as the river has cut down through deep deposits of historic placer mining debris that fills the floodplain.

At moderate to high river stages water backs up into the floodplain on the north side of the river, first filling sloughs and borrow pit channels and low-elevation ponds. Many small sloughs and ponds on the lower floodplain connect to the river at high water levels. During more extreme river stages, the river backs up onto higher-elevation terraces on the north side of the river from Discovery Park upstream to Bushy Lake, a complex of large borrow pit ponds and sloughs near Cal Expo. There is minimal stream channel and aquatic habitat structures such as islands in the reach with structure confined to the Highway 160 (RM 2) and Business 80 (RM 4) bridges. There are three channel islands 100-500 ft in length near the Business 80 bridge. Only one riffle occurs at the upper end of the reach at Paradise Beach, RM 4.9. Most of the north shoreline in the reach has extensive riparian vegetation and large woody materials, except in areas recently rocked for bank protection. The south bank is generally rocked levee with limited riparian vegetation, although experimental benches have been constructed with planted vegetation in many of the newly rocked levee banks.

Reach 2 - Lower Non-Tidal River (RM 4.9-11.6) (H-St, Howe, Lower Watt, and Gristmill Sites)

The middle reach of the LAR extends upstream from Paradise Beach (River Park) at RM 4.9 to Gristmill and Harrington parks at RM 11.6. The reach has more stream channel and aquatic habitat diversity than the lower reach, but fewer large flood plain features such as sloughs, lakes, borrow pits and canals, or wetland and upland terraces. It has a slightly higher gradient at 0.05 percent, and has more gravel and cobble substrate, mixed in with clay-stone bedrock and sandy reaches. Unlike the lower reach it has more islands and associated side channels, riffles and rapids. The floodplain narrows from about 2000 ft wide at the lower end to about 1000 ft over much of the remainder of the reach. The stream channel is several hundred feet wide, but narrows in places to 150 ft (e.g., RM 5.5).

Like the lower reach, this reach is also confined by levees, but unlike the lower reach it has narrower high terraces that rise quickly on each side of the river to the base of the levees. Gravel

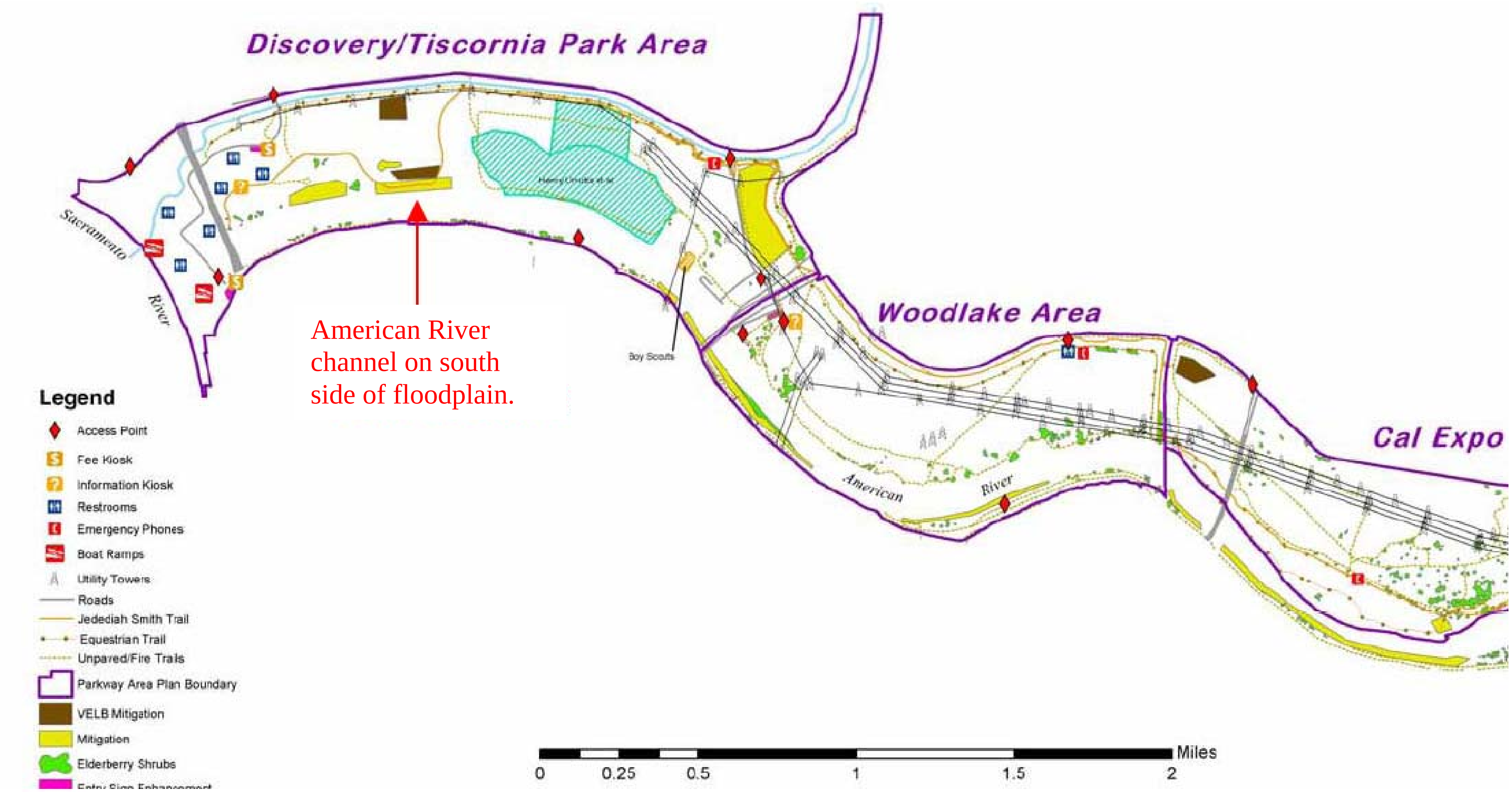


Figure 2. Survey Reach 1. (Source: SAFCA)

bars, channel islands, and riffles are located at River Park (RM 5), near the Howe (RM 8) and Watt Avenue (RM 9) bridges, and at Harrington/Gristmill accesses (RM 11). A main feature of the reach is long, wide, shallow stretches with clay-stone bedrock bottoms, alternating with two areas where gravel-dredger pits have been captured by the river: one between the Howe and Watt Avenue bridges and one upstream of Watt Avenue below Gristmill. These pit areas have ponds and sloughs that are connected to the river with sandy-soil islands partitioning the river from the pit areas. These pits are deeper than the river channel and out of the main flow of the river, except for the mid-river pit near Gristmill. Sandy shorelines of the pits and sloughs as well as the levee banks are generally well vegetated. Large woody materials including large cottonwood trees that have fallen into the river collect in these deeper pits during floods especially at the large pit located within the river channel below Gristmill (RM 10.5).

Reach 3 - Upper River (RM 11.6 to RM 23) (Goethe, Rossmore, Lower Sunrise, Sunrise, Sailor Bar, Nimbus)

The upper approximately one-half of the LAR has a higher gradient (0.08 %) than the lower reaches. Channel substrate consists of mostly gravel, cobble, and bedrock. The reach is un-leveed with some artificial bank protection. The reach extends upstream from Gristmill/Harrington parks to Nimbus Dam, and includes most of the salmon and steelhead spawning areas as well as much of the steelhead rearing area. The reach consists of seven major bar complexes that are formed by the natural meander of the river in its floodplain between naturally resistant clay- and sand-stone bluffs. Though much of the reach has gravel spawning riffle and run habitat, portions have bottoms consisting of armored cobble beds or bedrock that provide little spawning habitat. Many of the larger pools have also been scoured out by floods and have bedrock or cobble substrate. Descriptions of each of the sub-reaches follow.

Arden Bar (RM 12-13.5) (Goethe Site)

Arden Bar extends from the Harrington access (RM 12) upstream to the Jed Smith Bridge (RM13.5) on the north side of the river. The Goethe Site is located in the center of this reach on the south side of the river. This is one of the higher gradient portions of the LAR that includes bedrock formations that form the Arden Rapids just downstream of the Jed Smith Bridge. Downstream of the bedrock outcrops are extensive gravel deposits and a diverse channel structure that offers good spawning and rearing habitat for salmon and steelhead. Riffles, gravel bars, and channel islands and their associated side channels add to the diversity of the channel habitat. Though the interior of Arden Bar is highly developed (William Pond Recreation Area), the outer bar and river edge are more natural with extensive riparian vegetation on all but scoured bars adjacent to the river and small gravel islands within the main river channel.

One unique feature of Arden Bar is its gravel pits. The largest, Arden Pond, is an important recreational feature that is stocked with trout to support a put-and-take recreational fishery. Arden Pond escapes capture by the river except during major floods. Though the pond is protected by a large berm at its upper end, the berm is overtopped at flood flows and floodwaters pass through the pond and return to the river at the pond’s exit. High flows exiting the west end of the pond during floods have caused extensive scouring of vegetation along the river near the Harrington access.

The river has captured five smaller pits on the outer bar adjacent to the active river channel along the east side of the bar. A large portion of the river's flow at managed flows, perhaps 30 to 50 percent, now passes through a network of side-channels that connect the ponds before returning to the main river channel at mid-bar. The captured pits and joining side channels have extensive wetland and riparian vegetation along their margins, as well as considerable large woody debris. The captured pits are generally only several feet in depth with deeper portions only 8 to 12 feet in depth.

Goethe Bar (RM 13-15) (Goethe Site)

Goethe Bar is located on the south side of the river adjacent to and slightly upstream of Arden Bar. It extends from RM 13 upstream to RM 15. The Jed Smith Bridge (RM13.5) connects Goethe Bar to Arden Bar. Rapids occur at the lower and upper ends of the reach. Between the rapids is a long, slow-moving pool and glide opposite the center of the bar. Along the outer side of the bar, flood erosion has removed much of the shoreline vegetation. There are bank-side homes opposite the bar on the north side of the large pool and shorelines have been armored by the home owners to minimize erosion. Channel islands at the upper end of the reach under the SMUD power lines have lost much riparian vegetation during the late 1990 floods, but vegetation is recovering in recent dry years. The south shoreline at the upstream end of the bar has been rip-rapped to protect the bank and adjacent developments, and lacks riparian and SRA cover. The river at higher flows inundates the lower portion of the bar and side channels and offers considerable spawning and rearing habitat for salmon and steelhead.

Ancil Hoffman Bar (RM 14.5-16.5)

Ancil Hoffman Bar is located across the river and upstream of Goethe Bar from RM 14.5 to RM 16.5 on the north side of the river. The river reach adjacent to the bar as at Goethe Bar has rapids at its upper and lower ends with a long quiet pool opposite the middle of the bar. Like Goethe Bar, floods have scoured much of the vegetation from the outer side of the bar adjacent to the river and the bank opposite the bar. Braided channels located at the lower end of the bar near the SMUD power lines are extensive and unique to this section of the river, and the northern side channel has extensive riparian vegetation and spawning and rearing habitat for salmon and steelhead. The south bank is generally riprap bank or clay-stone bedrock.

Rossmoor Bar (RM 16-18.5) (Rossmoor Site)

Rossmoor Bar is located across the river and upstream of Ancil Hoffman Bar from RM 16 to RM 18.5 on the south side of the river. The river reach adjacent to the bar like Goethe and Ancil Hoffman Bars has rapids at its upper (San Juan Rapids) and lower ends with a long quiet pool and glide opposite the middle of the bar and a steep bluff opposite the bar. Portions of the pool against the north side bluff are relatively deep (15-20 ft) with well vegetated banks at the base of the bluff. Like the previous two bars, much of the vegetation along the outer portion of the bar adjacent to the river (south side) has been eroded away during floods. Floods have also taken a toll of riparian vegetation across much of the northeast portion of the bar. Unlike the previous two bars there are no islands or side channels in this reach.

Sacramento Bar (RM 18-20.5) (Lower Sunrise Site)

Sacramento Bar is located on the north side of the river across the river and upstream of Rossmoor Bar from RM 18 to RM 20.5 (Sunrise Bridge). Unlike the three bars downstream, Sacramento Bar has rapids and riffles adjacent to most of the bar and smaller deep quiet pools and glides. Much of the bar's shoreline and lower floodplain, and portions of high terraces have limited riparian vegetation due to flood scour and gravel mining. Like Arden Bar, high terraces have remnant gravel pits (5) of up to 1,000 ft in length. Like downstream bars, floods have scoured much of the vegetation along the outer side of the bar adjacent to the river. Gravel islands in the main river channel at the upper end of the bar have been scoured of vegetation in recent floods. A DFG gravel enhancement site is located on the north shore in the center of the bar.

Sunrise Bar (RM 20-22) (Lower and Upper Sunrise Sites)

Sunrise Bar is located on the south side of the river across the river and upstream of Sacramento Bar from RM 20 (near Sunrise Bridge) upstream to RM 22. Like other downstream reaches the Sunrise Bar reach has rapids and riffles at its upper and lower ends as well as a two large deep wide pool sections in the center divided by an island and rapids complex (Upper Sunrise Site). Gravel and cobble banks and islands along much of the bar have been scoured of vegetation in recent floods. The scoured south bank side channel of the island located between the large pools has been eroding into the south bank terrace and has reached portions of the bike trail and other park facilities. The upper most portion of the bar is a narrow cobble bar that includes a high-flow side channel. There are also several small side-channel habitats on the middle and lower bar that provide SRA habitat during higher river flows, but these side channels are dry under normal low flow conditions. There is a DFG gravel enhancement site at the lower end of the Bar.

Sailor Bar (RM 20-22.5) (Lower and Upper Sailor Bar Sites)

Sailor Bar is located on the north side of the river across the river and upstream of Sacramento Bar from RM 20 (near Sunrise Bridge) upstream to RM 22.5 at the Nimbus Hatchery pool. The reach has extensive gravel riffles, runs, and rapids in its middle and lower portions. The upper portion is adjacent to the Nimbus Hatchery pool, which is a large deeply scoured pool. The lower portion is adjacent to upper Sunrise pool, a deep scour pool between the lower Sailor Bar rapid and Sunrise rapids. The head of Sailor Bar extends into the river at the tail of the hatchery pool and has undergone considerable scouring in recent decades. At its upper end riparian vegetation was severely depleted by scouring during flooding in the late 1990's, but considerable willow and shrub vegetation has revegetated portions of the bar. On the middle portion of the bar is Sailor Bar Pond, a gravel pit captured by the river. The pond is only 6-8 ft at its deepest. Small areas of wetlands occur along the margins of the pond. Several small islands downstream of the pond in the middle reach have been scoured away in the late 1990 floods. A large island in the lower reach was scoured of its vegetation during floods but has revegetated in recent dry years. While gravel remains abundant in the river adjacent to the middle and lower reaches from continued bank scouring and DFG gravel introductions, the river adjacent to the upper portion (the hatchery pool tail-out) lacks gravel and has a predominantly cobble and bedrock substrate. A DFG gravel enhancement site is located on the main river channel adjacent to the captured gravel pit at the middle of the bar.

Nimbus Basin (RM 22.5-23) (Nimbus Site)

Nimbus Basin extends from the hatchery weir just downstream from the Hazel Avenue Bridge (RM 22.5) upstream to Nimbus Dam (RM 23). The reach includes the dam tailrace pool, Nimbus Bar on the south side of the Basin, Nimbus Bar riffle-glide in the main river channel adjacent to Nimbus Bar, and the bridge-weir pool at the lower end. The north and south shores have been scoured down to bedrock or large cobble with little gravel and riparian vegetation present in the stream or on Nimbus Bar. Though there is extensive holding water in the basin for adult salmon and steelhead, there is only a small patch of gravel spawning habitat at the head of the riffle. Some spawning and juvenile rearing habitat occurs on the bar at higher flood flows.

Fish Community

The LAR between Nimbus Dam and the mouth at the Sacramento River is an important spawning and rearing habitat for fall-run Chinook salmon (*Oncorhynchus tshawytscha)*, steelhead trout (*Oncorhynchus mykiss*), American shad (*Alosa sapidissima)*, and many native fish species including Sacramento splittail (*Ptychocheilus grandis*), Sacramento pikeminnow (*Ptychocheilus grandis*), Sacramento sucker (*Catostomus occidentalis*), tule perch (*Hysterocarpus traski*), and Pacific lamprey (*Lampetra tridentate*). In addition the LAR is seasonally important habitat for adult striped bass (*Morone saxatilis*) that migrate upstream into the LAR from the Sacramento River and the San Francisco Bay-Delta estuary (Bay-Delta). The steelhead trout have been federally and state listed as threatened. The fall-run Chinook salmon and Sacramento splittail are federal species of special concern.

Many of these fish species use the aquatic habitats of the LAR for spawning, rearing, and feeding. Gravel riffles and runs provide spawning habitats for many species including salmon and steelhead that deposit their eggs in gravel riffles, runs, and glides in higher gradient areas of the river from fall through spring. Shallow low gradient areas of the lower river floodplain are spawning habitat for splittail and rearing habitat for many of the fish species. Sacramento sucker and pikeminnow also migrate into the river from the Bay-Delta in large numbers to spawn and rear.

The steelhead population is part of the Central Valley ecological unit. The steelhead population of the LAR has declined from a combination of factors including dam construction (Nimbus and Folsom Dams), low flows, high water temperatures during summer rearing, predation by fish, over-harvest by man, complications involving hatchery production (e.g. competition, genetics, disease), water diversions, and poor spawning and rearing habitat conditions (DFG 1993).

Steelhead migrate into the river and spawn in winter and spring. Adult steelhead may be found in the river during any month of the year but primarily migrate into the river in winter and spring. The native steelhead were a spring-run, which migrated into the river in spring and then remained over summer and fall to spawn the next winter or spring (McEwan and Nelson 1991). Young steelhead emerge from the gravel in late winter and spring, and rear in the river until the following winter and spring before migrating downstream to the ocean as smolts. Some may remain in the river two or more years before migrating to the ocean. Unlike some Central Valley rivers, there is no significant population of native rainbow trout in the LAR.

Adult fall-run Chinook salmon begin migrating into the LAR in summer, gradually peaking in abundance in October and November where spawning is concentrated in gravel beds of the upper approximately 10 miles of the LAR. The run supports an extensive recreational fishery from late spring through the fall. Natural production of smolt salmon is supplemented by smolts produced at the Nimbus hatchery, which are transported by truck and released into San Francisco Bay.

Small numbers of splittail have been captured in recent years in the DFG fish trap located near the Watt Avenue Bridge (Snider and Titus 2000). Their presence in the trap is indicative of a portion of the Bay-Delta population migrating into the LAR to spawn in late winter and early spring. Splittail seek out shallow, flooded vegetation above the Delta for spawning. The LAR offers only limited amounts of such habitat.

The LAR is an important spawning river for the American shad Central Valley population. American shad where introduced from the east coast late in the 19th century and provide an important recreational fishery in the LAR, and in the Sacramento River and other tributaries. American shad migrate into the rivers in spring and spawn in late spring and early summer. The proportion of the Central Valley population that enters the American River may be related to river flows and water temperature (USFWS 1997). The shad run supports a popular spring-summer sport fishery through much of the LAR.

Striped bass are found in the LAR from spring through fall. A spring "run" into the river may occur from the lower Sacramento River and Delta. Little is known about the habitat requirements of striped bass in the river, though they are found in many of the habitat types. The striped bass support a recreational fishery in the LAR from spring through fall.

Methods

Survey Design

The 2003-2005 snorkel surveys were conducted twice per month generally from February through June. Surveys were conducted at 14 sites (Figure 1). One or two teams of divers, with two to three divers per team, conducted the surveys. Individual surveys were conducted over a period of two to four days. Additional supplemental surveys were conducted in the summer to locate concentrations of juvenile steelhead.

Sites were chosen to be representative of habitat in the various reaches of the river and to represent the broad array of physical habitat in the LAR. Sites were chosen systematically to represent the longitudinal distribution of fish in the river through the survey period. More sites were chosen in the upper river because this area is known to be the primary spawning and rearing habitat with a greater gradient and diversity of habitat. Choice of sites was influenced to some degree by accessibility, especially in the lower river where access was limited.

At each of the sites the available habitat area was visually surveyed and representative habitat units designated as sampling units. Units varied in size from 30 to 150 feet in length and 6 to 10 feet in width. Dimensions differed as a function of homogeneity of the habitat within the unit. For example, mainstem run units were generally 100-150 feet in length and ten 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 30 to 100 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 shapes) as they were laid out as two-dimensional features. In designating polygon/cell units we followed the general approach of Kocik and Ferreri.(1988), McCain (1992), and Thomas and Bovee (1993), where defined 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 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 clay 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, 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. Despite some sites having nearly 20 units, most units within a site had some unique habitat features or conditions that differentiated them from other units.

Sampling units were chosen from the available array of riffles, pools, runs/glides, 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 as done by McCain (1992); 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 high flows it was not possible to sample all units. Some units could not be sampled in low flow periods. In some cases other units were added or substituted. Generally, for each sampling period, surveys were conducted at most of the designated sampling units at each site. After February 2003, the Highway 160 site was substituted for the Discovery Park site in Reach 1, because we wanted to cover the experimental levee habitat restoration sites located at Highway 160.

Sites were generally accessed by vehicle or boat, and then units were reached by foot, boat, or swimming. During high flow periods, some units could be accessed only by small boat because of the danger of swimming across the river.

Sampling Technique

Snorkeling was conducted similar to other 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[5]. 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 channel of the river.

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. Some, especially schooling fish like pikeminnow and Chinook 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 American River substrate (Table 1).

[5] At times a second diver followed the data collector for the purposes of observing, training, or quality assurance checking. Also, scuba diving was occasionally used to survey deeper pools to determine if snorkeling was missing fish in deeper habitat units.

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 juvenile fish over 20 mm. Divers were trained on scale models as size is distorted underwater. Fish lengths were recorded in categories as follows:

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). Larvae and early juvenile suckers and minnows (principally pikeminnow) were not counted or included because of their great abundance and widespread distribution beginning in spring. Only when they reached approximately 20 mm in early summer were they counted by species and recorded on dive slates.

Temperature was recorded with hand-held thermometers at each site. Multiple temperatures readings were recorded in some units if divers thought significant temperature gradients were present. Generally, temperature varied little among all the sites sampled because of the relatively high flows from 2003 to 2005. Temperature variability at some sites was noticeable on warm late spring and summer afternoons in backwater units exposed to the sun.

Flow data were obtained from the California Data Exchange Center (CDEC) via the Internet. Additional temperature data was obtained from the USGS Internet site for the LAR Fair Oaks site.

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 standard unit size (600 square ft) were the dependent variables in analyses. In some analyses the log of the number was used “linearlize” the data.

Results

Snorkel surveys were conducted approximately twice per month from February to July 2003 - 2005 conditions permitting with supplemental surveys in August and September 2003 and 2004 (Table 2).

Table 2. Snorkel survey sampling periods - February to September, 2003-2005.

Standard Surveys	2003	2004	2005
Early February – Feb 1	February 4-5	February 5-10	NS
Late February – Feb 2	February 22-23	NS	NS
Early March – Mar 1	March 8-10	March 2-13	March 8-9
Late March – Mar 2	March 19-24	March 22-28	Mar 31-Apr 7
Early April – Apr 1	April 8-10	April 8-13	April 11-19
Late April – Apr 2	April 23-26	April 25-30	April 26-27
Early May – May 1	May 10-15	May 11-15	May 11-14
Late May – May 2	May 30-31, June 1-3	May 21-31	May 25-27
Early June – June 1	June 19-24	June 2-9	NS
Late June - June 2	June 30 - July 1	June 23-29	June 14-21
Early July – July 1	July 15-17	July 8-9	July 7-15
Late July – July 2	July 28-31	July 23-26	NS
Early August – Aug 1	NS*	August 3-4	NS
Late August – Aug 2	August 19-20	August 16-20	NS
Early September – Sep 1	NS	September 7-8	NS
Late September – Sep 2	September 30	September 21-22	NS

* NS = No survey

River Flows

The LAR flows during the 2003, 2004, and 2005 surveys were relatively high as these years were considered wet years. Base flows were 1,500 to 2,500 cfs (Figures 3, 4, and 5). Each year had winter flows in the 5,000-8,000 cfs range. In spring 2005 flows reached near flood levels of 15,000 to 25,000 cfs.

River flows in 2003 were relatively high at 4000-5600 cfs during the two February sampling periods, but declined sharply in late February falling to 2000 cfs in early March (Figure 3). Streamflow remained near 2000 cfs during the four March and April sampling periods, and then increased to near 6000 cfs during the two May surveys. In the mid and late June surveys flows were 2500 to 3000 cfs. Flow increased during July to near 3000 during the mid July survey and to near 4500 by the late July survey. By the final surveys in mid August and late September flows had again declined to and remained steady at 2000 cfs.

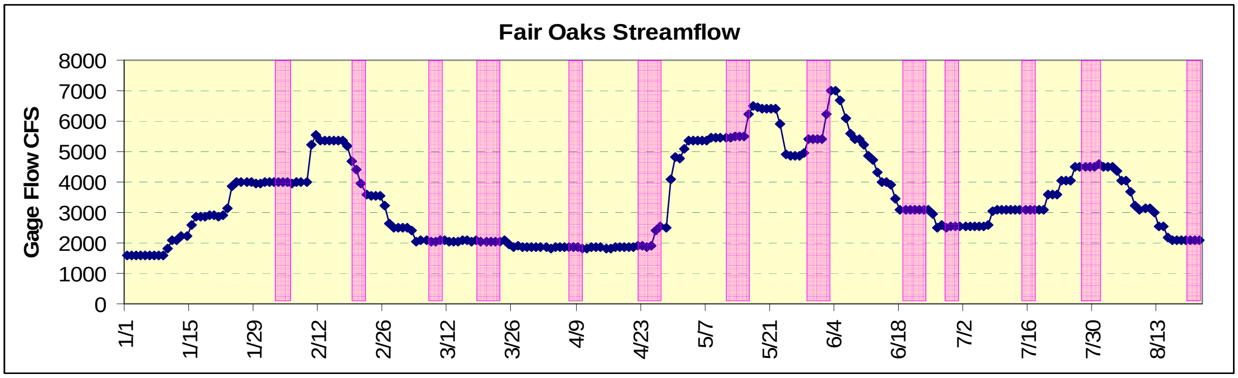


Figure 3. Flow at Fair Oaks during 2003 with survey periods highlighted. Source: USGS.

In 2004 surveys were conducted at flows from 1,500 to 8,000 cfs (Figure 4). The February survey was conducted at 2100 cfs, while the March surveys were conducted at 3,000 and 4,000 cfs. April surveys were conducted at 5,000 to 8,000 cfs and 2,300 to 3,000 cfs. May and June surveys were conducted at base flows of 1,800 to 2,500 cfs. July surveys were conducted during summer releases of 3,000 to 3,500 cfs. August and September surveys were conducted at the base flow of 1,500 cfs.

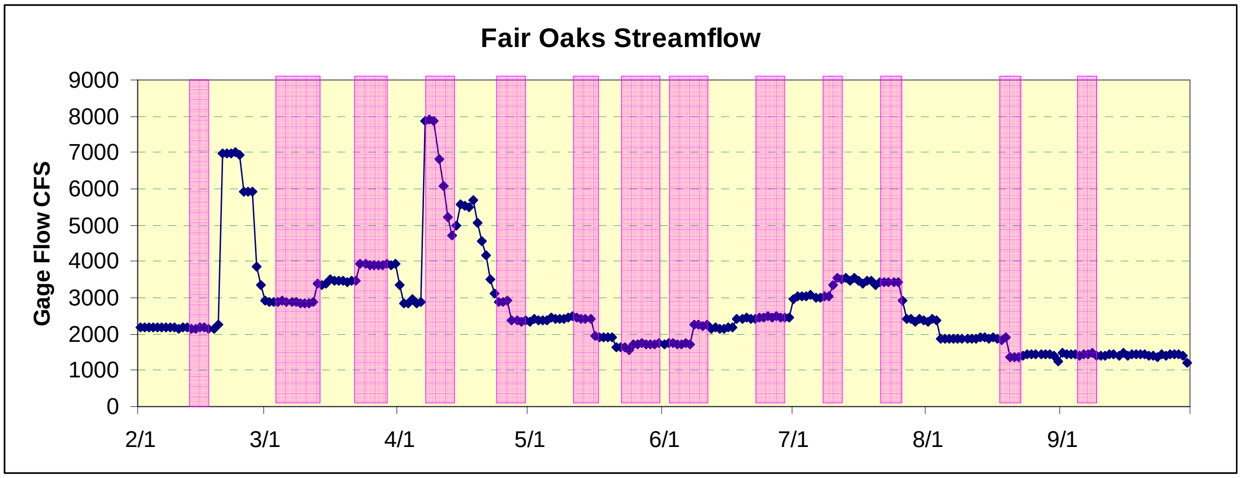


Figure 4. Flow at Fair Oaks during 2004 with survey periods highlighted. Source: USGS.

In 2005 winter surveys were delayed by high flows and turbid water until early March when flow was 3,000 cfs (Figure 5). Surveys in April were conducted at 4,000 cfs. May and June surveys were conducted at 6,000 to 8,000 cfs. The July survey was conducted at 3,500 cfs.

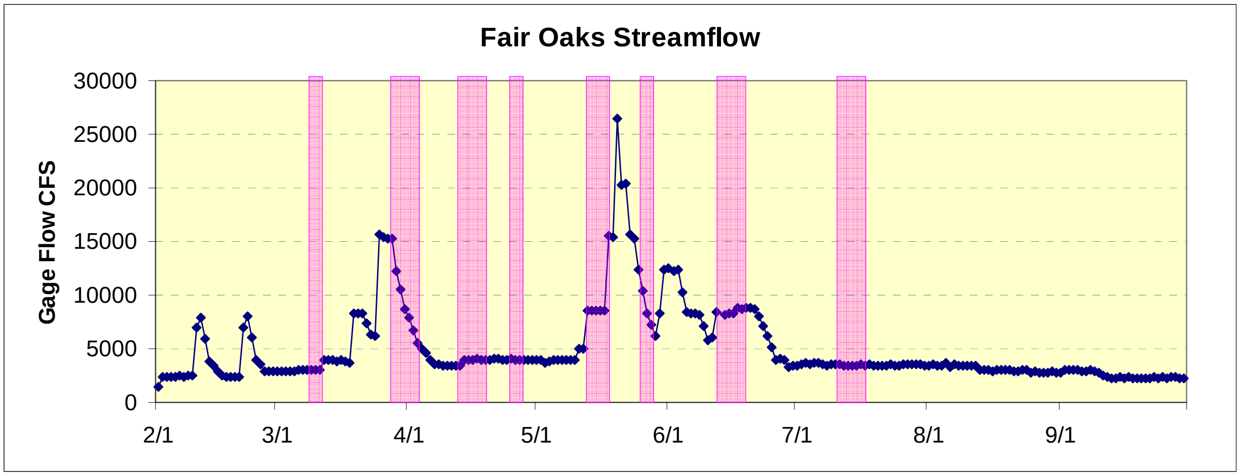


Figure 5. Flow at Fair Oaks during 2005 with survey periods highlighted. Source: USGS.

Water Temperatures

Water temperature varied among years, surveys, sites within surveys, and units within sites within surveys (Figures 6, 7, and 8). Generally, water temperature increased through the season and was warmer at more downstream sites. Higher water temperatures within sites occurred in backwater and margin habitats. Maximum differences among units within a site approached 6°C while the maximum difference within a unit was 4°C. During July the difference in temperature between a riffle and an adjacent backwater margin only a few feet away could be as high as 2 to 4°C in some units because of solar warming of the backwaters. At the same time the difference between the upper and lower river in the main channel was only 2°C. While warming was considerable in shallow riffles and backwaters in July, at flows approaching 5000 cfs there was limited heating of the main body of water passing down the river. In February the maximum water temperatures were 8-11°C. In March maximums reached 16°C. In April maximum water temperatures reached 19°C. By midsummer, water temperatures were in the 15-20°C range. The highest temperatures of 22-24°C occurred in late May of 2004 in shallow channel-margin riffles of the Watt, Gristmill, and Goethe sites under relatively low flows of 1600-1800 cfs. Main channel temperatures during this same period were 16-18°C even in the lower river below the Watt site. In contrast, in late May of 2003 and 2005 when river flows were in the 5,000-8,000 cfs range, maximum water temperatures were considerably cooler at 12-14°C.

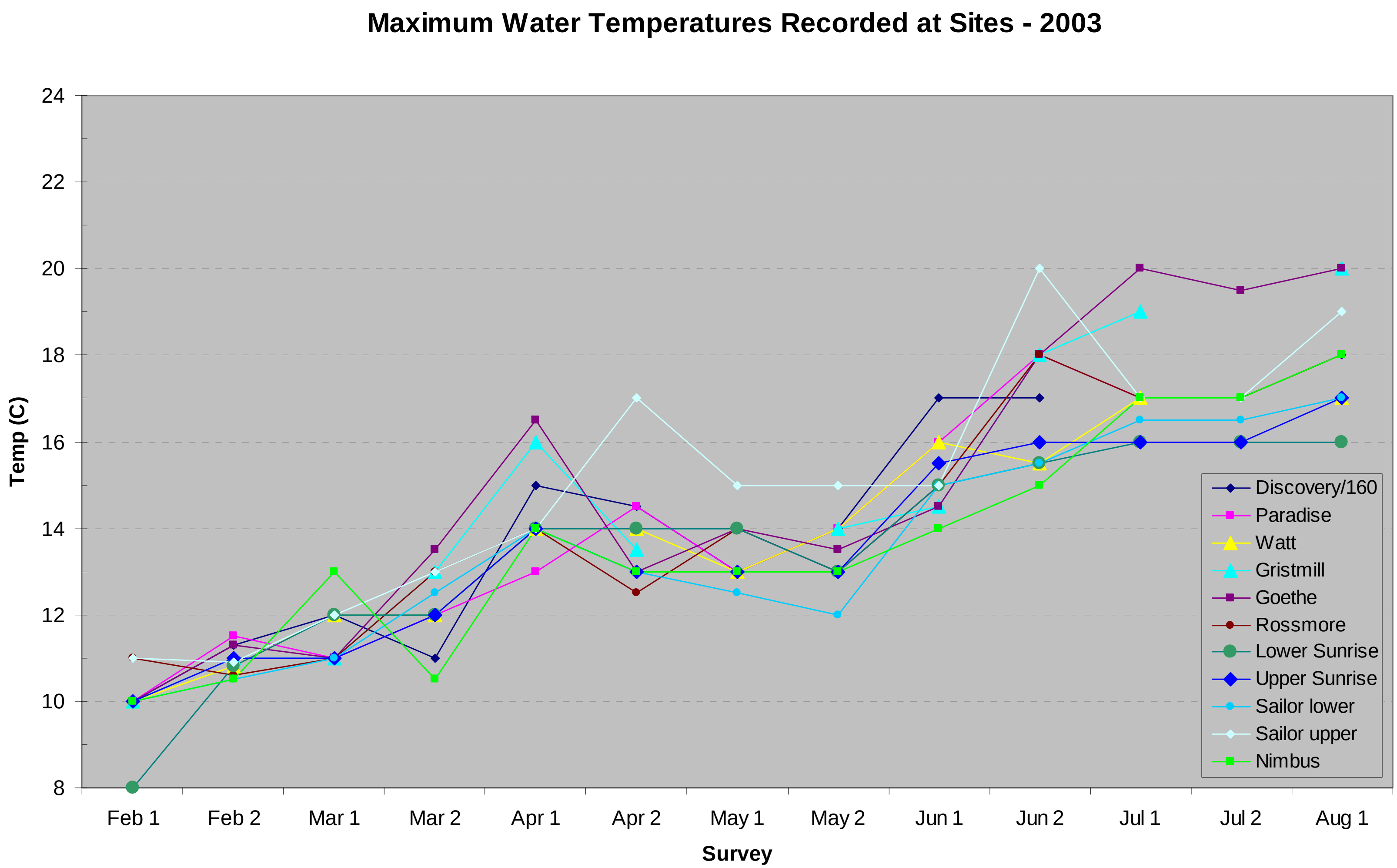


Figure 6. Maximum water temperatures measured at surveyed sites during twice-monthly surveys in 2003.

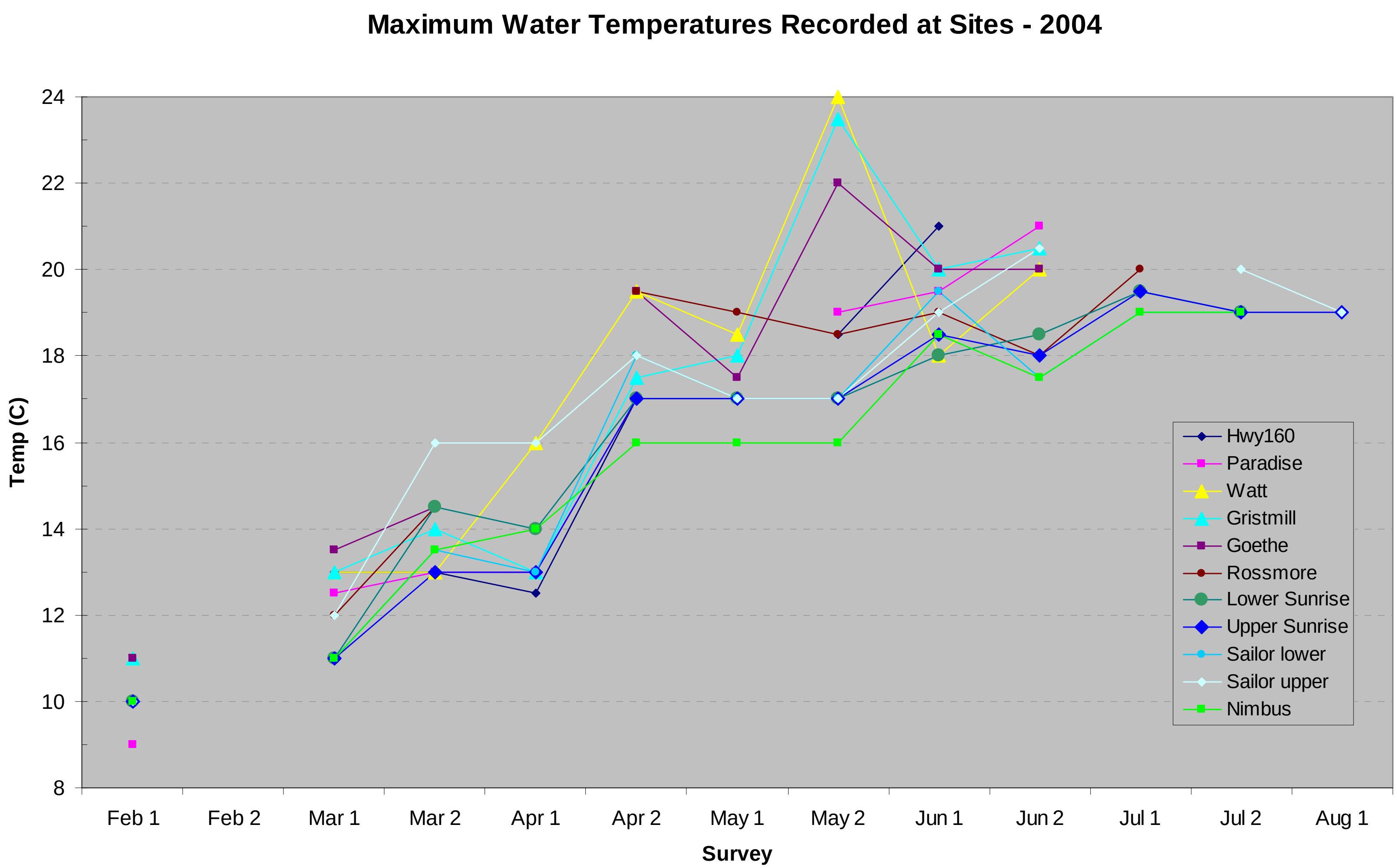


Figure 7. Maximum water temperatures measured at surveyed sites during twice-monthly surveys in 2004.

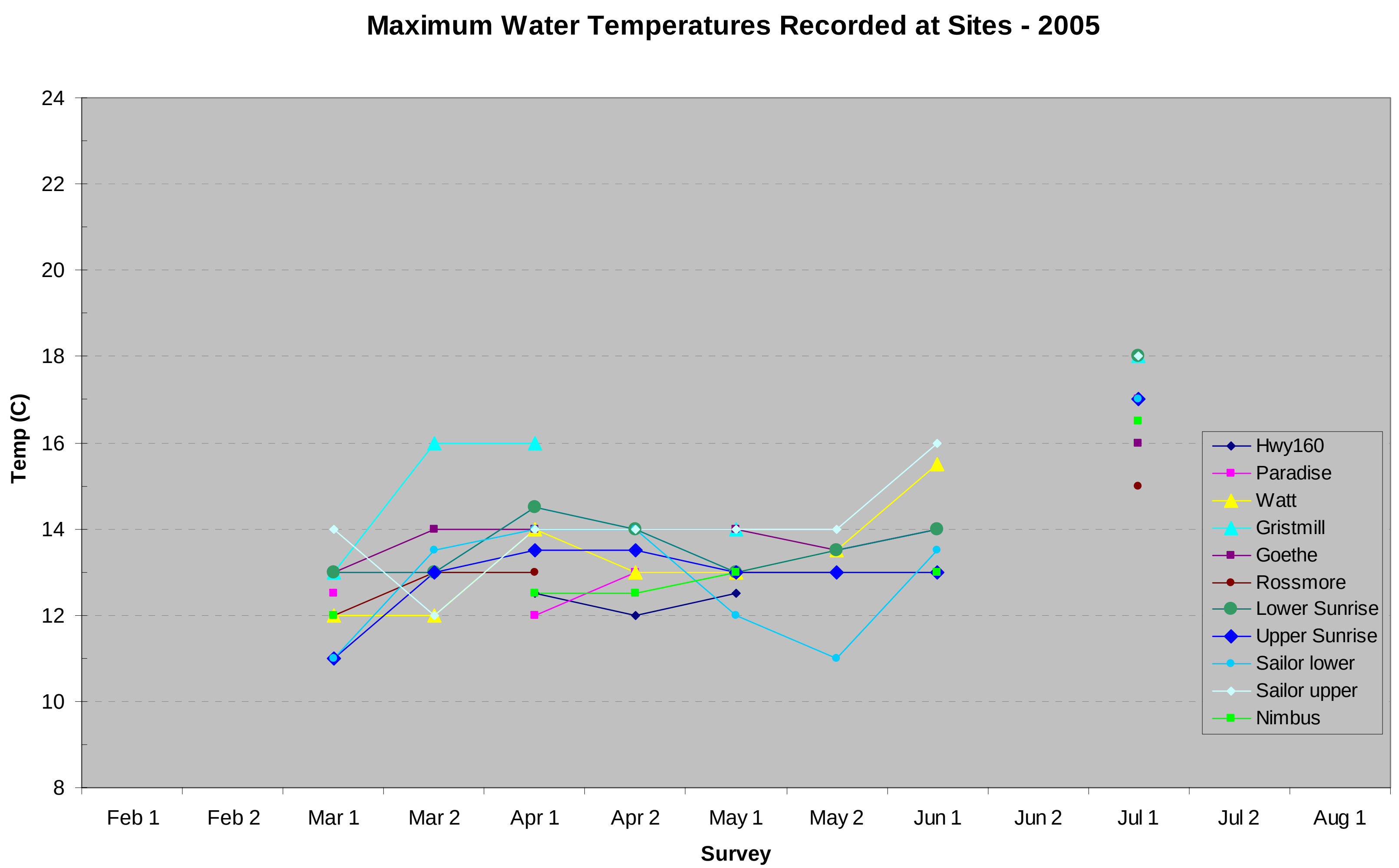


Figure 8. Maximum water temperatures measured at surveyed sites during twice-monthly surveys in 2005.

Fish Distribution and Abundance

The following species and life stages were commonly observed in the snorkel surveys:

- Chinook salmon (*Oncorhynchus tshawytscha)*: adults and young – in general we refer to 20-40 mm sized salmon as fry, 40-60 mm sized as fingerlings, 60-80 mm sized young as pre-smolts, and 80+ mm sized as smolts.
- Steelhead or rainbow trout (*Oncorhynchus mykiss*): adults and young – in general we refer to 20-40 mm sized trout as fry, 40-60 mm sized as fingerlings, 60-120 mm sized trout as pre-smolts (generally have distinguishable parr marks), 120-240 mm sized trout as smolts (generally silvery without parr marks), and 240-400 mm as subadults.
- Sacramento sucker (*Catostomus occidentalis*): larvae, juveniles, yearlings, and adults
- Sacramento pikeminnow (*Ptychocheilus grandis*): larvae, juveniles, yearlings, and adults
- Tule perch (*Hysterocarpus traski*): young and adults
- American shad (*Alosa sapidissima)*: adults
- Striped bass (*Morone saxatilis*): subadults and adults

In addition, the following species and life stages were occasionally encountered:

- Smallmouth bass (*Micropterus dolomieu*): adults
- Largemouth bass (*Micropterus salmoides*): young and adults
- Bluegill (*Lepomis macrochirus*): juveniles and adults
- Pacific lamprey (*Lampetra tridentate*): adults.
- Prickly sculpin (*Cottus asper)*: young and adults
- Carp (*Cyprinus carpio*): adults

The following sections describe observations by species. In addition to text figures, data are also referenced by charts and presented in a chart appendix.

Young Chinook salmon and steelhead, the target species of the surveys, were prevalent in the three years of survey from February through June (Figures 9-11). Numbers observed dropped off dramatically in spring. They also grew to larger size (Figures 12-14) and moved into deeper and faster waters where they were more difficult to observe. Highest numbers of Chinook were observed from February through April. Highest numbers of steelhead were observed in April and May.

Chinook Salmon

Survey Year 2003

In the 2003 surveys juvenile Chinook were widely distributed through the LAR in winter (Chart 1). The highest densities of salmon in the survey period (2 to 10 per square foot) were observed in late February in the upper river from Rossmoor upstream to Sailor Bar. Densities were greatest in river margin habitats with abundant cover including riffles, steep banks of runs and pools, and flooded backwaters. Much of the river habitat had abundant cover from flooded vegetation at the relatively high flows of 4,000 to 5,600 cfs (Figure 3). Densities were lower (1 to 2 per square foot) though relatively high in margin habitats with abundant cover in the lower river.

By early March 2003 coincident with flow reductions to 2,000 cfs salmon densities declined sharply in the upper river and increased in the lower river (Chart 2) where densities increased along steeper bank and levee units with abundant cover. Density reached 3 to 5 juvenile salmon per square foot on flooded planted benches of levees near the Highway 160 Bridge. Highest densities at 9 per square foot were in margins of side channel riffles at Goethe Park and Upper Sunrise sites that had abundant cover from overhanging willows or Arundo. Density was also high at the Lower Sunrise Site under the footbridge, which provided abundant cover.

In late March densities had generally dropped at or below 1 per square foot over the entire river (Chart 2). Highest densities were in the same locations as early March.

By early April, remaining juvenile salmon were concentrated in the upper portion of the LAR (Chart 3). Water temperature had increased sharply by April in many areas of the river including the Goethe Park site side channel where the temperature reached 18ºC. Density remained relatively high at 1 to 2 per square foot in four units that had abundant instream and overhead cover: the Goethe Park side channel (unit 9), the lower Sunrise footbridge (unit 1), the Lower Sailor Bar side channel beaver house (unit 1), and under the Hazel Avenue Bridge in Nimbus Basin (unit 1). By late April density remained relatively high only at Lower Sailor #1, which has extensive cover along the margin of a deeply scoured bedrock pool.

In May and June juvenile Chinook were scattered through the upper river in riffle and deep run margins with abundant cover (Charts 4 and 5). The majority of these fish were 60-100 mm pre-smolt and smolt-sized fish (Figure 12) that were wary and difficult to observe except in shallow riffles. Though we did not observe any at the beaver house at Lower Sailor Unit #1 snorkeling, we did observe them actively feeding on the surface nearby in morning and evening. We suspect they were in open water of the adjacent deep pool in large schools.

We observed small schools of smolt-sized Chinook in July and August in riffle and riffle margin habitats in Nimbus Basin (Charts 6 and 7). We occasionally noted schools of juvenile salmon feeding in deeper runs of the upper river through the summer.

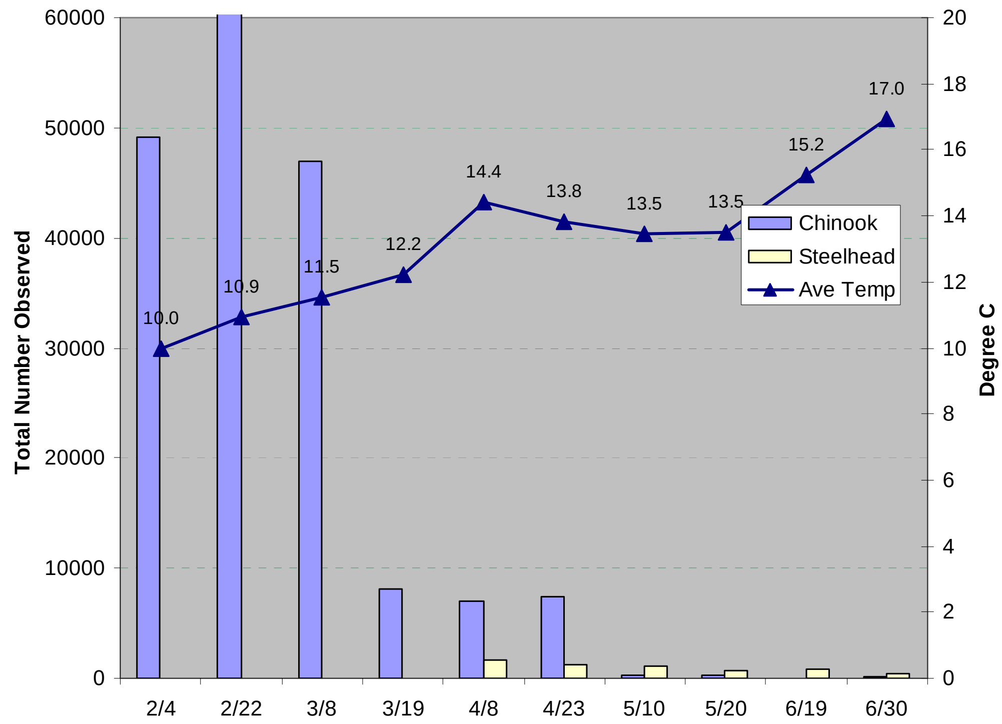


Figure 9. Total observations of Chinook and steelhead young in survey periods in 2003.

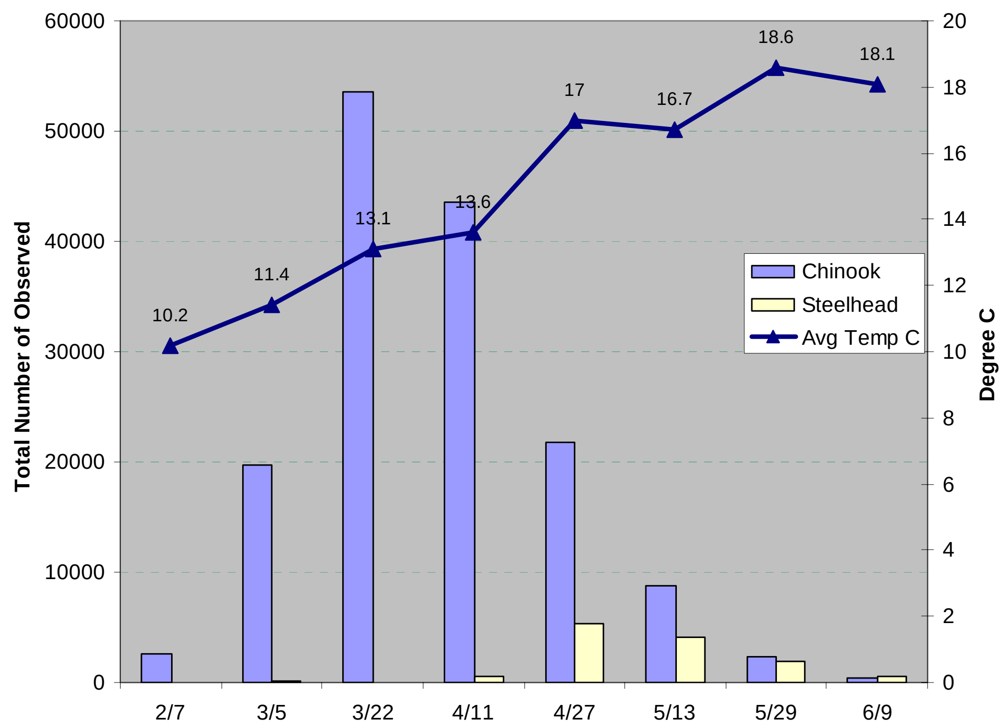


Figure 10. Total observations of Chinook and steelhead young in survey periods in 2004.

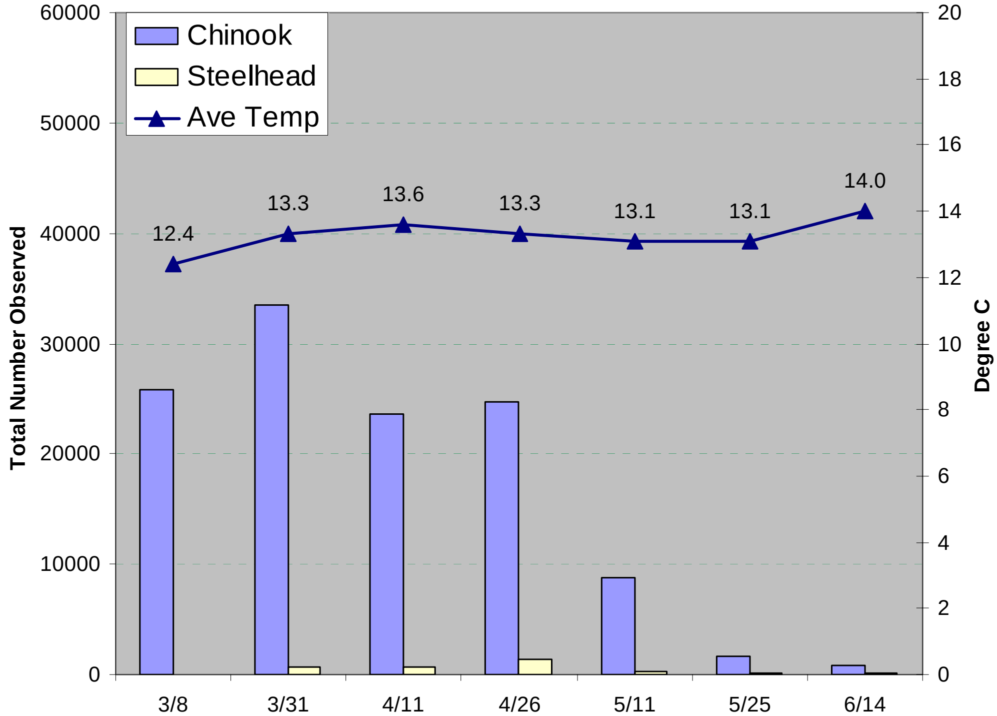


Figure 11. Total observations of Chinook and steelhead young in survey periods in 2005.

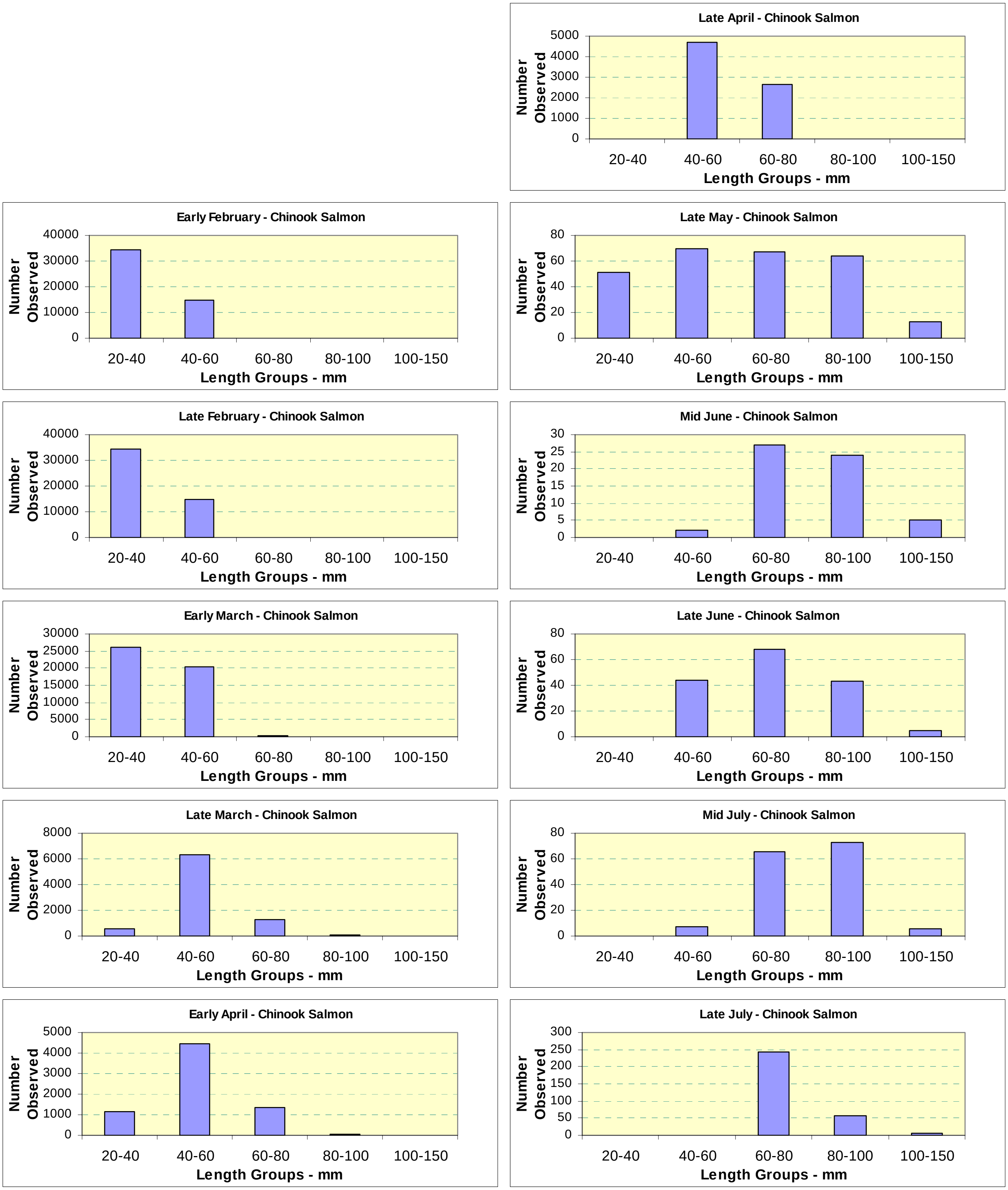


Figure 12. Length frequency of young Chinook salmon February through July 2003.

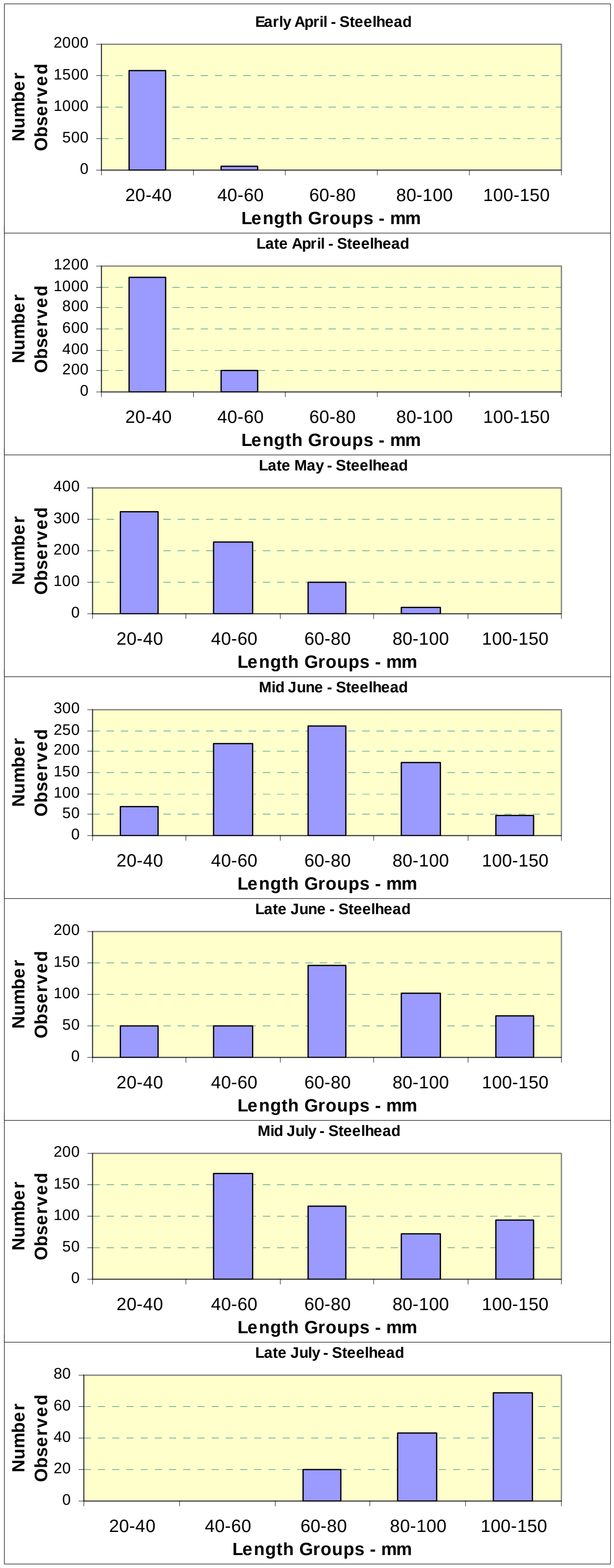


Figure 13. Length frequency of young steelhead trout February through August 2003.

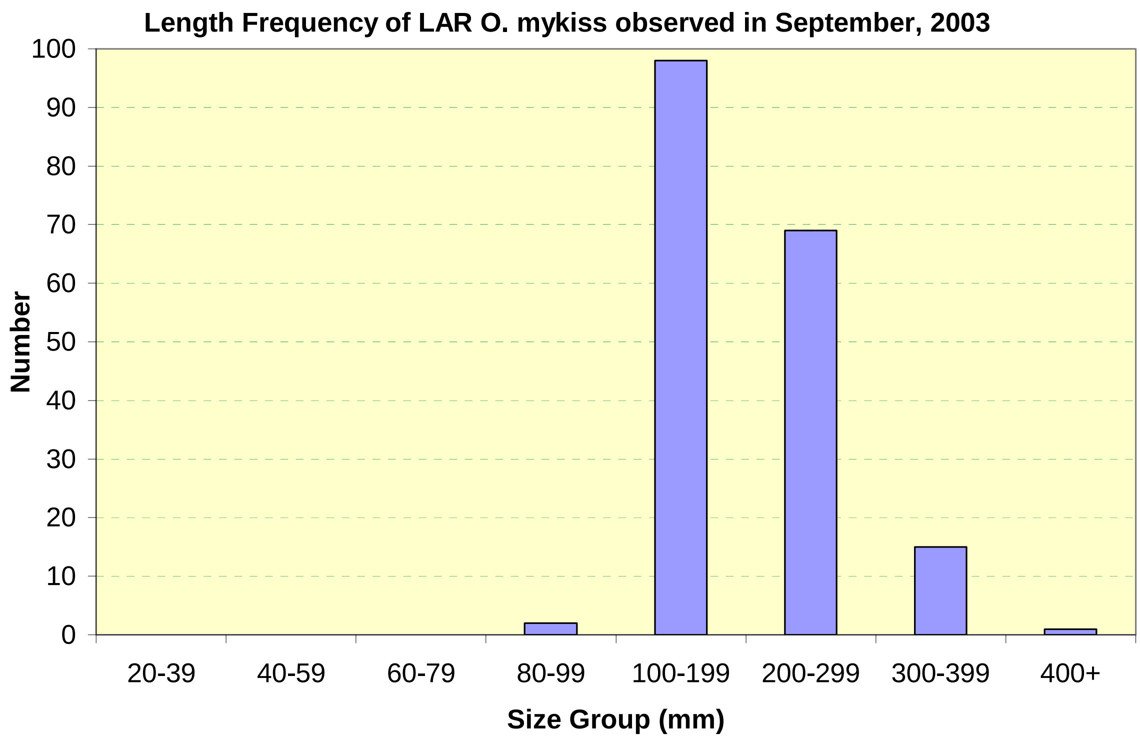


Figure 14. Length frequency of juvenile steelhead as observed in September 2003.

Survey Year 2004

A greater number of sampling sites and more sampling units provided a similar picture of juvenile Chinook salmon distribution and abundance in 2004 as in 2003. As in the 2003 surveys juvenile Chinook were widely distributed through the LAR in March (Chart 27) and April (Chart 28). The highest densities (2 to 10 per square foot) were observed in the upper river from Gristmill upstream to Sailor Bar. Densities were high in river margin habitats including riffles, steep banks of runs and pools, and flooded backwaters. The backwater units at the Watt, Rossmoor, and Upper Sailor sites had consistently high densities at 1 to 3 per square foot in early April when water temperatures were 13 to 16ºC, and a degree or two above the temperature of the main river habitats. Backwater unit densities declined sharply in late April as water temperatures reached 17 to 19ºC. Highest densities in the late April survey were at two steep bank units with extensive cover (Upper Sunrise #10 and lower Sailor #1) and a mainstem riffle margin with a backwater eddy and abundant cover (Upper Sailor #3) where water temperatures were 12 to 14ºC. Densities in the lower river sites downstream of Goethe Park dropped sharply in April as water temperatures reached near 18ºC across all sampling units (Figure 7). In May densities also dropped sharply at the upper river sites (Chart 29) when water temperatures reached 16 to18ºC.

Survey Year 2005

Patterns for juvenile Chinook observed in 2005 were similar to 2004. In the first survey in early March juvenile Chinook were widely distributed with densities moderately high at 1 to 4 per square foot (Chart 34). As in the previous two years fry salmon were abundant along most stream margins including steep banks, backwaters, riffles, and riprapped levee banks with cover.

As in the previous years density was higher in the upper river than the lower river through April (Chart 35). In the lower river in April density reached near or higher than 1 per square foot along steep natural banks and vegetated levee units, as well as riffles in the side channel at the University golf course and at Paradise Beach (Campus Commons) (Chart 35). In the upper river densities were higher in the Goethe, Upper Sunrise, and Lower Sailor side channels, as well as under the footbridge at Lower Sunrise, steep margins of Sunrise Rapids (units 8-10), and riffle margins of Upper Sailor site. In early April density was high in Sailor Bar Pond (unit #5) where water temperatures were 13 to 14ºC, which was one to two degrees warmer than the main river channel. Densities remained relatively high at these sites through April as water temperatures remained low in the 12 to 14ºC range. Density declined sharply in May despite water temperatures remaining in the optimal range of 12 to 15ºC range under high river flows.

Steelhead

Survey Year 2003

In the 2003 surveys fry steelhead were first observed in the late March survey (Chart 9). Their densities peaked in April (Chart 10) with most found in the upper river from Goethe site to Nimbus site. They were found in similar river margin habitats with abundant cover as were Chinook. In early May they were relatively abundant only in a side channel margin with abundant cover at Lower Sailor units 11 and 12 (Chart 11). In June (Chart 12) and July (Chart 13) young steelhead were scattered in riffles from the Watt site upstream to Nimbus Basin. By

August small numbers were observed in riffle/run habitats with highest numbers observed in the Goethe, Upper Sunrise, and Lower Sailor side channels (Chart 14).

Survey Year 2004

In 2004 young steelhead density peaked in late April and early May (Charts 30 and 31). Peak density was observed in the upper river from Rossmoor to Sailor Bar in river margin habitats. Highest densities were observed at the Upper Sunrise site, which is a major spawning area. Densities were low in late May and June (Chart 32). In early summer (late July and early August survey) young steelhead found predominantly in riffle habitats from the Goethe site upstream to the Nimbus site (Chart 33). As in 2003 greatest numbers observed were in side channels (Goethe #7, Lower Sailor #7, and Nimbus #7a), with slightly lower numbers observed main channel riffle margins (Goethe #1, Upper Sailor #3, and Nimbus #5a). In the late August survey 119 (58%) of the 200 juvenile steelhead observed were in the Goethe, Lower Sailor, and Nimbus side channels.

Survey Year 2005

Steelhead first appeared in abundance in 2005 in late April at Upper Sunrise (units 1 and 2) and Lower Sailor (units 11 and 12) side channels (Chart 37). Densities declined sharply in May with small numbers observed in the Upper Sunrise side channel (units 1, 2, and 4a) (Chart 38).

Sacramento Sucker

Sacramento sucker data were only analyzed in detail for 2003. Based on a cursory review, patterns observed in 2004 and 2005 were very similar.

Adult Sacramento sucker were common throughout the survey in main channel runs and pools, as well as deeper riffle areas (Charts 15-20). These areas ranged in depth from two feet to 15 feet or more. Bottom substrate varied from sand and gravel to cobble. Current varied from 1 to 4 feet per second at the surface.

Adult suckers exhibited spawning behavior from February through April. The number of adult suckers appeared to increase from late March to early April in what appeared to be a run from the lower river and perhaps the Delta. During this period we also observed a large run of Sacramento suckers moving upstream in the lower Cosumnes River from the Delta. Moyle (2002) noted that spawning runs occur in Sacramento River tributaries with peak spawning in March and April when water temperatures reach above 12°C, which in this survey occurred in late March and early April (Figure 3). Schools of 5 to 20 loosely associated individuals were common in most deeper runs and riffles throughout the river. Groups of adults exhibiting spawning behavior were observed in riffles and riffle margins (e.g., Upper Sunrise Unit 4) from February through April. By early May the average number in main channel runs was about 10 per 1000 square feet. Extrapolation of this density would expand to approximately 100,000 linear feet by 50 ft wide main runs of this habitat in the river and would yield a conservative estimate of 50,000 adult suckers in the LAR.

Young suckers were extremely abundant throughout the river by late May and early June. They were abundant along the margins of all habitats anywhere there was minimal current. This pattern continued through July as sucker larvae continued to hatch. Some young reached 20-40 mm in July and took on adult characteristics but remained in quiet backwater habitat often in association with young pikeminnow. By August, numbers of young sucker declined dramatically, but they had grown into a more observable size range. They were generally more abundant in the middle portion of the river from Watt to Upper Sunrise (Chart 25).

Yearling suckers (about 150-250 mm in size) were rarely observed in the river during the entire survey period. This may in part be due to their behavior to hide in the substrate or in backwater cover. One large school of yearlings of over 100 individuals was observed with a similar number of yearling pikeminnow in July in the Goethe side channel in Unit 9. Given the huge number of young and adults in the river, it appears that many young likely migrated out of the river after rearing sometime from late summer to early winter. This pattern is consistent with the anadromous behavior and life history of the Sacramento sucker in the Sacramento watershed described by Moyle (2002).

Sacramento Pikeminnow

Sacramento pikeminnow data were only analyzed in detail for 2003. Based on a cursory review, patterns observed in 2004 and 2005 were very similar.

Adult pikeminnow also exhibited what appears to be a run into the American River like suckers but not until late spring and early summer (Charts 21-22). In late June, schools of up to 40 adult pikeminnow were observed at various locations throughout the river. Many of these fish exhibited spawning coloration. Moyle (2002) observed pikeminnow to make upstream spawning migrations in April and May and spawn in gravel riffles when water temperatures reach 15-20°C. These temperatures were reached in riffles of the LAR consistently in late June. We observed large schools of mature pikeminnow holding in warmer backwaters of Sailor Bar Pond in June (Chart 21). Water temperature in the pond reached 20°C in portions of the pond where the pikeminnow were observed (Figure 3). By mid July this behavior was no longer apparent as adult pike minnow appeared to have moved to nearby riffles to spawn (Chart 22) in water temperatures in the 16-18°C range (Figure 4).

Despite what appeared to be a summer spawning pattern, young pikeminnow began to appear in shallow backwaters in late May with the young suckers. Apparently, some spawning occurred in early April when water temperatures reached into the 14-16°C range (Figure 3). Like suckers, pikeminnow young were very abundant throughout most of the backwater areas of the river by summer. They reached the 20-40 mm size range by mid July and were observed primarily in backwater areas with cover (Chart 23).

Yearling pikeminnow like yearling suckers were not commonly observed in surveys. Large schools of up to several hundred individuals were observed through the survey period consistently at two locations: Goethe Unit 9 and Lower Sailor Unit 1. Both these locations were relatively deep (6-8 feet) lower ends of side channels with abundant instream cover and low water velocity. In late winter yearling pikeminnow share this habitat at these two locations with large schools of salmon fry. By summer yearling pikeminnow were 200 to 300 mm in length. Small numbers of yearling pikeminnow were observed throughout the river through the study period. Large numbers of larvae and early juvenile pikeminnow were apparent through the summer. Like young suckers, many juvenile pikeminnow likely emigrate from the river in fall and winter given the high abundance of young in summer and the low numbers of yearling pikeminnow by winter and spring observed in the surveys.

Striped Bass

Adult striped bass are common visitors to the LAR. Many are very large and most certainly in the 20 to 40 pound range and perhaps bigger. We first observed adult striped bass in April. They appeared to be more numerous in June from what appears to be a run similar to suckers and pikeminnow. In 2003 they were principally observed in deep pools and ponds, as well as deeper main channel runs (Chart 24). In late July 2003 we conducted a continuous main channel downstream survey to document the distribution and abundance of stripers in the river. We observed striped bass throughout most of the upper river from Gristmill to Nimbus Basin. Small schools were observed all the way upstream to Nimbus Dam. One large school of 21 individuals was observed in Sailor Bar Pond. In many areas during the July survey we were unable to effectively see bottom in the deeper runs and pools with only eight feet of visibility. This is one reason for the lack of striped bass in the Sunrise pools in Chart 24b. Though striped bass we observed were seldom in water less than 6-8 ft of water, we have observed them foraging in shallower water. Suckers, American shad, pikeminnow, and juvenile salmonids likely make up most of their diet based on availability. FFC staff members have observed striped bass eating adult suckers, adult American shad, juvenile steelhead, and crayfish. Often striped bass were observed stalking schools of American shad. Partially digested carcasses of American shad were commonly seen on the river bottom and were probably regurgitated by adult striped bass.

In the 2003 July 28th snorkel survey and the September 19th scuba survey striped bass adults were observed in large numbers in the Nimbus Hatchery pool below the hatchery outlet. On September 19th striped bass were observed feeding aggressively on numerous dead juvenile trout washed out of the hatchery during the morning “cleanout”.

In the summers of 2004 and 2005 we observed fewer striped bass adults than in 2003.

Tule Perch

Tule perch were commonly observed in the LAR in all three years especially in summer. Recently born juveniles (they are livebearers) began to appear in July (Chart 26). Adults and young were found in deeper backwaters and riffle margins often near current and beds of submerged aquatic vegetation that is common in deeper riffle margins and backwater eddies.

American Shad

The occasional school of adult American shad was observed in the LAR beginning in late May and continuing through August of all three years. Shad were usually found in deeper pools and runs in current not far below riffles. They appeared to be actively feeding on drift or straining algae from the water by forcing water over their gill rakers. Schools appeared to either actively avoid or simply ignore divers. This behavior varied with location and survey period. The largest schools were observed in Nimbus Basin and the Nimbus hatchery pool during summer surveys, but were also observed downstream in most runs and pools as far as Goethe Park.

Largemouth Bass

Surprisingly we found largemouth bass more numerous than smallmouth bass. Largemouth adults and juveniles were relatively common even in the upper river during the three survey years. We observed several pairs of adults nesting in Nimbus Basin and Sailor Bar Pond in May 2003. We also observed adults in riffles and runs in relatively fast water. Young from 50-100 mm in length were commonly observed in small groups in the summer over much of the river. They were typically observed in backwaters near current in similar habitat to juvenile salmon and steelhead. The source of some of these largemouth bass young and adult may have been Lake Natomas or Folsom Reservoir upstream of Nimbus Dam.

Smallmouth Bass

Smallmouth bass were relatively rare. A few adults were observed in the lower river in spring and summer at the Highway 160 site in 2003. They were observed near bridge abutments and in deeper water near levees.

Pacific Lamprey

Small numbers of adult Pacific lamprey were observed during the spring. Most were dead and appeared to have recently spawned. Lamprey redds were commonly observed in riffles. Occasionally, pairs of adults were observed spawning in tailout habitat near the tops of riffles.

Prickly Sculpin

A few adult prickly sculpin were observed during the survey. These were actively seeking cover in the streambed, a behavior that likely explains why so few were observed. Jeff Koslowski (Jones and Stokes Associates, personal communication) noted that sculpin were readily captured in the Yuba River by electrofishing, but few were observed during snorkeling. Observations along the LAR on September 17, 2003 when flows were dropped to 1000 cfs for several hours to place the Nimbus Hatchery weir indicated prickly sculpin were indeed quite abundant in shallow cobbled riffles.

Bluegill Sunfish

A few bluegill sunfish were observed in backwaters of the upper portion of the river. These had likely passed over Nimbus Dam from Lake Natoma. Bluegills were also observed in the lower river in small numbers during the August 2003 survey.

Habitat Types

The survey sampling indicated that there are many habitat types in the LAR with a wide range of conditions that are used to varying extents by different species and life stages of fish. Based on our survey observations we categorized habitats by macro- and meso-habitat types as follows:

Macrohabitats:

- Cascades – rapids, with broken rolling water, boulder-rock substrate, moderate to deep: such habitats occur in only four locations (hatchery weir; Sunrise Rapids, San Juan Rapids, and Goethe Rapids).

- Riffles – shallow, broken water, with gravel or cobble substrate: occur on each of the bars at the downstream end of pools, often associated with both sides of islands.
- Glides/Runs – shallow to moderate depth, flat unbroken water, low to high velocity, any substrate: generally just downstream or upstream of riffles.
- Pools – Deeper, flat water, with low velocity, any substrate: found associated with all bars and the dominant habitat type in the LAR caused by excessive scouring of the channel with lack of gravel recruitment.
- Side Channels – channel separated from main channel by island or flooded bar: remaining side channels found in small numbers; were once more numerous before incising of the channel.
- Backwaters – zero to low velocity water body connected or disconnected to channel with variable configuration, variable substrate, may include flooded habitats: generally associated with high water, although found near lower end of islands, connections to borrow pits (e.g. Sailor Bar Pond), or lower ends of historic side channels that are no longer connected.

Mesohabitats:

- River Margin Bar – portion of channel on point bars; generally shallow with gradual slope and limited vegetation due to high flow scour; found on most bars at point.
- River Margin Bank – portion of channel opposite point bars, generally deeper with steeper slope, eroding banks, and more extensive vegetation: occur against bluffs and levees where river erodes bank or scours channel.
- Mid Channel/Open Water – mid channel or backwater areas away from banks and bars; generally shallow slope with large (high current) or small substrate (low current).

The combination of six macrohabitats and three mesohabitats yields 18 habitat types (Table 3).

Table 3. Habitat combinations of macro and meso habitat types.

	Macrohabitats					
Mesohabitats	Cascades	Riffles	Glides	Pools	Backwaters	Side Channels
Bar	X	X	X	X	X	X
Bank	X	X	X	X	X	X
Channel/Open	X	X	X	X	X	X

Each of these types can be characterized by physical habitat factors:

- Velocity – speed of current, zero to fast
- Cover – Instream and overhead shade and velocity cover. May be in the form of various types of vegetative materials, living (trees, shrubs, grass, etc.) and dead (logs, branches, twigs, and debris), or rock (manmade or natural), or white water.
- Substrate – silt, sand, gravel, cobble, boulder, and bedrock
- Depth – shallow to deep
- Bank Slope (lateral) – flat to steep
- Channel Gradient/Slope (longitudinal) – flat to steep

Generally all habitat units fit into one of the 18 types and is uniquely classified by physical characterists.

Habitat Use Patterns

Our next objective was to relate fish use to the habitat classifications by conducting statistical analyses of the fish observations (dependent variables) and habitat variables (independent variables) by sampling unit. Because this represents a multivariate space with variables non-independent variables (essentially a non-controlled experimental design) it is difficult if not impossible to determine cause-and-effect among relationships. For this reason, we also conducted Factor Analysis (principal component analysis) that analyzed the independent features or factors in the overall data array. The original variables are then related to the factors to determine commonality, or the degree each original variable is related to the factors or statistically independent features in the data array. The Factor Analyses presented generally focus on the first two factors that explain the most variance in the data set.

Despite this inherent problem typical of natural environmental surveys, we conducted tests of significance between two variables were either regression or analysis of variance. Dependent variables included in the analyses are young Chinook salmon, steelhead, pikeminnow, Sacramento sucker, and tule perch. Independent habitat variables include depth, velocity, substrate, bottom or bank slope, cover, river-mile, and water temperature. Analyses were conducted on data from the first survey in March, the second survey in April, and the August survey. Because the habitat variables were not independent, it was difficult to separate their individual effects on the density of individual fish species, or to make definitive statements as to the significance of differences among the variables or cause and effect. Where probabilities are less than 5 percent for observed differences being random, the relationships are deemed significant. However, because the variables are not independent, cause and effect cannot be inferred, although the association can be noted and further tested under experimental conditions (i.e., variables controlled).

The following analyses were performed on 2003 data unless otherwise noted.

Salmon and Trout vs Substrate

In early March the average number of young salmon observed (per standard 600-sqft unit) by substrate size category (Table 1) was significantly related to substrate size (Figure 15). Salmon fry were significantly more abundant in smaller and larger substrate sizes. This reflects their greater abundance in shallow backwaters and stream margins, as well as along steep bedrock and boulder (rip-rap) banks. They were least abundant in gravel and cobble pools, riffles, and runs.

In April when young salmon were larger they tended (but not significantly) to be more abundant in units with gravel and cobble substrate (sizes 3 and 4; Figure 16). Trout young showed a similar relationship to substrate (Figure 17). Variance in average number by substrate size group was high for both species because main channel runs were predominantly cobble and young trout and salmon were not found in fast water habitats lacking cover in April.

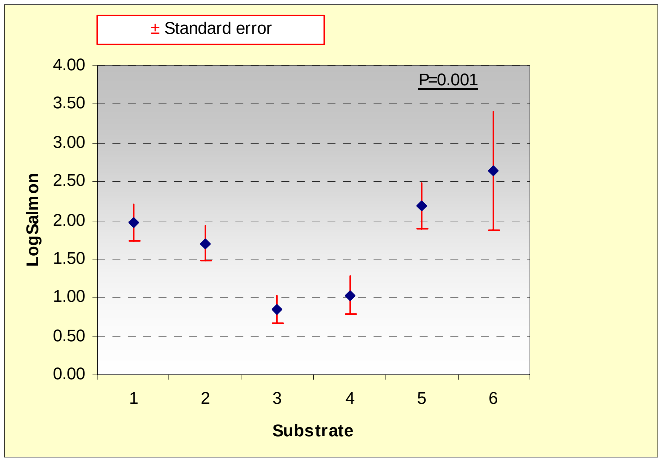


Figure 15. Average and standard error of the log of the number of young salmon observed in sampling units by substrate category in early March survey.

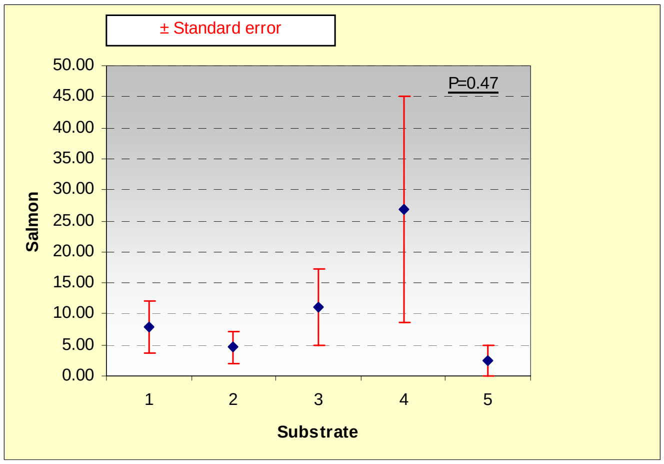


Figure 16. Average and standard error of the number of young salmon observed in sampling units by substrate category in late April survey.

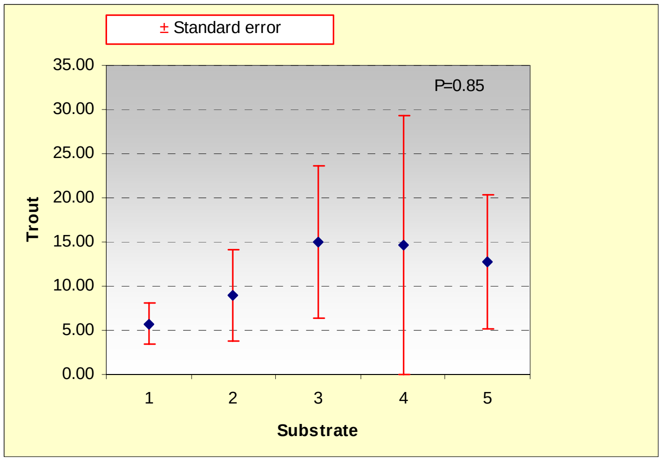


Figure 17. Average and standard error of number of young trout observed in sampling units by substrate type in late April survey.

Salmon and Trout vs Depth

In early March young salmon were slightly more abundant in shallow water (Figure 18); however, the relationship was not significant. Salmon were generally abundant in shallow water less than three feet deep, but sometimes they were also abundant in deeper water near steep clay banks. The high variability in abundance in deeper water reflects difference in cover at deeper sampling units and margin versus mid-channel units.

In the late April survey young salmon were generally observed only in waters less than four feet deep (Figure 19). Variability in the numbers of salmon observed among shallow stations was high again because salmon were found primarily in margin units with cover and not in channel or open areas, or margins without cover.

Trout young were found predominantly in waters less than three feet deep in late April (Figure 20). Greater numbers were observed in water 1 to 2 feet in depth. Again, variability was high and the relationship was not significant, because trout were not found in all units that had a 1 to 2 foot depth.

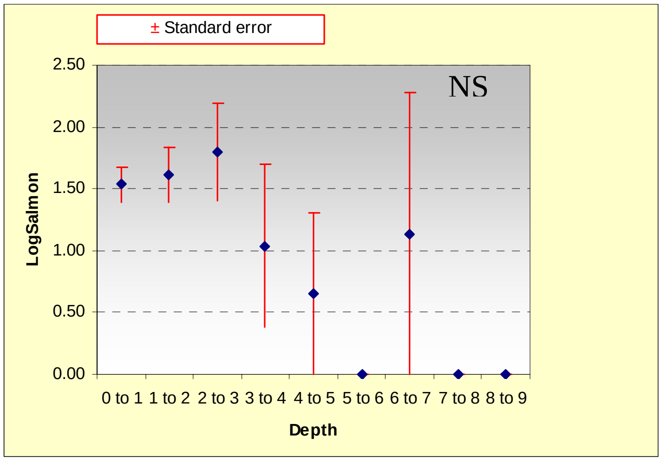


Figure 18. Average and standard error of the log of the number of young salmon observed in sampling units in early March survey by water depth.

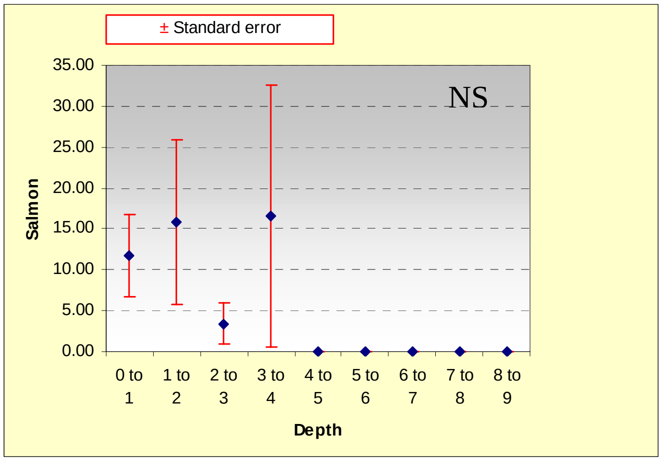


Figure 19. Average and standard error of the number of young salmon observed in sampling units in late April survey by water depth.

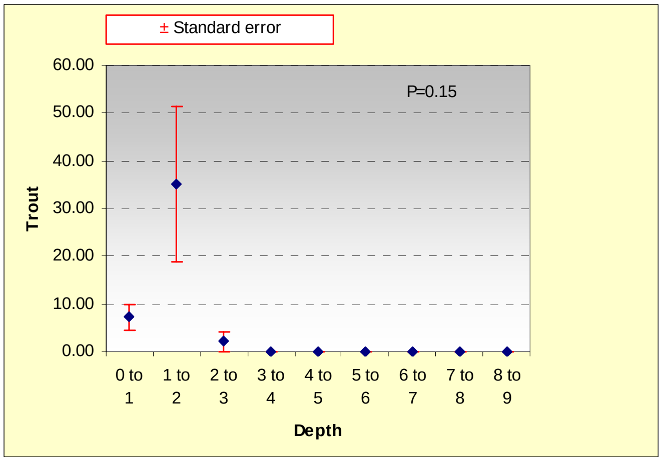


Figure 20. Average and standard error of the number of young trout observed in sampling units in late April survey by water depth.

Salmon and Trout vs Velocity

In the early March survey the number of salmon young observed was significantly higher in lower velocities (0 to 1 ft/sec) sampling units (Figure 21).

In late April young salmon were more abundant in velocities less than 1 ft/sec (Figure 22).

In late April the number of young trout observed in sampling units was also higher in velocities less than 1 ft/sec (Figure 23).

These April relationships were not significant because of high variability and high number of zero observations. When other variables are taken into account (see later results) the relationships are stronger. For example, velocity is important for salmon and trout if there is sufficient cover.

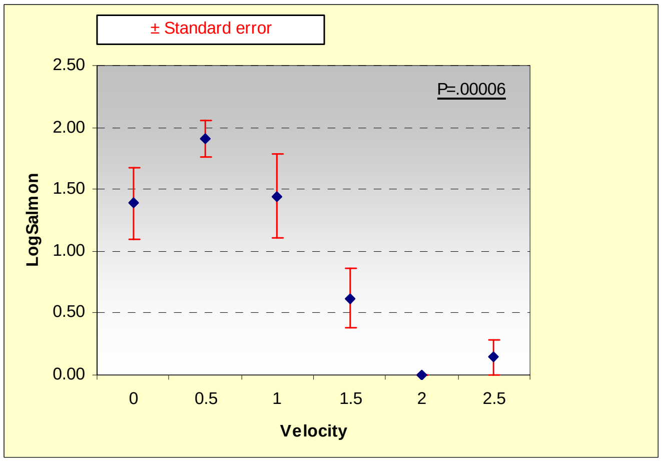


Figure 21. Average and standard error of the log of the number of young salmon observed in sampling units by velocity (ft/sec) in early March survey.

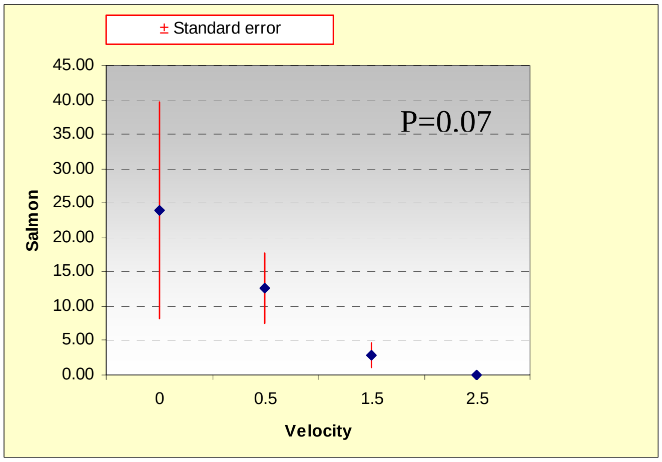


Figure 22. Average and standard error of the number of young salmon observed in sampling units by velocity (ft/sec) in late April survey.

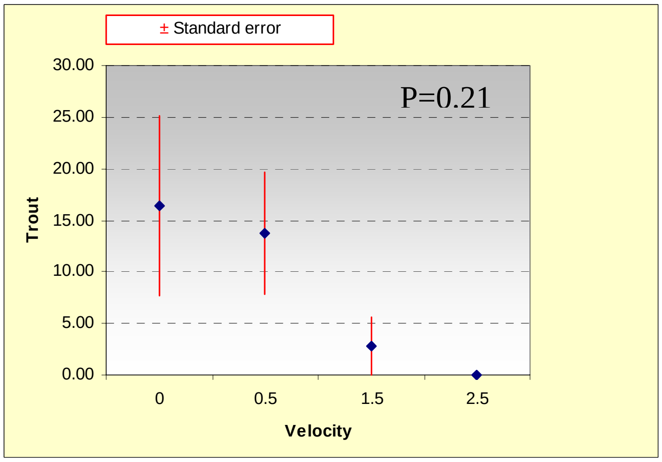


Figure 23. Average and standard error of the number of young trout observed in sampling units by velocity in late April survey.

Salmon and Trout vs Bottom Slope

In early March the number of young salmon observed in sampling units was significantly positively related to bottom or bank slope (Figure 24). Higher slopes occurred in sampling units with steep clay banks and in riffle margins with undercut banks.

In late April the number of juvenile salmon was again positively related to bank slope (Figure 25), although variance in the number observed among steeper-sloped units was high.

A similar pattern was observed for trout young (Figure 26). The higher average abundance in units with a slope of 2 is indicative of young trout being abundant in riffle margins with undercut banks.

In general, the very low numbers of salmon and trout observed on shallow and flat slope units surveyed reflects minimal use of main channel and bar margin habitat. Bar margin habitat is generally near-zero velocity, lacking in cover, and warmer than other habitats, features that appear to cause young salmonids not to use these habitats.

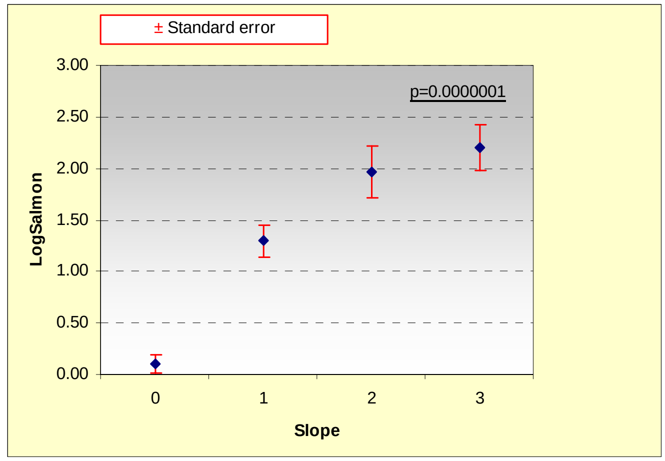


Figure 24. Average and standard error of the log of the number of young salmon observed in sampling units by slope category in the early March survey.

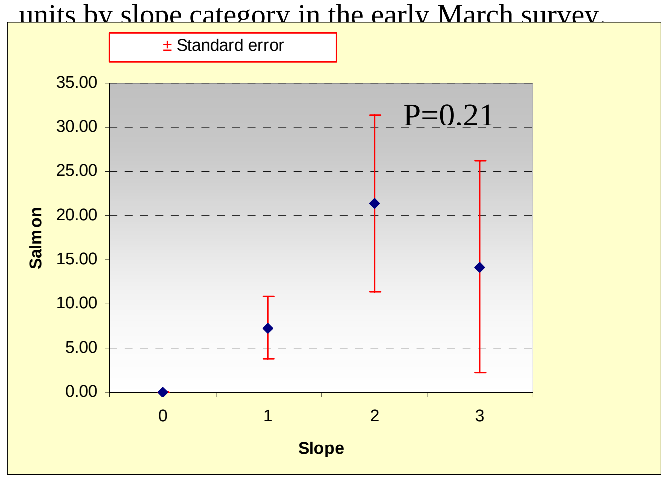


Figure 25. Average and standard error of the number of young salmon observed in sampling units by slope category in the late April survey.

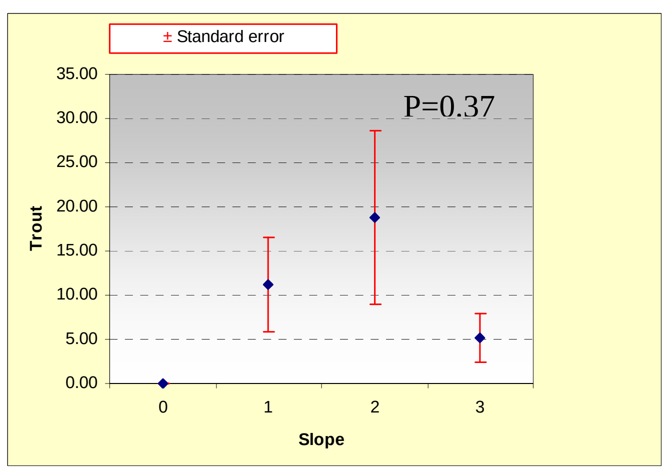


Figure 26. Average and standard error of the number of young trout observed in sampling units by slope category in the late April survey.

Salmon and Trout vs Cover

In early March the number of young salmon was significantly positively related to the amount of cover in sampling units (Figure 27).

In late April young salmon and trout numbers were significantly related to cover (Figures 28 and 29). Higher numbers were observed in the two highest cover categories. Note sampling units with categories 1 or 2 were not observed in late April survey. Variability was high in higher cover categories because not all high cover locations held salmon or trout. Many of the lower river sites had high cover in late April; however, water temperatures were high in the lower river, which led to fewer salmon using the lower river (Figure 30). Young trout did not disperse from the upper river spawning areas in large numbers to the lower river as of the late April survey.

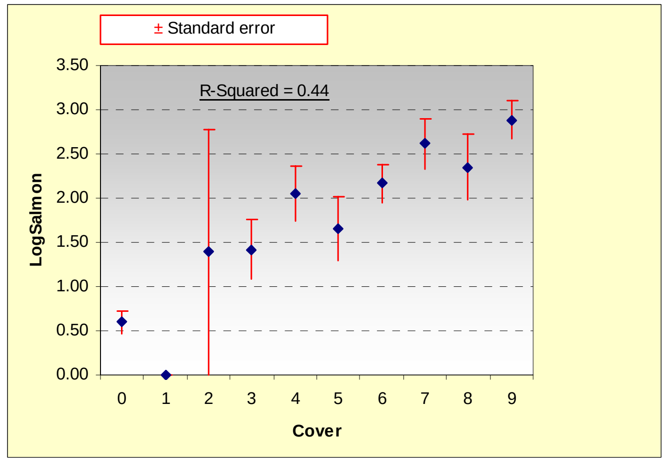


Figure 27. Average and standard error of the log of young salmon observed in sampling units by cover type in the early March survey.

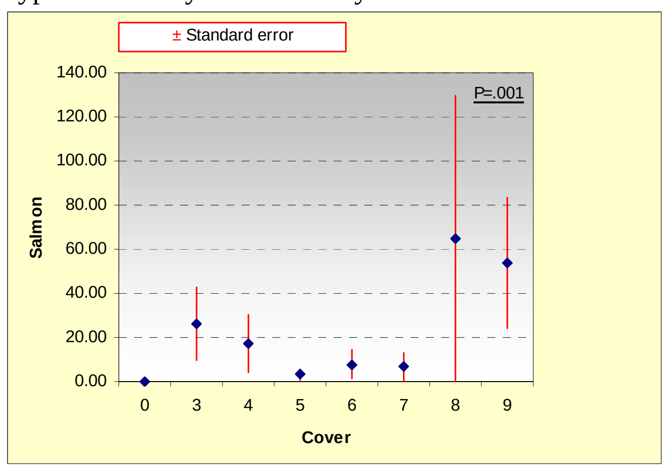


Figure 28. Average and standard error of the number of young salmon observed in sampling units by cover type in late April survey.

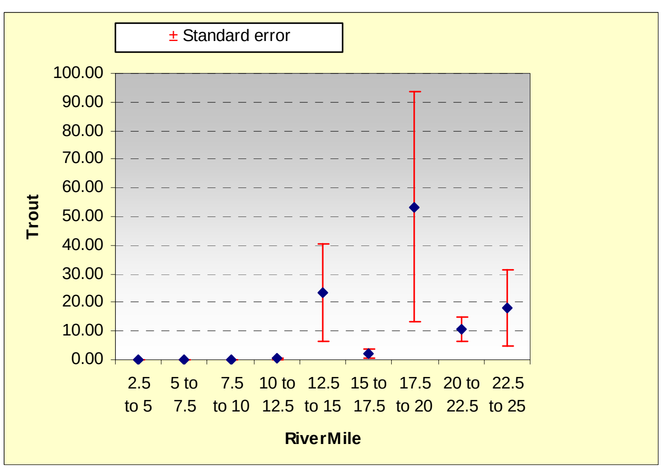


Figure 30. Average and standard error of the number of young trout observed in sampling units by rivermile in the late April survey.

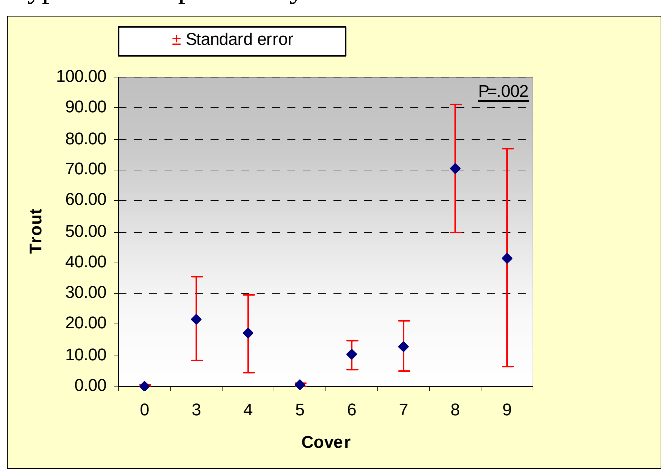


Figure 29. Average and standard error of the number of young trout observed in sampling units by cover type in the late April survey.

Cover by Rivermile

The amount of cover in sampling units varied only slightly by rivermile, but tended to be higher in the lowest and upper reaches of the LAR (Figure 31). Levees dominate both banks of the river between RM 5 and 12.

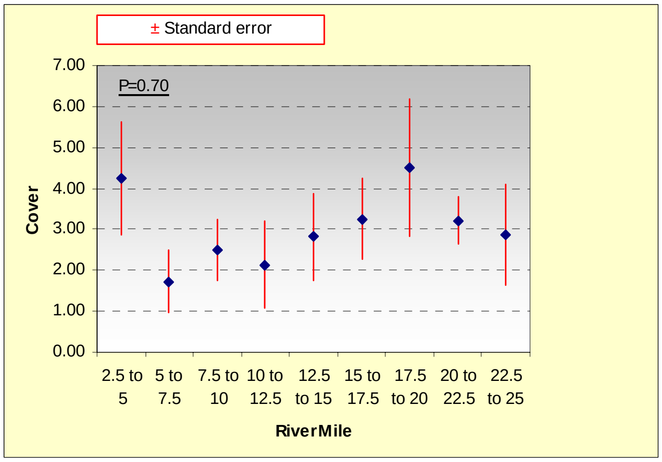


Figure 31. Average and standard error of cover type in sampling units by rivermile for late April survey.

Cover vs Slope

The amount of cover in sampling units is highly correlated with the bottom or bank slope (Figure 32). There is essentially no cover in flat slope areas such as mainstream runs and pools and only a relatively small amount of cover on banks with a shallow slope (slope = 1), which is the predominant slope on point bar margins. Undercut banks (slope = 2) generally had considerable cover. Steep banks (slope = 3) also had considerable cover.

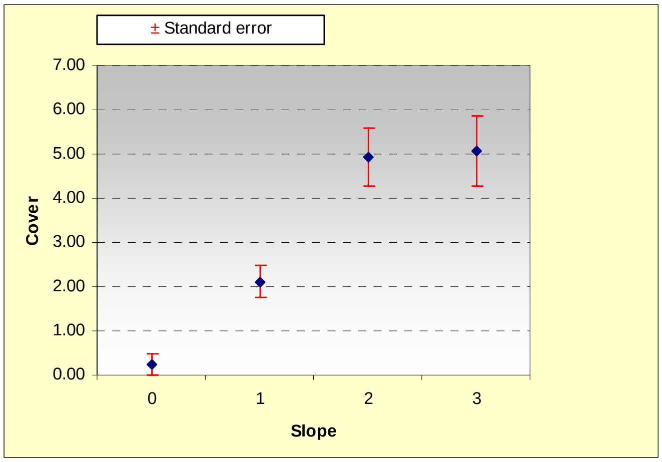


Figure 32. Average and standard error of cover type in sampling units by slope type for late April survey.

Velocity vs Depth

Velocity was highest in deeper sampling units (Figure 33).

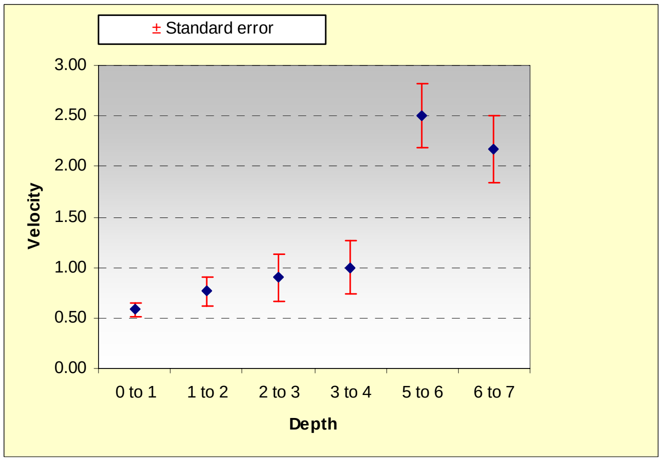


Figure 33. Average and standard error of velocity (ft/sec) in sampling units by depth (ft) category for late April survey.

Cover vs Velocity

Cover was significantly higher in lower velocity sampling units (Figure 34). Heavier cover generally occurred in units with water velocity less than 1 ft/sec. Above 2 ft/sec there was no cover within units sampled as these were generally mid-stream units or scoured or leveed banks.

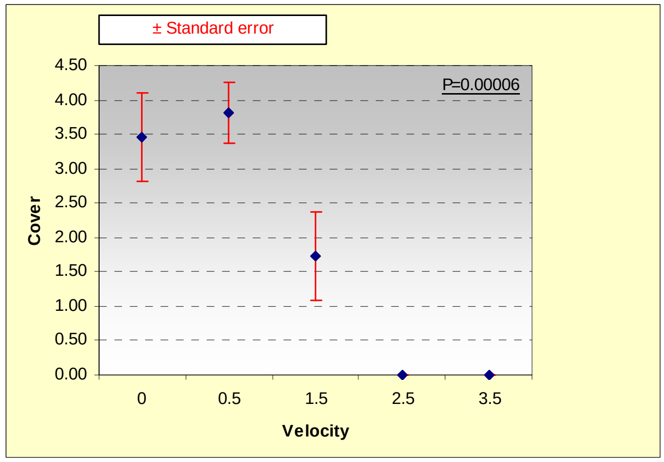


Figure 34. Average and standard error of cover type by velocity (ft/sec) category in late April.

Salmon and Trout vs Multiple Variables

Because variables were not independent (e.g., cover was negatively related to velocity), we conducted a multivariate factor (principal components) analysis of the full data array of variables for the early March, late April, and August 2003 surveys.

The analysis of the early March survey indicates that there were two primary independent features (factors/components) in the salmon analysis (Figure 35). Factor 2 was highly positively related to distance to spawning habitat and river mile. This factor simply picked out the close positive relationship between river mile and the distance of sampling units to spawning areas. Salmon and four of the physical variables showed little or no relation to Factor 2 as their commonality values were near zero. Substrate had a communality of 0.6 with Factor 2, which indicated larger substrate at units sampled in higher river miles.

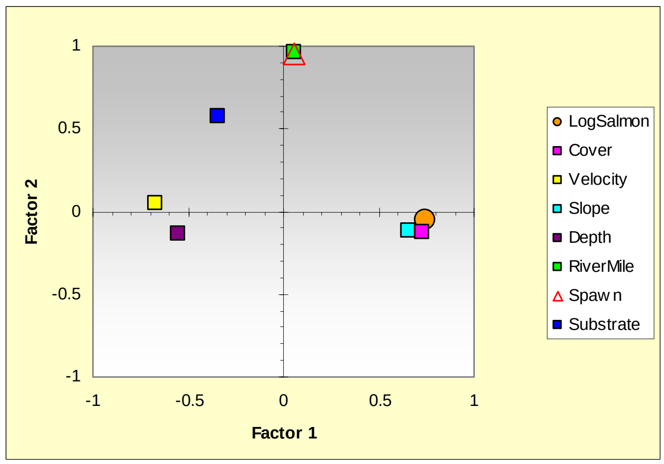


Figure 35. Factor analysis results for early March survey.

Young salmon, slope, cover, velocity, and depth were strongly associated with Factor 1. Young salmon were associated with high slope, high cover, low velocity, low depth, and smaller substrate.

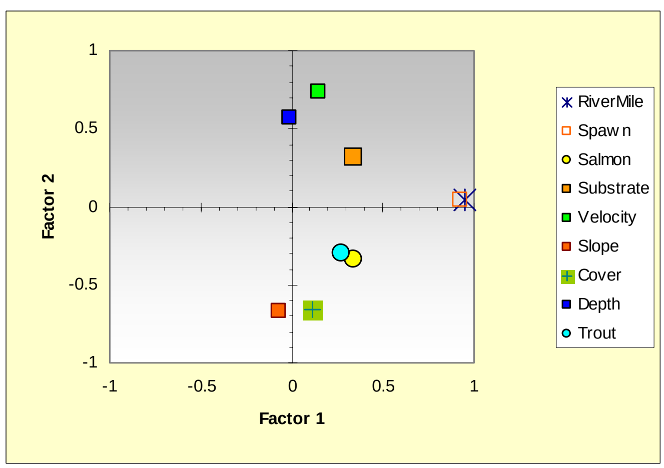


Figure 36. Factor analysis results for late April survey.

A factor analysis of the late April survey data indicates a very similar pattern of association among the physical variables (Figure 36). Young salmon and trout fell quite close in the multivariate space. They were positively associated with river mile and distance to spawning areas, and to cover and slope, while being negatively associated with velocity and depth.

Other Young Native Fishes vs Multiple Variables

A factor analysis of the August 2003 survey data indicates only one predominant factor (Figure 37). The habitat gradient extends from high slope and cover, low velocity and smaller substrate habitat to higher velocity, larger substrate, and less slope and cover habitat. Young sucker, pikeminnow, and tule perch had more communality with units with higher slope, more cover, smaller substrate, shallower and warmer water, and lower velocity.

Tule perch young were observed only in velocities of 0.5 to 1 ft/sec (Figure 38). None were observed in zero velocity sampling units or sampling units with velocities of 1.5 ft/sec or higher.

Tule perch were also most abundant in steep bank sampling units (Figure 39).

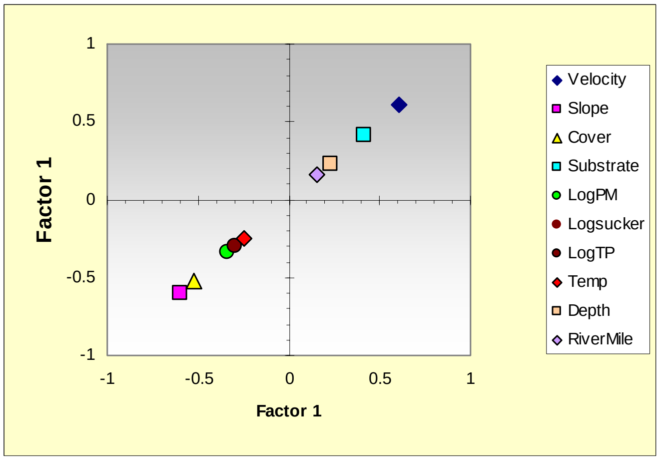


Figure 37. Factor analysis results for August survey.

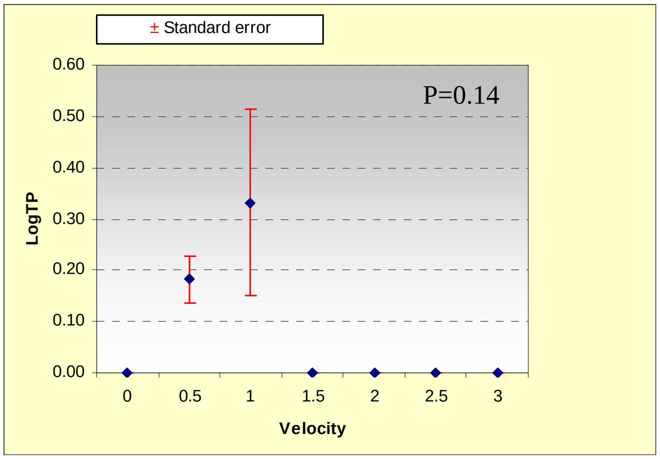


Figure 38. Average and standard error of the log of young tule perch observed in sampling units by velocity category in August survey.

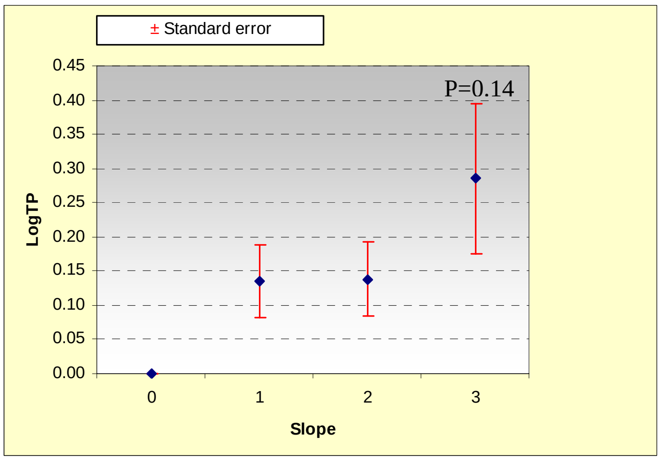


Figure 39. Average and standard error of the log of young tule perch observed in sampling units by slope category in August survey.

Pikeminnow young were also most abundant in steep slope units (Figure 40). Sucker young were equally abundant in shallow and steep slope units (Figure 41) reflecting that unlike trout and salmon they were abundant in the warm, shallow depth and slope, bar habitat.

The relationship between young sucker and cover was not as distinct as it was for trout and salmon, although they were generally less abundant in units with no cover (Figure 42).

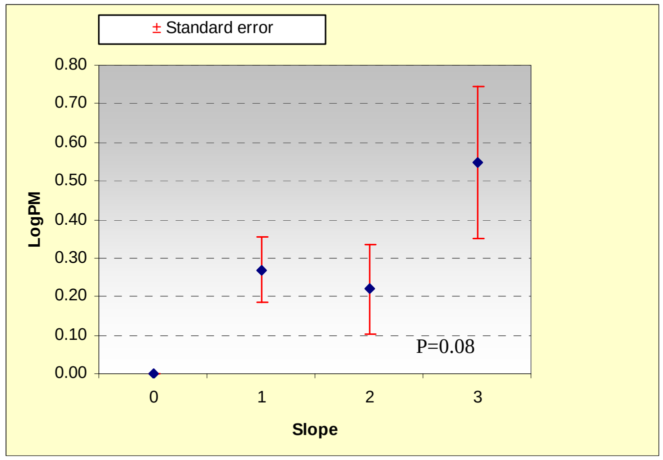


Figure 40. Average and standard error of the log of the number of young pikeminnow observed in sampling units by slope in August survey.

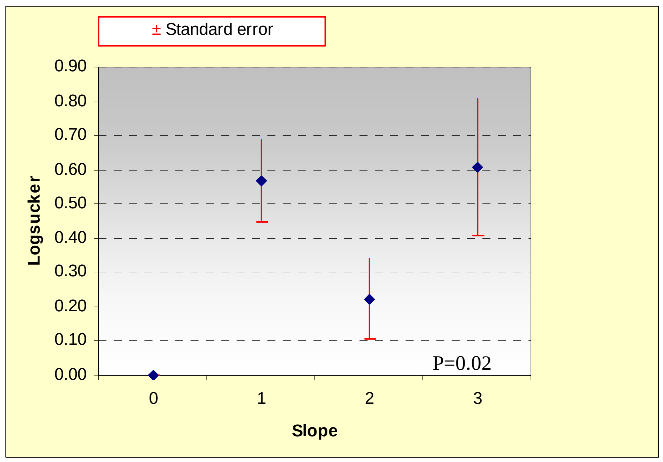


Figure 41. Average and standard error of the log of the number of young suckers observed in sampling units by slope category in the August survey.

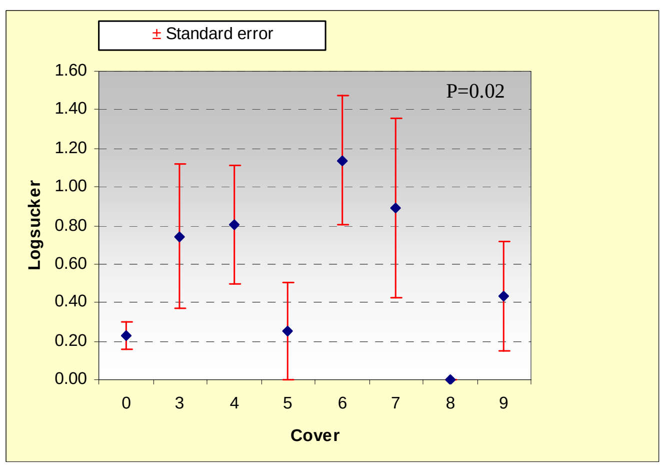


Figure 42. Average and standard error of the log of the number of young suckers observed in sampling units by cover type in August survey.

Young suckers were generally most abundant in water where velocities were 1 ft/sec or less (Figure 43). Young pikeminnow had a similar relationship (not shown).

Young suckers were more abundant in depths of 1 ft or less (Figure 44). Young pikeminnow had a similar relationship with depth (not shown), but were more common in deeper waters.

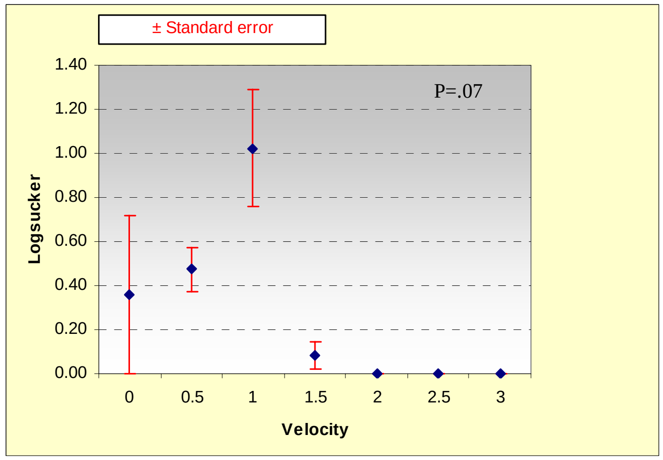


Figure 43. Average and standard error of the log of the number of young sucker observed by velocity category (ft/sec) in the August survey.

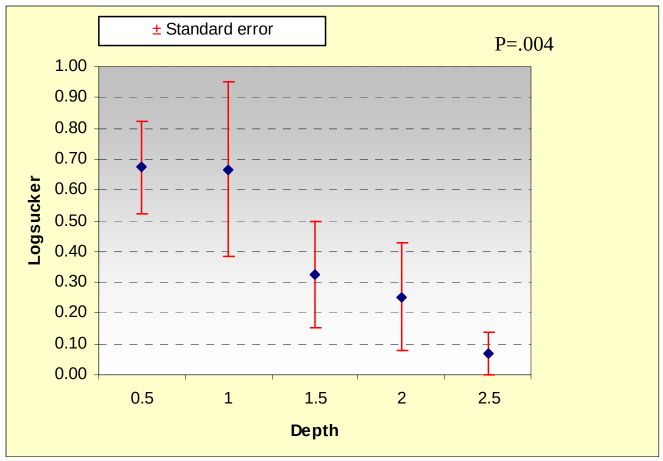


Figure 44. Average and standard error of the log of the number of young sucker observed in sampling units by depth category (ft) in the August survey.

Summer Habitat Use

Other than juvenile suckers and pikeminnow that were found predominantly in shallow river margins, during the summer most of the other fish in the lower American River were found in the deeper pools, mainstem runs and riffles, and side channel habitats (Table 4). Two surveys in September 2004 were designed specifically to observe summer habitat use under low flow (1500 cfs) conditions through a combination of scuba and snorkeling. Water temperatures were 18 to 20ºC with the lower temperature measured at Nimbus site and progressively higher temperatures downstream to the Watt site.

Only small numbers of juvenile salmon were observed with most occurring at the furthest upstream site at Nimbus. Generally salmon were observed in small schools in deeper mainstem runs. Their wary behavior made them difficult to observe.

Young steelhead were scattered through main channel cascades/rapids and side channel riffles. Main channel areas were generally high current areas including Goethe Rapids, Upper Sunrise Rapids, Hatchery Pool Cascade, and Nimbus Powerhouse Rapids. Side channels generally had the highest numbers observed possibly do to the more confined habitat being easier to observe juvenile steelhead in the 100 to 200 mm size range with these methods.

The striped bass were also found in the large rapids and associated pools usually just downstream of the heavy water in deeper habitats. Pikeminnow and suckers were generally found in the deeper runs and riffles of the main channel and side channels. Tule perch were found as they were earlier in summer in deeper margin habitats of main channel riffles and runs.

Table 4. Habitat use patterns in late summer 2004.

Location	Habitat	Chinook	Steelhead	Striped Bass	Pike minnow	Sucker	Tule Perch
Nimbus	Main channel	7	5	0	0	5	0
Nimbus	Main channel	2	1	0	0	12	0
Nimbus	Side channel	6	28	0	1	39	0
Hatchery	Main channel	0	22	0	0	0	0
Hatchery	Main channel	0	2	3	4	5	0
Hatchery	Main channel	0	11	0	0	0	2
Upper Sailor	Main channel	0	5	0	0	37	0
Upper Sailor	Main channel	0	3	2	6	27	20
Lower Sailor	Main channel	0	4	0	0	14	0
Lower Sailor	Side channel	0	17	0	0	0	0
Upper Sunrise	Main channel	0	4	2	0	2	0
Upper Sunrise	Side channel	0	1	0	3	8	0
Lower Sunrise	Main channel	0	0	0	0	0	35
Lower Sunrise	Main channel	0	0	0	20	0	84
Lower Sunrise	Main channel	0	0	0	2	2	10
Goethe	Main channel	0	7	0	0	0	0
Goethe	Main channel	0	9	0	0	0	11
Goethe	Side channel	2	70	0	3	0	0
Goethe	Back water	0	0	0	100	30	0
Watt	Main channel	0	12	2	12	90	37
Total		**17**	**201**	**9**	**151**	**271**	**199**

Discussion

Abundance and Distribution of Salmonids

Young Chinook salmon appear to spend only a month or two in the river before leaving the river. Many fry likely leave the river for the freshwater tidal estuary of the Delta based on the rapid decline in fry density in spring surveys and in the Watt Avenue screw trap (CDFG unpublished data) and the large number of fry observed throughout the Delta (DFG and FFC unpublished data). But many fry and fingerlings also remained throughout the LAR in February, March, and April in river margin habitats. Another exodus of juvenile salmon appeared to occur in late March and early April when margin habitats of the lower reaches warmed to 15°C. Most young salmon were gone from the lower river sites by late April. Regardless of water temperature, most appear to leave the lower and upper river by May, although schools of pre-smolts and smolt sized fish remain in deeper upper river habitats through the summer. Divers may have also missed schools of larger fingerlings and pre-smolts as visibility declined to only 6 feet during the high flows of May of all three years. Snider and McEwan (1993) noted that as salmon grow in the LAR more of them move to pool and riffle habitats and the proportion in backwaters declined. We also observed larger salmon (>100 mm) taking up individual territories in riffles and runs as observed by Jackson (1992).

Young steelhead were principally confined to the upper spawning reaches of the LAR. Only small numbers of young were observed below Geothe at Watt and Paradise where some spawning was noted by Hannon et. al. (2003). Unlike salmon, young steelhead did not use the deeper backwater margin habitat of the lower river and were principally confined to the higher gradient reaches near spawning areas of the upper river from Goethe to Nimbus where they remained through the summer.

Size/Growth of Salmonids

Young steelhead grew very rapidly from April to July, probably in the range of 1-mm per day (Figure 7). CDFG also observed this high growth rate in the LAR (Rob Titus, CDFG Sacramento, personal communication). The growth rate of young salmon in the upper reaches of the LAR during this same period appears much lower (Figure 6). One possible reason for this difference was that most of the salmon remained in schools in deeper pools feeding on surface insects, whereas young steelhead took up positions close to or in current within riffles feeding on drift. We speculate that the territorial feeding on drift in riffles provided more energy than feeding in schools in large pools. This theory is supported by the observance of the largest salmon young feeding in riffles and runs similarly to young trout, a behavior also noted by Jackson (1992). Being a tailwater river, the lower American River is likely a very productive river with high aquatic insect production that can provide for high growth rates of juvenile salmonids.

Relationship between water velocity and fish density

Within sampling units we do believe there is a relationship between water velocity and fish density based on a review of velocity data (Figures 22, 23, 34, 38, and 43). Obviously when units dry up and have zero velocity, they have zero density. In some cases under high velocity, density also declined because there was no remaining velocity refuges. For other units, low velocity may bring high water temperatures that precluded use of the unit. We believe the relationship between velocity and the habitat suitability of habitat units means there is an ultimate relationship between velocity and habitat suitability for the entire LAR. The relationship likely changed with time (e.g., year, season, weather factors, fish age and growth, etc.). Furthermore, with velocity among the habitat units primarily controlled by river flow in the LAR, then river flow would ultimately be related to river rearing capacity and potentially production. Bourgeois et al. (1996) found that fish density was most closely associated with velocity conditions in the two-week period prior to surveying.

Habitat Use Patterns

One of the objectives of the 2003 study was to associate fish occurrence to habitat conditions, and that careful measurement of the habitat characteristics of locations where fish were most abundant would help to define species and life stage habitat use patterns.

Baltz et al. 1987 stated that habitat choice of fish is "*presumably chosen by a fish in response to proximate factors to optimize its net energy gain while avoiding predators and minimizing interactions with its competitors*." What we observed supports this premise, as we saw cover important for salmon and steelhead particularly at the fry stage. With age, the young salmonids sought cover more closely associated with the greater food supply of riffles and runs.

Depth, velocity, substrate, cover, proximity to low velocity area for resting, and nearby higher velocity area for feeding, or the proximity of predators and competitors appear to be the primary determinants of habitat choice by young fishes in the LAR. Young trout, salmon, tule perch, pikeminnow, and suckers generally were more abundant in shallow water, near banks with moderate to steep (categories 2 and 3) slope, in lower velocities with cover, and often near river currents. Adult trout, salmon, sucker, pikeminnow, American shad, and striped bass were found mainly in the deeper runs and pools with little or no overlap with young.

Habitat use also varied among stream reaches because of changes in microhabitat preference with differing macrohabitat features such as stream morphology and water temperature as observed by Jackson (1992) and Roper et al. (1994). Through the spring and early summer young steelhead remained in the upper portion of the LAR, whereas salmon were found throughout most of the LAR. Emerging salmon fry took to the currents upon emergence as evident by the hundreds of seagulls feeding in every riffle and run of the upper river in February and March. The presence of many salmon fry in the lower river and estuary is further indication that they move from their spawning areas. Unlike salmon, steelhead fry were found predominantly near their spawning areas in the upper reaches of the LAR. Major spawning sites identified by Hannon et al (2003) were near Nimbus 7; Upper Sailor 3, 7, and 8; Lower Sailor 3 and 4; Upper Sunrise 1-6; Rossmoor 6 and 8; and Goethe 1, 3, and 7 units. However, by late summer steelhead young were more thoroughly distributed throughout the river in riffle habitats from Paradise to Nimbus.

Like Jackson (1992) and Roper et al. (1994) we found that fry and fingerling salmon used deep-water habitats not just shallow stream margins as preferred by fry steelhead. Within riffles and riffle margins salmon and steelhead young used similar habitat and were often observed together in mixed schools in riffles and runs. However, in both shallow and deep pools, backwaters, and connected ponds only yearling pikeminnow and young salmon shared the deeper water and backwater habitats in winter and early spring. Steelhead young were usually found in areas with some velocity and not in deep or backwater habitats. Along riffle and run margins with cover such as flooded grasses and some perceptible current, we saw young steelhead usually oriented into the current. Fry pikeminnow and suckers were found from late spring into summer in all types of margin habitat.

Jackson (1992) found that juvenile salmon did not use riprapped banks in the lower river. We found this to be true if there was little cover available. However; where extensive cover was present at riprap or rocked sites (Nimbus units 1 and 2; Lower Sunrise units 1 and 5, Hwy 160 units 5 and 7, and other lower river sites) salmon fry were often abundant.

Steelhead young moved progressively to deeper and faster water adjacent to their covered habitat as they grew in size into the spring and summer. Jackson (1992), Hartman (1965), Everest and Chapman (1972), Moyle and Baltz (1985), Cavallo et al. (2003), and Fontaine (1988) observed this same pattern. Steelhead fry also preferred cobble habitats over the smaller substrates found in backwater that were used by fry salmon, suckers, tule perch, and pikeminnow. Moyle and Baltz (1985) also noted this pattern.

Specific Habitat Associations

Snorkeling observations of fish and their habitat indicate distinct habitat associations for young Chinook salmon, steelhead trout, and other species. Cover is by far the most important factor governing young fish density in habitat units. Cover (from both velocity and predators) includes flooded vegetation, aquatic vegetation, instream and overhead woody material, boulders and cobbles, bridges and abutments, undercut banks, and overhead turbulence. Furthermore, river flow (and stage) greatly affects the availability and use of cover.

Young of all the species observed were associated with cover in similar ways. The primary difference was the season of use among the species. Salmon were the first young into the cover in winter. Soon after emergence, young Chinook gravitated strongly to cover over a wide variety of depths and velocities. This pattern continued through the pre-smolt phase (80-100mm) after which young salmon were more likely to be with similar sized steelhead young in open riffles (although often adjacent to escape cover) as observed by McCain (1992) and Jackson (1992). Newly emerged steelhead fry also gravitated strongly to cover when they emerged in spring, but mainly in shallow low-velocity water along riffle, glide, run, and pool margins. Fingerling and larger steelhead young also sought cover, but generally deeper cover closer to higher velocity currents. Juvenile pikeminnow also were strongly associated with cover in both shallow and deeper water. Larvae and early juvenile Sacramento sucker were associated with cover in all stream margins and backwater areas. Tule perch young also sought cover in backwaters and eddies adjacent to riffles and runs.

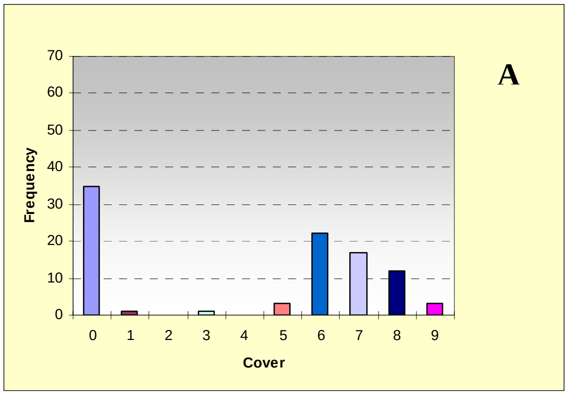
The amount of cover varies with stream flow in the LAR, as can be seen in winter 2003 (Figure 45). There was a decline in cover between late February and early March when flows dropped from 4,000 cfs to 2,000 cfs (Figure 3). Not only did the frequency of zero cover increase, units with higher cover indices lost part of their cover value. Because the figure includes the main channel sampling units that do not contain cover at most flows, the decline in cover of stream margin habitat is even more dramatic. The loss of cover in many sampling units is indicative of a river-wide drop in cover, which may be a reason for the sharp drop in densities and abundance of fry salmon in late March 2003 (Figure 46). McCain (1992) observed a similar declined in Chinook density in a tributary to the Smith River with loss of cover. He noted that the margin habitats with cover made up only one percent of the habitat, and that availability may be limiting emergent survival and early rearing success.

Instream cover offers the additional advantage of overhead cover. Woody material even beaver cuttings were highly sought out for cover by young salmonids. In deeper water, young salmon and pikeminnow used such cover extensively. In shallow water cover, salmon and steelhead would be the predominant users in winter and spring with young pikeminnow and suckers taking over in summer.

Instream cover has the further advantage of providing current breaks. Large blocks of clay-stone that have fallen into the river on steeper bedrock banks provide nooks and crannies that were heavily used by juvenile salmonids. Flooded lilies that grow on many shoreline areas of the upper river from tubers offer current breaks under higher flows. Schools of young salmonids were observed using cover of the lilies immediately adjacent to faster water riffles and glides (e.g., Upper Sailor Unit 7). Fishing line in riffles and glides that became encrusted with benthic filamentous algae provided cover for mixed schools of 80-100 mm salmon and steelhead during the summer (e.g., Upper Sailor Units 6a and 8). The cover provided by the algae was a combination of overhead (shade) and current break. Entire riffles and glides would be devoid of young salmonids except for small schools behind small areas of cover. Large woody material such as tree branches provided overhead and current cover and often attracted schools of young salmonids (e.g., Upper Sailor Unit 3). The most abundant current break cover was flooded grass and willows adjacent to riffles, runs, pools, and glides during higher flow periods. McCain (1992) noted that such habitat was important for rearing juvenile Chinook salmon during high flows.

At high flows (about 4,000 cfs and higher), cover habitat was extensive along river margins throughout much of the river. High flows resulted in flooded bank vegetation in most areas. During low flow periods (about 2,000 cfs and lower), the extent of flooded vegetation cover was reduced[6](see reduction in cover in Figure 45). Flooded vegetation included tufts of grass, and willow roots and branches, as well as rock and woody debris.

[6] At times during the low-flow periods high stage in the Sacramento River at the mouth of the LAR backs up water in the lower reach of the LAR and floods vegetation.



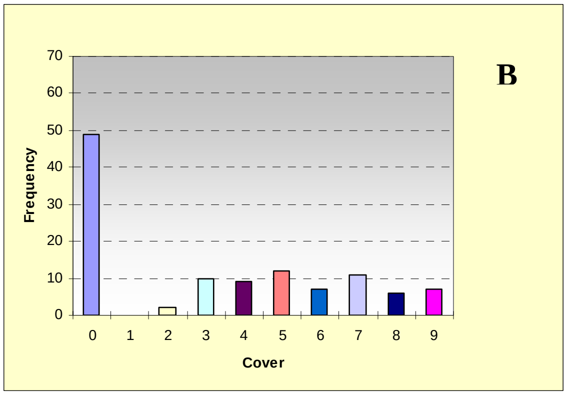


Figure 45a and 45b. (A) Late February 2003 habitat frequency among the sampling units; (B) Early March habitat frequency among sampling units.

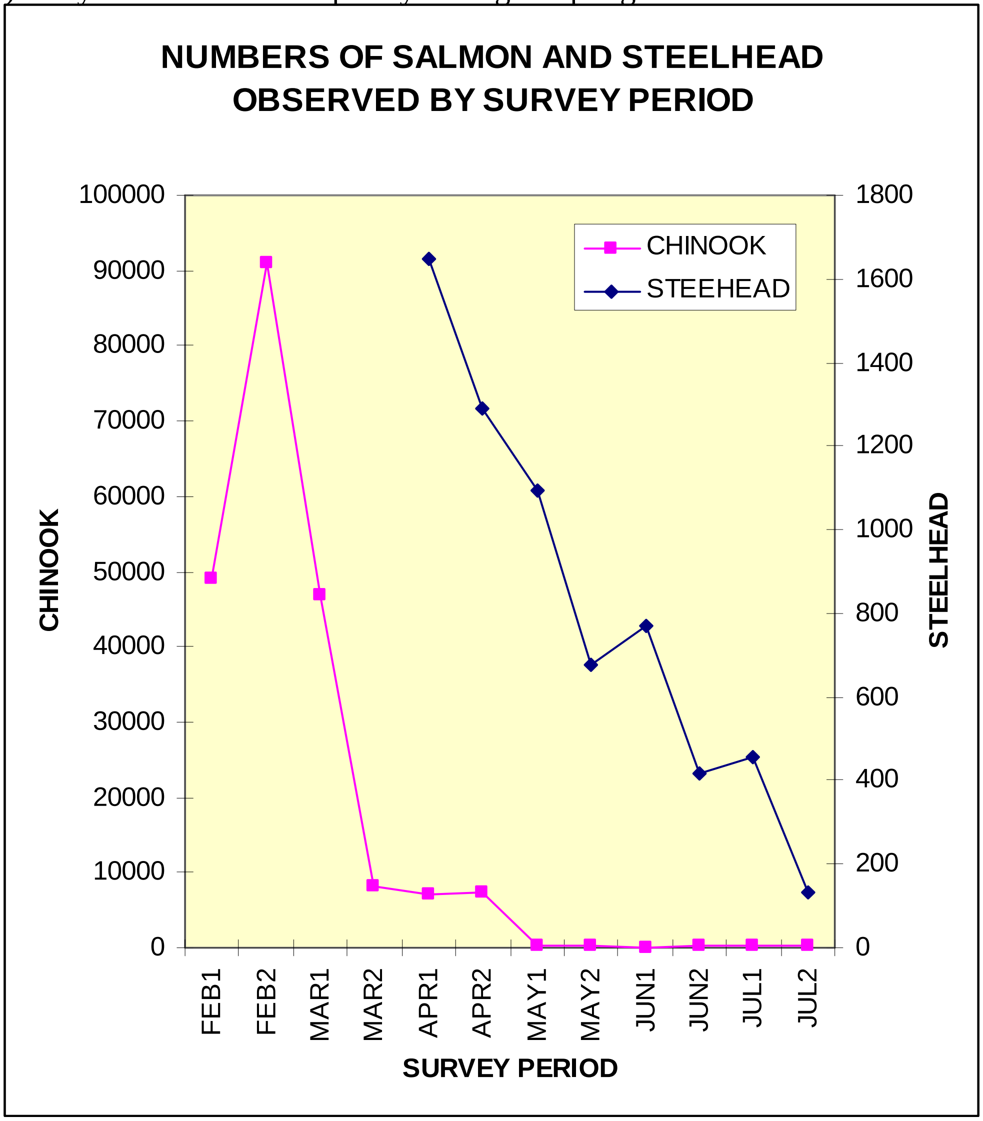


Figure 46. Total observations of salmon and steelhead young during the 2003 snorkel survey by time period.

Lower flows also reduced the extent of backwater and eddy habitat over much of the LAR. Less area of floodplain benches was flooded and the river was more confined to its higher velocity low-flow channel. Unshaded margins warm under lower flows as the extent of river heating increases in spring. Heating is not a problem in winter as warmer backwaters are in the salmon's optimal temperature range for growth of 12-15°C. In the winter, warm backwater habitat with cover was used extensively by young salmon and probably accelerated their growth. However, the reduction in the amount of cover during flow reductions appears to result in many young salmon leaving these units and either seeking out areas with more cover or leaving the river in early spring. Under lower flows, areas with remaining cover habitat are primarily the steep clay banks of the river where trees, shrubs, boulders, and woody debris provided overhead, instream, and current cover. Bridges and bridge abutment and pilings are also used. The steep claybanks of the upper LAR and steep vegetated levee banks of the lower LAR provide much of the cover in the LAR for the young salmon in low flow periods. These areas were locally important to young steelhead fry when flows were low.

In addition to the steep bank areas, under lower flows salmon and steelhead fry were often concentrated in sampling units with undercut banks of riffles, runs, and glides that provided cover under a wide variety of flows (e.g., Goethe Units 8 and 9, Upper Sunrise Units 1 and 2, and Lower Sailor Units 10 and 11). Most of these areas were side channels that were actively eroding and undercutting banks that had shoreline willow growth. These side channels also provided a considerable proportion of the steelhead spawning habitat of the LAR (see Hannon et al. 2003). The Goethe, Sunrise, and Sailor Bar side channels remained watered and functional at the 2000-6000 cfs flow range[7]. Their undercut banks also remained functional at these flows. Based on a review of the aerial photographs and flow data, and observations on the river, we estimate that these side channels lose their value to salmonids in the 1200-1500 cfs flow range. The Goethe side channel runs and pools become isolated at flows of about 1500 cfs.

Side channels have proven important in other rivers. Richards et al. (1992) connected gravel pits adjacent to the Salmon River in Idaho with side channels to the main river and between the pits. They found young Chinook salmon densities in the side channels with cover were several times those in any other habitats. Of the young Chinook salmon found in the side channel-pond habitat complexes, 35 to 80 percent were found in side channels with cover, which made up less than 10 percent of the available habitat. Young salmon showed significant avoidance of habitats without cover. Densities were high at up to 6 salmon per square meter, which was much higher that the 1 per square meter considered the carrying capacity for streams in that region of Idaho. (Note densities in units of the two side channels we sampled ranged as high as 10 per square foot or over 100 per square meter, but were more often in the 0.2-1.0 per square foot (2-10 per square meter) range in April when fish were of similar size as in the Richards study.) .

The margins of the LAR and its backwaters are essential habitat for young salmonids and other fishes because the current velocity of most of the river is too high for anything other than larger juvenile or adult fish. Even the adult fish concentrate in deeper pools near the bottom where the

[7] The Lower Sailor Bar side channel and Upper Sunrise side channels remain functional at 1000 cfs based on observations during the September 17th flow reduction; however, the Goethe side channel became disconnected at the upper and lower end riffles. We observed numerous dead, dying, and stranded prickly sculpin and young sucker and pikeminnow in the Goethe side channel on September 17th, 2003.

velocity is reduced. However, without cover the margins are generally not used except by larval sucker and pikeminnow. During most of the 2003 survey flows were high and after several dry years extensive grass and willow vegetation along the banks of bars, riffles, and pools provided cover. When flows dropped in March many areas that previously had cover and held many young salmon lost their cover and the salmon left for other areas. The principal areas left with cover were the margins of riffles, pools and runs with steeper or undercut banks where large woody material and clay-stone boulders provided current shelters and trees and shrubs (including willows, pampas grass, and Arundo) provided overhead cover.

Much of the shallow stream margin habitat is lost to young salmonids as viable habitat by late spring regardless of cover as water temperatures reach the stressful levels of 18-22°C in backwaters. At this point young suckers, tule perch, and pikeminnow take over the backwaters, as these higher temperatures are in the optimal range for the young of these species. From late spring through summer young salmonids are confined to cooler mainstem riffle and run habitat that has cover and current breaks; such habitat is limited to small areas of the upper portion of the LAR. Few salmonids were observed in the lower half of the river after late spring. In extreme cases under low flows and high temperatures, juvenile salmonids may be forced to thermally stratified deep pool (Nielsen et al. 1994), although we saw no evidence of this under the relatively high flows of summer in years 2003, 2004, and 2005.

The availability of cover in any year is affected by flow conditions in previous seasons and years. After a flood year when most vegetation along the river is scoured away, cover is likely minimal regardless of the flow and water level. For example, after flood years in 1997 and 1998, only limited vegetation remained on bars, islands, and streambanks of the LAR. In 2003 after several dry years most of the stream margins were flush with small willows and grasses. The relatively high flows in 2003, 2004, and 2005 provided ideal circumstance for providing cover from flooded vegetation.

Specific habitat associations between fish and physical habitat factors are presented in the following sections.

Microhabitat Preferences

Moyle and Baltz (1985) described microhabitat requirements of juvenile fishes in Central Valley streams. Young trout were found in water 20-50 cm in depth in velocities of 0-30 cm/s in substrates that were primarily cobble. These characteristics were similar to our observations. Moyle and Baltz found young suckers in similar depths but lower velocities and finer substrates, which is consistent with our observations. Also like Moyle and Baltz, we found adult suckers in deeper waters (4 feet deep or greater), near bottom, with surface velocities of about 2 ft/s, with gravel and cobble substrates. Also like Moyle and Baltz, we observed juvenile pikeminnow predominately in waters under 2 ft deep with surface velocities below 1 ft/sec in finer substrates than trout. We found fry pikeminnow in shallower stream margins in low velocity habitat. We found pre-spawn adult pikeminnow in deeper habitats with lower velocities including pond habitat. Spawning and post-spawn adult pikeminnow were found in water about 4 feet or deeper in velocities between 1 and 2 ft/sec with gravel and cobble substrate. Generally deep pools with depths greater than 10 ft often held some adult pikeminnow. Like Moyle and Baltz we found tule perch young in water with depths of 2-5 ft with surface velocity of approximately 0.5 ft/sec with fine sediment substrate and aquatic macrophytes or other cover.

Moyle and Baltz found trout in velocities of 0-30 cm/s, with a preference for mean water velocities of about 8 cm/s (0.3 ft/s). We found that the preferred velocity increased as the young trout grew, with velocities of about 0.1 ft/s shortly after emergence to velocities approaching 1 ft/sec at sizes near 150 mm in midsummer.

Waite and Barnhart (1992) also observed an increase in velocity and depth of preferred habitat as the young steelhead grew older and larger. They found steelhead fry occupied a restricted range of depths and low velocities near streambanks. As the fry grew stronger they used deeper and faster habitat. They found that fry preferred from zero to 0.5 ft/s, which was lower than other published studies for young trout. For juveniles they found a restricted preference near 1 ft/s that was also less than that found in other published studies. Their findings are consistent with our observations.

Bozek and Rahel (1991) found fry cutthroat trout were selective for depths from 3 to 20 cm and velocities less than 6 cm/s, which were consistent with our observations of trout fry soon after emergence. They suggested microhabitat of trout fry was generally less than 6 cm/s in water depths less than 3 cm in a variety of substrates. We found similar preferences but generally fry were in deeper water when associated with cover, which was the predominant situation. Bozek and Rahel also found that trout densities were related to the amount of spawning habitat in a reach, which appears to be the case in the LAR. Like Jackson (1992), Bozek and Rahel also found that microhabitat use varied with macrohabitat conditions in a reach particularly in reference to available cover and stream morphology. They found greater densities in small shallow streams, which is consistent with our finding of high densities in side channel habitats. They concluded that geomorphically diverse streams with different hydraulic characteristics were capable of creating suitable microhabitat for young trout in many different ways, a finding that very much describes our observations of LAR habitat. Jackson found suitable trout microhabitat within small areas of riffle macrohabitats, which is similar to our units within riffles (e.g., Upper Sunrise Units 1 and 2). He suggested that increasing the channel complexity and the abundance of lateral habitats could increase production of trout.

Other studies further indicate the importance of backwater habitats and large woody debris to young salmonids. Pratt (1984), Bjornn and Reiser (1991), and Naiman et al. (1993) noted the importance of riparian vegetation and natural flooding to create and maintain backwater habitats. Bugert (1985) and Bugert et al. (1991) found large woody material important to young salmonids for protection from predators.

On the lower Columbia River, Tiffan et al. (2002) conducted an extensive study of young fall Chinook salmon rearing habitat. They found that 99.9% of young salmon were found in depths less than 4.5 ft and in velocities less than 2 feet per second. They also found that lateral slope was more important and slope was inversely related to fish presence. We found this not to be the case as we found many young salmon on steep banks, the difference being that steep banks on the LAR are often vegetated with abundance of cover unlike those of the lower Columbia. They found highest densities at velocities of 0.3 to 0.7 ft/s, which is consistent with our observations.

They also found young salmon avoided riprap. As stated earlier, we believe this to be due to rocked sites having little streamside cover.

While Tiffan el al. recognized that cover was important in smaller streams, the importance of vegetation to fall Chinook salmon in mainstem habitats was "*unknown to them*". The predominant form of streamside vegetation in their study area was flooded terrestrial vegetation that covered less than 25% of the shoreline. They noted that field observations and underwater video failed to yield a relationship between subyearling Chinook salmon habitat use and vegetation. Vegetation, water temperature, turbidity, food availability, and the presence of predators were not included in their habitat model for the Hanford Reach of the Columbia River. They concluded that while higher flows would submerge more vegetation, such flows would reduce the amount of shallow water habitat along the river for rearing because of higher slopes and velocities near shore. They found this "paradoxical" because low flows were generally associated with poor in-river conditions and low survival during seaward migration. Based on our studies we believe that cover is an important factor in the LAR, which may be an indication that the LAR should be considered a "smaller stream" as compared to a large stream like the Columbia or Sacramento Rivers when it comes to producing young salmon and steelhead.

Brusven et al. (1986) found a strong association of 50-mm juvenile Chinook salmon to undercut banks in an artificial stream channel. House and Boehne (1986) also found greater numbers of young salmonids associated with instream cover and undercut banks. Such habitat on the LAR was also used extensively by juvenile salmon (e.g., Upper Sunrise Units 1 and 2).

Cavallo et al. (2003) found young salmon and steelhead used small instream or overhead objects as cover when small, but more open riffle habitat as they grew larger. Smaller steelhead favored small woody debris and submerged vegetation, whereas larger fish were more commonly associated with overhead cover. We observed this same pattern as fry trout were more commonly observed in flooded grasses, while larger fingerlings were more associated with undercut banks and larger cover of riffles. They also observed most young steelhead were found close to the shoreline and much of the river habitat was unused, as was the case in our observations for the LAR.

There is also a wealth of studies that relate the occurrence of large woody debris in salmon streams to salmon production (e.g., Brown et al. 1994). Jackson (1992) made the following observation about the LAR "*On all occasions where root wad/woody debris jams were available as a cover type, except [for one], large schools of juvenile Chinook salmon were observed.*" McCain (1992) concluded "*LWD is a primary element in forming potentially critical early rearing backwater habitat*". Our observations indicate that LWD is important from Nimbus to Discovery Park. Salmon use LWD for overhead and current cover and readily gravitate to habitat units with an abundance of such cover especially if it is in or near areas of current. In smaller streams LWD helps create habitat, whereas in the LAR LWD may have less influence on stream morphology because the stream forces are on a much larger scale in the LAR. That is not to say that large cottonwood trees and other LWD in some units in the LAR have not had some influence on local stream morphology by inducing lateral and vertical scour (e.g., Paradise Unit 10 and Goethe Unit 9). The addition of LWD in shallow faster water units such as side channels would increase bank slope and provide cover, attributes that we found were positively related to young salmonid density. LWD is generally absent from the side channels at least in the upper LAR. Root wads in selected locations (e.g., Upper Sunrise Units 1 and 2) provide cover and undercut banks.

Oversummering of steelhead young occurs in large pools and runs, as well as riffles especially in side channels. Cover in these instances comes from depth and broken water, as well as the physical cover of the stream margins.

Effect of Interspecific and Intraspecific Competition on Habitat Use

We found no obvious evidence of competition between young salmon and steelhead. Salmon fry densities dropped before steelhead emerged in numbers. Salmon pre-smolt density did drop sharply in early April after young steelhead became abundant. However, after April steelhead and salmon were often observed in mixed schools in the same riffle and run margin habitat with cover. In July we observed salmon and steelhead in open riffles feeding as individuals. Larger salmon and steelhead appeared to take dominant positions in these circumstances. While salmon and steelhead competed as individuals in the same school for position, we saw no overt signs of competition that favored one or the other species, other than steelhead young were generally larger by summer than salmon. In spring and early summer salmon used deeper water while steelhead did not.

Hearn (1987) defined competition as individuals competing for a common resource that is in short supply. Hearn also stated that competition is limited when other processes control populations. We believe there is competition occurring in the LAR for the limited feeding habitat with cover from predators. This limitation came into play in early March 2003 when flows dropped and the amount of cover habitat dropped dramatically. The decline in habitat likely caused many young salmon to seek out remaining good habitat or leave the river - we found evidence of both. Hearn (1987) related that stream salmonids compete for feeding positions where minimal currents and cover are immediately adjacent to currents where there is food from invertebrate drift. Such locations are predominantly where we observed salmon and steelhead young concentrated by summer in the LAR. In these localized feeding areas Hearn described what is referred to in the literature as localized dominance hierarchies, wherein the larger individual or more dominant species take up the best feeding position within the location. This behavior likely explains the higher growth of young steelhead and the dominance of feeding locations by larger young steelhead in summer observations. Hearn also acknowledged that territorial segregation leads to less aggressive behavior especially when food is abundant, which would explain why we observed little aggressive behavior – the fish simply seemed to know their place in the dominance hierarchy. Such behavior also appeared to rule behavior in schools of salmon feeding in deeper pools. With so few “good” feeding locations in summer it may be that there is abundant food in the LAR and thus the limiting factor in production is the availability of good feeding habitat. Heggenes (1989) found that restricted feeding habitat availability also produced a highly clumped distribution pattern for trout, which is similar to the patterns we observed.

Where large schools of yearling pikeminnow and young salmon occurred in some deeper locations, the two species were sometimes mixed upon disturbance but generally each species stayed to their own area, which may have been a few inches to feet away. Morning and evening feeding adjacent to these deep cover areas (e.g., Lower Sailor Unit 1) was usually dominated by young salmon. However, in summer when the salmon were gone, pikeminnow took up the same positions and feeding behavior.

While a shortage of cover habitat appears to lead to a juvenile salmon exodus from the LAR, a shortage of good feeding and refuge habitat may be limiting survival and production of young steelhead. Hearn (1987) refers to numerous studies where competition for habitat associated with peak fry densities can lead to density-dependent mortality controls on the population. He references papers where high densities were 12-31 trout fry per square meter. Our highest densities were over 100 per square meter for salmon and 5-10 steelhead fry per square meter. The precipitous decline in young steelhead observed in this study in 2003 (Figure 45) may be in part due to density-dependent mortality from lack of available good feeding and cover habitat. While this hypothesis remains untested, such a decline is consistent with the exponential increase in territory size with linear growth of trout length noted in the scientific literature by Keeley and Slaney (1996).

Young steelhead may be migrating downstream into the lower portions of the river and perhaps the Sacramento River in response to overcrowding in limited available habitat in the upper river. Screw trap data from the Feather River (Cavallo et al. 2003), Yuba River (CDFG unpublished data), Calaveras River (Cramer and Associates unpublished data), and American River (Snider and Titus 2000) indicate young trout move downstream through the summer. The fate of these young trout is unknown, although Cavallo et al. believe their chances of survival are limited given harsh downstream conditions particularly higher water temperatures. They also suggest the possibility of rearing in the lower river or perhaps the Sacramento River but such a behavior and life history pattern has so far been undetected. Koslowski (personal communication) observed yearling steelhead during summer snorkeling at the mouth of the Yuba River on the Feather River, but these were almost all hatchery (adipose clipped) fish. Koslowski also noted that few young trout were observed in the lower Yuba snorkel surveys despite trap data indicating a substantial movement of young trout into the lower river from the upper river.

The migration of young steelhead out of spawning and rearing areas of the LAR and other Central Valley tailwater streams may be from a natural adaptation for young steelhead to migrate downstream from headwater spawning reaches. Yoshiyama et al. (1996) pointed out that adult steelhead naturally migrated to the head of watersheds to spawn and that young dropped back to higher order streams to rear. Steelhead spawned in lower tailwater habitats of Central Valley rivers may be unknowingly dropping downstream into inferior habitats either in search of less crowded or better habitat, or simply gradually moving toward the ocean. This behavior pattern may be limiting steelhead production in Central Valley tailwater rivers.

Effects of Streamflow on Habitat Use and Abundance

While the March exodus of salmon fry from the American River was possibly a result of a loss of habitat as flows declined in the LAR, the reduction in salmon density between late April and early May 2003 (Figure 45) could be response to a near tripling of streamflow (Figure 2). Screw trap catches of pre-smolt salmon in the LAR and nearby Cosumnes River also showed this pattern (CDFG unpublished data). Cavallo et al. (2003) also observed a dramatic decline in the salmon density observed in snorkel surveys in the lower Feather River in April of 2002. Salmon density may have also declined by a shift in their habitat from shallow stream margins to deeper pool habitat, because most of the salmon observed in early May were in steep clay bank habitat (Chart 4). Observations of salmon in such habitat were complicated by a reduction in diver visibility due to the high flows and local storm water runoff.

Effect of Water Temperature on Habitat Use

Moyle and Baltz 1985 indicated that trout moved to faster water habitat at higher temperatures. Baltz et al. (1987) found that temperature proved to be a better predictor of where each species was found than velocity and substrate. Depth, velocity and substrate were correlated but depth and temperature limited the influence of velocity on microhabitat selection. We found that as temperature rose in the spring, salmonids were confined to the upper portion of the LAR. In summer, water temperatures in stream margin habitats rose to 20°C and trout were generally found in open riffles where water temperatures were 16-18°C.

Effect of Sampling Scale on Habitat Use

Wiens (2002) noted that responses of aquatic organisms to their habitat are scale dependent. As a consequence, relationships that are apparent at one scale may disappear or be replaced by other relationships at other scales. An example of this scale effect would be comparison of LAR salmonid use between riffles and pools. Our sampling indicates that for any riffle-pool complex at one of our sites, units can differ greatly in use within a riffle or pool and that the differences are due to distinct habitat differences within the units. A pool margin can hold many young salmon (e.g., Lower Sailor Unit 1). A riffle margin can hold more steelhead than another riffle margin (e.g., Upper Sunrise 2 versus 3). It is for these reasons that we believe we chose the appropriate scale for our sampling units. Our scaling seems consistent with suggestions by Lancaster (2000) who noted the importance of small-scale habitat refuges especially those with submerged vegetation for maintaining aquatic animals in streams. Many of our sampling units were such small-scale habitat refuges. Ward and Stanford (1995) noted the importance of habitat areas than are on the margins between a river and its floodplains. Many of our sampling units (e.g., side channels and backwaters) are located on such margins.

Relation between flow and rearing habitat

The relation between flow and physical rearing habitat has not been established as important for the LAR, although flow effects on water temperature have been identified (Water Forum 2001).

We believe that the flow history plays an important part in habitat development in the LAR. For example, the side channel development at the Upper Sunrise site was accomplished primarily in the 1997 flood. The flood scoured into the bank recruiting gravel and opportunities for riparian vegetation that subsequently provided undercut banks at a wide range of flows. High flows help to scour channels and create large woody debris. Low flows contribute to vegetation development in the floodplain and stream banks, which subsequently contribute to cover.

From Jackson's (1992) and ours studies it is apparent that flow does affect habitat and fish use of the habitat. Jackson found far less habitat and fewer young salmonids at 300 cfs and numbers of salmonids observed were less than at 3700 cfs. In our study we observed a sharp reduction in juvenile salmon when flows decreased and the amount of refuge cover habitat decreased. As flows declined in summer, we observed young steelhead and salmon to move into available riffle/run habitat where broken water provided cover.

Can Habitat Limitation affect Salmonid Production?

Grant and Kramer (1990) and Keeley and Slaney (1996) suggested that as fish grow their territories in streams increase in size and there is a corresponding decrease in density. From this phenomenon there is the suggestion that stream production of salmonids is limited by the capacity of the stream in terms of habitat. Population control is exerted through self-thinning (Dunham and Vinyard 1997). From our observations it would appear that habitat for young salmon and steelhead is limiting production in the LAR. The decline in density of young salmon and steelhead in the river from spring through summer (Figure 45) may be a function of self-thinning. Good habitat is limited and the density of salmonids decreased dramatically through the spring and summer. Having more habitat may not change the thinning rate, but it would result in more smolts produced. If the amount of good habitat is a function of flows and temperature, then flows and temperature can affect salmonid production. This basic theme has much support in the literature for stream salmonids. Marschall and Crowder (1995) suggest that food and space limitation may be theoretically indistinguishable. The amount of stream habitat has been related to fish production (e.g., Miller et al. 1985; Fausch et al. 1988).

Jackson (1992) stated that cover habitat was limited in the LAR even at the higher flow (3700 cfs). He implies that at higher flows or with greater amounts of habitat per specific flows salmonid production would be greater. We agree with his conclusion.

Can Predation and Competition Limit Salmonid Production in the LAR

Predation and competition are forces linked to self-thinning or density-dependent mortality. They can limit production directly by causing mortality or indirectly by affecting habitat use and the capacity of a habitat unit to produce salmonids. Predation by birds (seagulls, terns, mergansers, cormorants, herons and egrets) and fish (striped bass, adult trout, American shad, pikeminnow, largemouth bass, and prickly sculpin) causes direct mortality but also forces young salmonids to seek cover habitat that may be in limited supply or where available food is limited. Competition between larger and smaller individuals may result in smaller individuals being displaced to other habitats where the risk to predation is higher, foraging conditions are poor, or the food supply is less than adequate (Dunham and Vinyard 1997).

Kelsey et al. (2002) found competition in the form of aggressiveness of young trout that induced exclusion and stress on young Chinook salmon. The fish used in their experiment were larger hatchery smolts and may not be indicative of young wild salmon and steelhead. Though we saw no overt form of such aggressiveness in our surveys, we did observe larger sizes among trout than salmon in units were they coexisted, which may in part be due to size-selective mortality.

Predation is likely a significant factor in the survival and production of young salmonids in the LAR. Pikeminnow and prickly sculpin are known predators of young salmonids (Jackson 1992; Brown and Moyle 1981). Yearling and adult pikeminnow and prickly sculpin are sufficiently abundant in the LAR that they likely significantly affect mortality of fry salmon and steelhead. Other predators we have observed in the LAR include striped bass, largemouth bass, American shad, and otters. American shad enter the LAR by the tens of thousands just as fry steelhead become abundant. American shad are known predators on young salmonids (Red Bluff Predation Study – USFWS/USBR unpublished data).

It would seem that predation as an indirect force occurred when fry salmon and steelhead were seeking cover habitat in late winter and early spring. However, by summer with the populations and densities greatly thinned, predation would take the more density independent form of simple direct reductions in the numbers of young salmon and steelhead. By summer the flocks of seagulls and mergansers are gone and the herons and egrets had switched to juvenile suckers and pikeminnow.

Given the size of most young salmon and steelhead in the summer (100-150mm) the greatest threat likely comes from striped bass, a species non-native to the trout's habitat and one that is a renowned predator. The salmon and steelhead did not genetically adapt under the influence of striped bass predation, and thus may be highly vulnerable to striped bass predation. From our observations, steelhead and salmon young in the 100-150 mm range are likely prey of striped bass because young suckers and pikeminnow are too small for the striped bass in spring and summer. We have observed 20-lb stripers in a foot of water in riffles searching for prey. We observed schools of young salmon and steelhead in riffles and just downstream nearly as many adult striped bass waiting in slightly deeper runs. Given the small number of young steelhead left in the LAR by summer (we observed less than 200 in our late July 2003 survey), and the large numbers of stripers we have observed (55 in the early July 2003 survey and nearly a 100 in the late July 2003 survey), it would seem that the threat is substantial and the potential effect significant. During our September 19th 2003 scuba survey of the Nimbus Hatchery pool, four divers observed numerous adult striped bass but no young steelhead, where steelhead had been abundant earlier in the summer. The adult striped bass were sustained by frequent releases of dead juvenile salmonids from the hatchery cleaning process.

Emigration - Are Salmon Fry Washed from the River by High Flows?

One of the life history traits of Chinook salmon is that some populations leave the rivers soon after emergence as fry, similar to pink and chum salmon (Healey 1991). Those populations where young leave before summer are considered "ocean type", while those that leave after over-summering are "stream-type". The fall run Chinook populations in the Central Valley are generally considered ocean type because they migrate to the ocean before summer. Ocean type can leave the rivers as fry in winter or as subyearling smolts in spring. Both patterns are evident in the Central Valley (Kjelson 1981). The question remains as to where fry rear - in the rivers or estuary or both – and what is the importance to adult escapement of the two life history types. This is an important question for the American salmon because it determines whether rearing habitat in the LAR is important for salmon production. CDFG screw trap collections indicate that most young salmon leave soon after emergence as fry and that little rearing occurs in the river (Snider and Titus 2000). However, tagging studies indicate that fry found in the Delta have a much lower potential survival than those rearing and leaving the rivers as smolts, with the latter indicating that salmon rearing in the river is important (Williams 2000).

Our observations indicate that while most young salmon leave the river as fry or fingerlings, they do spent some time rearing, possibly up to a month before leaving. Although a mass exodus was indicated in our data and the DFG screw traps in early March, we also observed substantial rearing in the 9 miles of the lower river below CDFG's Watt Avenue screw traps in February and March. Brown et al. (1992) also noted young salmon rearing in the lower portion of the LAR. A month of rearing in the lower river would allow the young salmon to reach the pre-smolt stage of (60 mm) before leaving for the estuary assuming a high rate of growth of about 1-mm per day.

The exodus we observed was not due to fry being "washed" from the river as it occurred as flows dropped from 4000 cfs to 2000 cfs. Furthermore, there is a misconception that high flows bring high velocities to the lower river. The higher the flow the more the lower river backs up at the mouth and the lower river becomes an extensive backwater.

Williams (2000) related that early emergent fry tend to emigrate directly, whereas later emerging fry rear for some period before emigrating. The early emergers in January and February led to the highest densities in our study (5-10/sqft), which was a likely reason for inducing emigration out of the upper spawning reaches of the river past Watt Avenue to the lower backwaters of the river. However, later emergers in March were faced with less available habitat and habitat already saturated with larger earlier emergers.

Williams also discussed whether the fry emigration was a forced, density-dependent behavior, or a volitional behavior. "*In the American River, the lack of larger juveniles in the seine samples early in the year when fish density is still low suggests early emigration is volitional, rather than a response to fish density or territorial behavior*." We found that densities were highest in early winter and declined sharply by late winter. We believe the early exodus from the river is caused at least in part by lack of small-scale habitat refugia, a phenomenon described by Lancaster (2000), in combination with intense predation by birds.

We also concur with Brannon (1972) that early Chinook fry move quickly and that the behavior is genetic factor as suggested by Hoar (1958). Brannon stated that emigration is a group behavior that starts with an appetite for current and ends when currents wane. This pattern seems consistent with our observations of fry moving strongly with the currents after emerging (as evident from the seagull feeding behavior in February) and then building up in large schools in upper river margins and lower river backwaters.

Our observations indicate that high densities of fry regardless of their size in February led to overcrowding in the small-scale habitat refuges of the upper river, which was exacerbated further in March when there was a sharp drop in flow and refugia available. The schools of salmon were simply too large and bird predation pressure too high, that many fry were probably not getting sufficient ration to sustain themselves, and thus had to move on. Others that had been growing for some period may have also reacted to the high densities and loss of habitat by emigrating. Many were forced to the lower portion of the river where there is more low velocity edge habitat with abundant cover.

Many remained in the lower river until April when higher water temperatures may have induced emigration. Northcote (1962) found water temperature to be a controlling factor in the emigration of juvenile salmon in Canadian rivers - as temperatures reached above 15°C young Chinook salmon tended to emigrate. The second exodus we observed after late April 2003 (Figure 45) may have been due in part to this behavior pattern as lower river temperatures reached 15°C and above. The Water Forum (2001) stated that water temperature might directly contribute to the triggering of seaward migration. "*The relatively early emergence and emigration currently observed in the lower American River is likely a result of the temperature-moderating effect of Folsom and Natoma lakes, or resulting from the different runs of Chinook salmon that historically spawned upstream in the American River Basin*." "*The timing of juvenile Chinook salmon emigration in recent years is comparable to that observed during 1988 and 1989, but is much earlier than that observed during 1945 through 1947 period*." A further reason for the second exodus in 2003 is the much increased flows and associated higher turbidities in early May.

The fact that both snorkeling and screw traps tend to underestimate the numbers of larger later stages of young salmon in the LAR indicates that more salmon may rear later into spring and through the summer than previously believed. As stated earlier, we saw large schools of pre-smolt salmon feeding in deeper habitats in May and divers were unable to approach or accurately count these fish given visibilities of only 6 to 8 feet. Similar schools of smolt-sized salmon were occasionally observed in deeper pools during the summer.

The question remains as to what is the relative contribution of fry that rear in the river to those that rear downstream in the estuary, and how important whatever rearing in the river is to the adult escapement to the river.

Can Snorkel Data be used for Habitat Suitability Criteria

Williams (1999) states that what matters is whether using Habitat Suitability Criteria (HSC) produces habitat suitability curves that are significantly different so that they may be used to support decisions about instream flow. We suggest that rather than having HSC for individual species and life stages, that HSC for each species and life stage be developed for each habitat unit. The sum of the habitat units would then provide the amount of habitat available at different flows.

Freeman et al. (1999) stated that actual linkages between biota and instream habitat should be evaluated by testing relations between population dynamics and availability of habitat. As stated above, we believe snorkel data can be used to relate flow to habitat conditions and fish density in individual habitat units and that habitat value can be related specifically to flow conditions. Flows can be related to specific micro and macro habitat conditions in each unit, as well as salmonid young densities. If habitat quality and availability can be related to fish production such as sustaining higher densities and growth, then we will have the link Freeman et al. describe between biota and habitat. If production of young salmonids can be related to flow and habitat conditions, as well as adult escapement, then flow/habitat conditions can be related to adult production.

Freeman et al. suggests that the uncertainty in HSC that results from sampling variability and unobservable effects of biotic and abiotic factors on habitat use and population variability can be reduced by doing the following:

- *Increasing sample sizes (i.e., the number of independent habitat use observations) can reduce uncertainty due to sampling variability.*

- *If remaining variability is so large that the limits of preferred habitat ranges cannot be accurately detected, then the ''weak'' test described in Thomas and Bovee (1993) and Freeman et al. (1997) will likely fail to reject the null hypothesis. Then we would conclude that we do not have enough information to delimit habitat requirements.*
- *Tests can be useful for screening out criteria that are not appropriate for the target stream.*

Waite and Barnhart (1991) concluded that the range of suitable habitat for young salmonids might be broader for large, low-gradient rivers as compared to steep, high-gradient streams they studied. One reason for this is that rivers like the LAR are far more complex than smaller streams and fish are able to find what they need in terms of depth, velocity, food, and cover from predators and velocity in a wider variety of ways and habitat conditions. So rather than find the amount of habitat at varying flows that fits the microhabitat needs of each fish through traditional IFIM, we should evaluate the quality of the habitat in each habitat unit as it varies with flow to support the needs of each fish species and life stage.

The information collected in the snorkel survey may also be suitable for aquatic HEP (Terrell et al. 1982). The difficulty will be in identifying what are the limiting factors in specific habitat units to determine the relationship between flow and the value of the habitat unit (Bisson et al. 1982). In British Columbia, scientists have pursued this approach (Levy and Slaney 1993), and believe that there are methods for assessing the capacity of individual habitat units for each species and life stage. However they relate that the technique requires careful survey of each unit and many individual units defined within a stream. The 2003-2005 snorkel surveys were designed with these guidelines in mind. This scale of habitat unit is also consistent with potential restoration actions that may be taken in the future (Lewis et al. 1996).

Were Years 2003-2005 Representative?

Jackson (1992) snorkeled the river from 1989 to 1991 – all extreme drought years after drought years. Our surveys were conducted from 2003 to 2005, relatively wet years especially for late spring, but certainly unlike a flood year typical of the late 1990's (or 2006). Jackson had much lower flows and often higher water temperatures. Putting the two data sources together provides a more complete picture of what happens in the LAR under differing water year types.

Problems Identified

Snorkeling as a sampling technique is certainly not without its unique problems. Snorkeling tends to underestimate density because of avoidance in combination with poor visibility. The LAR in years 2003-2005 at times had marginal visibility at 6 to 8 feet as compared to visibilities near 20 feet in other snorkel surveys (e.g., Roper et al. 1994; Yuba and Stanislaus Rivers). Fish also tend to hide in substrate and cover. Though we tried to follow the fish into cover, we certainly could not see them all.

Accuracy has been the most common criticism of the snorkeling techniques. Water clarity is the greatest concern. Being able to sample shallow water is another. High variability in habitat and habitat use is another problem frequently mentioned. The ability of divers to differentiate fry salmon from steelhead is another. Experiments to test accuracy of snorkel counts versus electrofishing have generally showed good correlation between visual counts and electrofishing mark-recapture estimates (Bozek and Rahel 1991; Hankins and Reeves 1988; Zubik and Fraley 1989; Hillman et al. 1992, Roper et al. 1994).

A particular concern was that we were missing salmon and steelhead hiding in the substrate. Bradford and Higgins (2001) found Chinook and steelhead to be more nocturnal in spring and summer – sometimes hiding in the substrate during the day. They concluded that the phenomenon is well documented during the winter, but spring and summer is more variable. Our experience on the Yuba River in cobbled side channels was that most steelhead fry hid in substrate in the summer and that it took electrofishing to get them out. This behavior in the Yuba River may have been associated with low channel flow, as water levels were quite low, and there was a general lack of cover. We saw some evidence of the hiding behavior in the LAR when steelhead first emerged in March. Some fry we observed sought shelter in the substrate when approached, especially if little vegetative cover was nearby. When flooded vegetation was available fry appeared to readily seek such cover and could be easily observed and counted at short range. However, there is no doubt we missed steelhead fry because of their tendency to hide in the substrate. It may be that in uncovered riffles and run margins, fry were hiding in cobbles more so than in cover areas. We do not believe this is a problem for Chinook fry as their schooling behavior seems to preclude hiding as individuals in the substrate. We observed little or no substrate hiding behavior when we observed Chinook fry, as they tended to escape as a school by running.

Roni and Fayram (2000) found that juvenile salmon and trout hid during the day during the winter at low water temperatures (<7°C) but were more readily observed with night snorkeling. We were concerned with this potential problem and believe it may have been a problem in early February when water temperatures were below 10°C at some locations. However, once water temperatures exceeded 10°C we were less concerned because Chinook fry were readily observed in schools throughout the study sites. Limited night snorkeling in 2004 and 2005 did not indicate any difference from the day, although observation appeared more limited at night.

Hillman et al (1992) also found snorkeling accuracy varied with water temperature. The accuracy of visual counts of age-0 Chinook salmon and steelhead was about 70% when water temperature was above 14°C, but declined to 20% below 9°C. At temperatures between these extremes accuracy was about 50%. Hillman et al. also found that snorkelers underestimated the numbers of small steelhead (< 100 mm in fork length) by 40% or more if these fish occupied stations in water shallower than 15 cm. We found it very difficult to count fish in such shallow water and often resorted to above water observations simply by the diver rising out of the water to make observations at the shallow edge extremes of sampling units.

Rogers et al. (1992) found accuracy of snorkeling for population estimates better in summer than winter when compared to electrofishing, but generally snorkeling provided lower estimates. We agree that for units that could be effectively sampled with electrofishing, density of salmonids and other fishes may have been higher than we observed via snorkeling. However, the LAR is a larger stream with less cover than the Oregon coastal streams sampled by Rogers et al. and many units we snorkeled could not have been effectively electrofished. Snorkeling also allows observation of undisturbed fish in their natural habitats, whereas electrofishing tends to capture fish that are escaping or in hiding areas. When electrofishing, the fish are generally not seen until they are shocked and that may be long after they have been disturbed. With snorkeling, fish observations were generally made of fish that had not been disturbed. Thus snorkeling would seem to be more accurate at providing an unbiased representation of habitat use patterns especially in smaller sampling units.

Another concern was that our sampling units did not have homogeneous habitat and that fish tended to focus on particular subsections of a unit for whatever reason. For example under an undercut bank, young salmonids tended to focus on the upper end where current and food were closer. Microhabitat preference also came into play as depth and velocities often varied with a unit. We were content with the notion that the general characteristics of the unit along with its range and availability of specific microhabitat components was sufficient to relate the abundance of fish observed to the general habitat conditions in the unit. We believe that the typical unit size we chose is an improvement on the larger units normally chosen by habitat type (e.g., riffle-run, pool-glide, Roper et al. 1994) in that our units had more homogeneous habitat and a wider array of habitat characteristics. We also were able to identify small-scale habitat refuges (Lancaster 2000).

At some point there are tradeoffs in the scale of sampling from microhabitat and macrohabitat, and that the solution is to choose a scale of mesohabitat on the scale that we employed in this study. We tried multi-scale sampling by subsampling even smaller units (10-20 square feet) within our sampling units, but this proved too time consuming and a severe strain on resources. Furthermore, based on observations we did not feel confident that concentrations of fish observed in smaller subunits were there because of the conditions in the subunit or those of the larger unit. It was also hard for the diver to decide in which unit a school of young salmon that spread over a unit should be catalogued. We felt that the larger unit had the full array of characteristics that likely attracted fish to the area.

Thomas and Bovee (1993) suggested using smaller sampling units (1-by-3m cells). They considered cells usable for HSC if any of the microhabitat variables fell into the usable range. The union of optimum and usable cells was called suitable. We avoided small units because the fish appeared to be responding to conditions within the larger units – that is fish were using more than just the attributes of their immediate habitat. This may be in part due to the LAR being a larger stream than described by Thomas and Bovee. Furthermore, because of avoidance we could not be sure where the fish actually were at the time we approached. At times we observed them feeding near current only to escape to deeper cover when approached. Our larger sampling units also represented what appeared to be categories of habitat types that were readily identifiable and relatively easily mapped.

Jackson (1992) stated: *"The physical constraints on snorkelers and divers to survey fast and/or deep water has often resulted in partial coverage and biased data collection and may affect the habitat preference. Changes in flow can greatly increase or decrease the lateral areas usable by juvenile salmon, particularly in riffles and shallow glides."* We agree with his assessment.

Levy and Slaney (1993) in reporting on a habitat assessment workshop noted that workshop participants generally agreed that methods exist for assessing the capacity of individual habitat units to support salmonids. Although each species and life stage may have alternate uses for each unit, standard methods could be adopted for survey and inventory at this level. Participants recognized that a great deal of regional variation exists and that it may be necessary to develop a regionalized approach to assessment. The problem they were most concerned with was that habitat units on the Bisson et al. (1982) level can be relatively small and that such units require careful survey techniques and that there may be a large number of units in any watercourse. It was partially for these reasons that we chose a relatively large number of habitat units at the mesohabitat level. We felt that if we could show real differences in use at this level, then we were observing real difference in habitat selection and value to the fish.

Hankin and Reeves (1988) described methods of estimating total fish abundance and total habitat area in small streams based on rapid visual estimation procedures (snorkeling in the case of the fish estimates). When compared with other methods, underwater observation techniques compared well, and correlations between visually estimated habitat unit areas and accurately measured areas (total reduction with multi-pass electrofishing) were high. They suggested assigning estimation responsibility to experienced observers to reduce sampling error.

Williams (1999) questions the wisdom of statistical tests based on the occupancy of cells because cells are not homogenous, so depth, velocity, substrate, and cover in the cells may not be well represented by single numbers. He also questioned whether occupancies of cells by fish can be considered independent events. He suggested that with schooling fish, observations of individual fish are not independent and that a school observed might be considered as one observation. He suggested that cells should be made large enough that fish within one cell are unlikely to influence the occupancy of adjacent cells. We agree with all of William's comments and considered them in setting up our sampling design.

How good is the Physical Habitat of the Lower American for Juvenile Salmonids?

While water temperature in combination with flow is considered the critical habitat factors in the LAR for salmonids, the lack of small stream habitat, especially shallow water riffle/glide habitats, in the LAR may be an important limitation to natural production of steelhead (Water Forum 2001). Cavallo et al. (2003) also found "*small stream*" habitats lacking in the lower Feather River. Our observance of steelhead densities being highest in relatively rare side channel habitats especially in units with cover indicates that the small stream habitats may be important in the production of steelhead in the LAR. Cavallo et al. also suggested that lack of small stream habitat in the lower Feather River limited steelhead production. Hannon et al. (2003) report that less than 10 % of the 1,300 adult steelhead escapement to the American River are wild fish. Such low escapement of wild fish is likely a consequence of lack of habitat for spawning and rearing (food and predator avoidance).

In smaller streams riparian habitat and large woody debris along with adequate spawning gravels and riffle-pool ratios are often considered important factors in salmonid production (Barton et al 1985). These parameters have not been measured in the LAR. Site-specific plan-form geometry surveys were recommended at the Functional Analysis Workshop for the LAR (August 2002 workshop notes).

Is the LAR Supporting Native Fishes?

Based on our observations, the LAR appears to function as a spawning and rearing area of five abundant (Chinook salmon, steelhead, Sacramento pikeminnow, Sacramento sucker, and tule perch) as well as two common native fish (Pacific lamprey and prickly sculpin). These native species dominate the fish communities of the LAR. The only common non-natives are striped bass, largemouth bass, and American shad. The striped bass and American shad adults are only seasonal visitors with little or no rearing of young in the river. Overall, migratory fish dominate the fish community, especially in the upper portion of the LAR. Non-migratory native species common to the Delta and Central Valley streams including sculpin, hitch, blackfish, hardhead, dace, and roach were rare or not observed. The close proximity to the Delta makes the LAR a natural spawning river for migratory Delta native species including Sacramento splittail, tule perch, Sacramento sucker, and Sacramento pikeminnow. We observed no adult or young splittail. May and Brown (2002) describe the LAR as being within the Large Rivers Group of Central Valley fish communities with cool temperatures, higher velocities, and higher flows maintaining a dominance of the native fish in the fish community. The strong hydrological forces of the LAR likely limit the fish community of the LAR to those well adapted to seasonal migration into rivers. Control of the fish community composition by hydrological factors is consistent with the findings of Grossman et al. (1998), who concluded "*that environmental variability manifested through variations in flow had a much stronger impact on both assemblage structure and patterns of microhabitat use and overlap than either habitat limitation or predation*."

There may be an inherent weakness in the LAR to support young steelhead trout or the Rainbow Trout Assemblage and its associated habitat types identified by Moyle (2002). Swift water and riffles are far less abundant than pools. Banks are not well shaded nor frequently undercut. Logs and root wads are not abundant. Native fishes like the speckled dace, hardhead, and roach that are representative of the Rainbow Trout Assemblage are rare. Moyle suggests that tailwaters with their swift currents and low temperatures like the LAR naturally exclude native minnows and suckers. We believe the two main reasons for the difference are (1) small stream habitat is lacking and (2) predation by non-natives such as striped bass, largemouth bass, and American shad affect species assemblages. In the lower Yuba River tailwater above Daguerre Point Diversion Dam, hardhead, dace, and roach are more abundant than in the LAR despite similar flows, water temperature, and habitat. Predators including pikeminnow, striped bass, black bass, and American shad from the lower Yuba and Feather Rivers cannot pass the Daguerre Point Diversion Dam. Jeff Kozlowski (Jones and Stokes Associates, personal communication) also theorizes that prickly sculpin populations are limited above Daguerre Point Dam because the dam limits their upstream movement. He further hypothesizes that young trout are rare below Daguerre Point Dam due in part to high densities of prickly sculpin (competition and predation). Furthermore, native suckers and tule perch cannot pass the diversion dam on the Yuba, thus further limiting competition effects on the species of the Rainbow Trout Assemblage in the river above the dam.

We concur with Moyle that the tailwater habitat of the LAR has a structural diversity and habitat and environmental gradients that limit the Rainbow Trout Assemblage and thus wild steelhead production. One of these factors may be spawning habitat quantity and quality. The reason may be a lack of structural landscape diversity and natural disturbance processes such as gravel recruitment (CALFED 2000; Ward and Tockner 2001). One rare feature is islands and their associated side channels. Many islands have been lost to flood scour or have been purposely destroyed to improve the flood bearing capacity of the river. Habitat in the lower river has been greatly altered by bank protection and levees. Bars in the upper river hold the scars of the dredger mining. Cavallo et al. (2003) had similar conclusions for the lower Feather River in explaining why young trout were confined to only the upper mile of the river near the hatchery. We snorkeled these habitats in the lower Feather River with the DWR crews in 2002 prior to conducting our surveys in the American and also observed most young trout were confined to habitat units in side channels of the Low Flow Channel near the Feather River Hatchery. In both the American and Feather rivers floodplain connectivity has been greatly altered. Ward and Tockner (2001) noted that maximum species diversity occurs when there is an optimal mix of patch and edge habitat where rivers and their floodplains interact to a great extent.

Another consistent problem for the LAR is marginal water temperatures during steelhead egg incubation. With most spawning occurring from February through early April, the incubation temperature at times exceeds the 12°C to 15°C upper range for salmonids.

Potential to Restore Salmonid Habitat

Because the LAR is a highly disturbed river with altered sediment transport, channel morphology and dynamics, river flow, and riparian habitat, restoring the river to proper function for steelhead and salmon production is no easy matter. From ours and other surveys it is apparent that the LAR lacks good spawning and rearing habitat for salmon and steelhead. What habitat types offer the best return are presently unknown. Snorkel surveys that relate fish density to specific habitat types under varying flow regimes in the LAR offer a way of relating flows to habitat improvements and salmonid production. With more information on the relationship between habitat and smolt production, we will be able to plan and prioritize habitat restoration.

Based on the 2003-2005 survey results, we believe site specific HSC for trout and salmon could be developed. By studying units under different flow regimes we can relate HSC value of habitat units to flow. A similar recommendation for site-specific stage discharge relationships came out at the LAR Function Analysis Workshop (Workshop notes 2002). We believe this would be a reasonable alternative to the standard PHABSIM approach to IFIM habitat studies for the purpose of determining optimal flows or alternative habitat restoration for the LAR (such a study was undertaken in the early 1980’s by the FWS). Our suggested approach may be easier for estimating habitat for multiple species and life stages particularly when flow and habitat vary substantially among and within years. Coupled with habitat mapping we can relate flow to habitat availability to determine what habitats are limiting at different flows. We plan to test such an approach on the Stanislaus River in summer 2006.

We also believe the approach has utility to be applied in other Central Valley streams particularly those that have regulated hydrology regimes. While each stream is likely to have specific habitat flow relationships, the basic approach should be adaptable to the circumstances of each stream. Like microhabitat associations, the mesohabitat relationships identified using habitats units of the size in this study should be reasonably consistent from stream to stream. The relationship between the habitat amount and salmonid and other population levels may differ considerably. We believe this approach will overcome what Levy and Slaney (1993), Castleberry et al (1996), Kondolf et al (2000), and Williams (2000) refer to as significant difficulties in the understanding and modeling of freshwater rearing of salmonids.

Recommendations by Railsback et al. (1999) and the above researchers appear consistent with the approach adopted in this study. Railsback et al. propose dealing with this problem of scale mismatch by developing suitability data from observations in cells with a spatial scale comparable to the resolution of the hydraulic modeling. The challenge will be to make the cells the right size so that the habitat features are distinct and distinguishable among cells, and relatable to fish preferences. Kondolf et al (2000) recommended that this kind of understanding should be developed by careful observational studies. Williams (2000) suggests something along the lines of Jackson's (1992) snorkeling survey technique. We believe the answer is along the lines of the snorkeling design applied in this study.

If we can relate habitat value to populations, then it may be possible to manipulate habitat through restoration of the stream channel and floodplain to increase production at whatever flows are available. This will reduce the need to change flows to maximize habitat value and salmonid production under existing habitat conditions. Small changes in habitat may increase salmonid production without changing flow regimes.

Will habitat restoration in the LAR lead to improved populations of wild salmon and steelhead? Lewis et al. (1996) observed that habitat restoration has been at the autoecological level where habitat is constructed to provide shelter or food, but seldom for a net gain in production of the target species. He believes this is due to a lack of understanding as to how habitats link to populations. This is true for the LAR because we have no confirmed links between physical habitat and the production of salmon and steelhead. Such links can be developed by increasing habitat available and observing if there is a corresponding increase in production on a unit, site, reach, and river wide scale.

Production estimates and mortality rates could be related to habitat conditions and ultimately flow. Production could be related to habitat availability and perhaps to flow as accomplished by Marshall and Britton (1990) for Coho salmon production in a small stream. Evidence of density-dependent mortality can be sought. Habitat restoration actions could be related to potential production of young salmonids. With such information perhaps a consensus can be reached on the amount of flow necessary for rearing of young salmon and steelhead in the LAR, or the amount of habitat to be provided for specific flow regimes.

- We recommend that HSC be developed for each habitat unit or typed-groups by species and life stage, and that these relationships be combined for each species and life stage to define the total value of habitat for the LAR as a function of flow. We believe this approach will help to solve the many problems associated with IFIM as identified by Williams 1996, 1999, 2000; Kondolf et al. 2000, and Hatfield and Bruce 2000.

Several approaches along these lines are listed below:

1. Hardy et al. (2002) – Utah State University Institute for Natural Systems Engineering, Utah Water Research Laboratory - Applied spatially explicit 3-D channel topography and 2-D hydraulic modeling and substrate/cover mapping for Chinook fry habitat modeling. Instead of IFG4 modeling - Utilization of spatially explicit three-dimensional channel topographies in conjunction with two-dimensional hydraulic modeling and substrate/cover mapping provides new opportunities for fish habitat modeling. This paper describes the

conceptual development and application of a Chinook fry habitat model. The model is based on the integration of three-dimensional channel topographies including substrate and cover mapping with two-dimensional hydraulic solutions. The model explicitly incorporates a distance to escape cover component in addition to depth, velocity, and substrate characteristics at a location in the river channel. This model will be tested in summer 2006 on the Stanislaus River.

2. Railsbeck et al. (2003) – Humboldt State University – Individual Based Models that simulate habitat in 2-D units
3. Rosenfeld et al. (2000) – relating landscape-level attributes to snorkel counts.
4. Muhfeld et al. (2000) – relating habitat use determined from snorkeling to micro, meso, and macrohabitat in a large river. Such an analysis may show where restoration priorities should be.
5. Rubin et al. (1991) – developing HSC based on fish use of 2-D habitat units.

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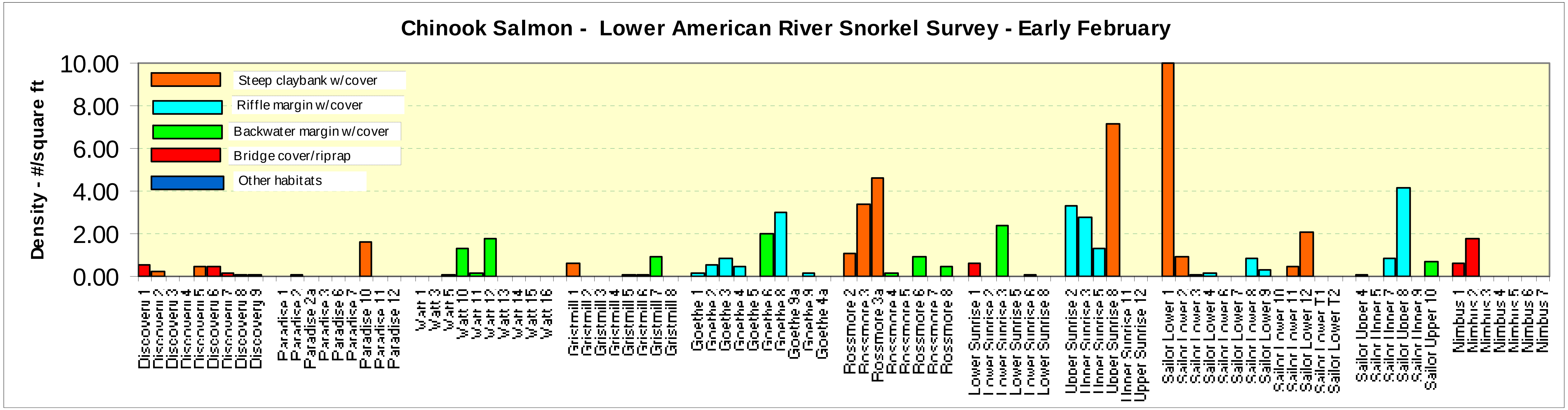
Charts

Appendices

Appendix A – Aerial and Other Photographs of Sampling Units

2003 Charts

Chart 1. Juvenile Chinook Salmon – February 2003



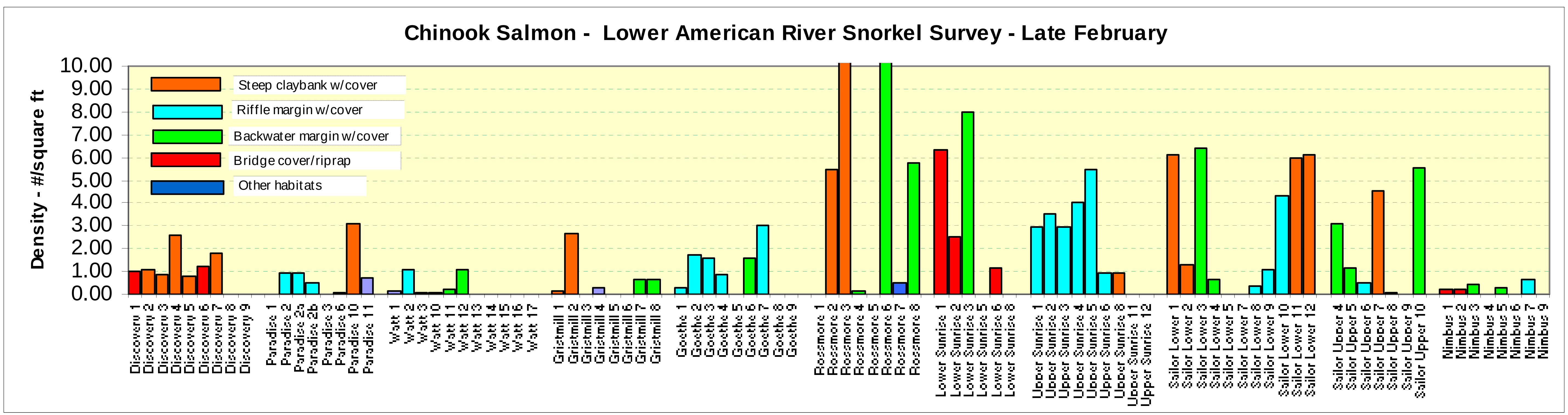
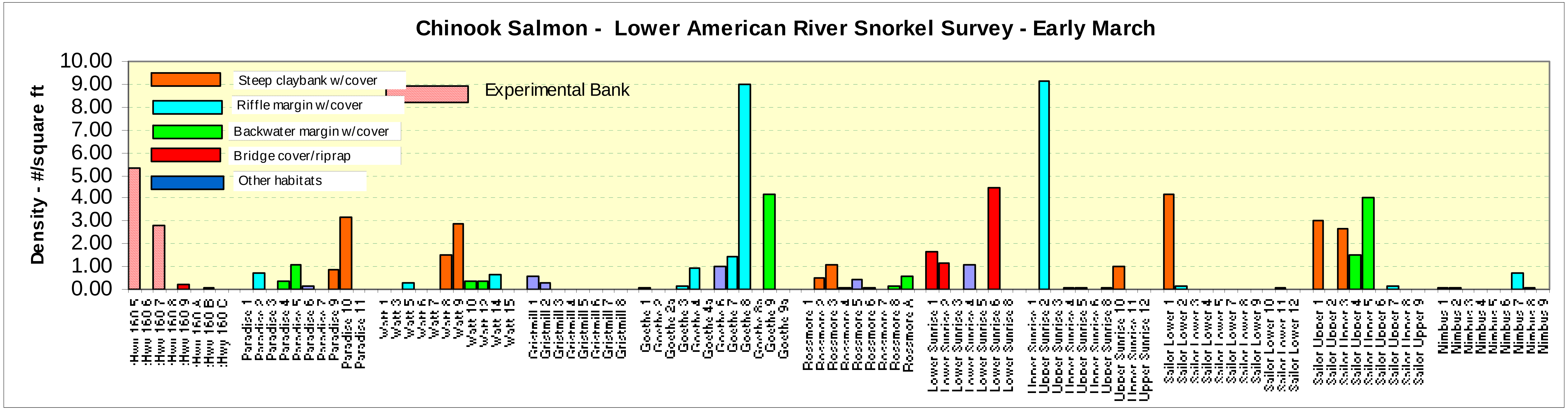


Chart 2. Juvenile Chinook Density – March 2003



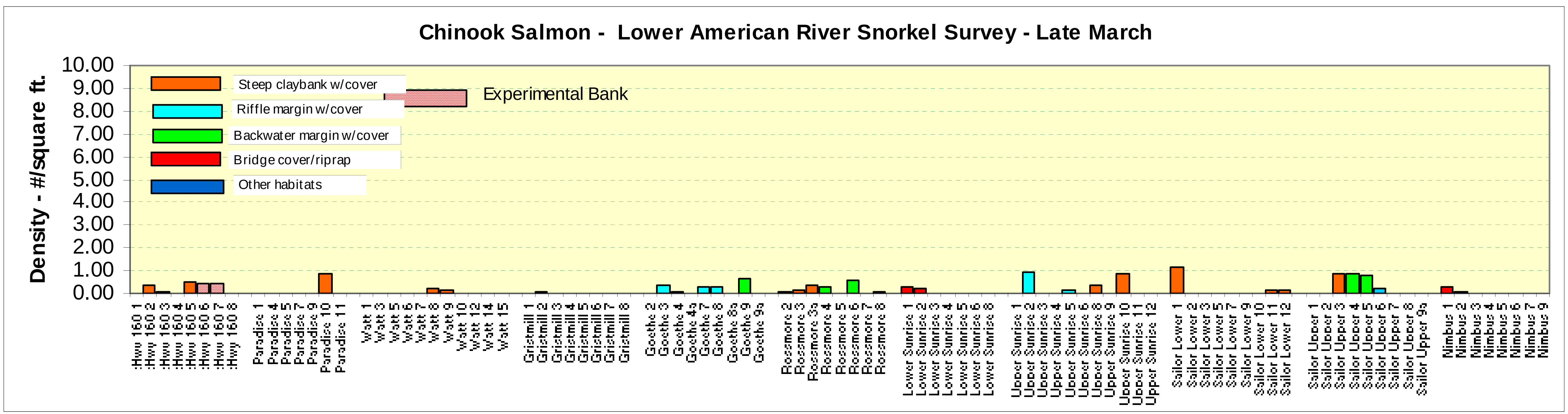
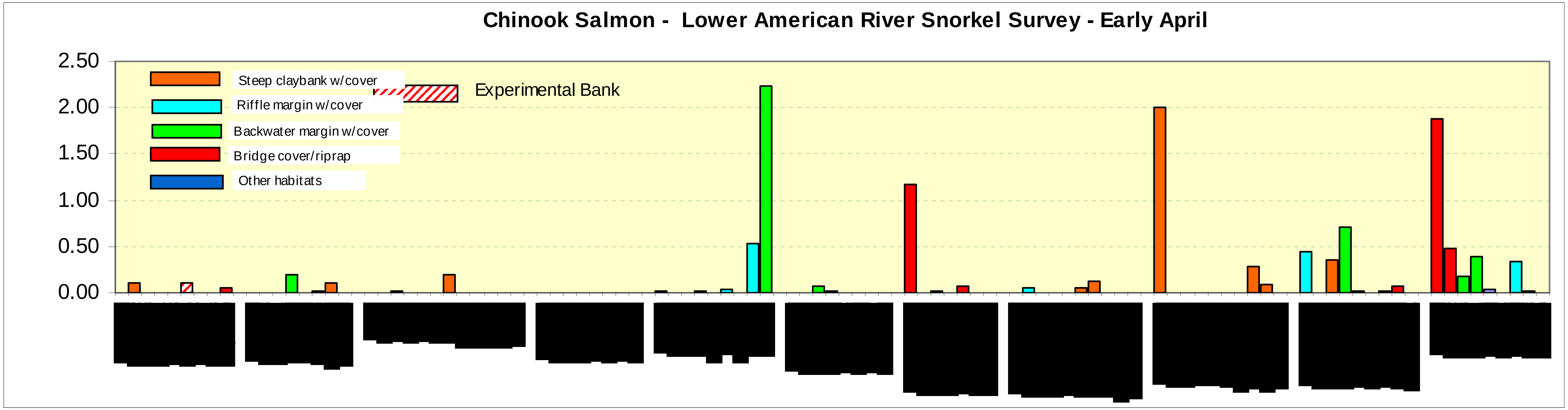


Chart 3. Juvenile Chinook Density – April 2003



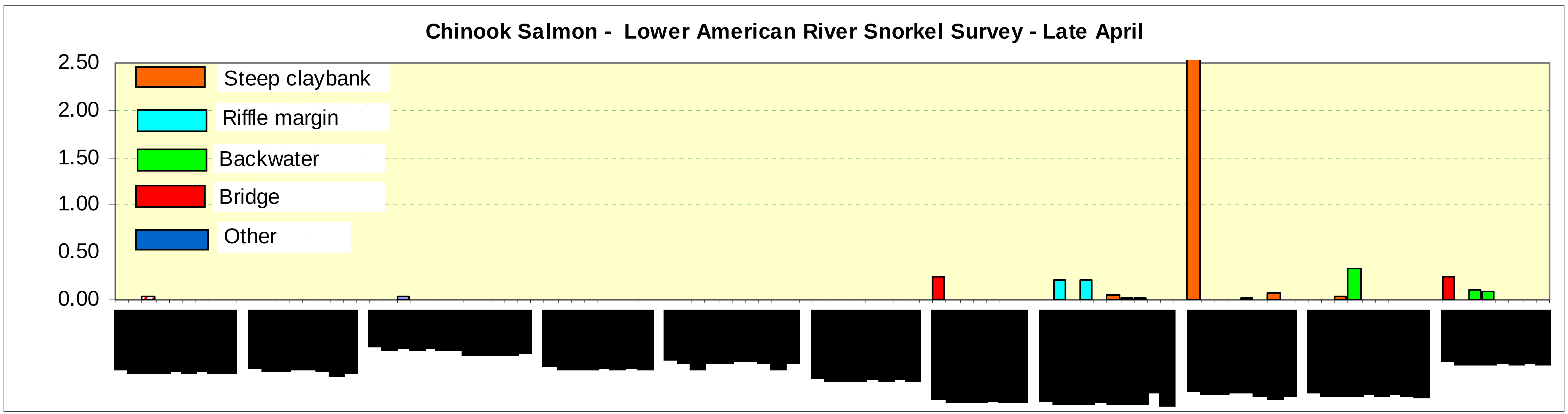
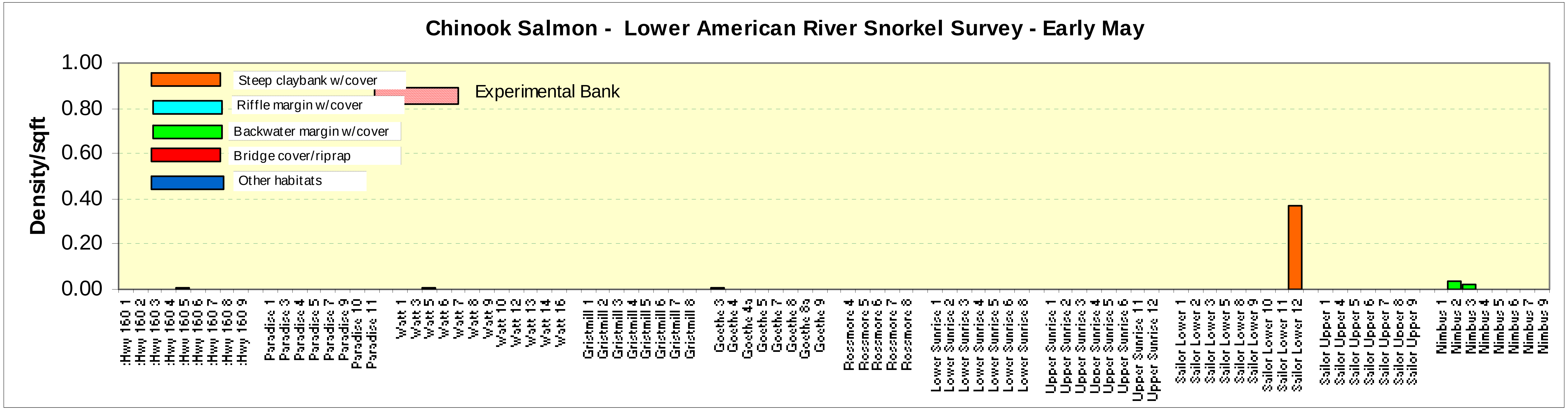


Chart 4. Juvenile Chinook Density – May 2003



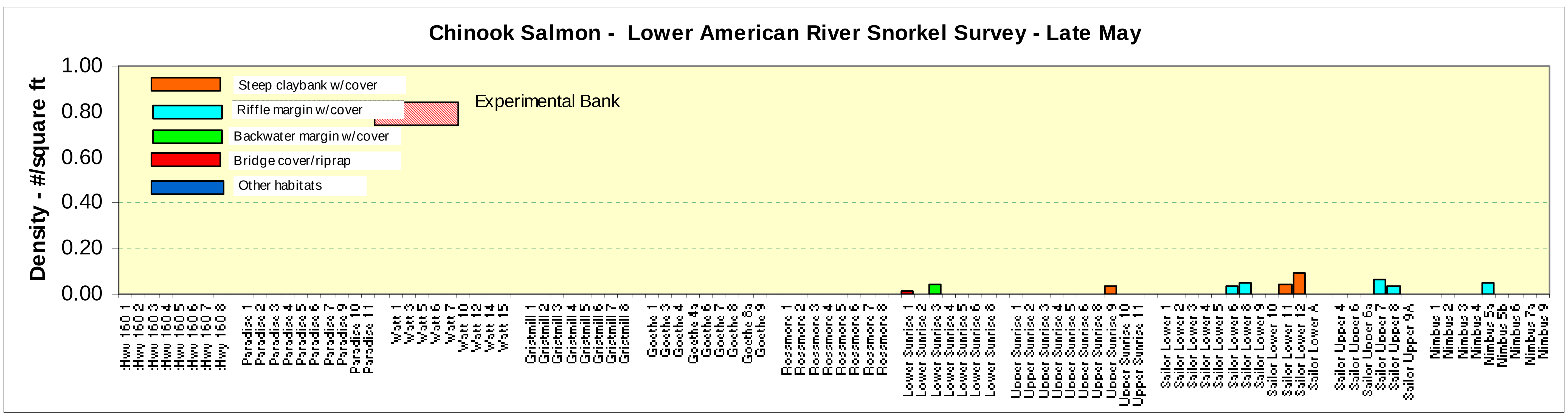
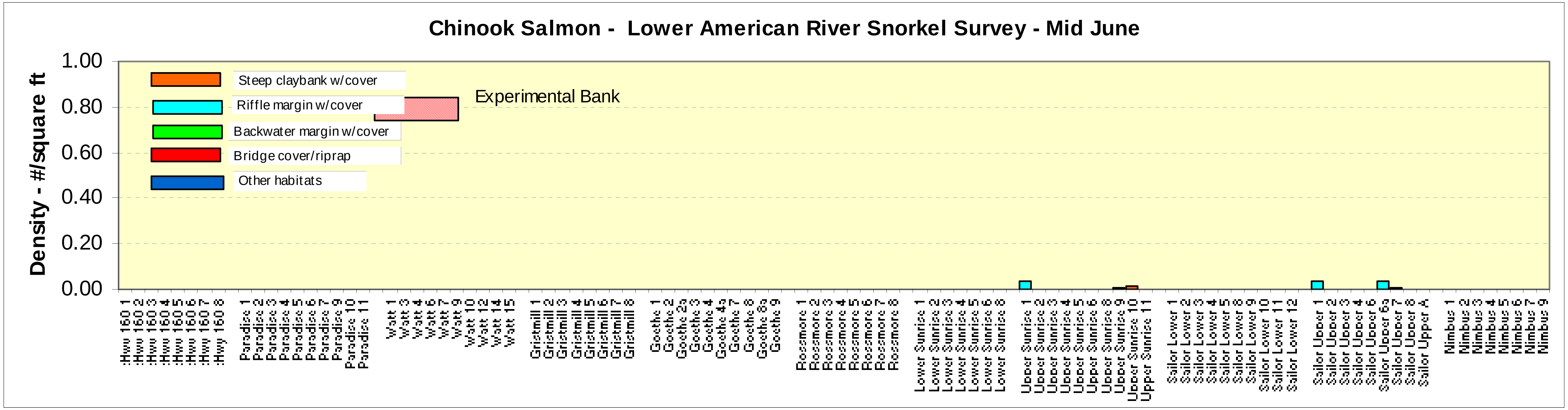


Chart 5. Juvenile Chinook Density – June 2003



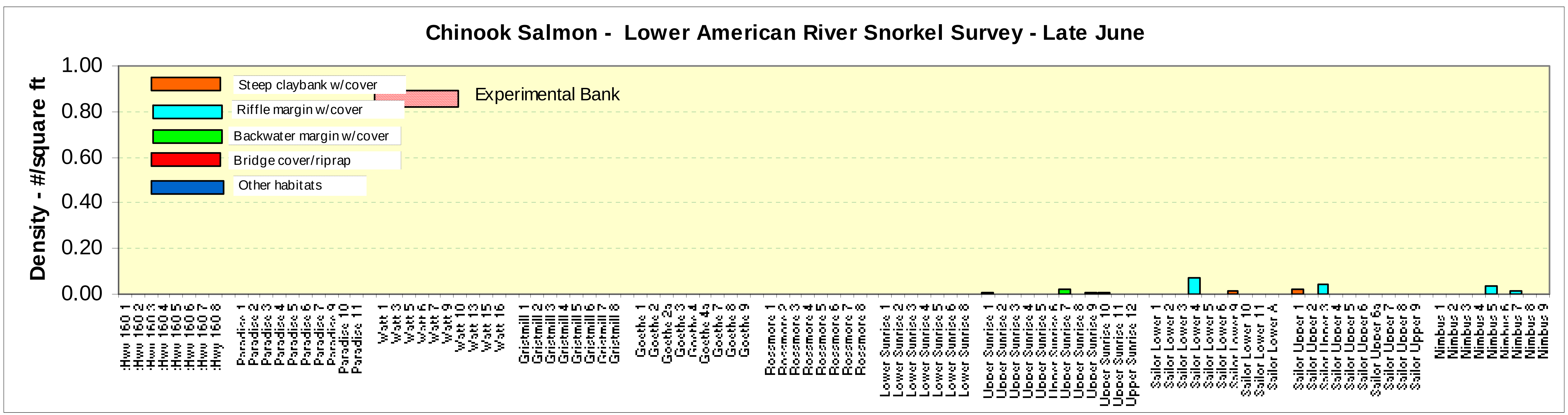
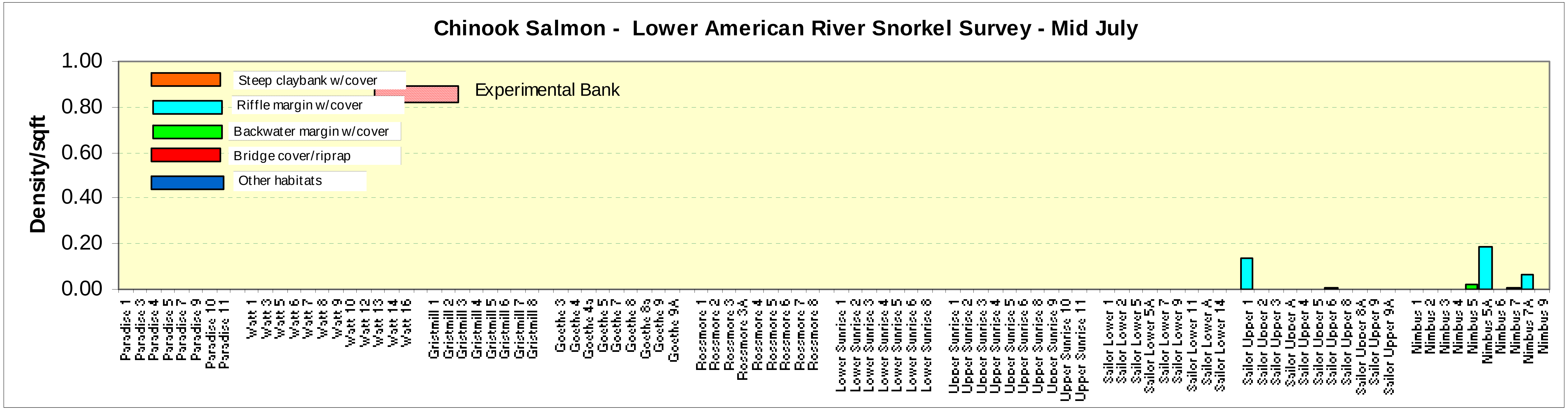


Chart 6. Juvenile Chinook Density – July 2003



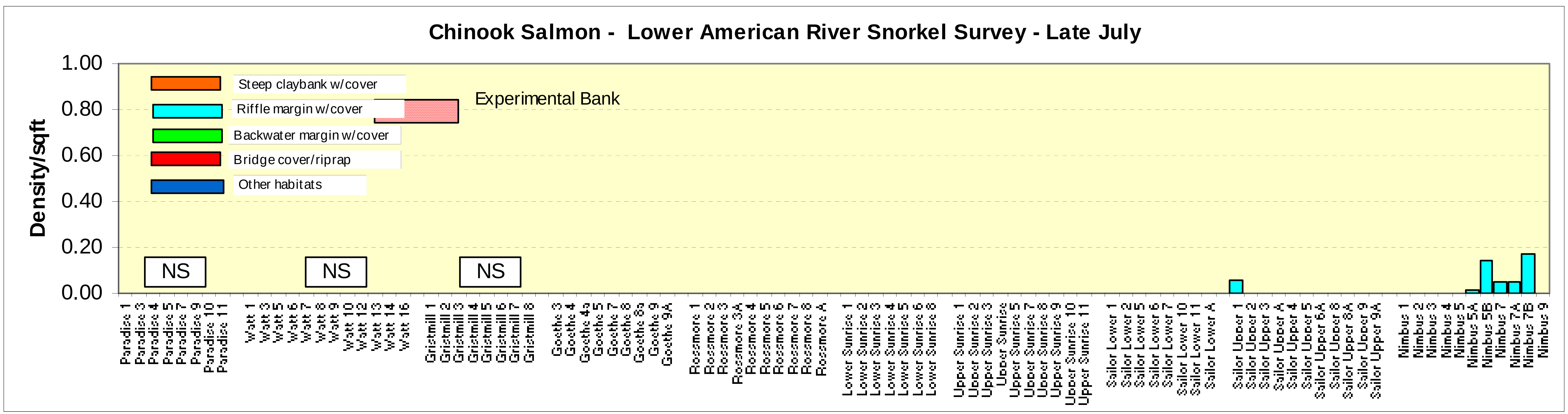


Chart 7. Juvenile Chinook – August 2003

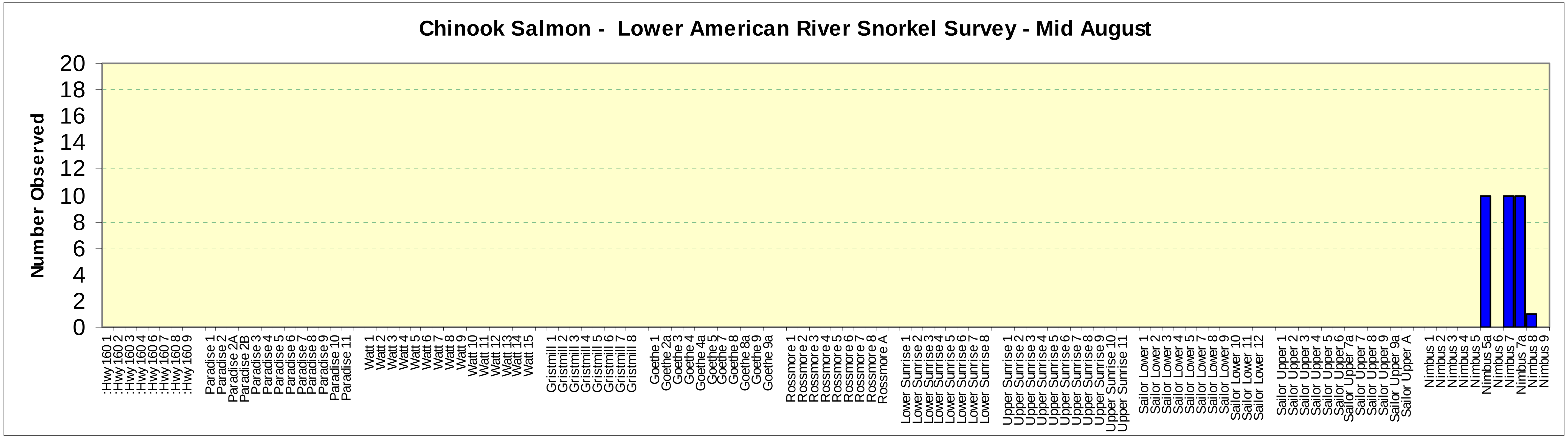
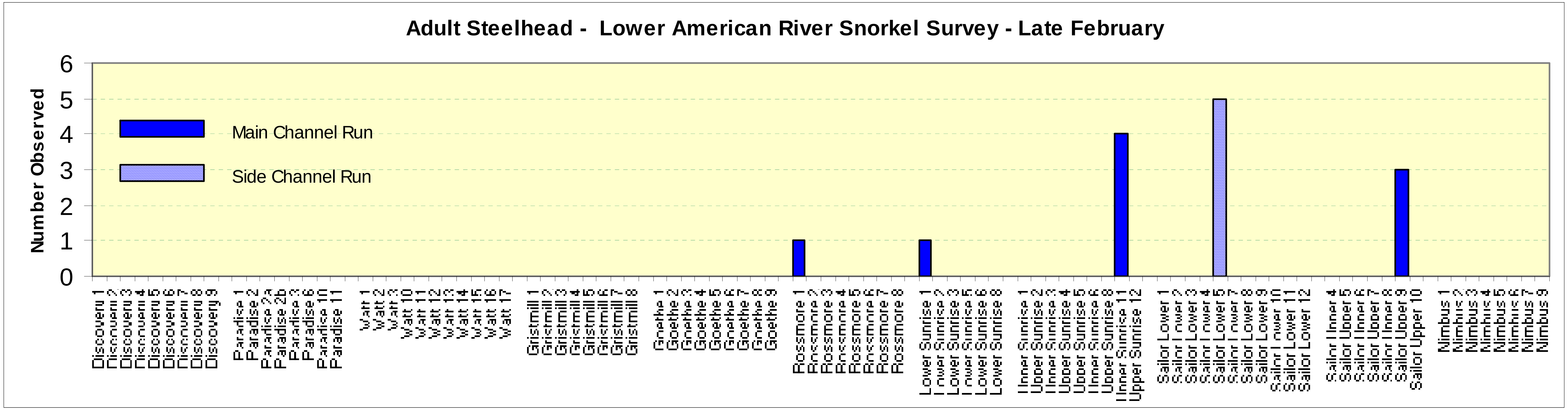


Chart 8. Adult Steelhead Feb-Mar 2003



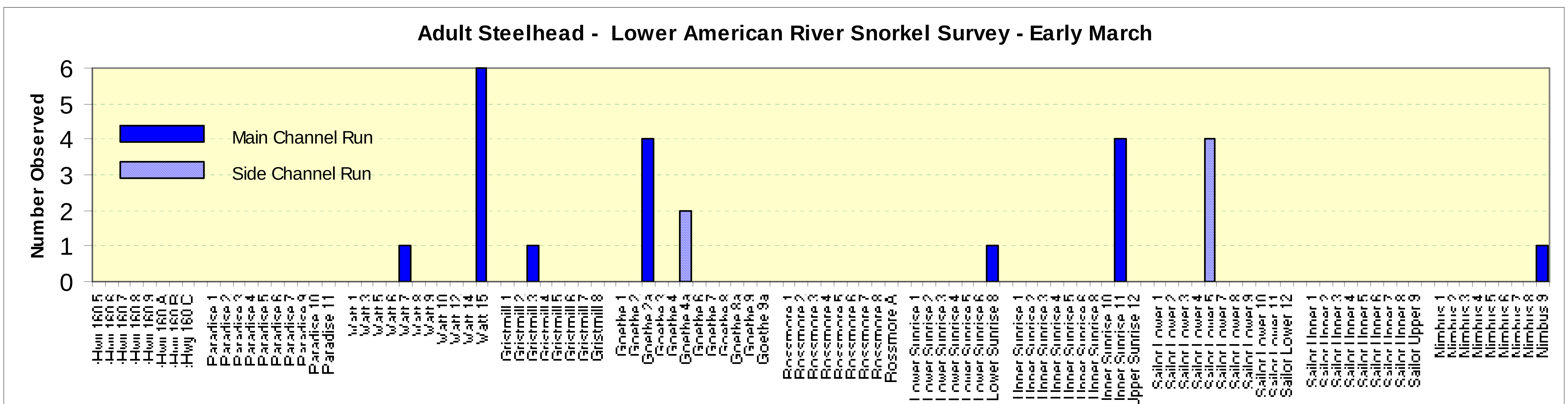


Chart 9. Juvenile Steelhead Density – March 2003

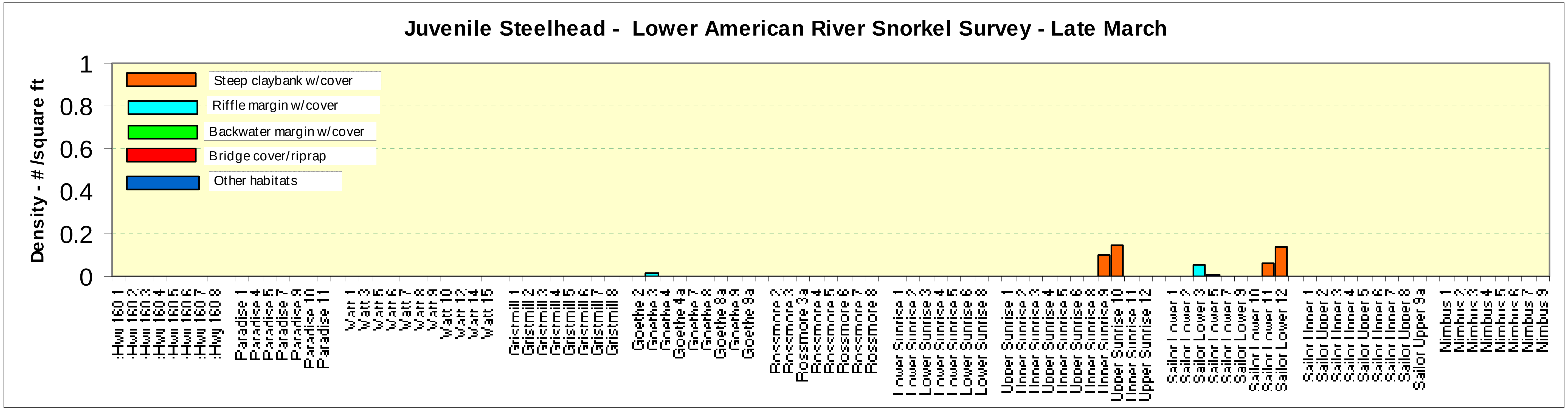
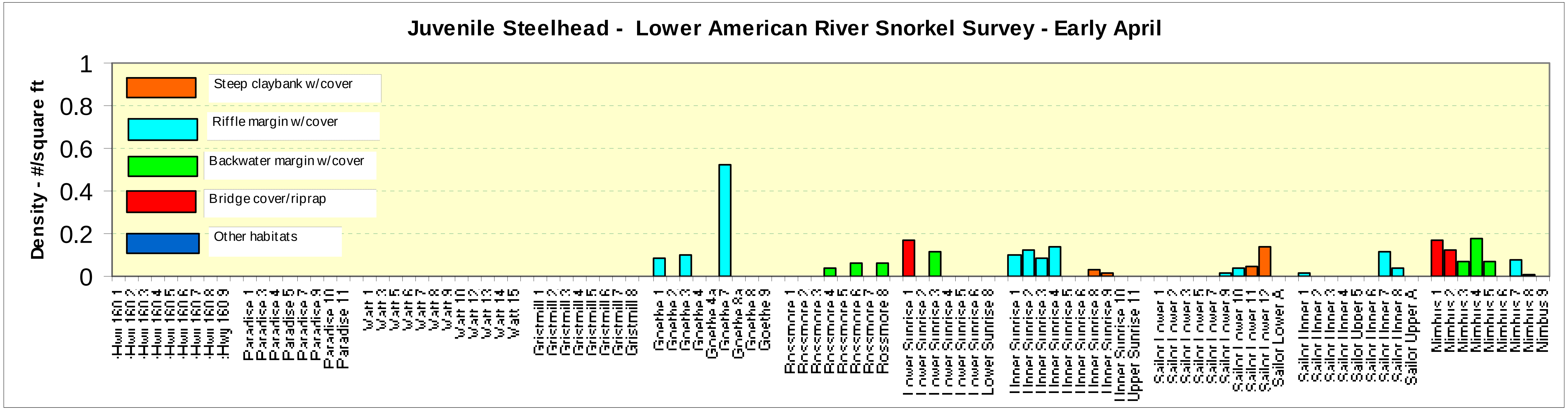


Chart 10. Juvenile Steelhead Density – April 2003



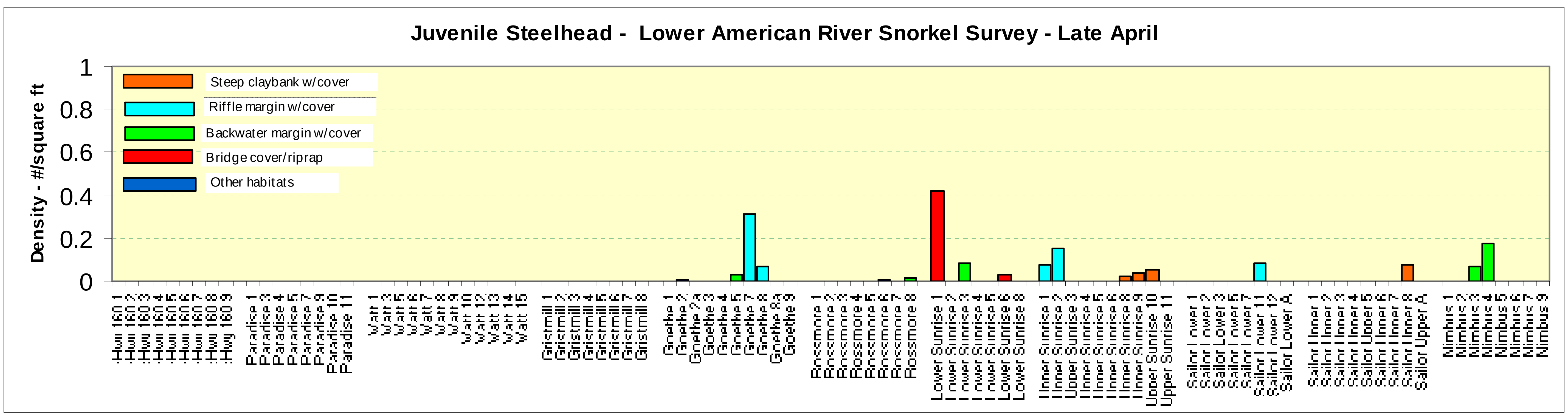
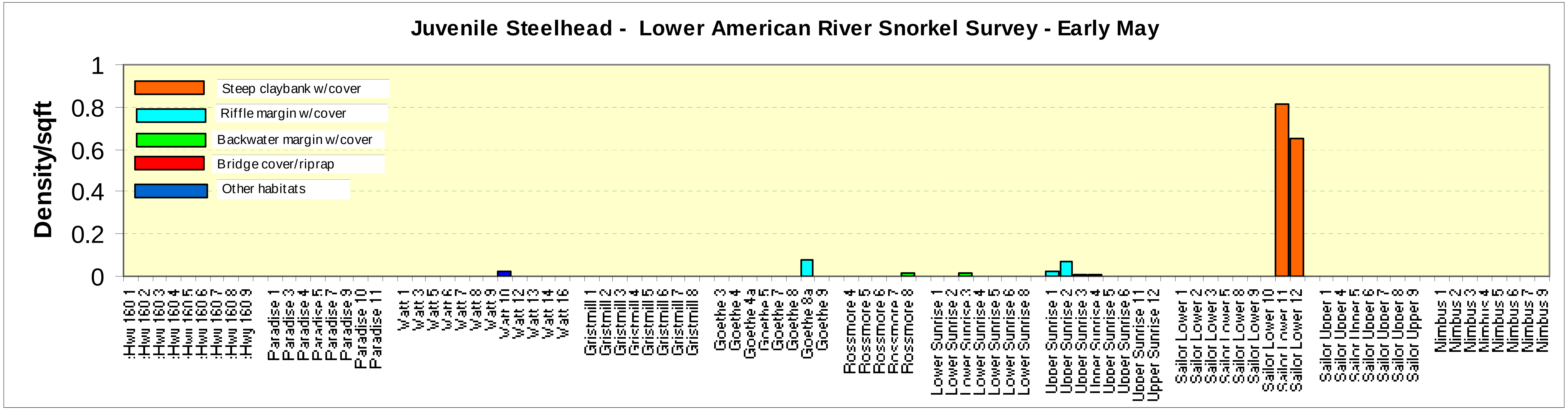


Chart 11. Juvenile Steelhead Density – May 2003



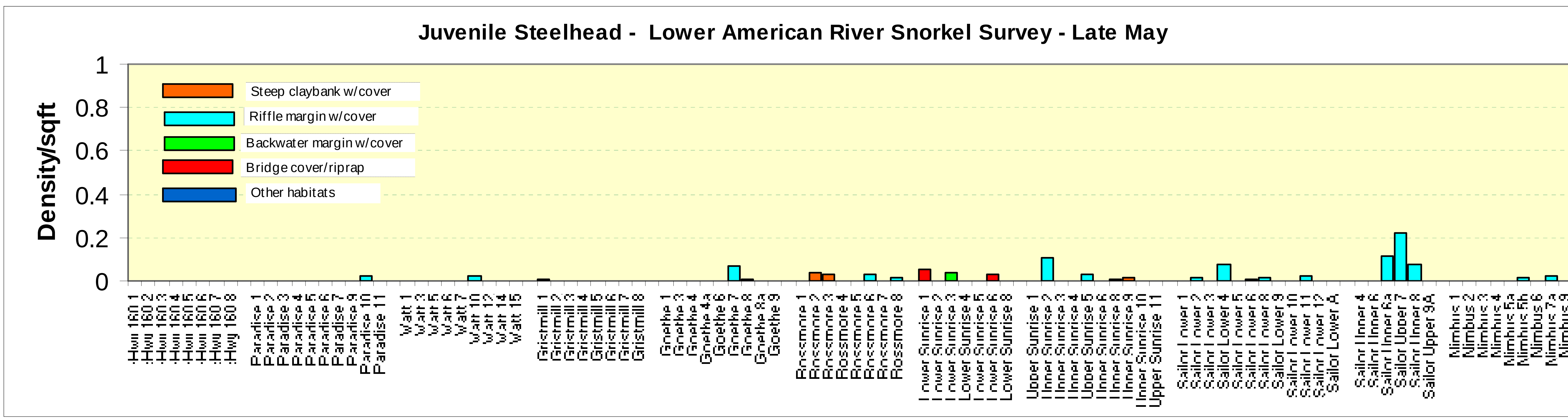
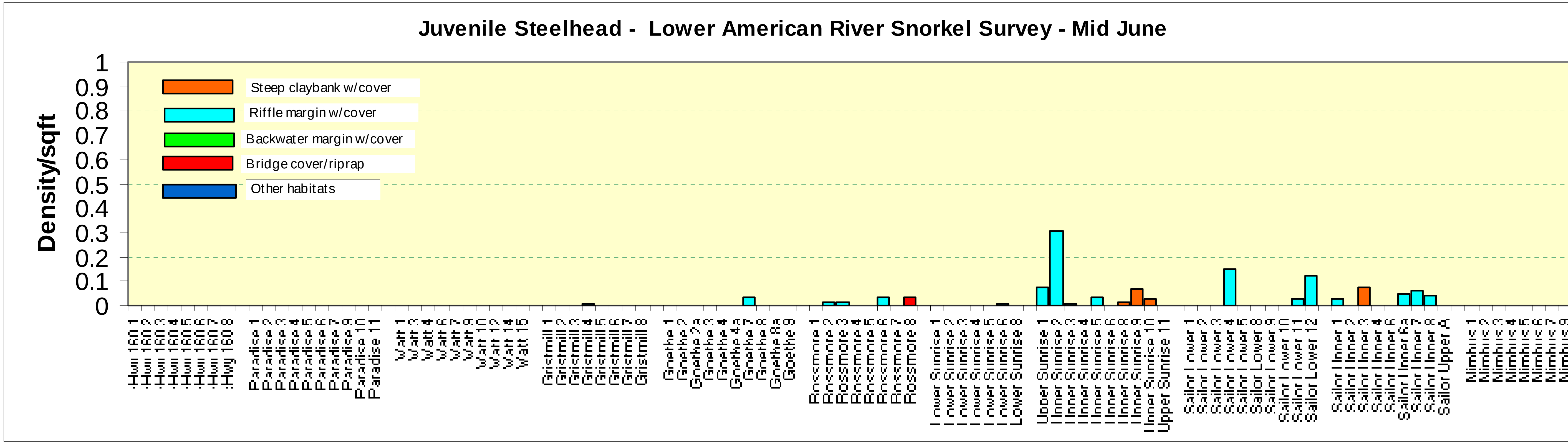


Chart 12. Juvenile Steelhead Density – June 2003



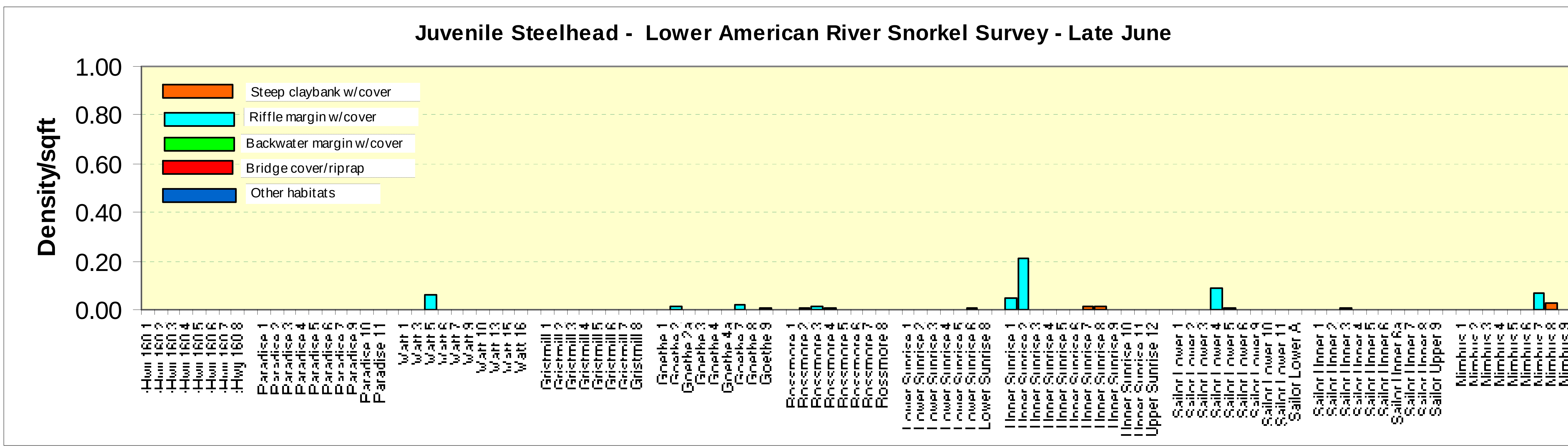
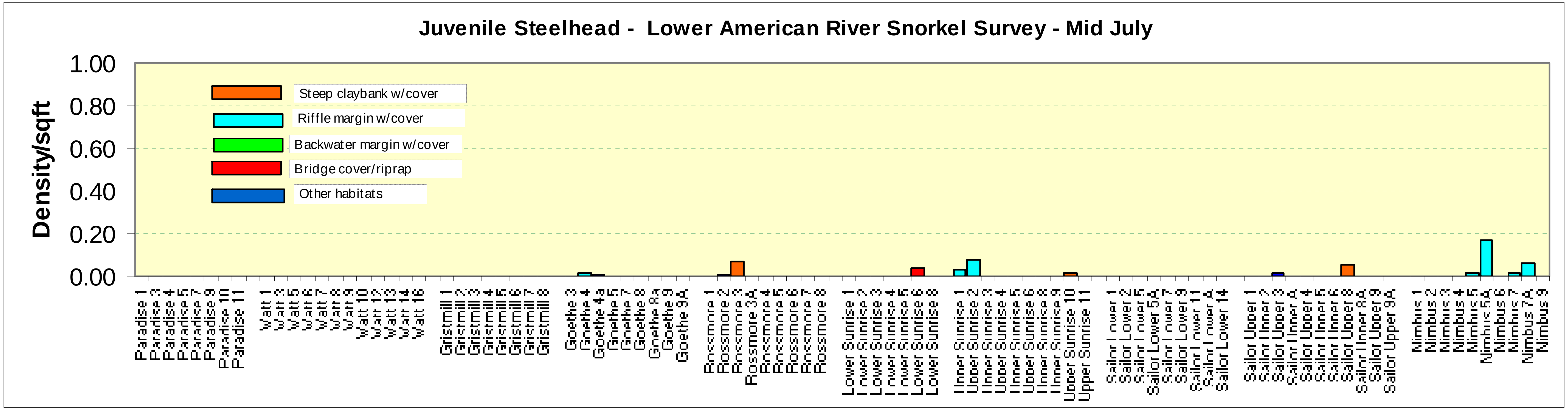


Chart 13. Juvenile Steelhead Density – July 2003



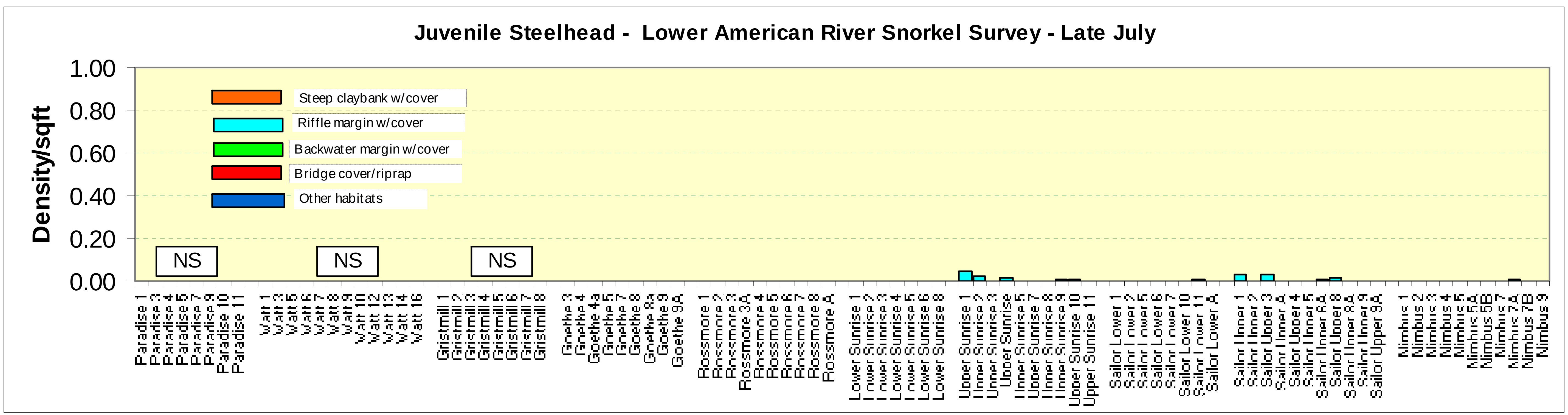


Chart 14. Juvenile Steelhead Number Observed – August 2003

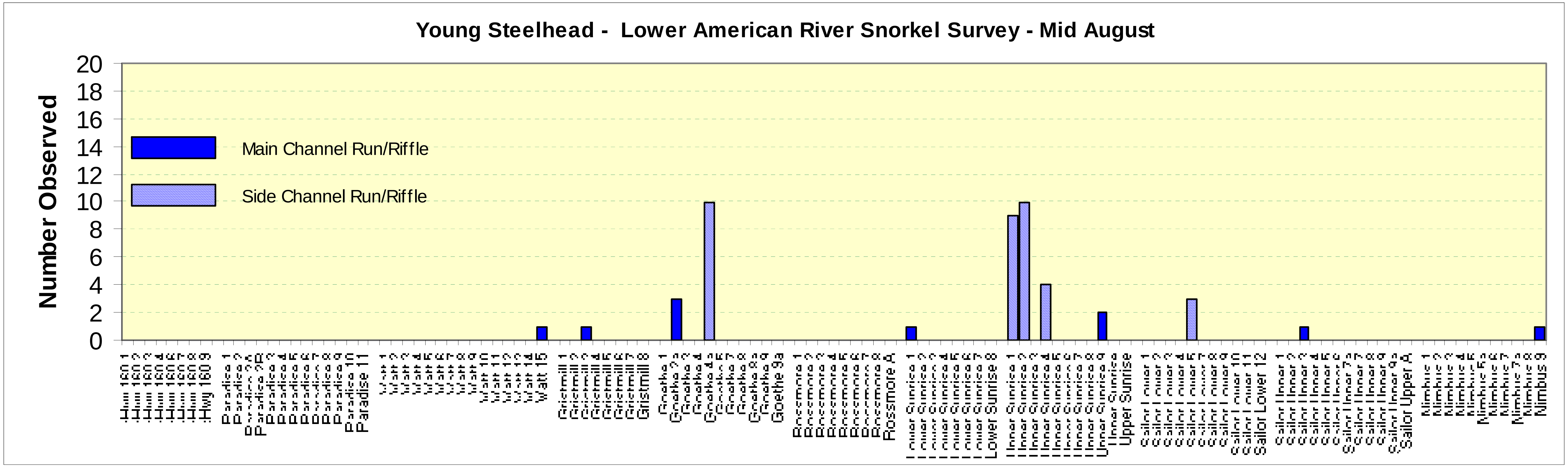
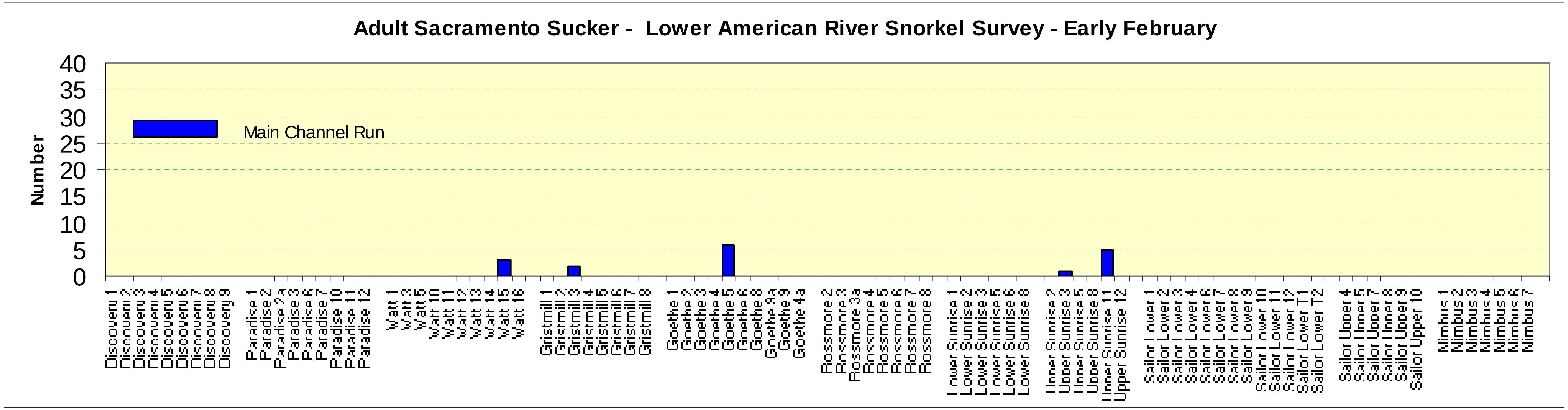


Chart 15. Adult Sacramento Sucker – February 2003



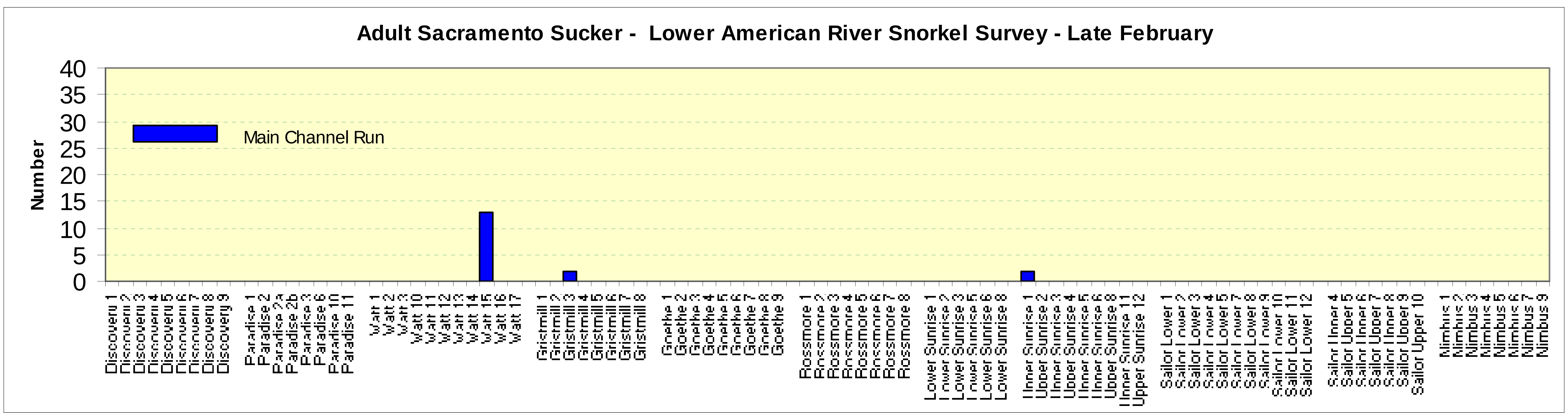
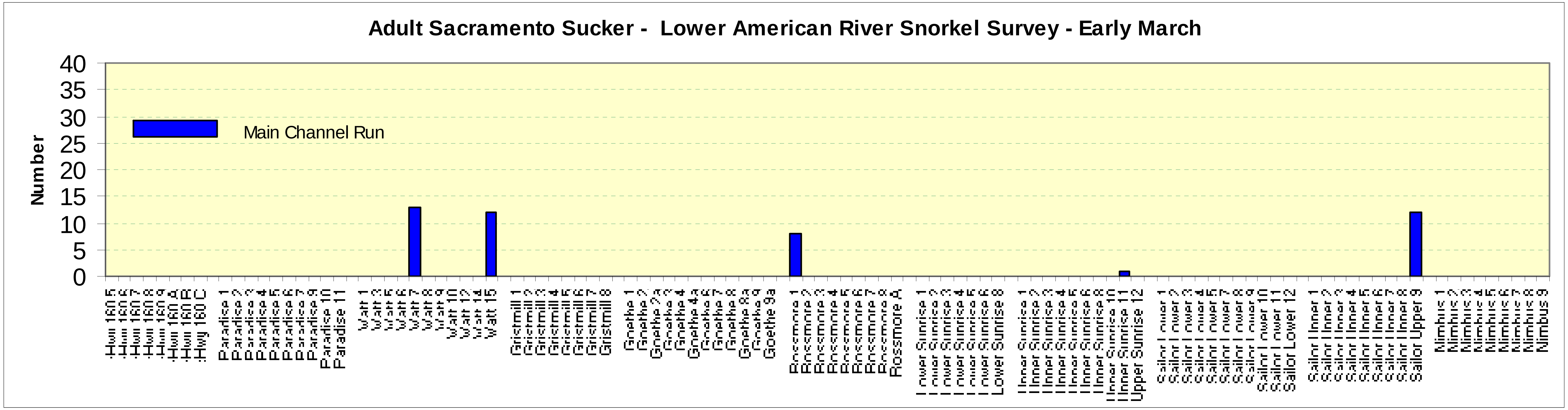


Chart 16. Adult Sacramento Sucker – March 2003



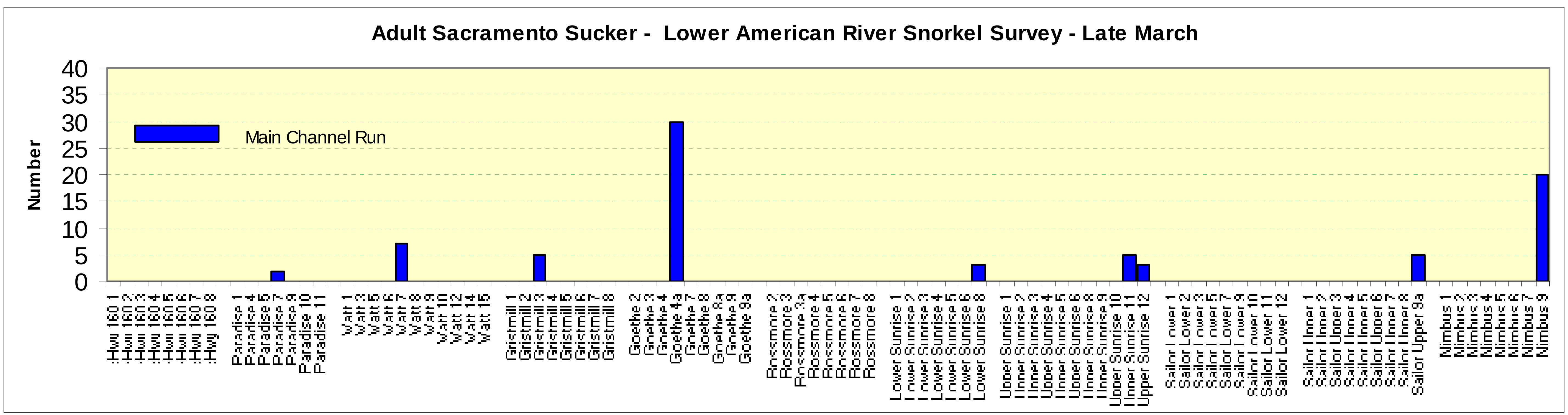
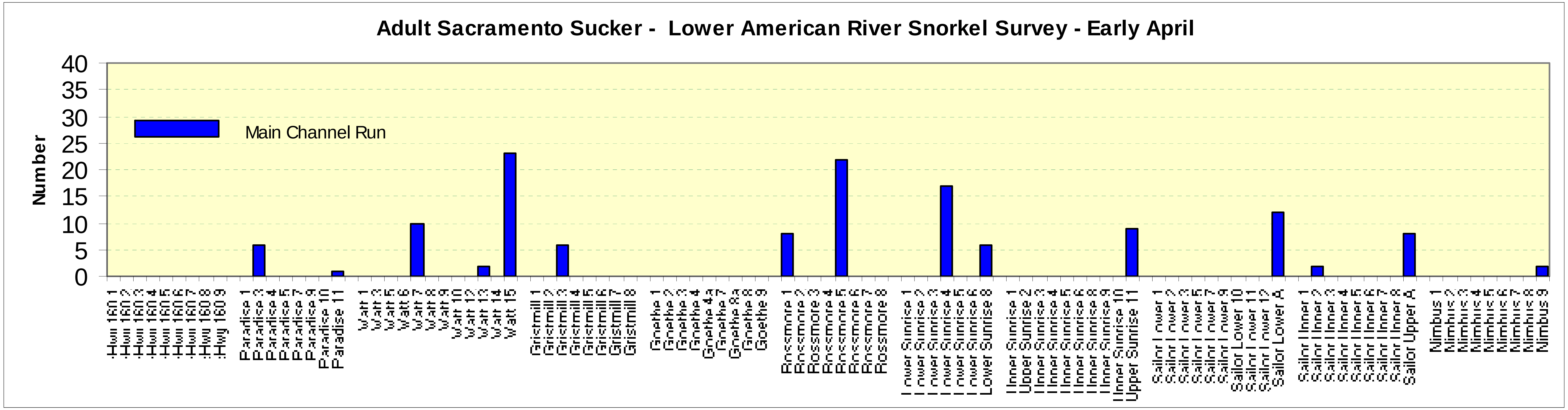


Chart 17. Adult Sacramento Sucker – April 2003



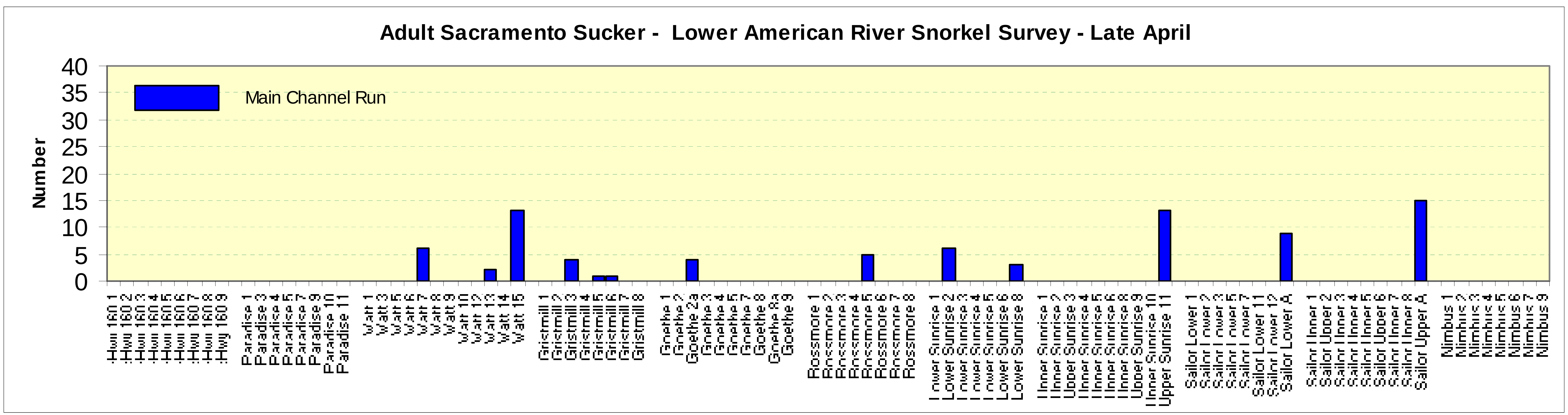
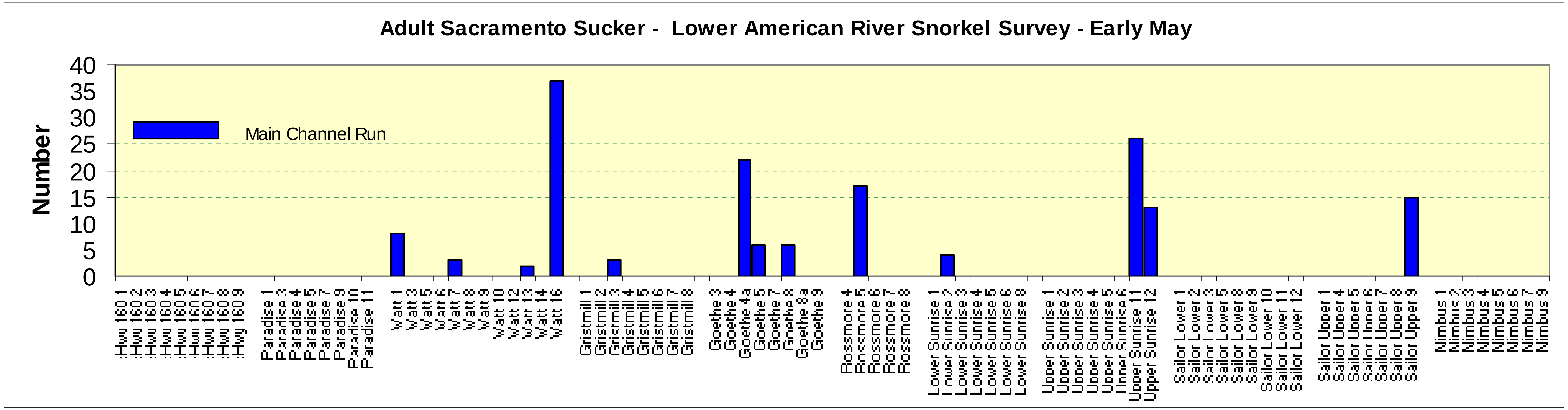


Chart 18. Adult Sacramento Sucker – May 2003



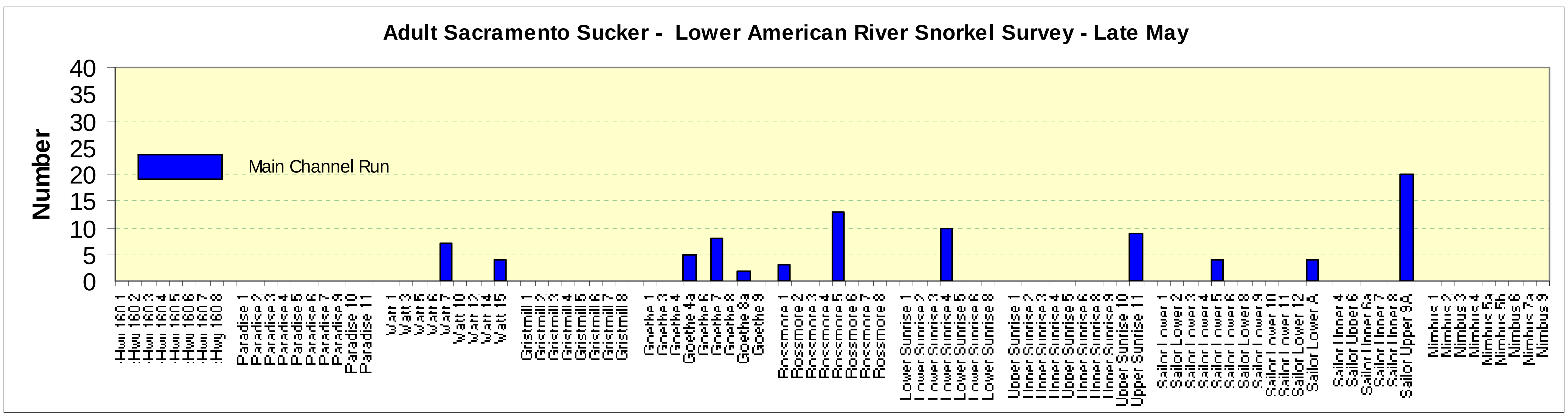
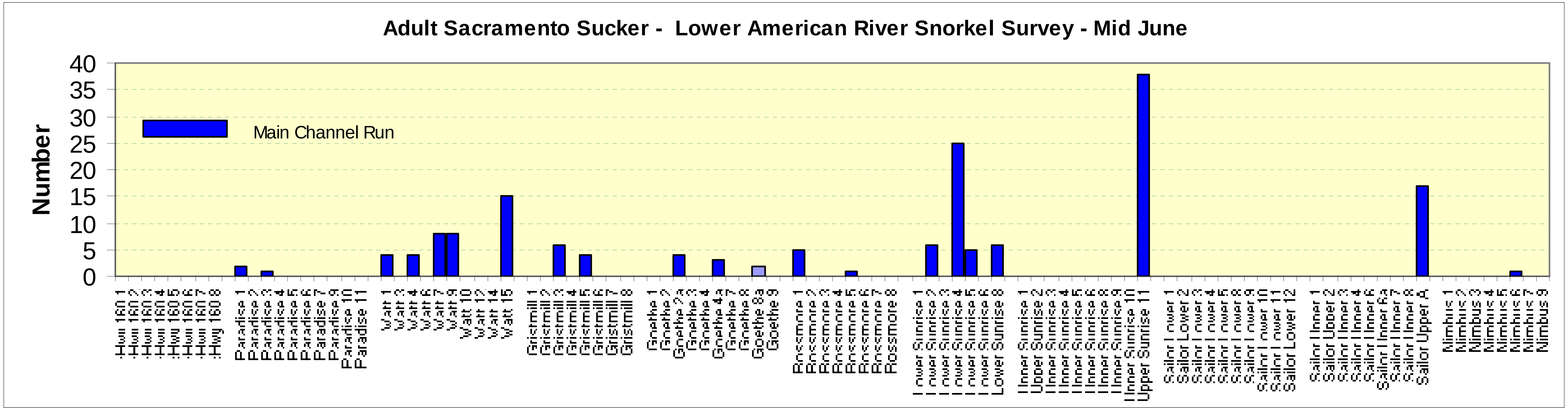


Chart 19. Adult Sacramento Sucker – June 2003



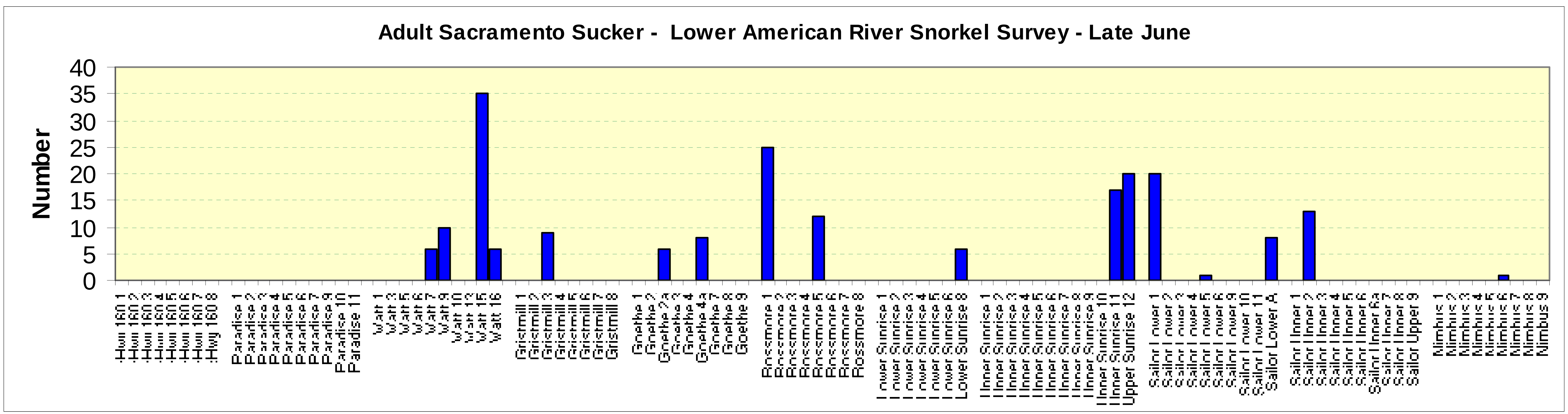
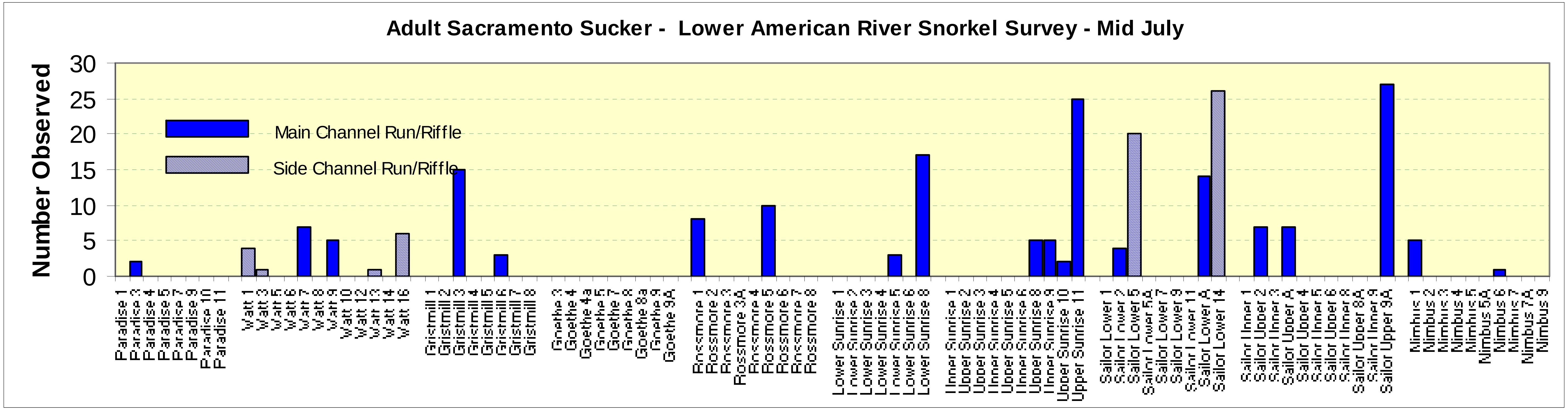


Chart 20. Adult Sacramento Sucker – July 2003



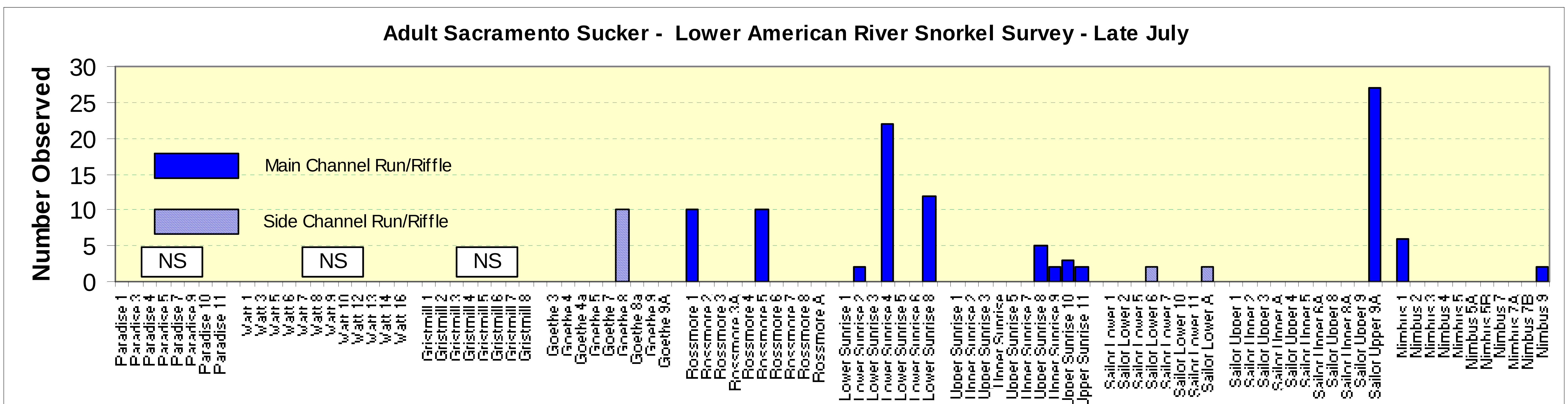
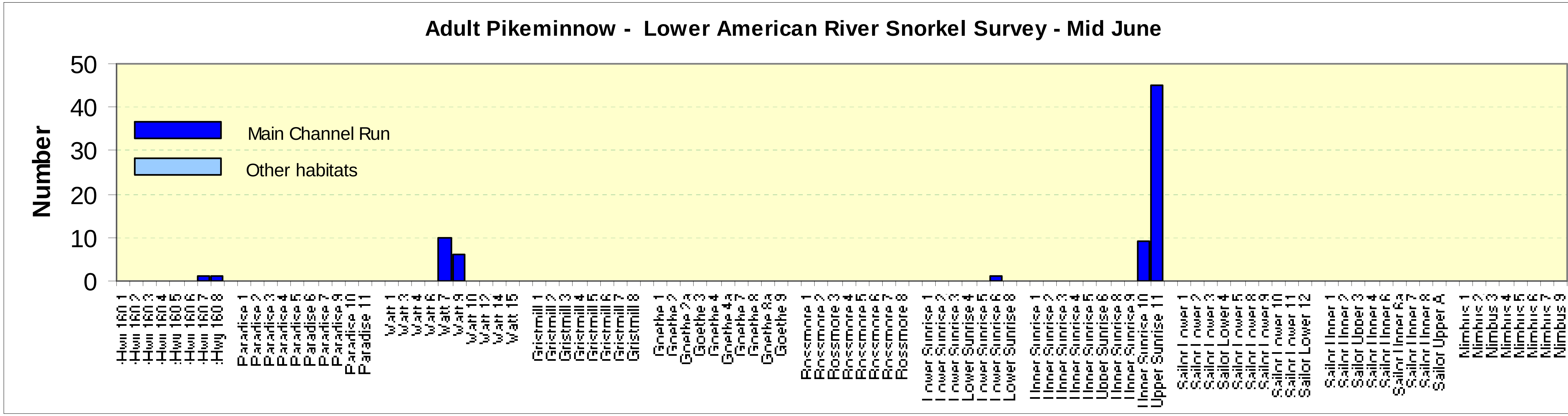


Chart 21. Adult Pikeminnow – June 2003



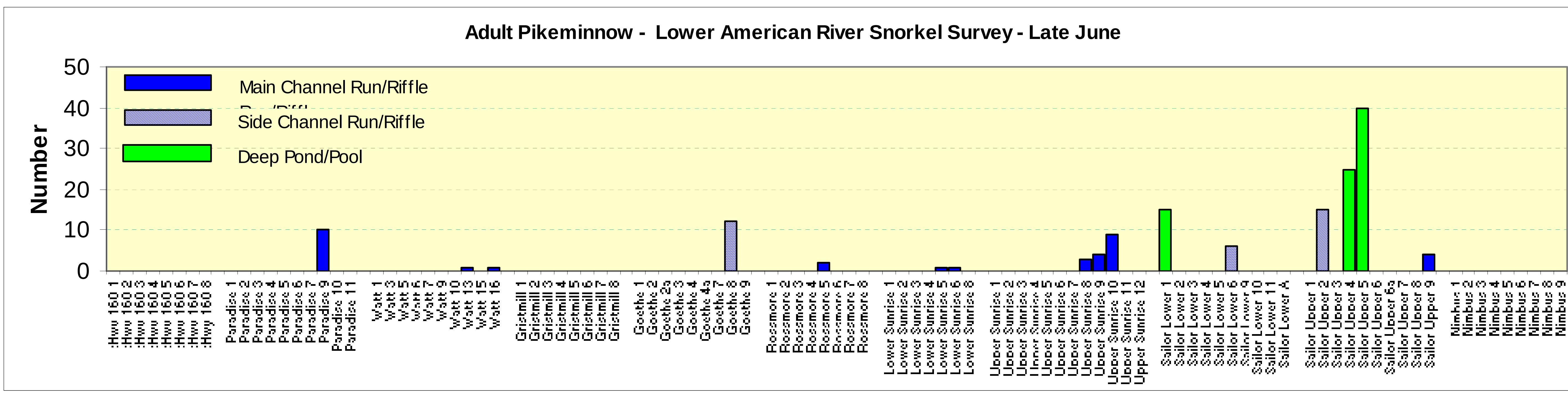
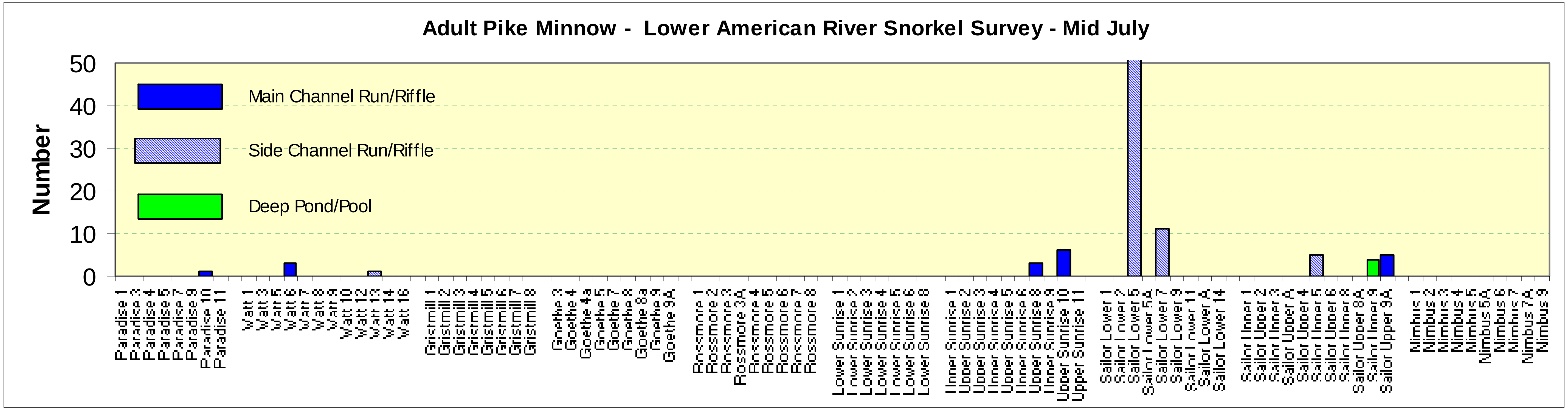


Chart 22. Adult Pikeminnow – July 2003



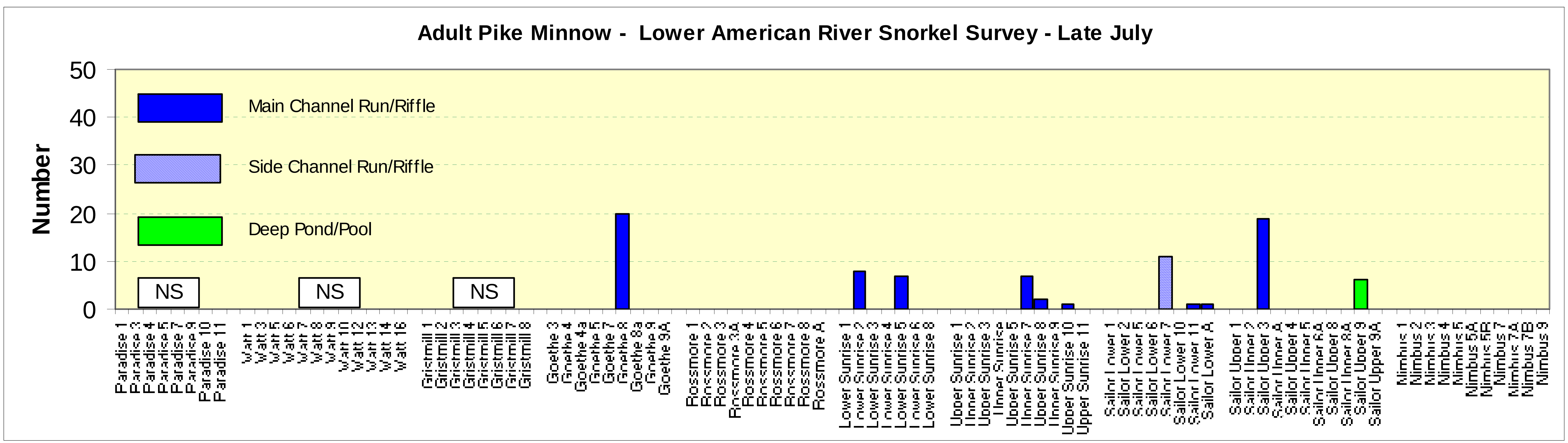
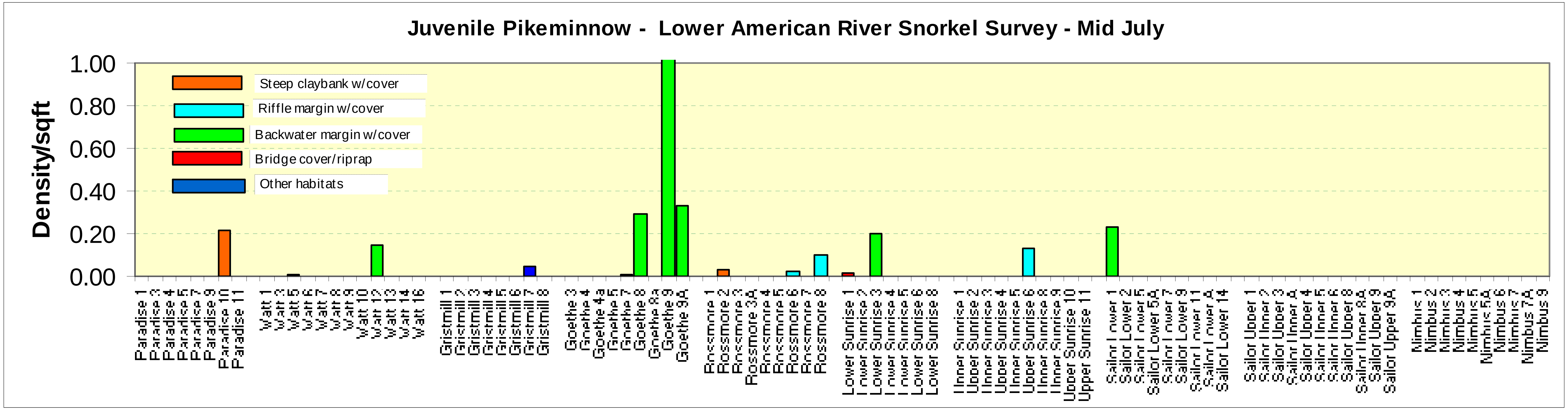


Chart 23. Juvenile Pikeminnow – July 2003



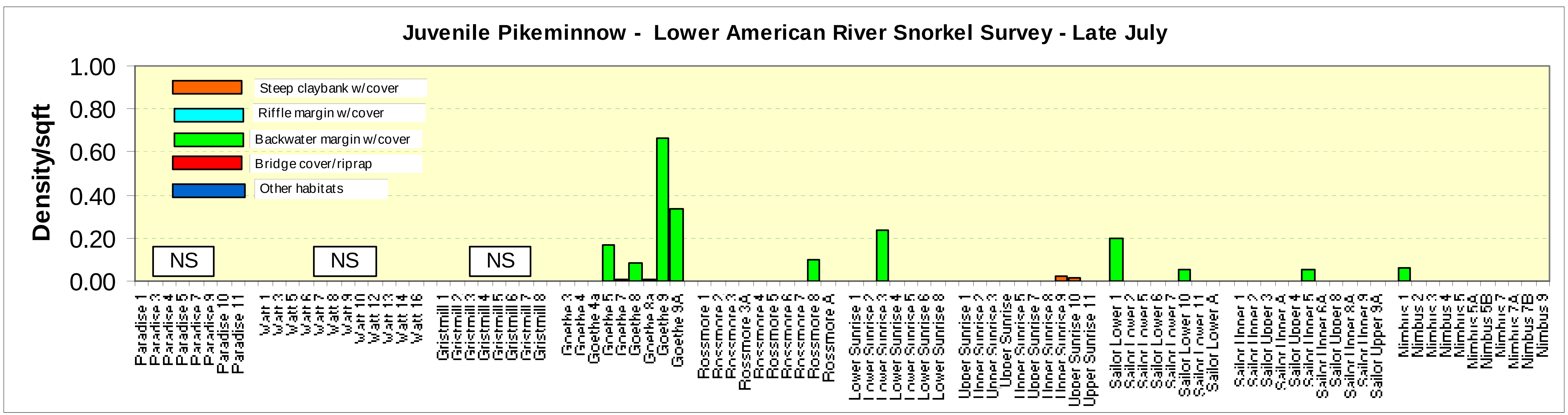
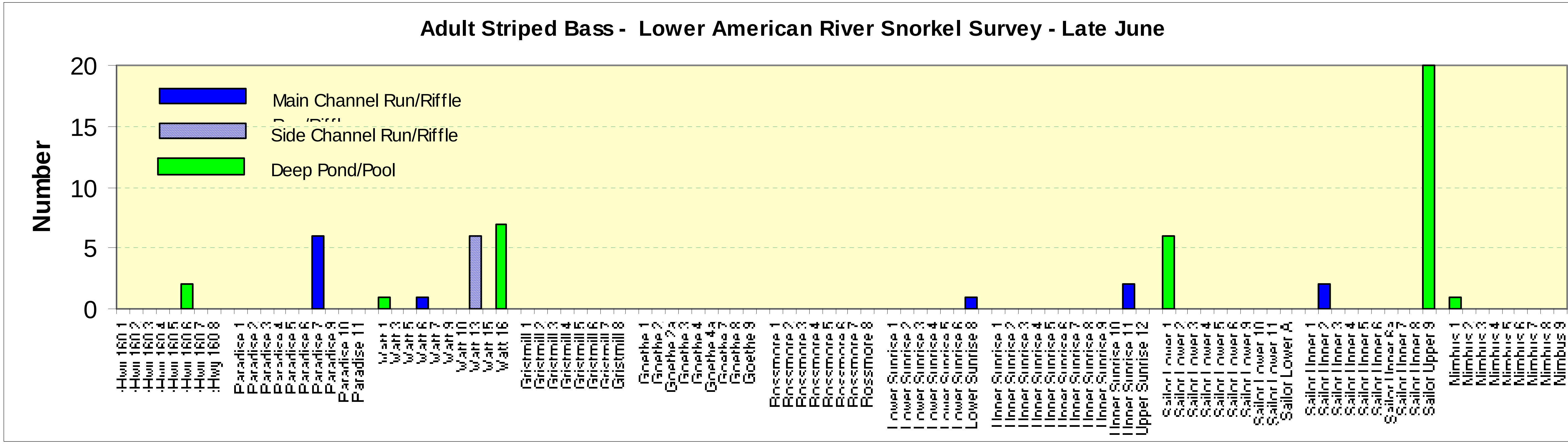


Chart 24. Adult Striped Bass – June-July 2003



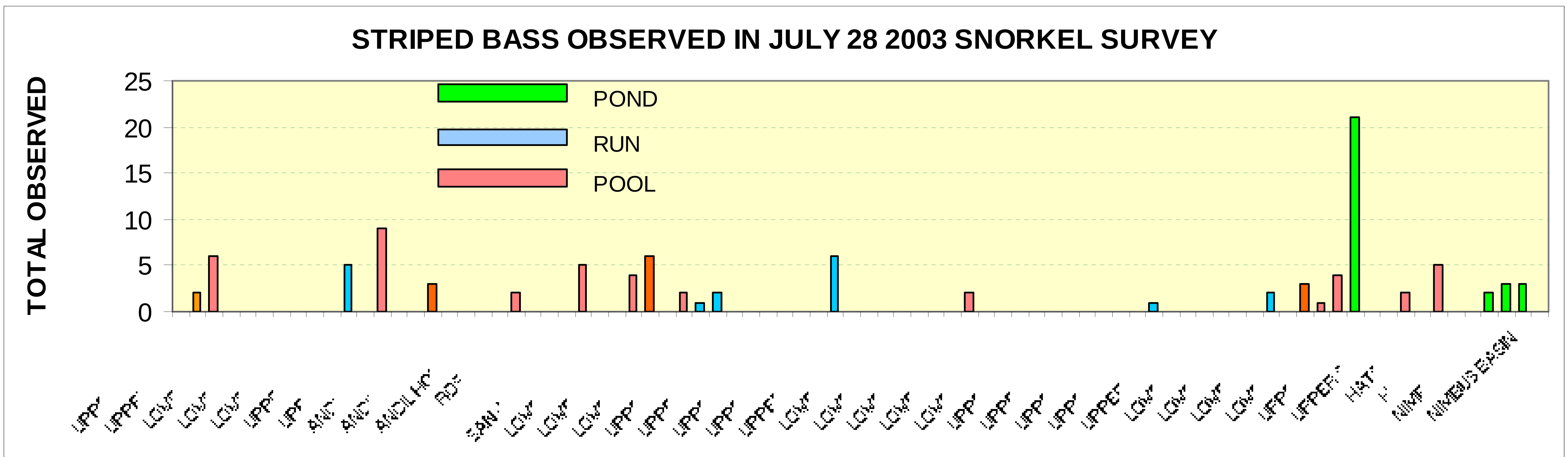


Chart 25. Juvenile Sacramento Sucker – August 2003

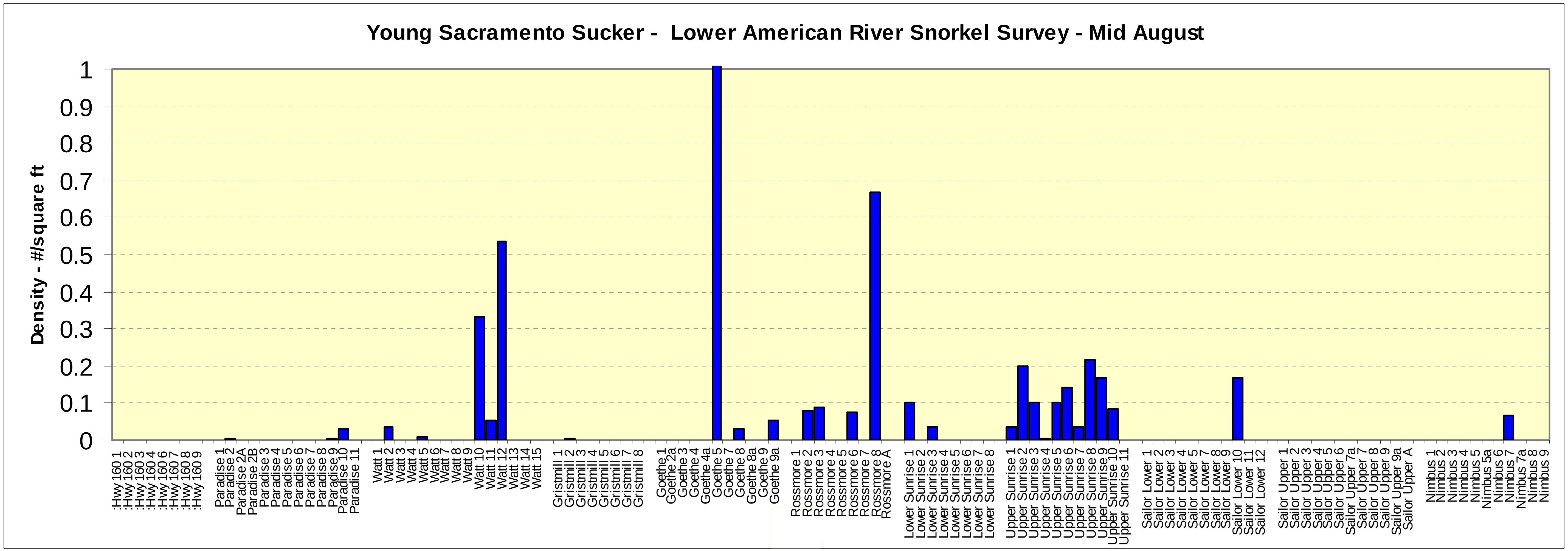
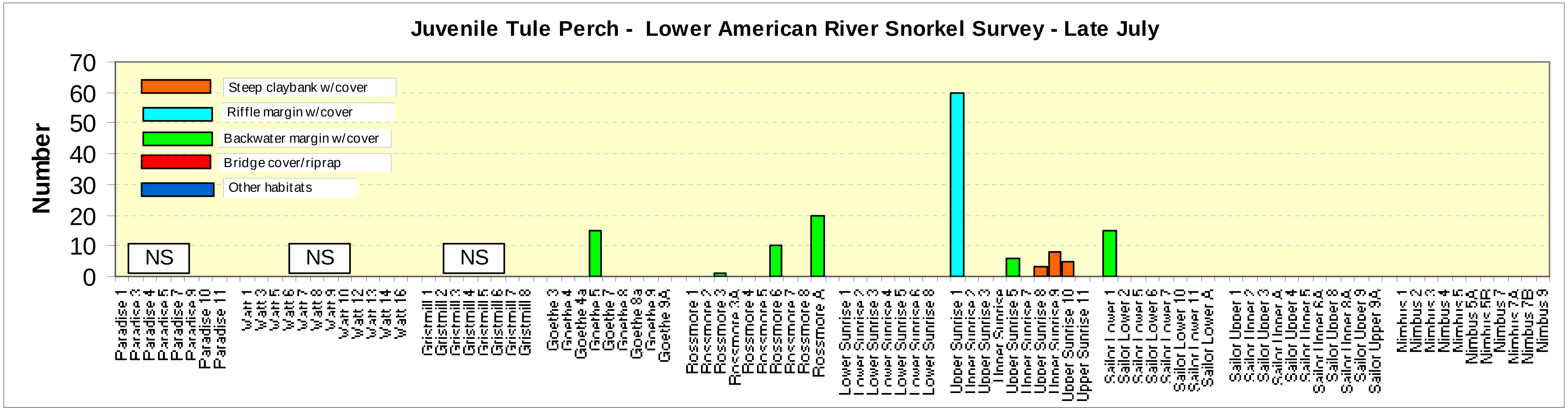
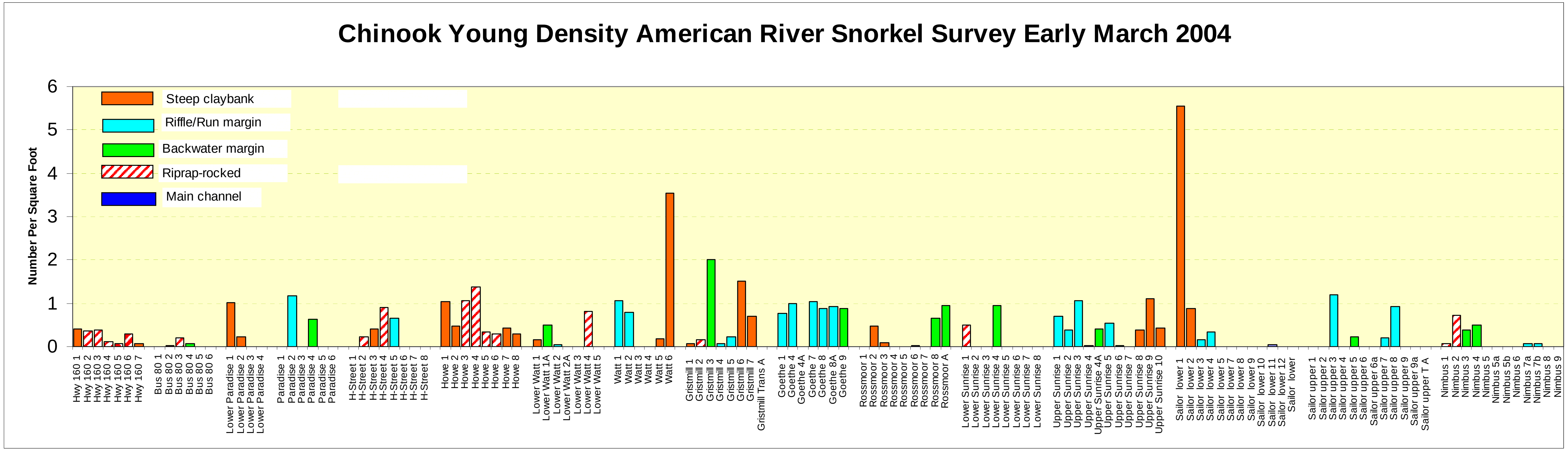


Chart 26. Juvenile Tule Perch – July 2003



2004 Charts - Chart 27. Juvenile Chinook Salmon – March 2004



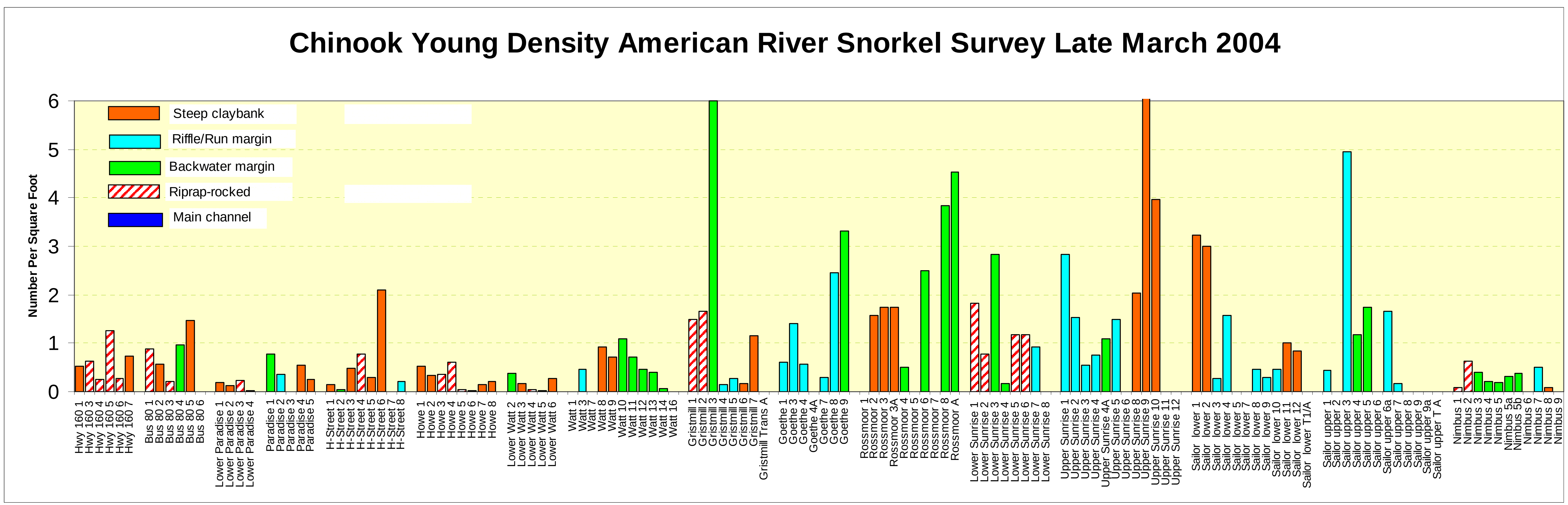


Chart 28. Juvenile Chinook Salmon – April 2004

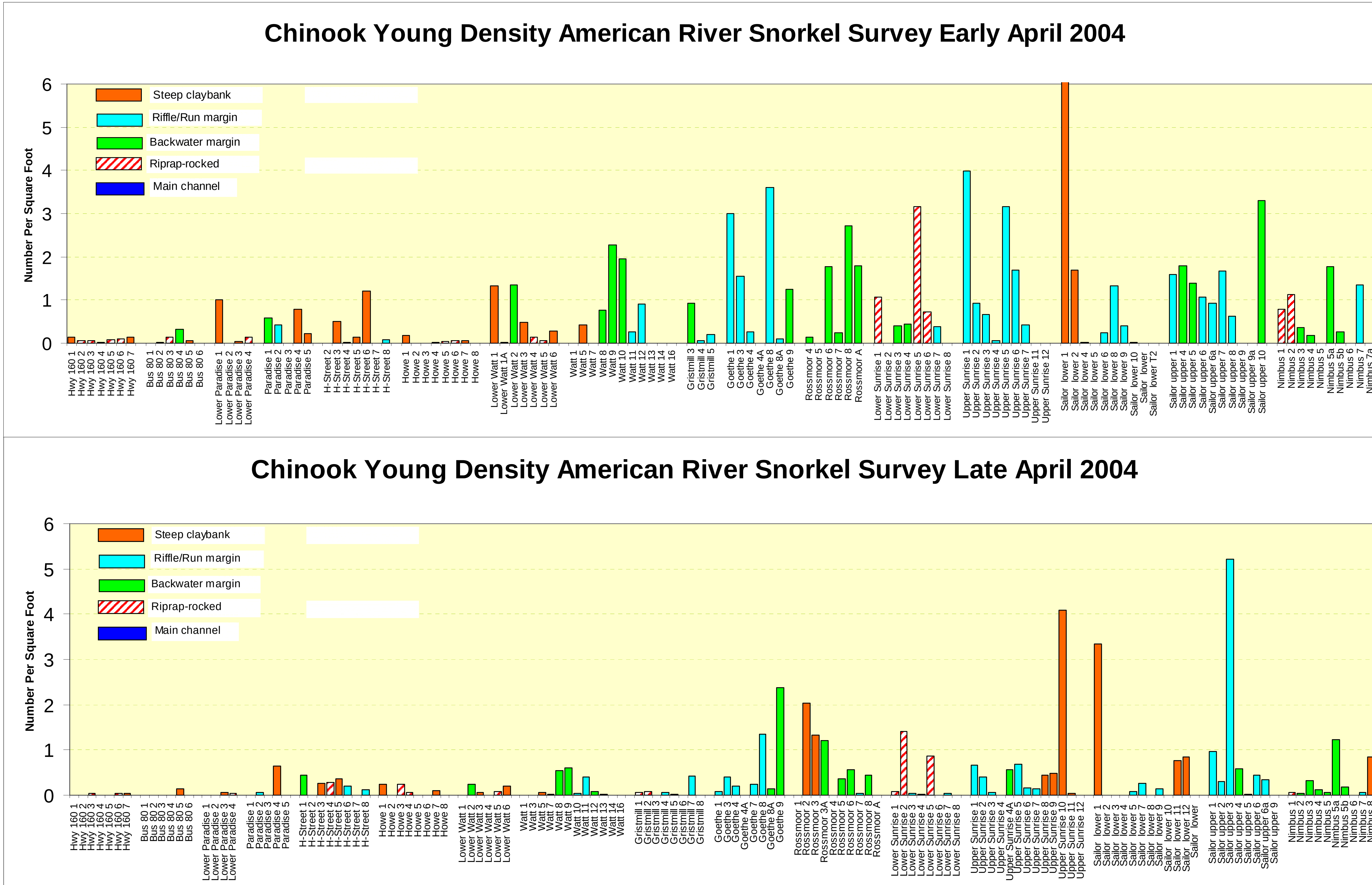
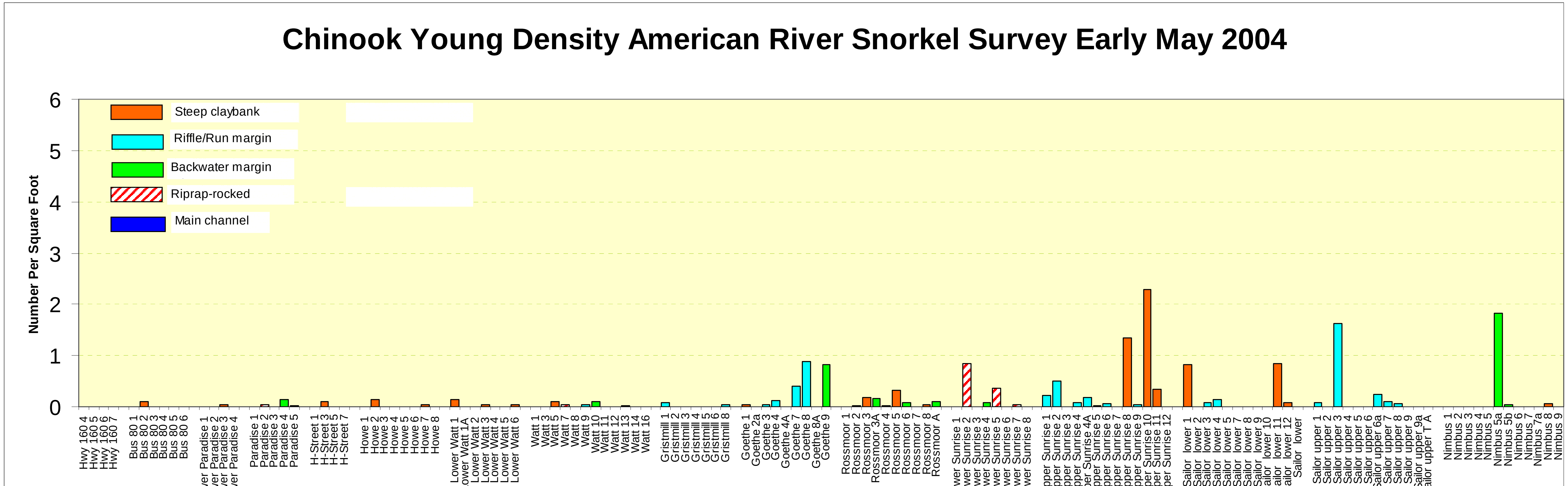


Chart 29. Juvenile Chinook Salmon – May 2004



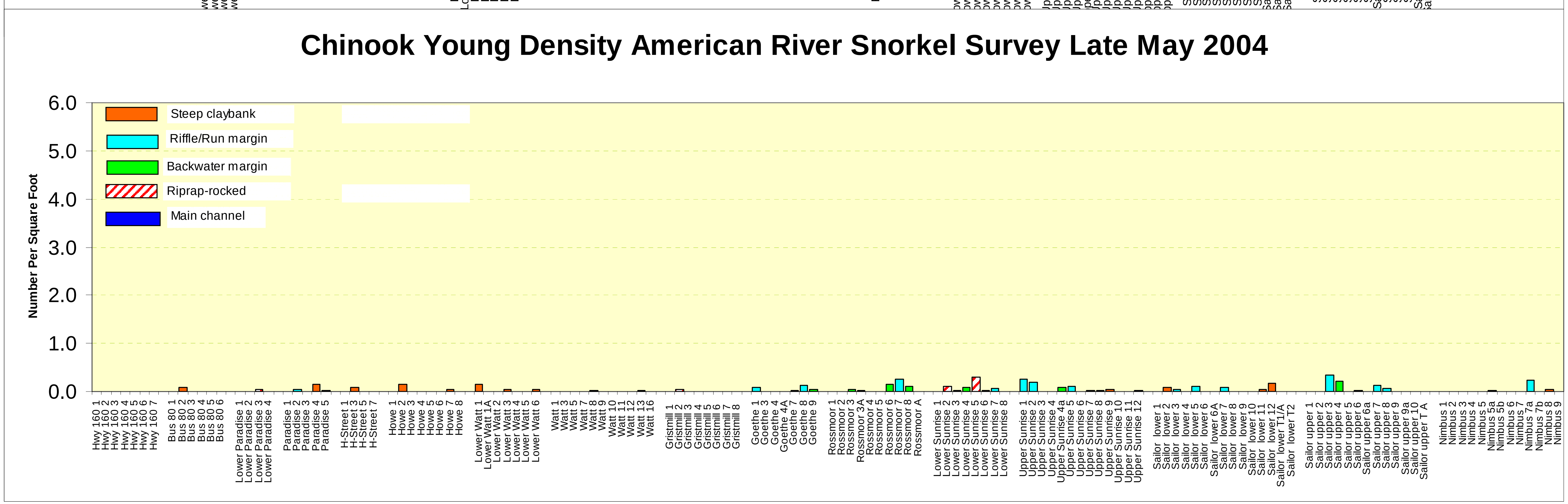


Chart 30. Juvenile Steelhead – April 2004

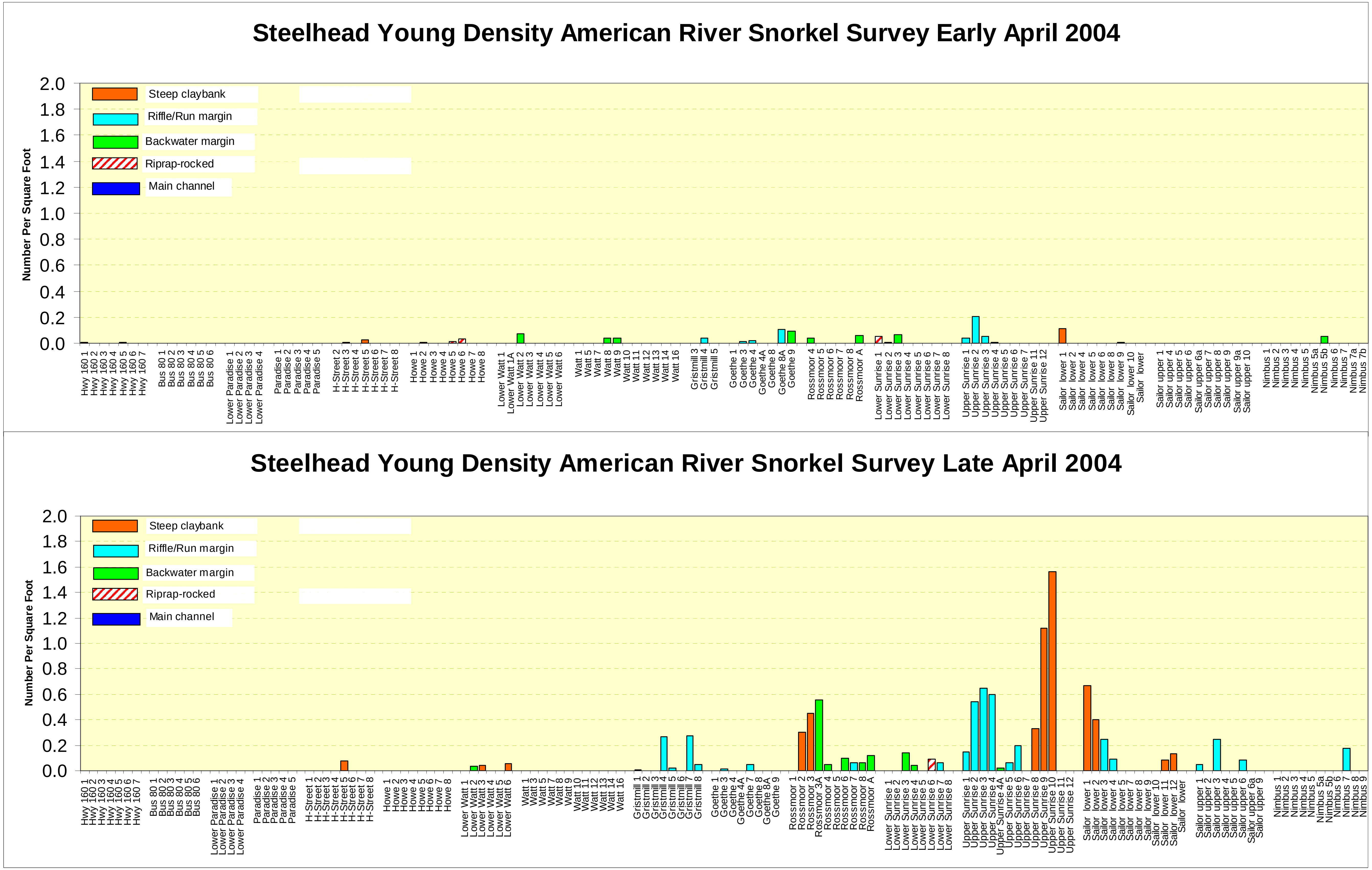
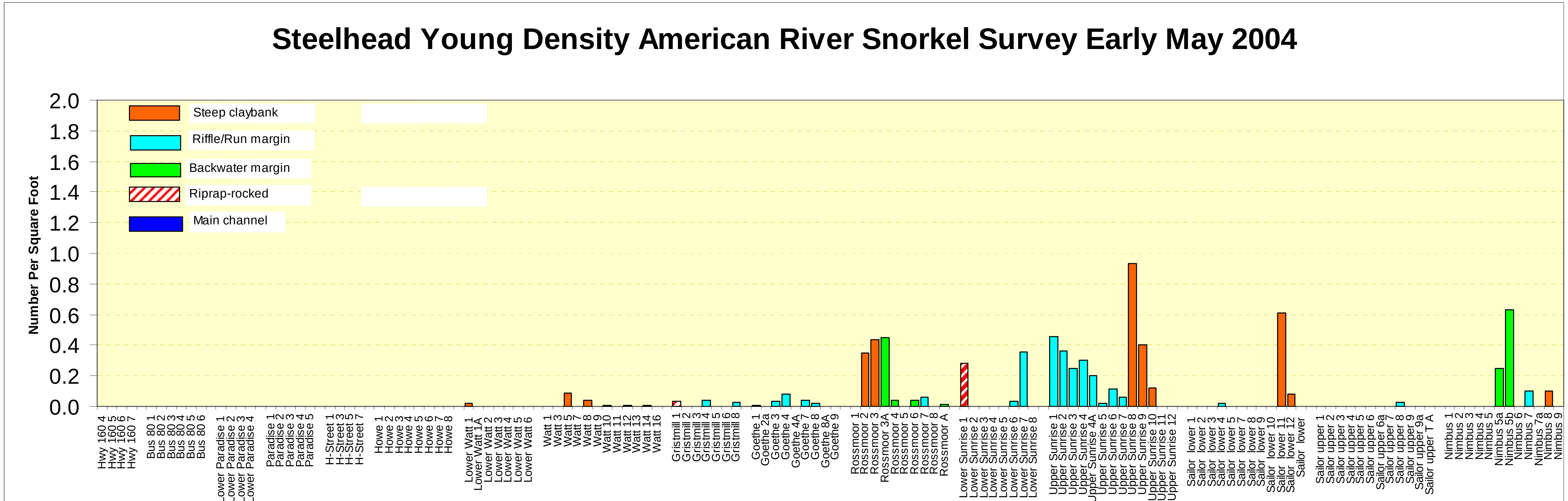


Chart 31. Juvenile Steelhead – May 2004



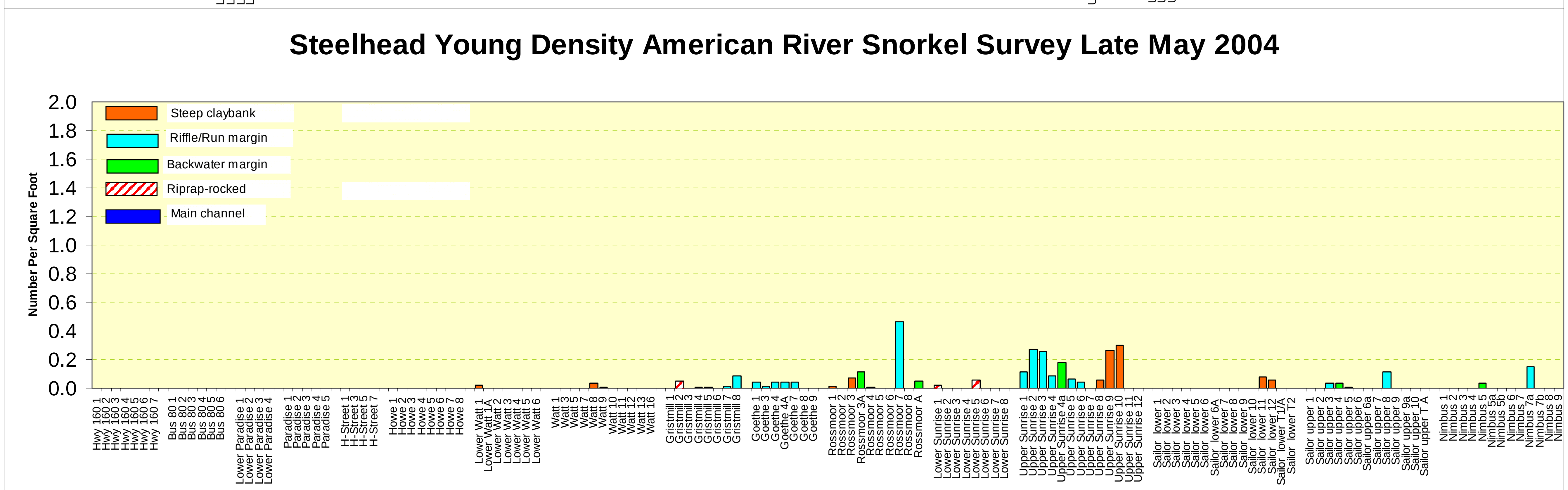


Chart 32. Juvenile Steelhead – June 2004

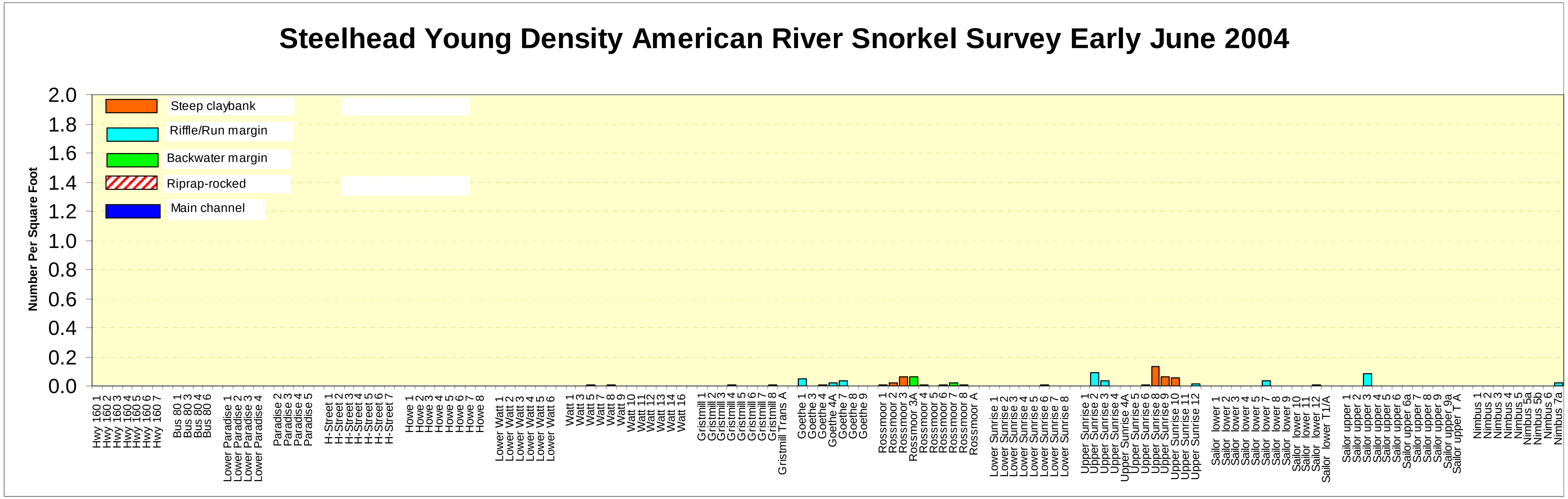
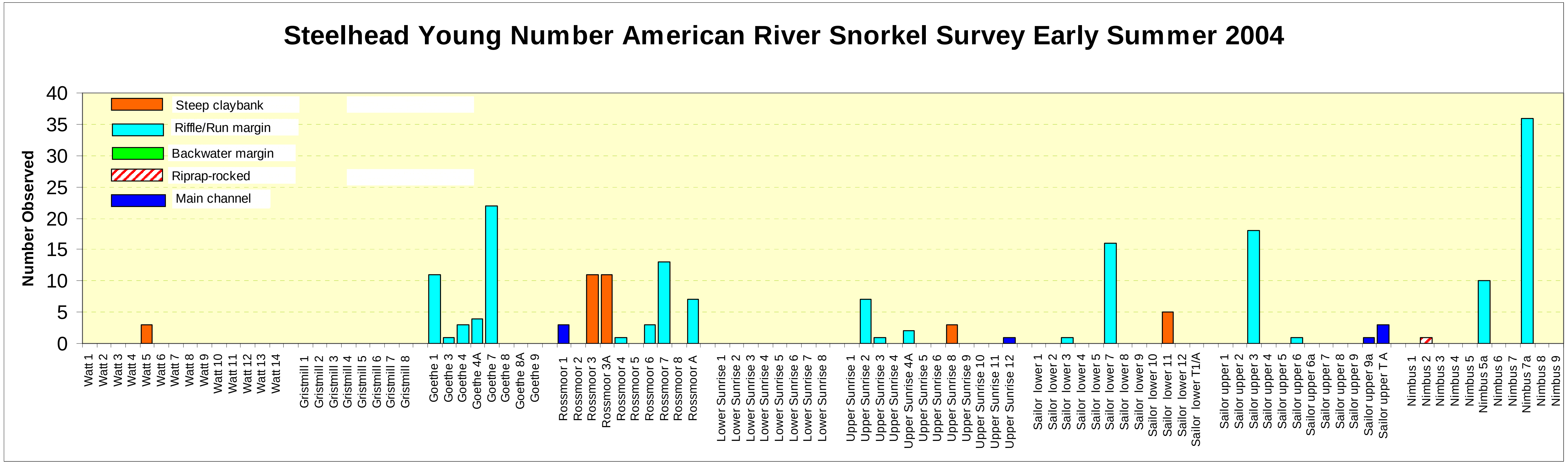
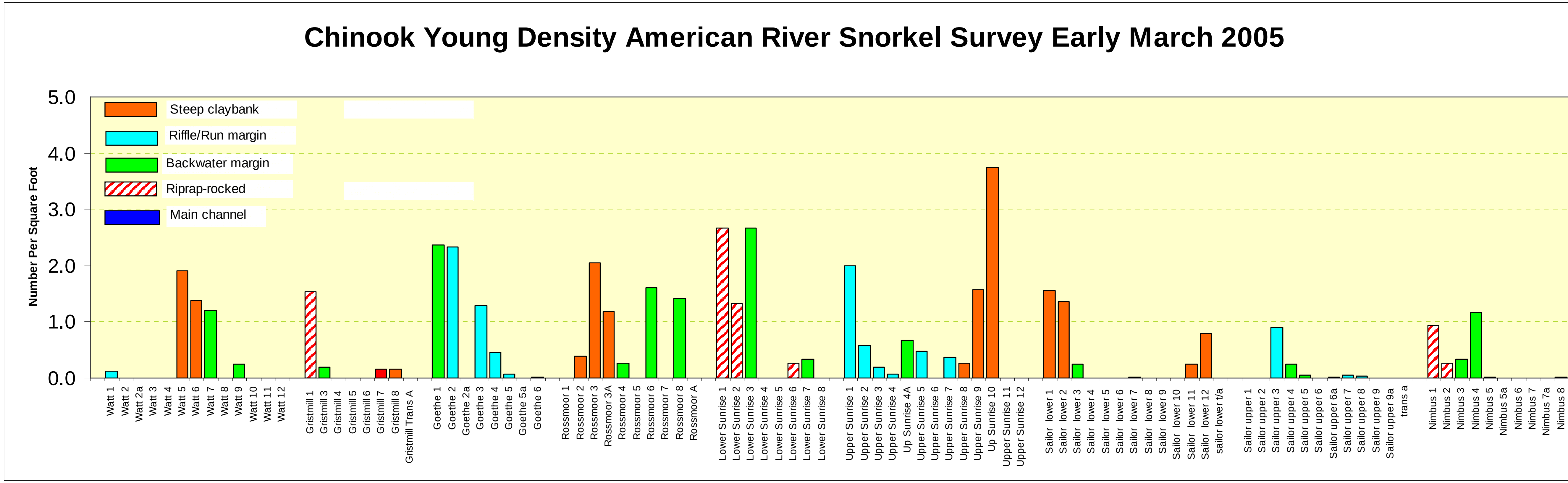


Chart 33. Juvenile Steelhead – July 2004



2005 Charts - Chart 34. Juvenile Chinook Salmon – March 2005



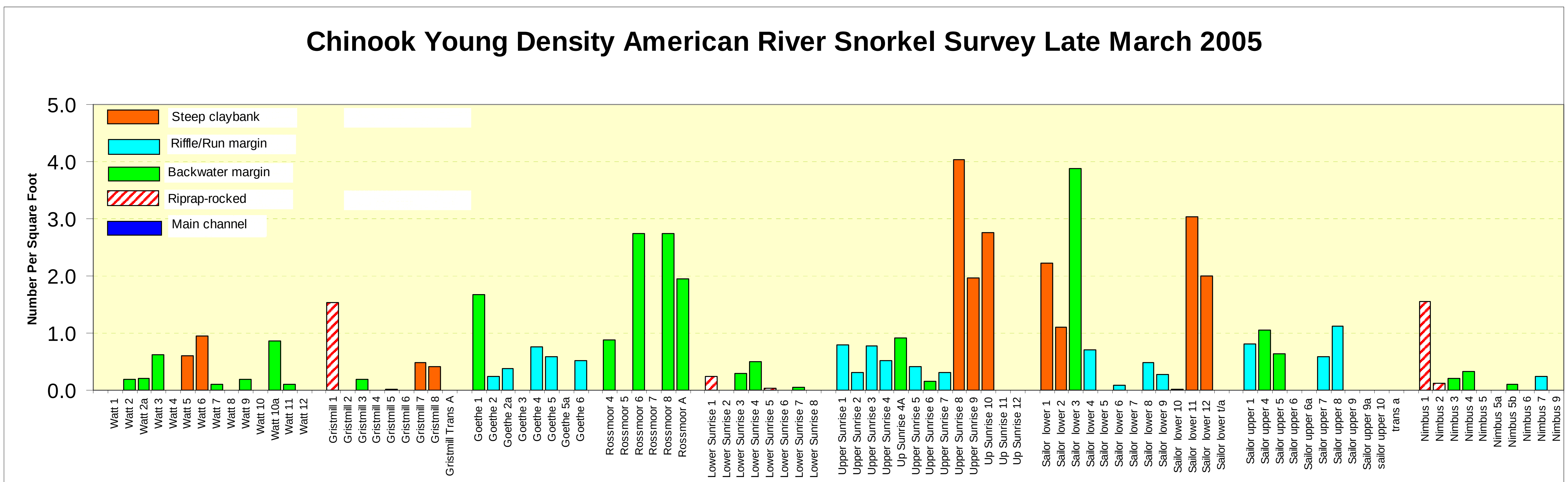
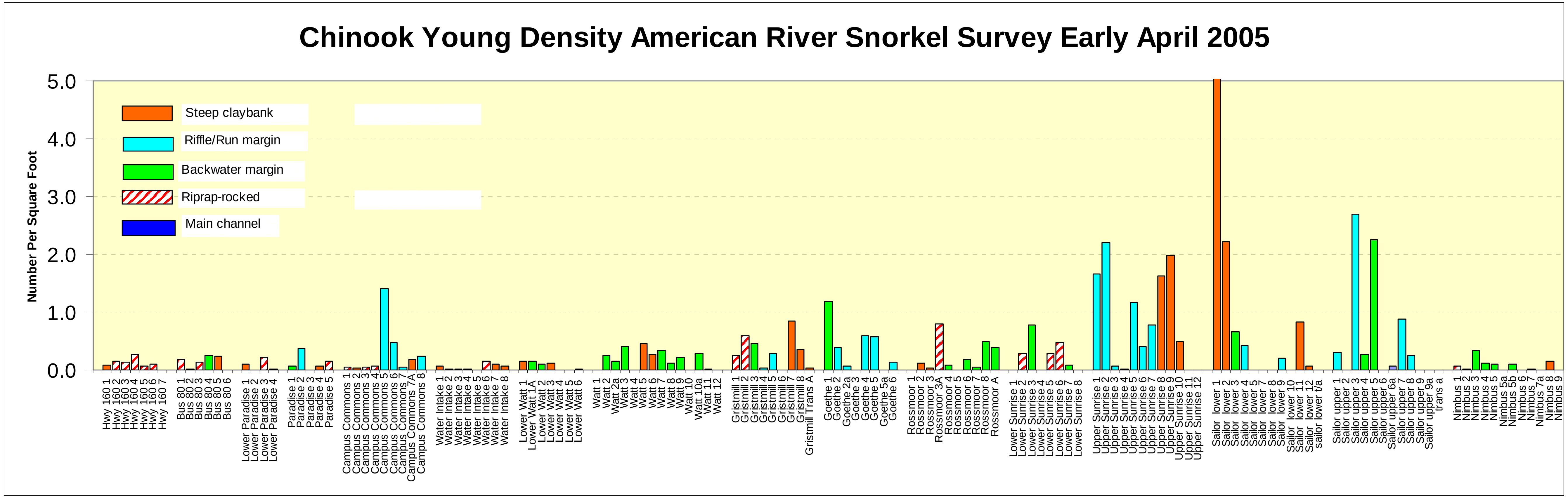


Chart 35. Juvenile Chinook Salmon – April 2005



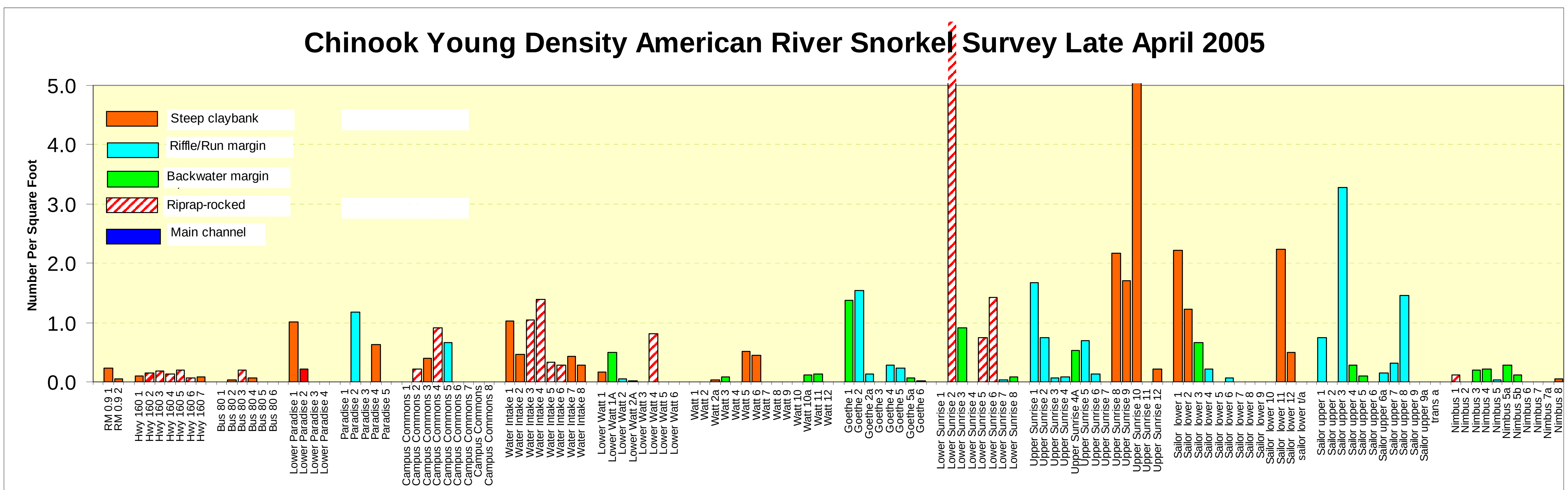


Chart 36. Juvenile Chinook Salmon – May 2005

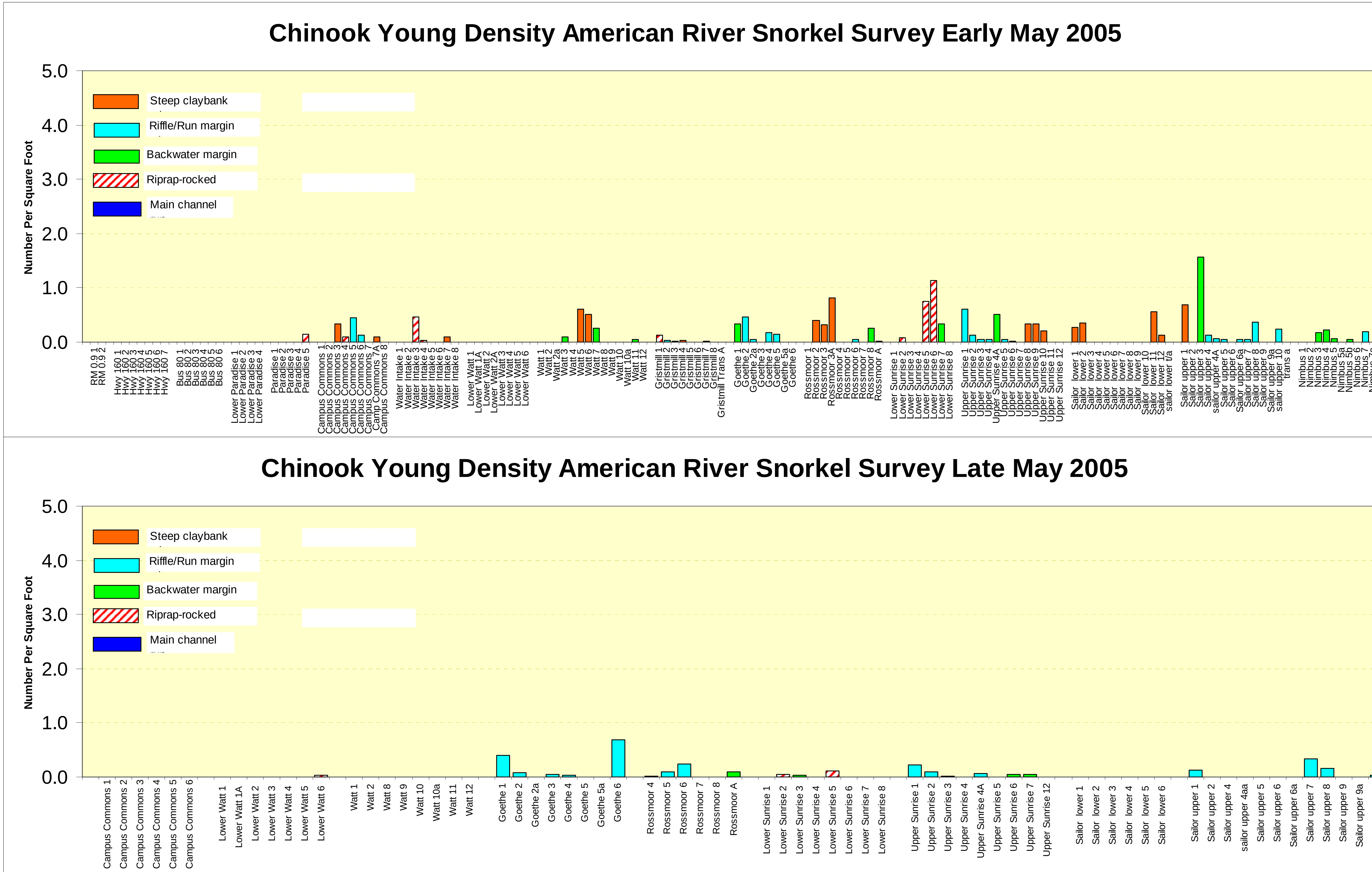


Chart 37. Juvenile Steelhead – April 2005

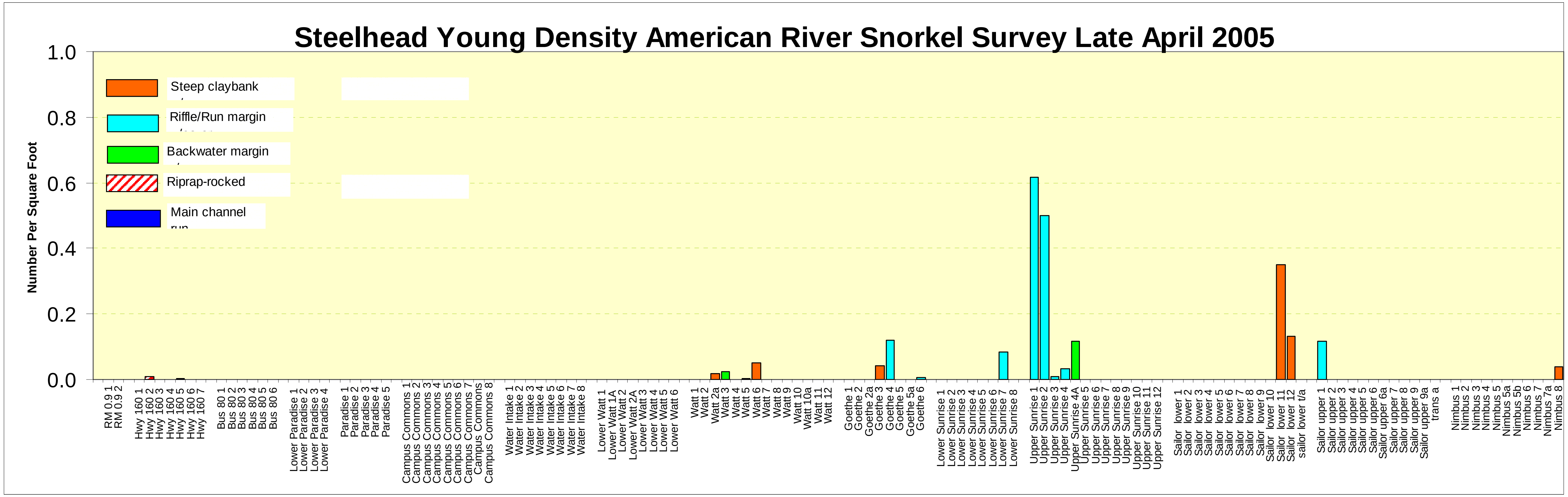
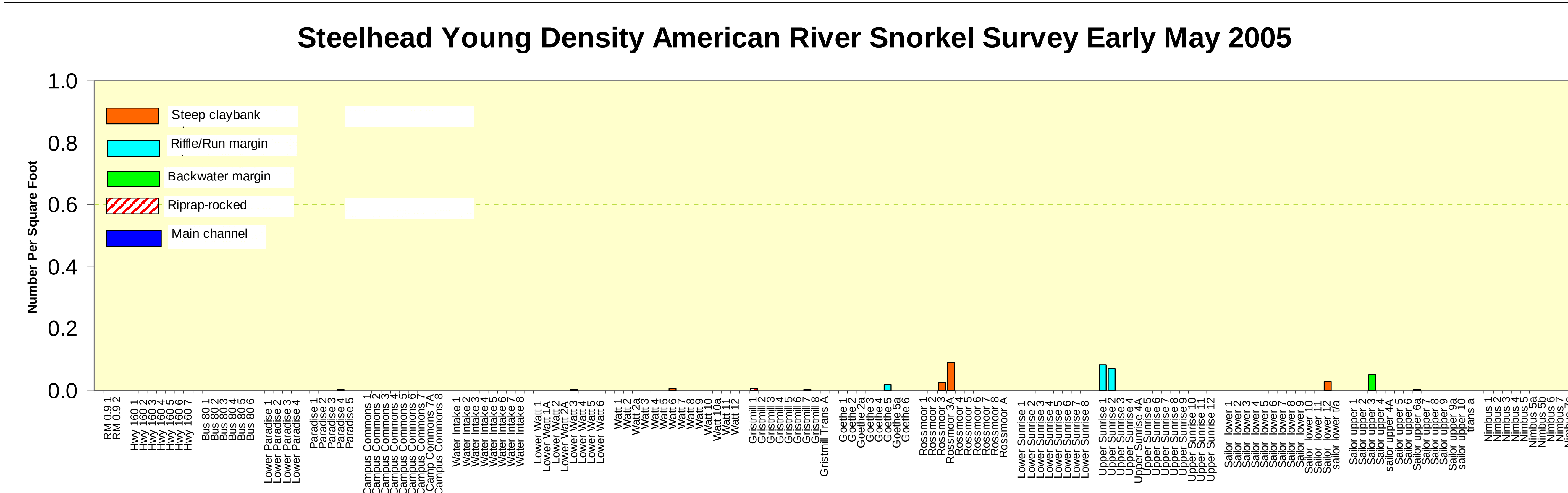


Chart 38. Juvenile Steelhead – May 2005



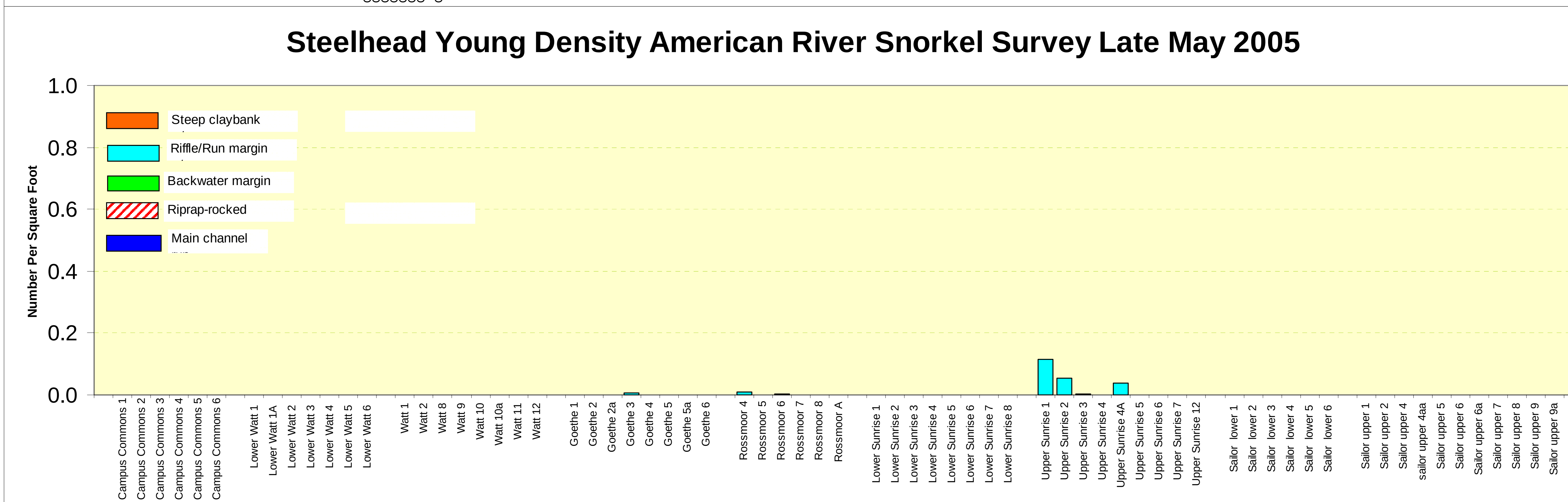


Chart 39. Juvenile Steelhead – June 2005