A BASIN-WIDE SNORKEL SURVEY OF THE SAN PEDRO CREEK STEELHEAD (ONCORHYNCHUS MYKISS) POPULATION.

A thesis submitted to the faculty of
San Francisco State University
In partial fulfillment of
The requirements for
The degree

Master of Science
In
Biology: Marine Biology

by

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San Francisco, California

May, 2005

CERTIFICATION OF APPROVAL

I certify that I have read A basin-wide Snorkel survey of the San Pedro Creek steelhead (*Oncorhynchus mykiss*) population by Richard Michael Johnson, and that in my opinion this work meets the criteria for approving a thesis submitted in partial fulfillment of the requirements for the degree: Master of Science in Biology: Marine Biology at San Francisco State University

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A BASIN-WIDE SNORKEL SURVEY OF THE SAN PEDRO CREEK STEELHEAD (ONCORHYNCHUS MYKISS) POPULATION.

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2005

I conducted a habitat assessment and snorkel survey of San Pedro Creek, San Mateo County, California, during Fall of 2004. A total of 749 steelhead were observed, 392 young of year (YOY), 243 age 1, and 104 age 2 individuals. Steelhead were observed in all four tributaries snorkeled, although the upper reaches of the mainstem and the entire Middle Fork had higher than average densities of YOY and age 1 steelhead. Age 2 steelhead densities were greatest in the mid to lower reaches of the mainstem. All three steelhead age-classes demonstrated a significant preference for pool habitat over flatwater habitat throughout San Pedro Creek indicating that when closely related competing species like coho salmon are absent, steelhead prefer deeper, more energetically favorable habitats. The presence of juvenile steelhead throughout the upper reaches of the watershed indicates that despite several culverts, there are no complete barriers to adult migration on the mainstem. The high densities observed throughout the Middle Fork indicate that it provides essential habitat which must be preserved for the survival of San Pedro Creek's steelhead population.

I certify that the Abstract is a correct representation of the content of this thesis.

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Chair, Thesis Committee Date

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Introduction

Pacific salmon

Historically, all six species of North American Pacific salmon utilized streams as far south as central and even southern California for spawning and rearing of young (Wolf & Zuckerman, 1999; Moyle, 1994). In the last few decades, environmental change, coupled with the over exploitation of salmonid populations and severe impacts to essential freshwater habitat have caused the ranges of this family of fish to contract and become restricted to more northerly latitudes. Pink (*Oncorhynchus gorbuscha*) and Sockeye (*Oncorhynchus nerka*) salmon are now extinct from California, while Chum (*Oncorhynchus keta*) salmon have been reduced to three very small populations (Wolf & Zuckerman, 1999; Moyle, 1994).

The Steelhead (*Oncorhynchus mykiss*) is perhaps one of the most resilient species of Pacific salmon. Historically it had the most southerly range (Behnke, 2002: Wolf & Zuckerman, 1999; Shapovalov & Taft, 1954), was the most abundant anadromous fish in the Pacific southwest (Israel, 2003; Barnhart, 1986), and had perhaps the most flexible life history (Israel, 2003; Shapovalov & Taft, 1954). This is not to say that steelhead populations have been unaffected by environmental and anthropogenic-caused change over recent years, however. Steelhead were once abundant throughout the interior basins of California and Oregon and even into western Idaho. Many of these populations have become extinct – as a direct result of damming, water diversion, and damage to habitat (Moyle, 1994). Throughout Southern California, steelhead have declined by 99%, with many runs now extinct. On California's North Coast, populations have not been reduced as drastically, but the populations inhabiting the Sacramento and San Joaquin River systems are now fractions of their 1960's levels primarily because of the construction of dams that block 90% of their spawning habitat (California Trout Inc, 2004) (Figure 1).

The endangered species act (1973) led to the use of Evolutionary Significant Units (ESUs) to group steelhead populations into geographically and reproductively distinct or isolated units (six throughout California) and designate their conservation status. In response to the plummeting numbers of steelhead, the National Marine Fisheries Service (NMFS) has listed the species as either Endangered or Threatened in nearly every river they inhabit within California.

The central California coast ESU encompasses streams from the Russian River in the north to Aptos Creek which marks the southern boundary. All naturally spawned populations of Steelhead and their progeny from within this area were listed as threatened on August 18, 1997 (Federal Register, 1997). Of 122 streams south of San Francisco Bay known to have contained steelhead, 47% have reduced production from historic levels and 33% no longer support populations (California Trout Inc, 2004). Central coast stocks of steelhead have been impacted heavily by urbanization (particularly in the greater San

Francisco Bay Area), agriculture, water diversion, migrational barriers and general habitat loss (California Trout Inc, 2004).

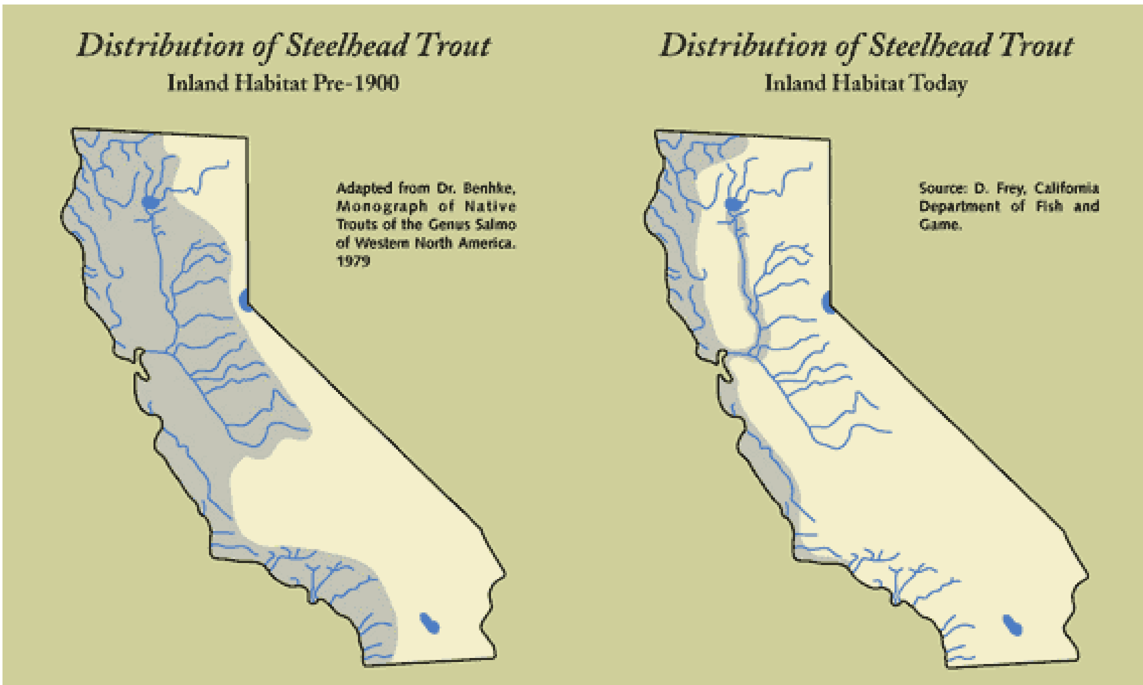


Figure 1. Steelhead distribution throughout California, before 1900 and present day.

Conservational efforts

The worrying decline of Pacific salmon, including steelhead, throughout California has led to much research and restoration activity by governmental natural resource departments and private conservation organizations (Department of Fish & Game, 2005; California Trout, 2004; United States Geological Society, 2004; Ketcham *et* *al*, 2003: Lawson *et al*, 2002; Nakamoto, 1998). The regular monitoring and assessment of native salmon populations throughout California is required to further understand the organisms and their freshwater requirements, the responses of such populations with respect to environmental change, and the potential for restoration and rehabilitation.

Regular monitoring programs include habitat assessment surveys, juvenile assessment surveys, smolt surveys, spawner surveys, and spawning redd assessments (Ketcham *et al*, 2003; Hankin & Reeves, 1988). Many surveys couple an extensive habitat assessment, focusing on the available habitat for salmon, with a fish survey often performed during times of low flow (Ketcham *et al*, 2003; Nakamoto, 1998; Lau, 1994; Dolloff *et al*, 1990; Hankin & Reeves, 1988). A detailed habitat assessment "is critical in determining the limiting natural and human factors that affect water chemistry and aquatic biological communities" (Fitzpatrick *et al*, 1998) and is therefore an essential component to any salmonid survey. Workers are then able to relate fish patterns throughout the creek to habitat type and availability, and then preserve and or enhance such productive elements of the creek.

Steelhead habitat requirements

Like other members of the salmonid family, steelhead inhabit creeks with clean, cool, well oxygenated water. Steelhead habitat preference changes according to both season and fish age: During the summer young steelhead utilize shallow, fast flowing areas of the creek, found in shallow flatwater zones and riffles, migrating to deeper pools for the winter (Harvey & Nakamoto, 1997). Older, larger fish demonstrate preference for deeper pool habitat year-round while returning adults require deep resting pools as they ascend the creek to spawn.

While inhabiting shallow creeks, the level and complexity of cover is very important for steelhead. This is especially true during summer and fall when flows are minimal and water levels are often very low. Recent research focused on the habitat preference of various salmonids has highlighted the importance of creek-side wooded riparian zones to salmonids including steelhead. Such wooded riparian zones are important for the following reasons:

- The roots of bank-side vegetation help to stabilize creek banks. This helps hold soil in place along the river bank and slow water velocities, thus reducing the potential for erosion – which may lead to an increased load of fine sediments in the creek (Bails *et al*, 2001).
- These root structures often become exposed; and when submerged, add complexity to the creek habitat, providing excellent cover for juvenile steelhead (Spence *et al*, 1996).
- Wooded riparian areas keep water temperatures within the creek cool during summer months through shading. Shading can also minimize water

evaporation from the creek, allowing pools suitable for juvenile steelhead to remain throughout the summer – essential in small tributaries like those found in the headwaters of San Pedro Creek (English *et al*, 2000).

- Fallen trees or branches contribute woody debris to the creek channel providing fish with direct cover and or refuge from strong currents.
- Such woody debris provides food for aquatic insects, important prey for juvenile Steelhead.
- Slow down run-off, improving overall water quality by slowing the transfer of sediment and pollutants to the creek, and additionally trapping stream sediments, allowing them to settle out (Bails *et al*, 2001; English *et al*, 2000).

Therefore riparian zones are essential for the overall health of the entire creek's ecosystem. Dense, low-lying vegetation in the understory, in addition to partially submerged root systems and undercut banks add habitat complexity which provide shelter and refuge for juvenile steelhead and for spawning adults.

San Pedro Creek

Just south of San Francisco, in the city of Pacifica, lies San Pedro Creek - a typical small coastal stream which supports a self-reproducing steelhead population. Despite 19th century alterations to sections of the creek, San Pedro supports the most viable steelhead trout population in San Mateo County (Fish And Wildlife Service, 1990). Unfortunately, the creek no longer supports coho salmon - last seen in the 1950s (in Davis, 2004; in Chan, 2002). The San Pedro Creek Watershed Coalition (SPCWC) formed in 1998, together with many concerned Pacifica residents, are determined the steelhead will not suffer the same fate.

Monitoring programs to date

San Pedro Creek's steelhead have been the focus of several past studies (Titus & Erman, 2000; Sullivan, 1990a; Sullivan, 1990b: Anderson, 1974), as well as a more recent investigation during Autumn 2001 (Hagar, 2002). Direct survey techniques have utilized underwater visual observations or fish capture methods like electrofishing, while indirect survey methods such as those employed by Hagar (2002) through the qualitative and quantitative study of available habitat, have also been used to assess the health and status of the Creek's steelhead population.

The most recent study to date was a creek-wide habitat assessment conducted by Hagar Environmental Science (Hagar, 2002). The survey encompassed the Main stem, Middle fork, South fork and Sanchez fork. Hagar quantified the creek into distinct habitat types and subsequently determined their suitability to steelhead. Visual counts of juvenile steelhead were also incorporated into Hagar's survey; although these were 'above-water' observations subject "...to bias involved with visual estimates." (Hagar, 2002), and therefore may not be considered a highly accurate survey.

Historically, spawning areas were widespread throughout the creek but were most numerous in the North and Middle Forks (Figure 2). Hagar (2002) discovered that San Pedro's Middle Fork continued to support high densities of juvenile steelhead, thanks to successful spawning in the region, whereas potential for steelhead spawning and rearing throughout the North Fork had been completely destroyed – a direct result of the North Fork being confined to an underground culvert.

Hagar concluded that the best spawning habitat was located within the Middle Fork while the main stem provided the most suitable habitat for rearing juveniles to smolt size. Other sections of the creek such as the South Fork and Sanchez Fork were observed to have a potential for spawning and juvenile habitats, although visual steelhead counts in these areas were very low. Hagar's survey also recognized several potential in-stream barriers to adult and juvenile migrations. The Capistrano bridge crossing was thought to be the most significant barrier due to a substantial one-meter drop from the fish ladder to the surface of the downstream pool.

More detailed and accurate surveys of juvenile salmonid populations have been performed on various creeks in the United States, Canada and Europe by using the 'electrofishing' method (Ketcham *et al*, 2003; Snyder, 2003; Roni & Quinn, 2001; Johnson, 2000; Nakamoto, 1998; Smith, 1998; Crisp, 1993; Cowx & Lamerque, 1990; Dolloff *et al*, 1990; Lau, 1984; Anderson, 1974) or by utilizing underwater visual methods such as snorkelling (Ketcham *et al*, 2003; Kahler *et al*, 2001; Flebbe, 1999; Higgins, 1994; Dolloff *et al*, 1990; Sullivan, 1990b; Chapman, 1988; Hankin & Reeves, 1988). Estimates of fish abundance based on snorkel surveys have been shown to be highly accurate when compared with estimates from electrofishing surveys on the same reach (Brown & Ketcham, 2002; Flebbe, 1999; Dolloff *et al*, 1990). Electrofishing has lost popularity over the last decade because of potentially harmful effects on salmonids, other fish species, and aquatic invertebrates (Snyder, 2003; Mueller, 2002). Snorkelling as a method of population assessment has the advantage that it is totally non-invasive to the fish and their habitat. Consequently, snorkel surveys are much preferred when dealing with threatened or endangered fish species such as steelhead.

During the summer and autumn of 1989, Sullivan (1990b) conducted a snorkel survey to monitor the distribution and abundance of juvenile steelhead throughout the lower sections of San Pedro Creek's mainstem. Sullivan was able to classify juveniles into three separate age classes (Young of year {YOY}, Age 1, and Age 2) based on size, a method which has also been used on the Lower Hayfork Creek (Higgins, 1994). The high abundance of trout observed by Sullivan indicates that there was suitable habitat in the lower portion of San Pedro Creek to sustain many juvenile steelhead. As Sullivan concentrated on the lower reach of the main stem, no visual counts were made further up in the watershed including areas such as the Middle Fork where spawning habitat is widespread.

In 2002 a flood control project was implemented throughout the lower 1km of San Pedro Creek's mainstem (US Department of the Interior, 1990). The channel was diverted from its previously altered, straight course and given a more 'natural' meandering route through a specially created flood plain area (Collins *et al*, 2001). The flood plain has been extensively planted with riparian shrubs while the creek has received some habitat enhancement, with the addition of large woody debris and rootwads to increase habitat cover and complexity. My survey was the first steelhead population survey since the completion of the flood control project.

Project goals

The main objective of this study was to provide a comprehensive and detailed analysis of the present state of San Pedro Creek's steelhead population (post-flood control program) - complimenting Hagar's 2001 habitat assessment survey and expanding on Sullivan's 1989 mainstem snorkel survey. These previous studies have provided useful information on juvenile steelhead abundance, steelhead behaviour with respect to microhabitat use, and potential barriers to steelhead migration. However, they have been either geographically limited (Sullivan, 1990), or made use of less accurate fish survey techniques (Hagar, 2002). By using underwater visual observations and surveying the entire basin, this project provides an accurate and comprehensive picture of the San Pedro Creek steelhead population. The findings can thus be used as 'base-line' information detailing the health of the steelhead population. Any future creek-based projects that hope to improve the steelhead habitat can use the data gathered during this study to determine the level of success. This paper reports research designed to address the following objectives and test the following hypotheses:

- Determine steelhead distribution, habitat usage and densities throughout San Pedro Creek and present a comparison of age-class densities in different habitat types based on average densities found throughout the stream.
- Determine if certain 'productive' areas of the San Pedro Creek system exist that support greater than average steelhead numbers.

- H_0: All parts of the creek are similar in terms of steelhead abundance.

- Determine if steelhead are selective in their habitat choice.
    - H_0: Steelhead are found in all habitat types at similar densities.
- Determine if age-class differences exit between habitat types.
    - H_0: No significant difference exists between habitat use by different age classes.
- Determine if total barriers to steelhead migration exist on San Pedro Creek.

Methods of Study

Study Area

San Pedro Creek is a perennial stream situated in northern San Mateo County, California. Located approximately 13km south from San Francisco County's southern boundary, the creek drains a small watershed in the order of 8 $miles^2$ / $20km^2$ (Figure 2) and has an average annual precipitation of 38.2 inches / 970mm (22 year average). San Pedro Creek's cool, clean headwaters (composed of the Middle and South Forks) begin life high in San Pedro and Montara mountains of the Coast Range, within San Pedro Valley Country Park and McNee State Park. The headwaters descend and travel westwards through well-vegetated riparian zones within the park before they converge, forming the main stem, close to the park's western boundary.

The mainstem, lacking the dense riparian influences of the headwaters', continues westward through a grove of eucalyptus trees before being channeled through an artificial box culvert, part of Oddstad bridge. West of Oddstad, San Pedro creek combines with the highly urbanized North Fork. Unfortunately the North Fork, a major tributary and once an important spawning area for adult steelhead, has been completely transformed into an underground culvert which lacks habitat, and therefore lacks any potential for steelhead recovery while it remains in this state. The main stem continues to flow west down the valley floor, through the Linda Mar District of Pacifica for about 3.5km. In addition to Oddstad bridge, Linda Mar bridge, Capistrano bridge, Adobe bridge and Peralta bridge are all influential structures to the hydrodynamics, sediment transfer and fish migration throughout San Pedro creek.

After meandering through a recently developed flood control plain for the final 600 meters, San Pedro Creek discharges into the Pacific Ocean just North of Point San Pedro at Pacifica State Beach. Residential and commercial developments shadow both banks of the creek throughout the valley except the south bank of the recent flood control development.

Historically, due to the abundance of suitable spawning and rearing habitats, San Pedro Creek has supported a population of wild steelhead trout. Anadromous salmonids such as steelhead form an important link between marine and terrestrial environments by the extremely efficient transferal of energy and nutrients from the expansive oceanic environment to the confines of freshwater rivers and creeks which benefit and support many aquatic and terrestrial species associated with creek ecosystems (Willson & Halupka, 1995). For thousands of years, before European settlers arrived in California, the native Ohlone people depended upon adult steelhead returning to San Pedro Creek each year as an important source of food and spirituality (Morrall, 1978).

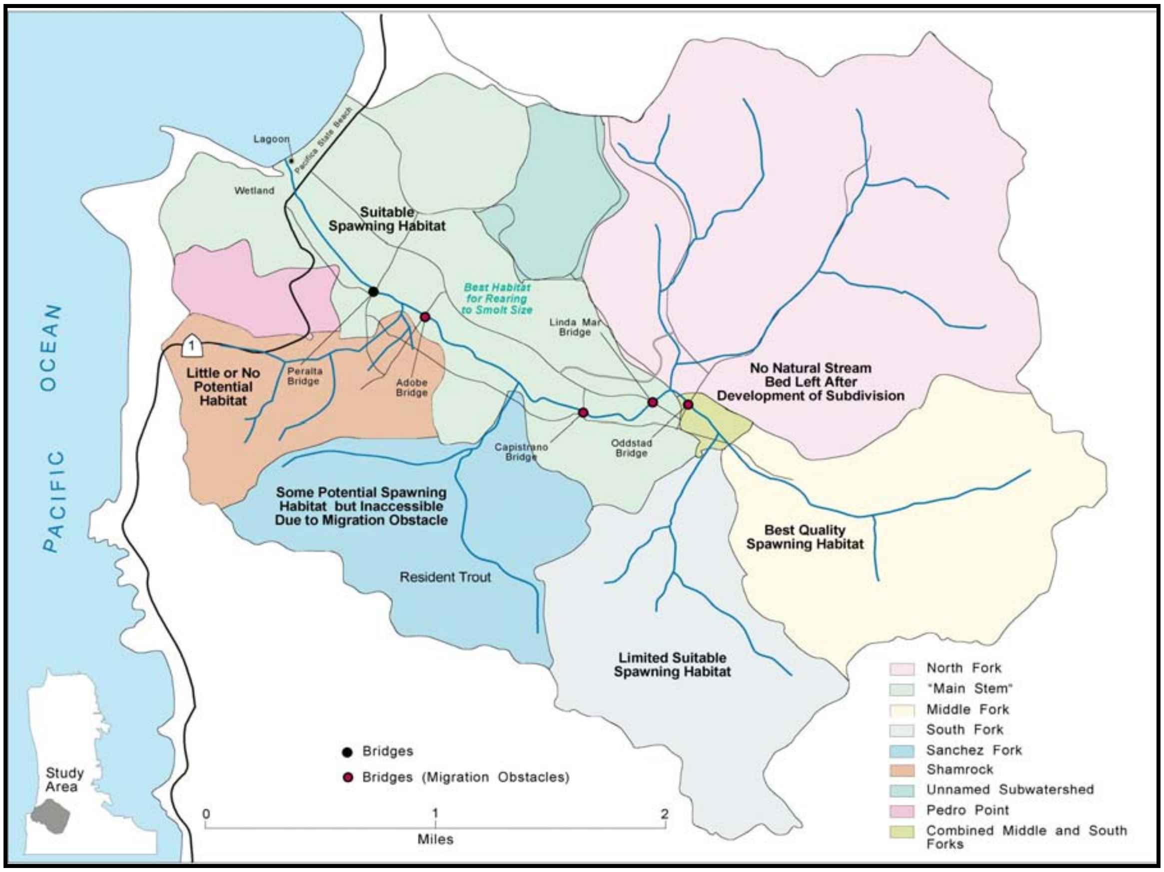


Figure 2. San Pedro Creek Watershed & its steelhead potential as determined by Hagar's 2001 study.

San Pedro Creek Steelhead Life history

Adult Steelhead enter San Pedro Creek on high tides during late winter and the spring after winter rains have caused the creek to swell and cool water temperatures preside (Sullivan, 1990). Once in freshwater they tend not to feed and slowly begin to ascend to suitable spawning locations usually characterised by coarse gravel and cobble substrate and a suitable flow rate. Such locations are often situated at the interface of the riffles and pools where flow rate and levels of dissolved oxygen are suitable for egg survival and growth (Keeley & Slaney, 1996). Eggs are then laid in a depression known as a redd, after excavation by the horizontal female's vigorous tail fanning. After the eggs are fertilized by the male, repeated tail fanning by the female causes egg burial which will protect them from predation and sudden fluctuations of water temperature. Following spawning, Steelhead may descend the creek and head back to the marine environment only to return and reproduce in later seasons. This iteroparity sets them apart from other species of Pacific Salmon which spawn once only, dying shortly after, in the creek close to their redd.

Successfully fertilized eggs hatch after about 25 to 35 days (Shapovalov & Taft, 1954). Hatchlings or alevins remain buried in the substrate until their yolk sac is depleted and the mouth parts are formed. Emergence from the gravel thus corresponds with the initiation of active feeding which is directed mainly at the larvae of aquatic insects. Juvenile Steelhead or parr become territorial as their size increases and they demand greater resources (Keeley, 2000). Preferred habitat also changes, as older, larger juveniles move into deeper, more complex habitats with increased cover. Juvenile Steelhead typically remain in San Pedro Creek between two to three years before undergoing massive physiological and behavioural changes during the smoltification process which prepares them for life in the ocean. Smolts leave the creek for the ocean during the spring. Smolts descend in large groups after their territorial instincts give way to a shoaling behaviour which they maintain whilst in the ocean (McKinnell *et al*, 1997). In the ocean steelhead grow rapidly. For every month spent at sea they average growth rates of 2.5cm in length while feeding on squid, small fish and crustaceans (Behnke, 2002). After spending between one and three years in the ocean, steelhead begin to mature sexually and migrate back towards their natal creek, helped by their complex homing behaviour (Israel, 2003). The returning adults will wait until the water levels in the creek are high enough for them to begin to ascend and eventually spawn themselves.

Juvenile steelhead identification

Steelhead and rainbow trout are somewhat variable in color and body shape (Moyle, 2002). Juvenile trout display 5-13 oval parr marks along the lateral line, display white to orange coloured tips on the dorsal and anal fins, with a spotted caudal fin. When compared to other salmonids, the interspaces (spaces between parr marks) on juvenile steelhead are often wider than the parr marks themselves. Their head is blunt with a short jaw; the maxilla not extending past the eye. Numerous small, circular black spots also cover their back and adipose and dorsal fins (Figure 4).

Survey Methods

Analysis was performed by a snorkel survey covering almost the entire basin comprising the entire mainstem, the South, Middle, and Sanchez Forks. Like Sullivan's earlier 1990 study, steelhead were counted and the microhabitats, where fish were observed, recorded. A basin-wide habitat assessment survey (Flossi *et al*, 1998; Dolloff *et al*, 1990) preceded the snorkel survey, determining regions of suitable habitat for juveniles, whilst noting potential barriers to upstream adult migrants and juvenile movement throughout the creek.

Habitat Assessment Survey

The goal of a typical in-stream salmonid habitat assessment is to gauge the general habitat types present and record their frequency and distribution throughout the system of interest. It is useful to determine where in the watershed suitable steelhead habitat exists and also to identify factors that may limit steelhead use of the watershed (Hagar, 2002). Certain types of habitat are known to be more suitable for various life stages of anadromous fishes, including steelhead (Reiser & Bjornn, 1979). As juvenile steelhead spend many months or even years in the same small creek, it is important that a varied assemblage of habitats exists for these various life stages and range of fish sizes present. A healthy stream, abundant with steelhead, would therefore be expected to exhibit great habitat diversity with particular habitats such as deep pools found in abundance. Degraded streams often become excessively uniform systems losing habitat diversity, habitat quality and in some cases totally lacking certain habitat types required for steelhead populations to exist. Conducting a habitat assessment is therefore the first step in determining the health of a system and its physical potential for supporting a steelhead or similar salmonid population.

San Pedro Creek's habitat was surveyed over the course of several weeks during September and October of 2004. The Habitat Assessment involved a walking survey of streams in the watershed where access was possible. No surveys were conducted on the North fork due to its highly urbanized state. Figure 3 outlines the survey reaches surveyed on each fork. Distances covered for the habitat survey and snorkel survey are detailed in Table 1.

Figure 3. San Pedro Creek habitat survey reaches. (Overleaf)

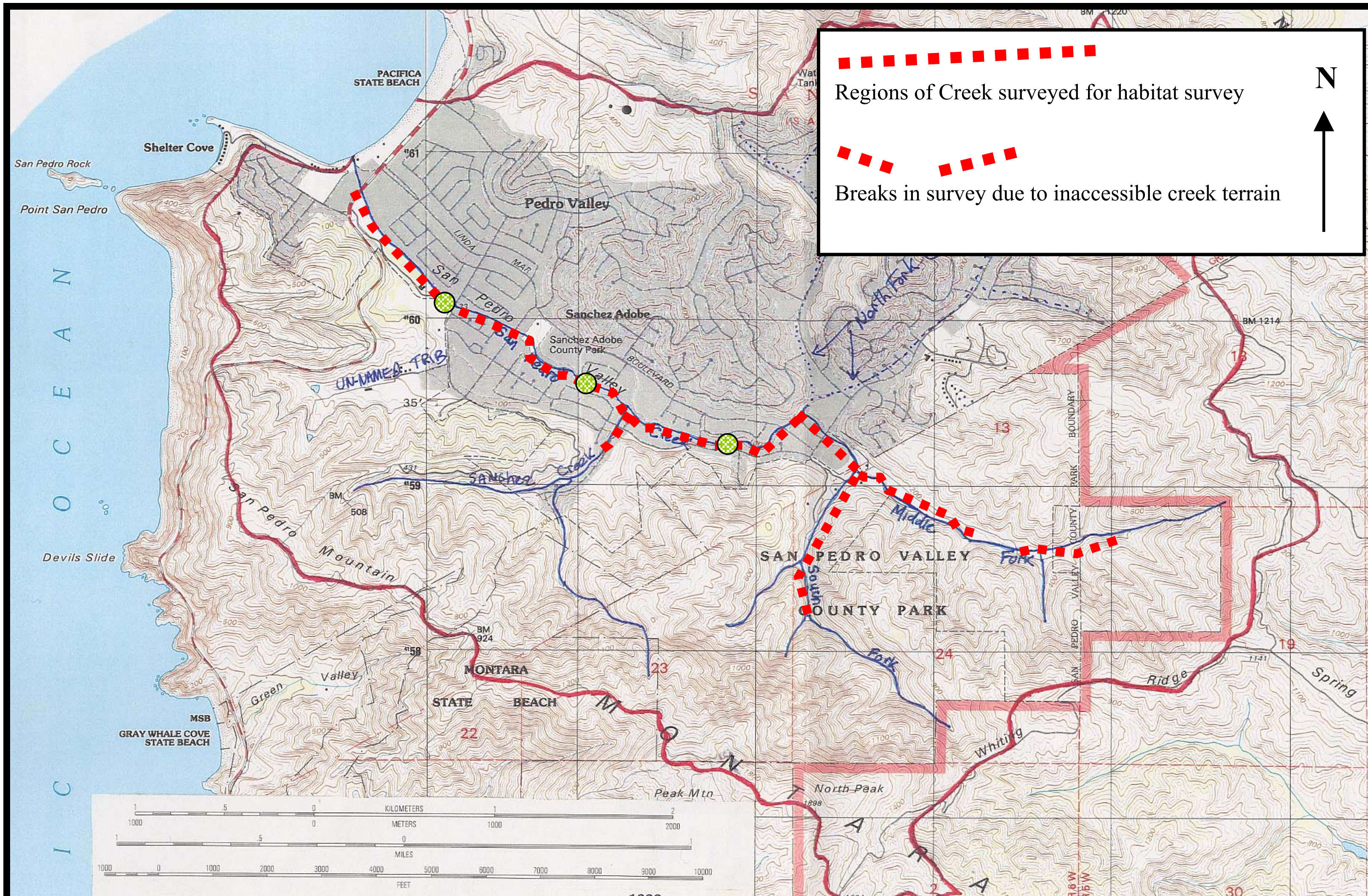


Figure 3. San Pedro Creek habitat survey reaches. Green circles on mainstem indicate separate reaches.

Section of Creek	Habitat Survey length	Snorkel Survey length
Mainstem	4020.5m	2107m
Middle Fork	1148.5m	201.5m
South Fork	896.5m	152m
Sanchez Fork	269.5m	47.5m

Table 1. Survey distances throughout San Pedro Creek basin.

Surveyed creek reaches were mapped and partitioned into stretches of distinct hydrological features and habitat units which were classified. Habitat classification was performed in accordance with the California Salmonid Stream Habitat Restoration Manual (Flosi *et al*. 1998) using the standardized three letter abbreviations adopted by CDFG. Upon classification, units were subject to the following quantitative and qualitative analyses:

- **Length** of unit was recorded to nearest 0.5m.
- **Width** was recorded along three unit transects to nearest 0.1m.
- **Maximum depth** was recorded for pools and flatwater units to the nearest cm.
- **Substrate** class and size was visually estimated for unit.

- **Unit Shelter** was estimated and the percentage of unit covered was recorded for three types: (i) Over story cover (canopy cover); (ii) Under story cover (bank side overhanging vegetation); (iii) Aquatic vegetation.
- **Undercut bank** presence along unit was recorded.
- **Woody debris** in unit was recorded. Debris was either classed as large woody debris (>100mm diameter), or small woody debris (<100mm diameter).
- **Rootwad** presence in unit was recorded.
- **Bubble curtain** presence in unit was recorded.
- **Additional observations** were noted for units with unusual features, water quality etc.
- **Snorkel suitability** was recorded for each unit. This was based on: (i) unit depth (must be deep enough to allow at least complete mask submersion [about 20cm]); (ii) unit accessibility; and (iii) unit clarity/openness (some units were too messy to allow for safe snorkelling).

Units that were deemed suitable for snorkelling were recorded and flagged with high visibility flagging tape. Following this criteria, most pools were flagged in addition to suitable flatwater units. No riffle units were selected due to the depth constraint.

The habitat assessment was completed during the Fall months when water levels and flow-rate throughout San Pedro Creek are lowest. Therefore this assessment should only be applied to this season as habitat features and units may differ significantly during periods of increased flow. Late summer and fall creek conditions are expected to be the most limiting to juvenile steelhead survival because of the low flows leading to decreased wetted surface area, the reduction of suitable habitat and shelter (The Trinity River Task Force, 1994) and result in elevated water temperatures throughout the creek (Geis, 1982).

Snorkel Survey

The second stage of the overall survey involved the assessment of steelhead abundance and distribution throughout San Pedro Creek. Snorkelling was used because it has proved to be a highly effective survey technique in many small streams and creeks in Northern California and the Pacific Northwest (Hankin & Reeves, 1988) and is a harmless, noninvasive survey method for aquatic ecosystems.

Due to the small size of San Pedro Creek only one snorkeller was needed to survey each habitat effectively. At least one additional person was on hand for recording data and was necessary for safety reasons. The survey crew would discuss an appropriate plan of attack after noting the unit's shape, location of undercut banks, location of woody debris and the unit's thalweg (deepest channel).

The snorkel survey began at the downstream end of the unit to minimize any initial disturbance to the fish and to prevent the water from 'silting up' with disturbed sediment. Slowly edging upstream, the surveyor would look towards the unit's deeper bank or along the thalweg. This was important as pool residents were likely to use the deepest channel for escape to another part of the pool. Steelhead counts were made by counting individual fish when they were passed as the diver moved slowly upstream, which helped to avoid multiple counts of individual fish. Undercut banks, woody debris, root masses, or any other types of in-stream cover were closely examined with a standard diving light with hope to detect any sheltering fish. The snorkeller continued upon reaching the upstream crest of the unit which he would carefully exit. Any fish encountered in the unit were called out to the bank-side recorder. Fish ages were estimated and classified into age-classes depending on the individual's estimated length (Figure 4).

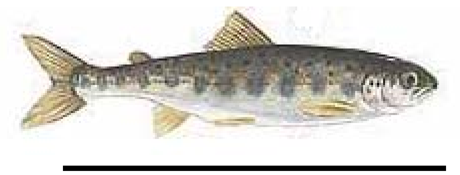
If large numbers of fish were observed in a unit, a second pass was required to allow for a better estimation of fish abundance, an average of the two counts calculated. In the event of such multiple passes, at least 20 minutes was allowed between each pass to allow fish and disturbed sediment to settle.

Figure 4. (Overleaf) Length/Age-class categories of steelhead in San Pedro Creek.

Age Classification

Sullivan's study from 1990 declared that the juvenile steelhead in San Pedro Creek can be separated into three distinct year classes. This study confirmed those findings and allowed the survey to separate observed individual steelhead into the following categories:

Young of year steelhead. (From eggs deposited during winter 2003/2004)

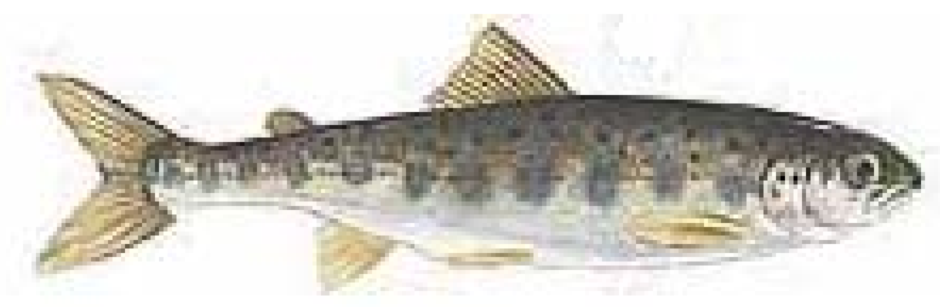


Fork length ≈ 70-90mm

One year old steelhead. (From eggs deposited during winter 2002/2003)

Fork length ≈ 100-130mm

Two year old steelhead. (From eggs deposited during winter 2001/2002)



Fork length ≈ 140-160mm

Data Analysis

Because of heterogeneous variances between fish densities, I analyzed the effects of habitat type and age-class on the average densities of steelhead throughout San Pedro Creek using a Kruskal-Wallis non-parametric test (Tables 18-23). Because units that had very low densities of fish skewed the results, I transformed the data using Log (density + 1) to reduce the effects of many zero counts and some extremely low fish densities (Tables 18-23). Each steelhead age-class was treated separately with ranked steelhead density compared to habitat type. Habitat was one of three types: Pool, Pool/Flatwater, and Flatwater. Fish density within a habitat was treated as the test variable while habitat type was treated as the grouping variable for all three age-classes.

Additionally, I analyzed the effect of habitat depth on the abundance of all three steelhead age-classes using a regression curve. For the regression analysis I also transferred the data using Log (abundance +1) to account for units that were lacking steelhead (Figures 19-21).

Results

San Pedro Creek Habitat Assessment

Mainstem Habitat

The mainstem is San Pedro Creek's longest branch. This study surveyed the mainstem's entire length from the Highway 1 Bridge to the confluence of the Middle and South Forks, more than 4km upstream. The mainstem was partitioned into four separate 1km reaches (Figure 3). This enabled comparisons between reaches to determine if habitat differences existed (Figure 5) and determined if overall fish abundance and fish age-class abundance between the lower and upper reaches of the mainstem differed significantly (Tables 11-14). During the survey, the mainstem's average wetted width was 3.2m and was characterized by a relatively low gradient, with long stretches of flatwater being the dominant habitat type (Table 2; Figure 5). Pool habitat was also commonplace along the mainstem with multiple deep pools, greater than 1 meter in depth, present at the time of survey. The mainstem contained the largest and deepest pools of the entire creek, although riffle habitat was limited with less than a quarter of the mainstem falling into the riffle category (Table 2; Figure 5).

There were four major culverts on the mainstem – all where roads crossed the stream. The road crossings at Adobe, Capistrano, Linda Mar and Oddstad have each altered the natural stream habitat and present potential obstacles and perhaps in cases of extremes of water flow, complete barriers to fish movement. The mainstem is also influenced by suburban development along almost its entire length – an estimated 19% of the entire watershed being developed (USACE, 1989). Houses back onto the creek along much of its course and litter input from storm drains is a common problem. The discharge from the completely culverted North Fork can also bring polluted water into the mainstem, especially during 'flash floods': heavy urban run-off from the North Fork's watershed has led to high levels of pollutants detected in the mainstem, including extremely high levels of coliform bacteria including *E. Coli* and *Streptococcus* - the source of which is unknown, but currently under investigation (Larson, 2005).

Due to the suburban development along much of its banks, the main stem has lost most of its natural riparian corridor. This has affected bank stability, leading to increased levels of erosion, and ultimately, a greater sediment load entering the creek. In-stream woody debris, recruited from bank-side trees constitutes a natural and healthy addition to San Pedro Creek's steelhead habitat. With the loss of riparian zones, woody debris recruitment is seriously reduced from these and downstream areas of the creek. Any woody debris which does make it into the creek is actively removed by the city of Pacifica to reduce the risk of flooding to bank dwelling property owners.

The San Pedro Creek flood control project, conceived after heavy flooding in 1982, proposed the construction of a flood plain along the lower 600m of the mainstem.

The project was initiated in 2000 by the U.S. Army Corps of Engineers (USACE) (McDonald, 2004). Finished in Fall of 2002, the project involves a meandering channel with access of flood flows to a constructed inner floodplain (Collins *et al*, 2001). The project also features a wetland area downstream of the Highway 1 Bridge to emulate the function of wetlands, historically present in the area. This project, intended for flood reduction, will have a significant effect on San Pedro Creek's steelhead population. With this in consideration there have been efforts to create fish habitat within the project area. Large Woody Debris has been used to naturally scour pools, allowing cover for steelhead while additionally helping bank stability. Still only a few years since project completion, there is need for the riparian zone to mature which will provide a direct increase in overhead cover, as well as in-stream cover, through the recruitment of woody debris

Mainstem Reach 1

Reach 1 was the lowest of the four mainstem reaches. It began just upstream of the Highway 1 Bridge and terminated 1km upstream, 160m below Adobe Bridge. The lower 600m of the reach consisted of the recently developed flood control project (FCP). Reach 1 was characterized by a relatively low stream gradient: pool and flatwater were dominant with limited riffle habitat. In comparison to the mainstem's upper reaches, reach 1 had the most pool habitat for its length with just under 50% of the reach classified as pools (Figure 5), three of them over 1m in depth. All three of these deep pools were located in the flood control project. The FCP was characterized mainly by long stretches of flatwater, many with lateral scours having formed marginal pools. Several riffles were recorded, all exhibiting good quality spawning gravel. Although reach 1 had a bridge crossing about 180m above the upstream end of the FCP at Peralta road, the bridge was free spanning, and by allowing a natural stream flow and substrate beneath, did not present an obstacle to fish migration. Riparian cover throughout the FCP at the time of study was poor. Above the FCP, overhead cover increased substantially.

Mainstem Reach 2

Reach 2 progressed upstream for a further 1km ending at an artificial weir with residential housing near Solano Drive on the right bank. Reach 2 had higher average stream gradient than the lower reach apparent with the increased abundance of riffles and several high gradient cascades present (Figure 5). Reach 2 had less overall pool habitat than the lower reach although more deep pools (>1m) were present throughout this second reach. The first obstacle to fish migration on the mainstem was the Adobe Road Culvert which provided a stream crossing at the lower end of the reach. Here the mainstem has been altered to flow through a basic concrete box-culvert, 2.2 meters wide and 15.5 meters long. At the culvert's downstream mouth was a 30cm raised-step from the pool below Adobe Bridge. Wooden beams have been anchored to the culvert base, designed to help fish passage. Riparian cover throughout the second reach was patchy, some units benefiting from quite dense overhead cover while others were very exposed. In some cases, gabions and large boulders had been placed in the effort to reduce the rates of bank erosion. Riparian zones have also been affected by creek-side residences, some areas having decks raised on stilts perched over the creek. Such residential zones may also reduce the abundance of low-lying under-storey vegetation, very important cover for steelhead, such as native grasses, ferns, and blackberry brambles.

Mainstem Reach 3

Reach 3 continued from the artificial weir another 1km upstream, ending 250m upstream of Capistrano Bridge. Sanchez Fork entered the mainstem in the lower section of the reach. Average stream gradient seemed lower than reach 2 which was demonstrated by the lowest abundance of riffle habitat observed throughout the mainstem. Pool habitat was second only to the first reach, with three pools greater than a meter in depth present while several high gradient cascades added to the complexity of the reach (Figure 5). Capistrano Road Bridge is the second and perhaps the greatest obstacle on San Pedro Creek's mainstem. Built in the early 1970s, the structure comprises two sections of Denil fish ladders with a large resting pool in-between. The entrance to the first ladder, was elevated more than one meter above the downstream pool. Directly above the Capistrano Road Bridge, the creek has been channelized into a straight concrete ditch that stretches for approximately 200m upstream. Like the mainstem's second reach, riparian cover was patchy throughout reach 3. The concrete ditch region immediately upstream of Capistrano Bridge was highly exposed, most of its length completely lacking overhead cover.

Mainstem Reach 4

Reach 4 continued another 1km upstream before terminating at the confluence of the Middle and South Forks. Approximately halfway up the fourth reach, the North Fork enters the mainstem. Above this point the mainstem became considerably reduced in size. Reach 4 had the lowest abundance of pool habitat on the mainstem but the highest abundance of riffle habitat (Figure 5). The third and fourth obstacles to fish migration on the mainstem are both on reach 4. The mainstem's third obstacle is formed by the culvert below the Linda Mar Bridge. The culvert is 23 meters long, approximately 5 meters wide featuring a wide flat culvert base with a raised step almost 15cm above the downstream pool.. The final obstacle on the mainstem is at Oddstad Bridge where a double (side-by-side) box culvert 18.5 meters in length, each culvert 3 meters wide, lies perched about 30cm above the downstream pool.

Total # units surveyed	**Length Surveyed (m)**	Number of units classified as pools	Pool length(m)	Number of units classified as flatwater	Flatwater length(m)	Number of units classified as riffle	Riffle length(m)	Number of units classified as culvert	Culvert length(m)
248	**4020.5**	129	1488	43	1514	92	938	4	80.5
	% of total	48.1	37.0	16.0	37.7	34.3	23.3	1.5	2.0

Table 2. Mainstem total habitat composition.

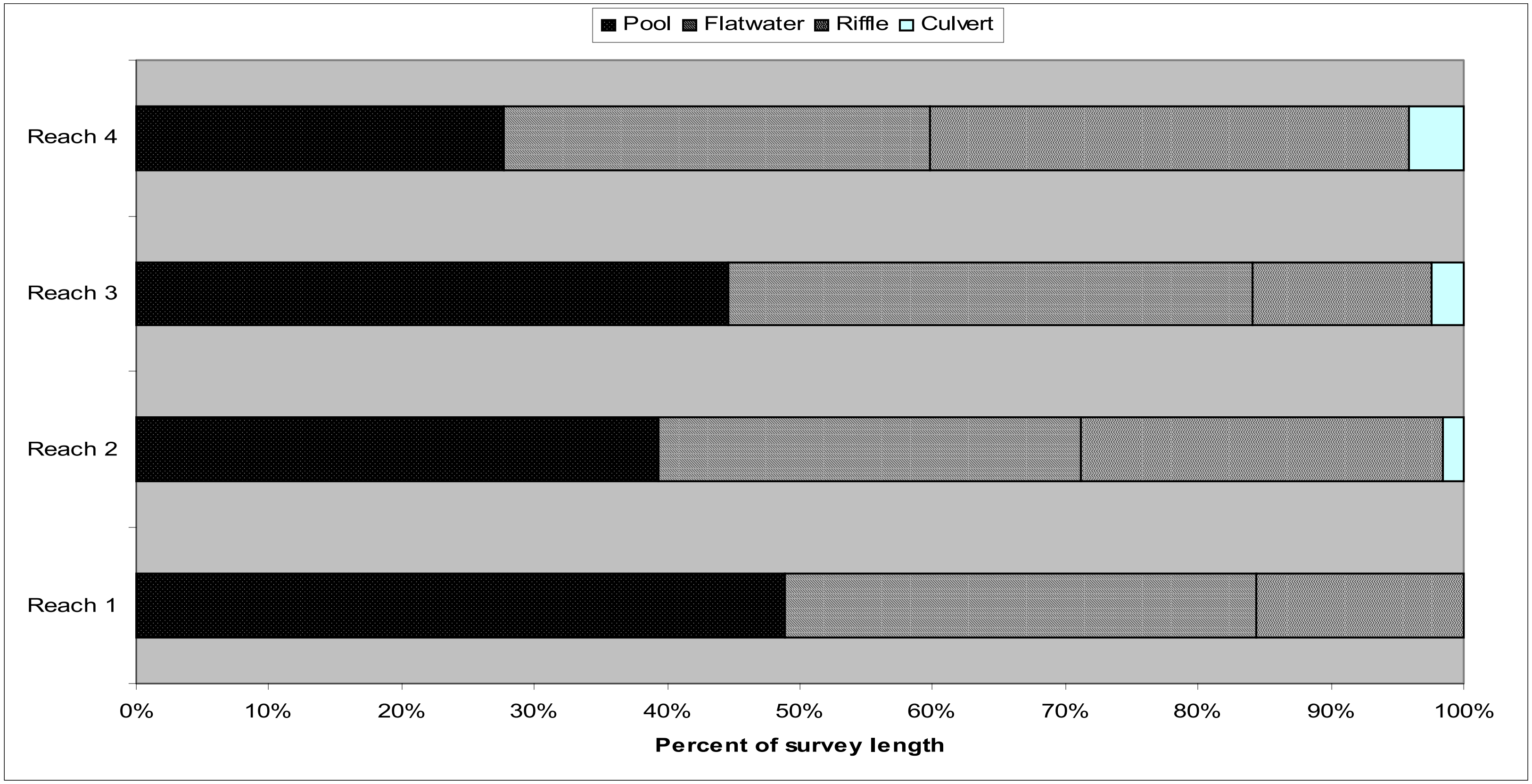


Figure 5. Mainstem fish habitat type by reach.
Reach 1 began at the Highway 1 bridge and ended 1km upstream, 160m below Adobe Bridge. Reach 2 continued 1km further upstream, ending 140m below Sanchez Fork. Reach 3 continued another 1km upstream ending mid-way between Capistrano and Linda Mar Bridge. Reach 4 represents the final 1km of mainstem terminating at the Middle/South Fork confluence.

Sanchez Fork Habitat

Sanchez Fork is a small tributary draining the south west of the basin. It enters the mainstem between Adobe Bridge and Capistrano Bridge. During this survey, only the lower 270m of Sanchez Fork, beginning at its confluence with the mainstem, were assessed. Above this, the creek had been restricted to a corrugated metal culvert for 40m, while it flowed beneath a church car park. A vertical drop of 2 meters from the culvert mouth to the pool below had eliminated the possibility of adult steelhead from ascending any further up Sanchez Fork and was a complete barrier for any upstream fish movement. In contrast to the mainstem, Sanchez Fork had a fairly steep gradient, with much higher water velocities at the time of survey. The average wetted width of Sanchez Fork was only 1.5m, making it the smallest of the tributaries surveyed.

Much of Sanchez was classified as flatwater habitat (Table 3; Figure 6). The gradient and water velocity of Sanchez Fork's flatwater habitats were such that they were classed as Runs and Cascades. These particular habitats are often associated with salmonids especially steelhead, due to high dissolved oxygen levels, clean, fast flowing water and heterogeneous substrates. Pools were present in the short stretch surveyed; however, all but one were relatively shallow (<40cm). The one deep pool (>1m), was a large plunge pool which had formed directly below the metal culvert terminus. The remaining pools tended to be associated either with bedrock formations or old, concrete structures. Apart from the deep plunge pool, pool size was small - averaging just over 4m in length. Riffles were the second most abundant unit type. Because of Sanchez Fork's steep gradient, the riffle zones throughout Sanchez Fork tended to be much steeper and thus classed as high gradient riffles. Substrate tended to be diverse throughout most of the reach with bedrock, boulders, cobble, and gravel all present. The availability of good sized gravel and lack of fine sediment suggest that parts of Sanchez fork would be suitable for adults to spawn provided they were able to ascend.

Besides the corrugated metal culvert, two concrete culvert sections were observed along the surveyed stretch of Sanchez Fork. The first, approximately 125m upstream from the confluence with the mainstem, was a rectangular culvert, 20m long, with a flat, uniform base. The second was 70m further upstream and looked to be the remains of a box culvert, only the base now remaining.

Overhead cover tended to be good throughout Sanchez Fork, providing good cover for fish and allowing for the recruitment of woody debris. Woody debris was present in two units and could clearly provide cover for juveniles or spawning adults. Understory bank cover was reasonable throughout, allowing fish shelter along the edges of banks, while several areas with undercut banks were noted, allowing important areas of shelter, and refugia from the strong current.

Total # units surveyed	**Length Surveyed (m)**	Pool Abundance	Pool length(m)	Flatwater Abundance	Flatwater length(m)	Riffle Abundance	Riffle length(m)	Culvert Abundance	Culvert length(m)
31	**269.5**	9	37.5	16	122.5	12	90.5	2	28
	% of total	23.0	13.9	41.0	45.5	30.8	33.6	5.1	10.4

Table 3. Sanchez Fork habitat composition.

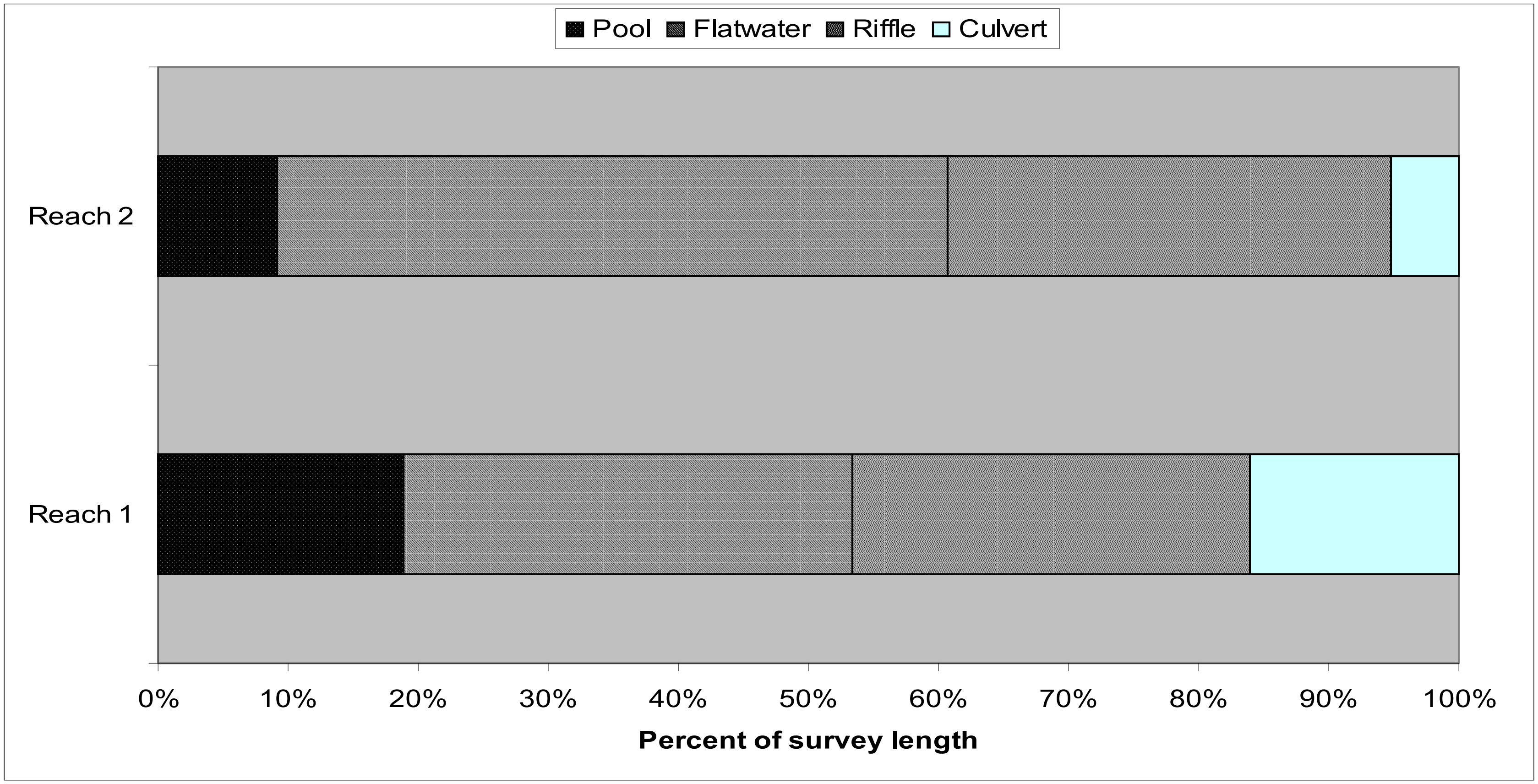


Figure 6. Sanchez Fork habitat type by reach.
Reach 1 began at its confluence with the mainstem, continuing 125m to the upstream end of the culvert. Reach 2 continued 154m upstream, terminating at the base of the corrugated metal pipe.

Middle Fork Habitat

The Middle Fork was surveyed in two separate sections. The first section was surveyed from its confluence with the South Fork, and continued until extremely dense vegetation and large jams of woody debris prevented further access, some 930m upstream. The second section began some 70m below the Weiler road bridge, continuing until 150m upstream of the bridge.

During the time of survey, the Middle Fork had a low flow rate, probably a result of its relatively small drainage area (Hagar, 2002). Average wetted width on the lower section was 2.1m. Further upstream the flow was much reduced. As a result, the average wetted width was just over 1m. The Middle Fork had a low gradient overall as it meandered through the low-gradient structural valley within San Pedro County Park. Towards its upper reaches, as it approaches the foothills at the head of the valley, the gradient increases significantly.

A total survey length of 1138.5m was conducted on the Middle Fork (Table 4). In terms of habitat: pools, riffles, and flatwater zones were all observed in similar abundance throughout the Middle Fork (Figure 7). Pools were much smaller on average than those on the mainstem, with an average length of 4.6m. Middle Fork pools were also shallower, the average depth being 44cm: many pools were relatively shallow (<40cm); several were deeper than 60cm, the deepest pool being 75cm deep. The high percentage of quality riffle zones, important for water oxygenation and ideal steelhead spawning sites, indicate that the Middle Fork has great potential for steelhead spawning, having also been observed in previous surveys (Hagar, 2002). Low gradient flatwater zones were common, and provided the ideal habitat for steelhead, preferring shallow, flowing water.

Only one culvert remains on the Middle Fork, and may create an obstacle for ascending adult steelhead. The 13m long, 2.5m wide concrete box culvert, located 80m above the downstream confluence, supports a small bridge crossing in the San Pedro County Park. The culvert's design incorporates a 45˚ bend half way through - which may reduce flow velocity and enhance upstream fish passage. A second culvert which used to exist further upstream, deemed to be a total barrier to migration, was dismantled and replaced with the Weiler Ranch Road Bridge in July 2001. The new bridge is a free-spanning structure, allowing the creek to flow in a natural state, with no impediment to steelhead passage.

Cover throughout the Middle Fork was excellent. A mature, wooded, riparian zone followed the channel from its headwaters down to the mainstem confluence. Dense, low-lying vegetation in the understory, in addition to complex root systems and undercut banks, provided shelter and refuge for juveniles and possibly for spawning adults in the winter. Woody debris was abundant throughout the Middle Fork, providing complex habitat, creating scour pools and to divert flow creating backwater pockets – sometimes essential for steelhead, especially adults during high flows.

Total # units surveyed	**Length Surveyed (m)**	Pool Abundance	Pool length(m)	Flatwater Abundance	Flatwater length(m)	Riffle Abundance	Riffle length(m)	Culvert Abundance	Culvert length(m)
112	**1138.5**	54	250.5	47	406.5	50	479	1	13
	% of total	35.5	22	30.9	35.7	32.9	42.1	0.7	1.1

Table 4. Middle Fork habitat composition.

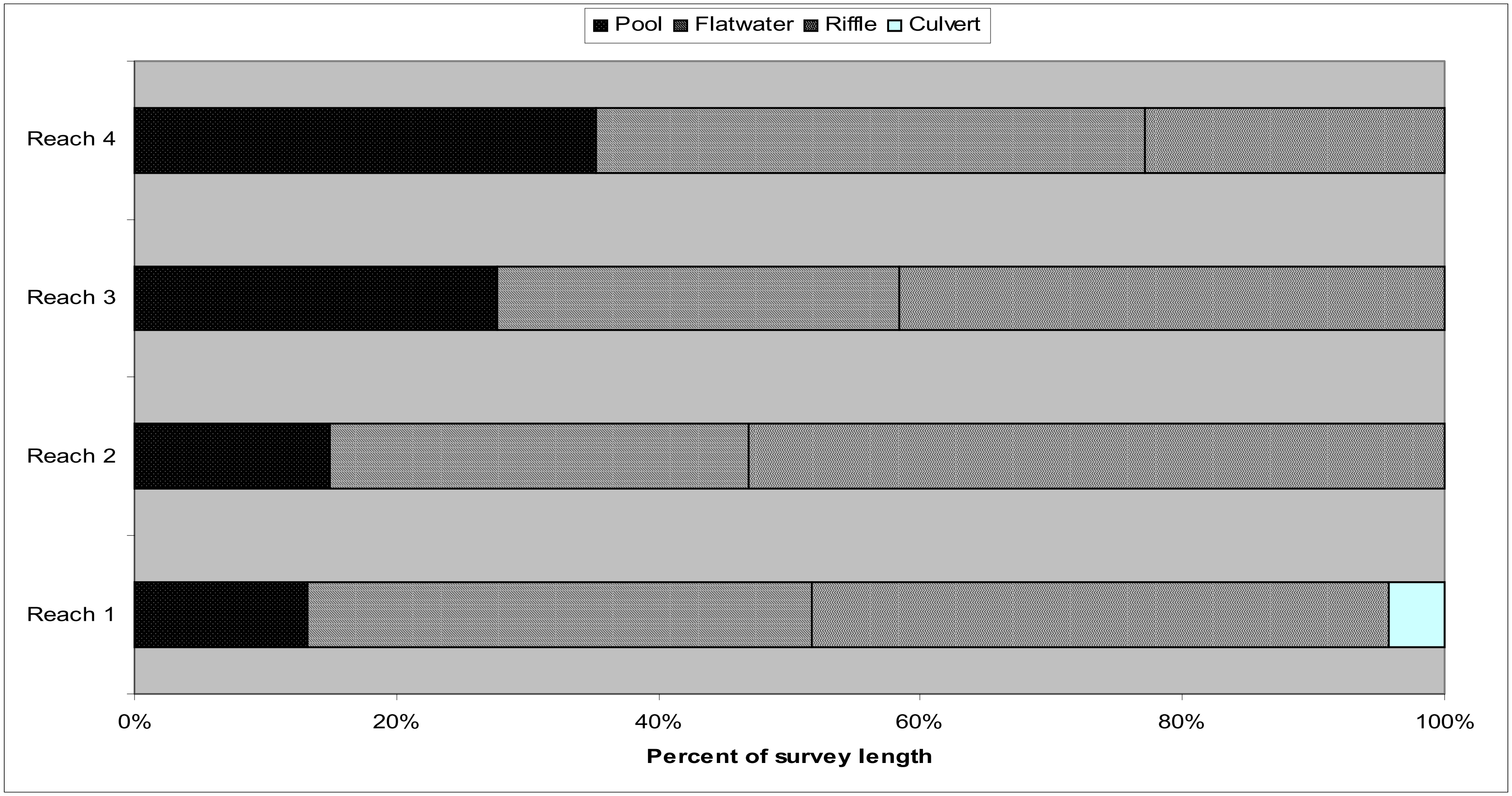


Figure 7. Middle Fork fish habitat by reach.
Reach 1 began at the confluence with the South Fork and continued 300m upstream. Reach 2 represents the 300m – 600m stretch of creek. Reach 3 represents the stretch from 600m – 900m. Reach 4 represents the final stretch of creek surveyed (just over 200m in length) which ended due to impassable vegetation.

South Fork Habitat

The South Fork was surveyed from its confluence with the Middle Fork, terminating almost 900m upstream, at the North Coast County Water District (NCCWD) diversion. The South Fork's upper reaches passed through forested land, owned by the NCCWD. The lower reaches, however, flowed through well vegetated riparian zones, located in San Pedro Valley County Park. The majority of the channel length was surveyed, although it was necessary to by-pass small sections, due to very dense brush and overhanging vegetation. The South Fork survey ended at the water diversion because it poses a complete barrier to upstream movement of fish. Therefore there would be no steelhead found above the diversion, although resident rainbow trout would almost certainly exist.

In terms of wetted width, the South Fork was similar in size to the Middle Fork with an average wetted width of approximately 2m. The South Fork's gradient and water discharge were greater, however, resulting in much faster water velocities throughout.

Surveyed stretches of the South Fork consisted primarily of flatwater habitat (Table 5; Figure 8). Given the relatively steep gradient of the South Fork, like Sanchez Fork, almost all of these flatwater units were sub-categorized as runs and cascades. The South Fork was unique among the tributaries surveyed in that bedrock was regularly exposed along its length. This hard erosion-resistant bedrock has enhanced the formation of some nice pools throughout the stream, and promoted the South Fork's steep gradient.

In the 1960s, the course of the South Fork was artificially straightened to allow easy water diversion for a trout farm built on the South Fork's banks. This channel straightening would have had a major impact on the stream gradient and certainly accounts for the present condition of the South Fork. Bedrock has also influenced the formation of many plunge pools, the most common pool type found in the South Fork. On average, pools were smaller and shallower than those on the Middle Fork, with an average length and depth of 3.7m and 38.7cm respectively. In several places along the creek were small, naturally formed waterfalls, their heights between 50 and 90cm, again products of the exposed bedrock. These small waterfalls will act as barriers to the movement of juvenile steelhead during the summer and periods of low flow. Additionally an old concrete weir, possibly used for water diversion for the old trout farm (Hagar, 2000), will also act as a barrier to the movement of young steelhead. It is unlikely that this structure, or the natural weirs, will restrict the movement of adults during the winter months, since higher flows will minimize the influence of such obstructions. Waterfalls and plunge pools such as these may provide additional shelter for juvenile steelhead and resident rainbow trout, in the form of 'bubble curtains' which can be very effective, especially against visual predators.

The majority of the South Fork's riffle habitat was classed as high gradient riffle zones due to the steeper grade of the South Fork. Water velocities over such areas were higher than those over low gradient riffles on other parts of San Pedro Creek.

Overhead cover was very good along the entire length of the South Fork. Along the lower reaches, a mature riparian zone provides shelter, excellent coverage, and allowed for the recruitment of woody debris. This dense riparian zone thinned toward the upper reaches as the South Fork flowed through a mature forest. Although there was a distinct lack of undercut bank on the South Fork, well developed under-story vegetation, in addition to complex root systems, provided shelter and refuge for juveniles and spawning adults. Woody debris was present in small quantities along the South Fork allowing for complex habitat and the formation of scour pools in those areas.

The level of siltation on the South Fork was the highest of all tributaries surveyed. While it was not apparent exactly why this was the case, recent bank erosion observed close to the NCCWD site may be partly to blame. Silt and other fine sediments are known to be deleterious to the health of steelhead (Bash *et al*., 2001; Cordone & Kelley, 1961), the South Fork should be closely monitored to assess the exact cause(s) of the siltation and appropriate remediation measures be taken.

Brook's Creek entered the South Fork slightly downstream from the NCCWD. At the time of survey, this small tributary was mostly dry creek-bed - an intermittent trickle appearing occasionally between patches of dry pebbles. As there was no possibility of juvenile steelhead inhabiting such a reach, no habitat assessment was carried out. During high flow, however, there may be enough water present in this creek for adults to ascend, spawn, and their progeny to reside, until declining water levels force them down into the South Fork itself.

Spawning potential on the South Fork was not limited by any major obstructions to adult ascent as there were no culverts, or other major artificial structures below the NCCWD. Additionally, the South Fork contained large quantities of suitably sized gravel for successful steelhead spawning. Perhaps the major limiting factor to successful spawning on the South Fork was the presence of silt and other fine sediments, which, in large quantities, can lead to prenatal or early postnatal mortality in young steelhead (Bash *et al*., 2001).

Total # units surveyed	**Length Surveyed (m)**	Pool Abundance	Pool length(m)	Flatwater Abundance	Flatwater length(m)	Riffle Abundance	Riffle length(m)	Culvert Abundance	Culvert length(m)
84	**896.5**	28	103.5	53	560	15	146	0	0
	% of total	29.2	11.5	55.2	62.5	15.6	16.3	0	0

Table 5. South Fork habitat composition.

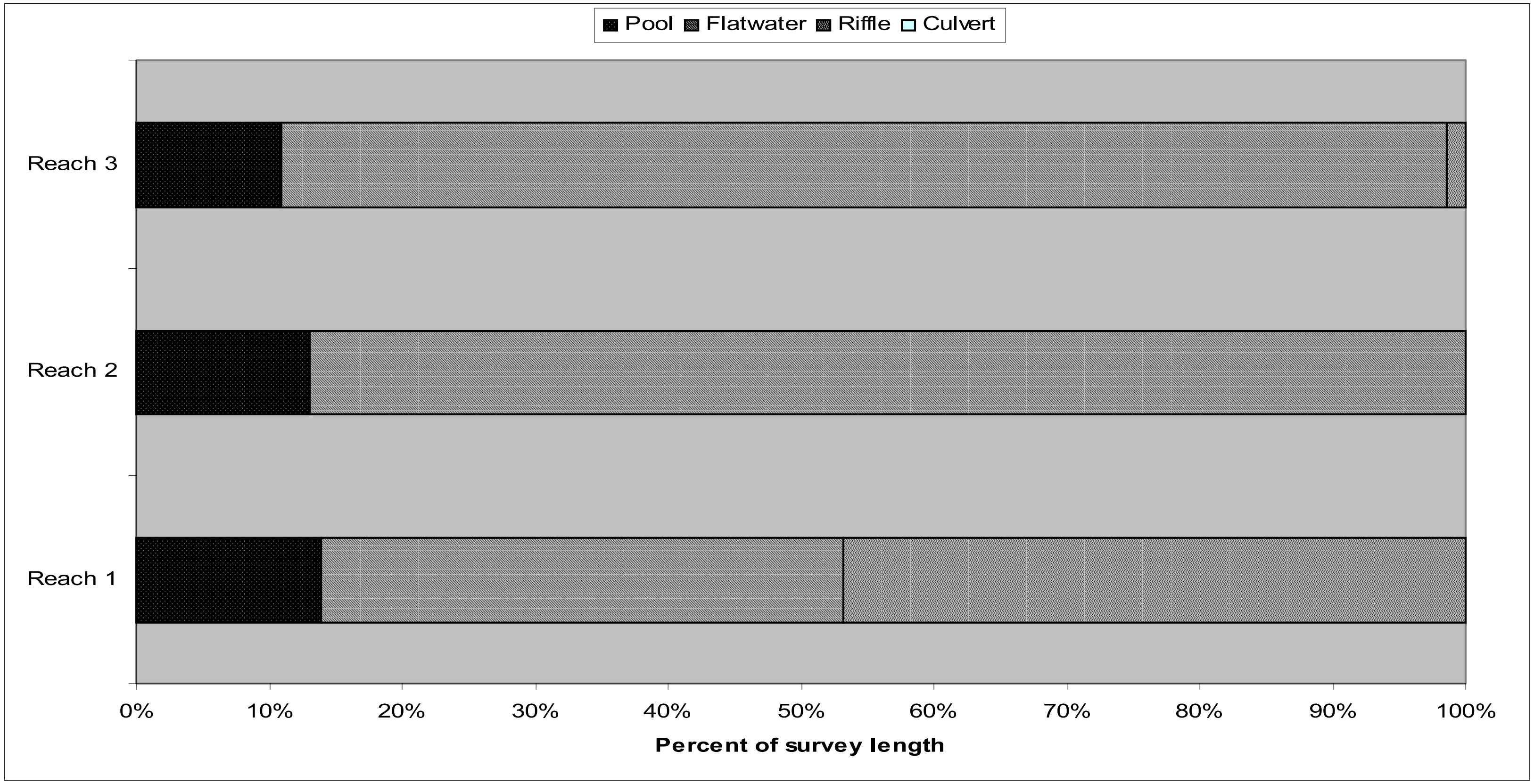


Figure 8. South Fork fish habitat by reach.
Reach 1 began at the confluence with the Middle Fork and continued 300m upstream. Reach 2 represents the stretch of creek from 300-600m. Reach 3 represents the final stretch (600-900m) of survey terminating at the North Coast County Water District diversion.

San Pedro Creek Snorkel Survey

Mainstem Snorkel Survey

Snorkel surveys were conducted throughout the mainstem on five separate days: October 22nd; November 5th; 19th; 26th; and December 15th. During this time, the snorkel survey covered 2107m of the mainstem, just over 52% of its entire length. Snorkelling was prevented when creek depth was below 20cm, dense brush and vegetation made passage impossible, or when poor water quality was apparent. A day's snorkel survey would always end at either a culvert or a weir. This would minimize the effects of in-stream migration on counts, the low flows making it very unlikely for them to pass such obstacles.

Low water level and flow rates throughout the creek enabled the majority of survey units to be small and fairly discrete. This allowed them to be surveyed relatively easily and permitted reasonably accurate fish counts. The exception was the reach within the flood control project - the lower 600m of the mainstem. Units throughout this region were often very long (up to 60m), wide (up to 8m, averaging 4m) and were lush with in-stream aquatic vegetation. Data from units within the flood control project must therefore be treated with some caution as fish abundance recorded in this region may not be very accurate.

Mainstem Steelhead Counts

The mainstem had the highest counts of all three steelhead age-classes and resident rainbow trout (Table 6, Figure 9). Given the mainstem's size (the largest of all tributaries), and the length surveyed (survey length was longer than that of any other tributary), this was not particularly surprising. Table 6 presents the age-class break down of steelhead in the mainstem and tributaries.

	YOY Steelhead	**Age 1 Steelhead**	**Age 2 Steelhead**	**Resident Trout**
Mainstem (4020.5m)	216 (42%)	208 (39%)	97 (18%)	7 (1%)
Sanchez Fork (269.5m)	11 (69%)	5 (31%)	0	0
Middle Fork (1148.5m)	133 (81%)	26 (16%)	4 (2%)	1 (1%)
South Fork (896.5m)	32 (78%)	4 (10%)	3 (7%)	2 (5%)
Creek-Wide Total	**392**	**243**	**104**	**10**

Table 6. Abundance of steelhead from San Pedro Creek Snorkel Survey. (Proportion of total).

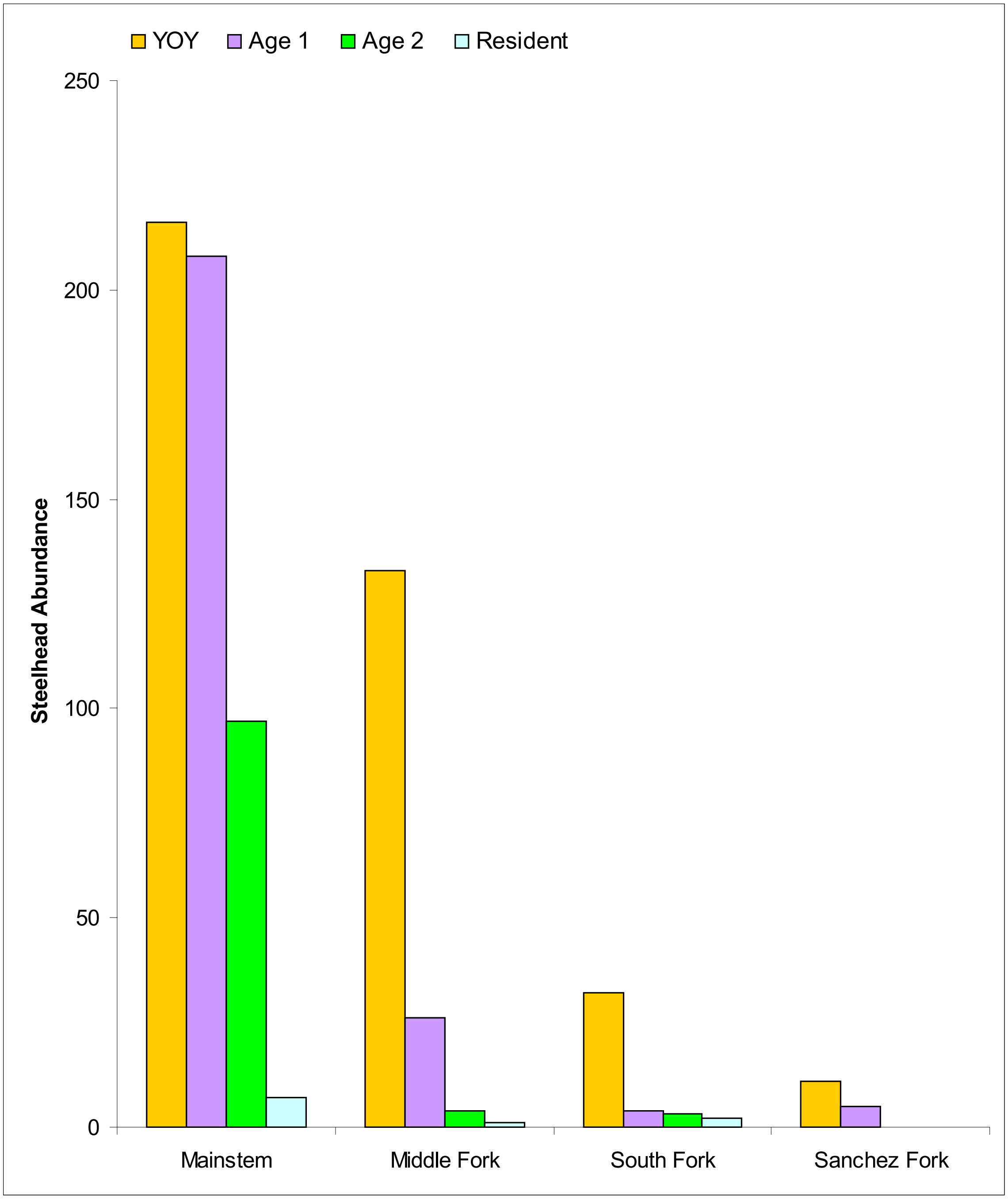


Figure 9. Steelhead abundance in San Pedro Creek's respective tributaries.

Salmonid population surveys report fish abundance in two ways:

(i) Fish abundance can be calculated per given unit of length e.g. (fish /10m).

(ii) Fish density can be calculated per given wetted unit area e.g. (fish /m^2).

In order to allow comparisons between previous studies on San Pedro Creek and similar studies on different creeks, this survey presents fish data in both one (fish /unit of length) and two (fish per unit area) dimensions: Figures 10 and 11 respectively.

The results of the snorkel survey thus show that Young of the Year steelhead were the most abundant age class in the mainstem with an abundance of just over 1 fish for every 10m of creek or approximately 0.07 fish per m^2. Age 1 steelhead were only slightly less abundant, with just under 1 one-year-old steelhead for every 10m of creek or just under 0.05 one-year-old steelhead per m^2 of creek surveyed. Age 2 steelhead were much less abundant throughout the mainstem, approximately 0.5 fish counted for every 10m- approximately 0.02 fish per m^2. The small number of resident trout observed throughout the mainstem was mirrored by their very low density (0.04 resident trout for every 10m or 0.0015 residents per m2 of creek). These abundance standardizations allow direct comparison between the abundances of steelhead age-classes among the four tributaries of this survey (Figures 10 & 11).

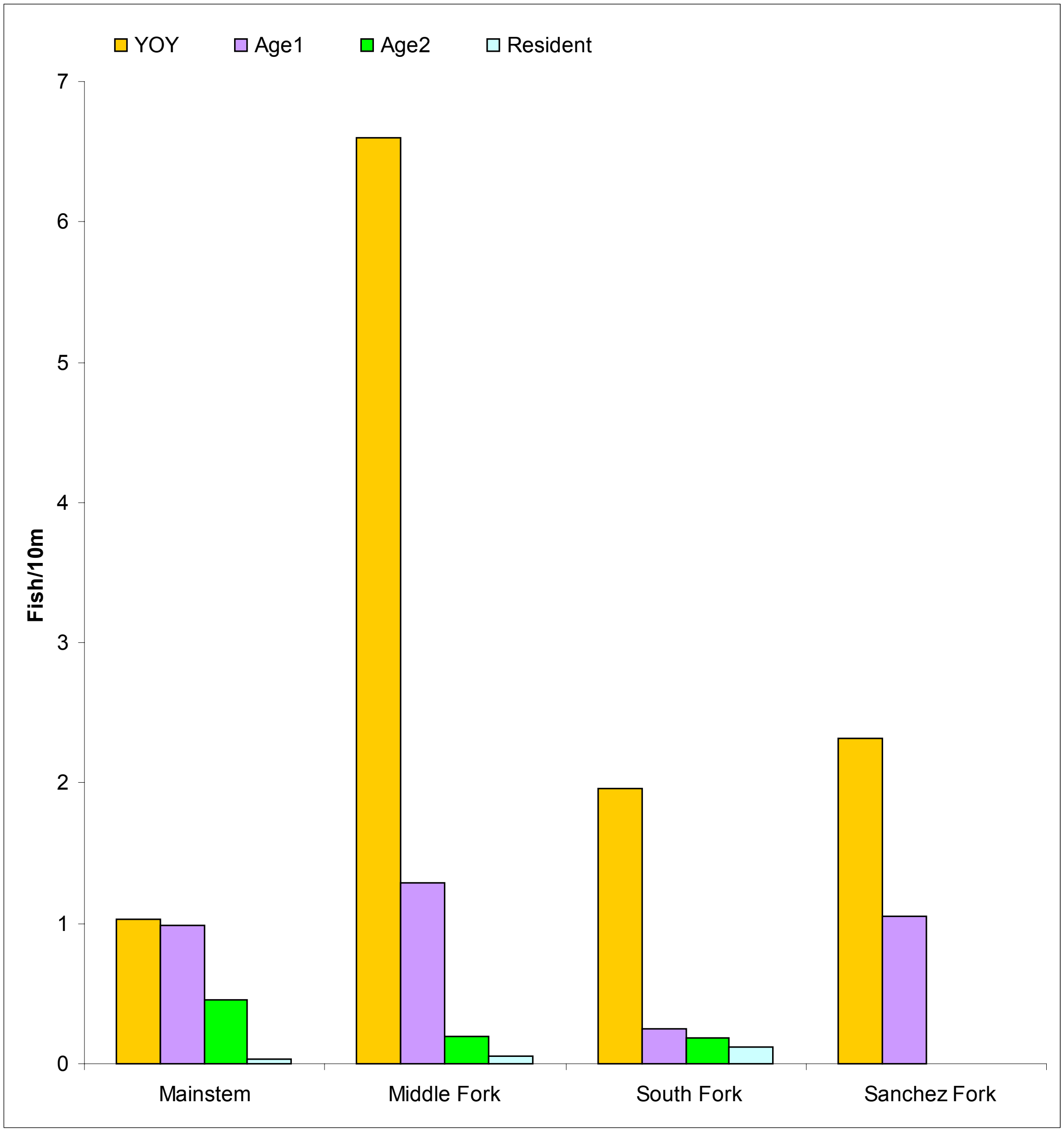


Figure 10. Standardized steelhead abundances (fish/10m) among all four tributaries.

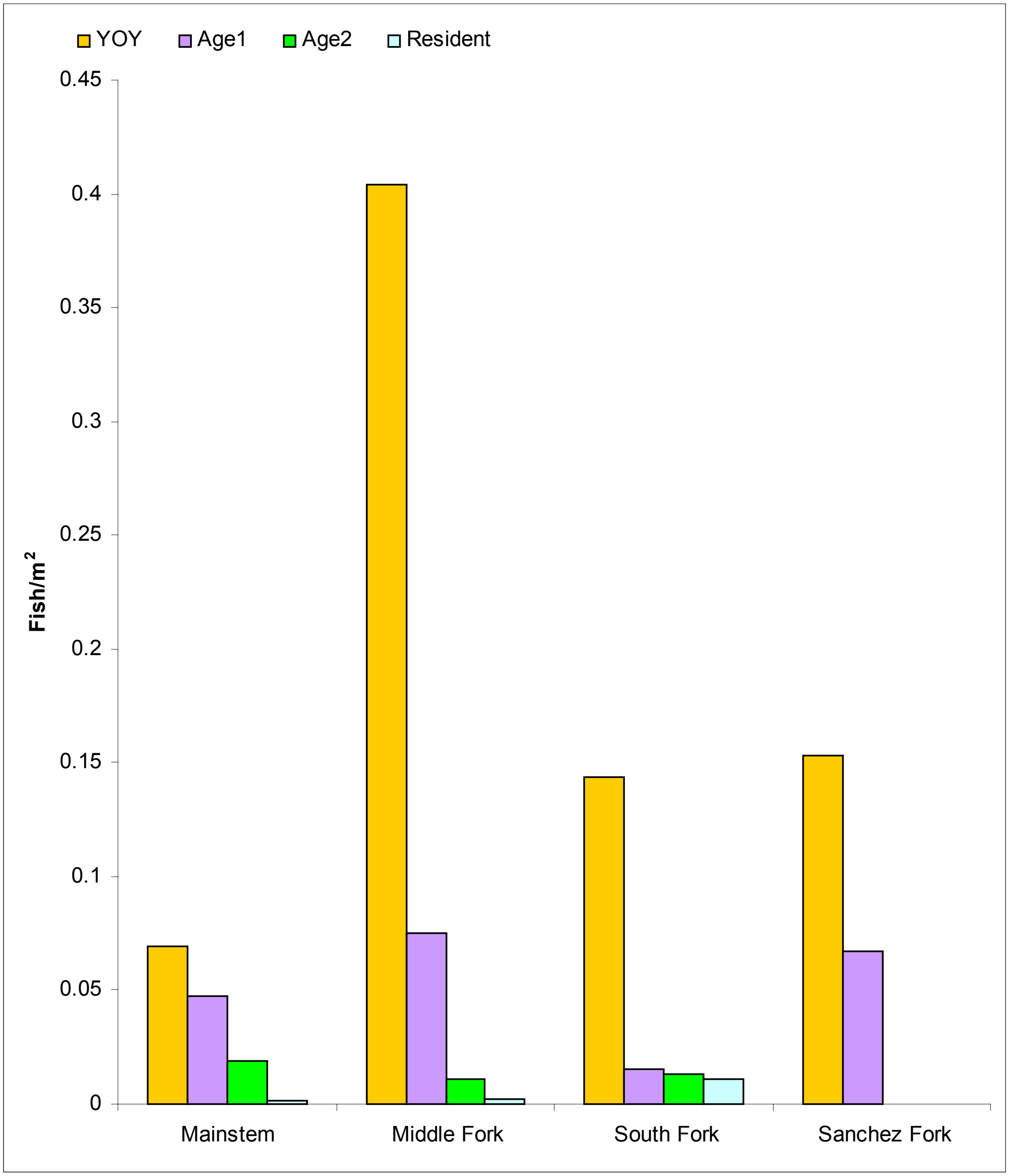


Figure 11. Standardized steelhead densities (fish/m^2) among all four tributaries.

Spatial distribution of Steelhead throughout mainstem

The distribution of steelhead throughout the mainstem, determined by observations, was not random. Nor was it uniform: steelhead were not observed in equal numbers, equally spaced throughout the creek. Instead they demonstrated aggregated dispersion patterns; long stretches of the mainstem had very few fish while others proved to be distinct 'hot-spots', high in steelhead numbers (Table 7, Figure 12).

	YOY	Age 1 Steelhead	Age 2 Steelhead	Resident Trout
Total number observed	216	208	97	7
Unit average	0.069	0.048	0.019	0.0015
Maximum unit density	1.5	0.75	0.28	0.06

Table 7. Steelhead density, (fish/m2), throughout mainstem.

Distribution of 'Young of year' steelhead

A total of 216 YOY were spotted throughout the mainstem, the most numerous age-class on the mainstem and the highest abundance of any tributary. These YOY steelhead were observed in very low numbers throughout the lower reaches of the mainstem however: long reaches were surveyed without spotting a single fish. From the Highway 1 Bridge up to Adobe Bridge, only 2 snorkeled units out of 24 contained YOY. From Adobe Bridge to Capistrano Bridge, 19 units out of 53 snorkeled contained YOY.

Observations of YOY increased suddenly between the culverts at Capistrano and Linda Mar Bridge (10 out of 17 units contained YOY). The highest abundance recorded in a single unit was 27 individuals, residing in a 29m-long unit of flatwater/pool habitat (0.31 fish/m^2), approximately 30m below the culvert at Linda Mar Bridge. Numbers decreased immediately below Linda Mar Bridge, but increased again once upstream. The 4m-long pool, directly below Oddstad Bridge had the second highest abundance with 20 individuals, and the compact dimensions of this pool gave it the highest density of YOY steelhead anywhere in the mainstem (1.5 fish/m^2). YOY were absent from only one unit above the Linda Mar Bridge. Throughout the mainstem YOY were observed in pool, flatwater and riffle habitats.

Distribution of Age 1 steelhead

A total of 208, Age 1 steelhead were spotted throughout the mainstem. These fish were found to be in highest abundance throughout the middle and upper reaches of the mainstem. Below Adobe Bridge, very few steelhead were sighted. As previously mentioned however, counts from the flood control project may not be particularly accurate. Below Adobe Bridge, only 2 out of 24 units contained Age 1 steelhead. Between Adobe and Capistrano observations of Age 1 steelhead increased dramatically, 32 out of the 53 snorkeled units containing Age 1 fish. The unit with the highest abundance of Age 1 fish in the mainstem was located between these bridges. A total of

22 individuals were observed, residing in a 35m long, 3.5m wide pool. Given the pool's large dimensions, the density of steelhead in this unit was 0.179 fish/m^2. Between Capistrano and Linda Mar Bridges, 11 out of 17 snorkeled units contained Age 1 steelhead. Between Linda Mar and Oddstad, 8 units out of 13 contained Age1 fish. Interestingly, the unit with the highest density of YOY also proved to have the highest density of Age 1 steelhead. This 4m-long pool, directly below the Oddstad Bridge, had an abundance of 10 individual Age 1 fish. The density of Age 1 steelhead in this unit was (0.75 fish/m^2). Upstream of Oddstad Bridge, 7 out of the 13 snorkeled units contained Age 1 steelhead. The two units with the highest densities of Age 1 steelhead were both located at the downstream end of culverts; Linda Mar Bridge culvert and Oddstad Bridge culvert. Out of the total count of 208 Age 1 steelhead, only 4 of these fish were spotted in flatwater units. The remaining 204 steelhead were all observed in pools.

Distribution of Age 2 steelhead

A total of 97, Age 2 steelhead were observed throughout the mainstem. Unlike the smaller steelhead age-classes, Age 2 steelhead were most abundant throughout the mainstem's middle and lower reaches. The majority of these fish were observed in the reach between Adobe and Capistrano.

Below Adobe Bridge, 6 out of the 24 units snorkeled contained Age 2 fish. Between Adobe and Capistrano, 23 out of the 53 snorkeled units contained Age 2 fish.

The highest abundance of Age 2 steelhead in a single unit was 15 fish residing in a fairly long scour pool, situated at the confluence with Sanchez Fork. This pool also had the highest density of Age 2s for the entire mainstem at 0.28 fish/m^2. Between Capistrano and Linda Mar, 4 out of 17 snorkeled units contained Age 2 steelhead. Between Linda Mar and Oddstad, 3 units out of the 13 contained Age 2 fish. Above Oddstad, only 2 out of the 13 snorkeled units contained Age 2 steelhead. Only 5 of the 97 Age 2 steelhead spotted were seen in flatwater habitat, the others all observed in pools.

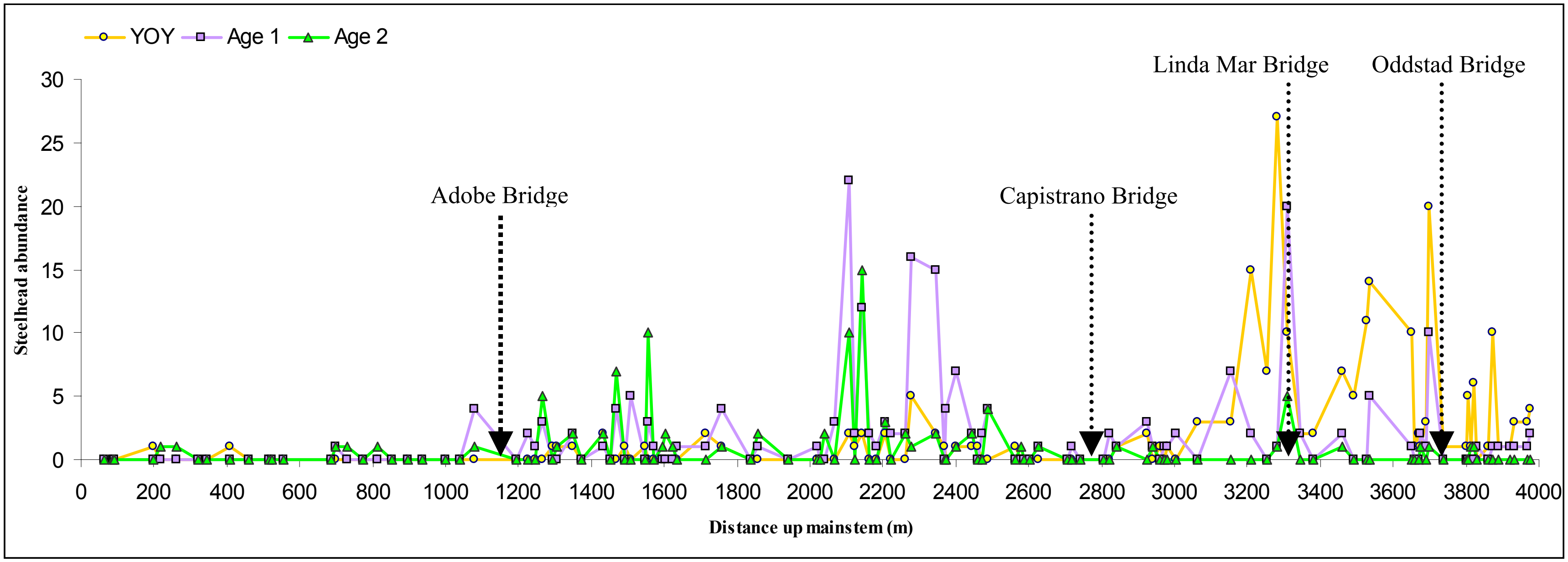


Figure 12. Spatial distribution of steelhead age-classes throughout San Pedro Creek's mainstem. Major culverts are indicated by arrows.

Sanchez Fork Snorkel Survey

The Sanchez Fork Snorkel Survey was conducted on November 3rd. The survey covered just 47.5m of Sanchez Fork, due to shallow water depth, 17.6% of the distance surveyed during the habitat assessment. Snorkeled units were all very small in Sanchez Fork, allowing for reasonably accurate counts.

Sanchez Fork Steelhead Counts

Given the small size of Sanchez Fork and the limited fraction actually snorkeled, absolute steelhead counts were the lowest of any branch surveyed (Table 6; Figure 10). Only YOY and Age 1 steelhead were observed in Sanchez Fork. A total of 11 YOY steelhead were spotted throughout Sanchez Fork, and were the most abundant age-class (Figure 13). These YOY steelhead were observed in 8 out of the 9 units snorkeled, and were seen evenly in both pool and flatwater habitats. A total of five, Age 1 steelhead were observed in Sanchez Fork. They were spotted in 4 out of the 9 units snorkeled; and the majority of them (4/5) were spotted in pools.

The standardized abundance of YOY steelhead observed in Sanchez Fork was actually the second highest, after the Middle Fork, with 2 YOY spotted every 10m of creek surveyed (Figures 10 & 13). Age 1 steelhead within Sanchez Fork were in similar abundance to Age 1s in the mainstem, about 1 fish spotted every 10m (Figure 13). Even though relatively low numbers of steelhead were observed in Sanchez Fork, the small unit sizes resulted in relatively high fish densities (Table 8).

	YOY	Age 1 Steelhead
Total number observed	11	5
Unit Average	0.27	0.171
Maximum Unit Density	1.38	0.604

Table 8. Steelhead density (fish/m2) throughout Sanchez Fork.

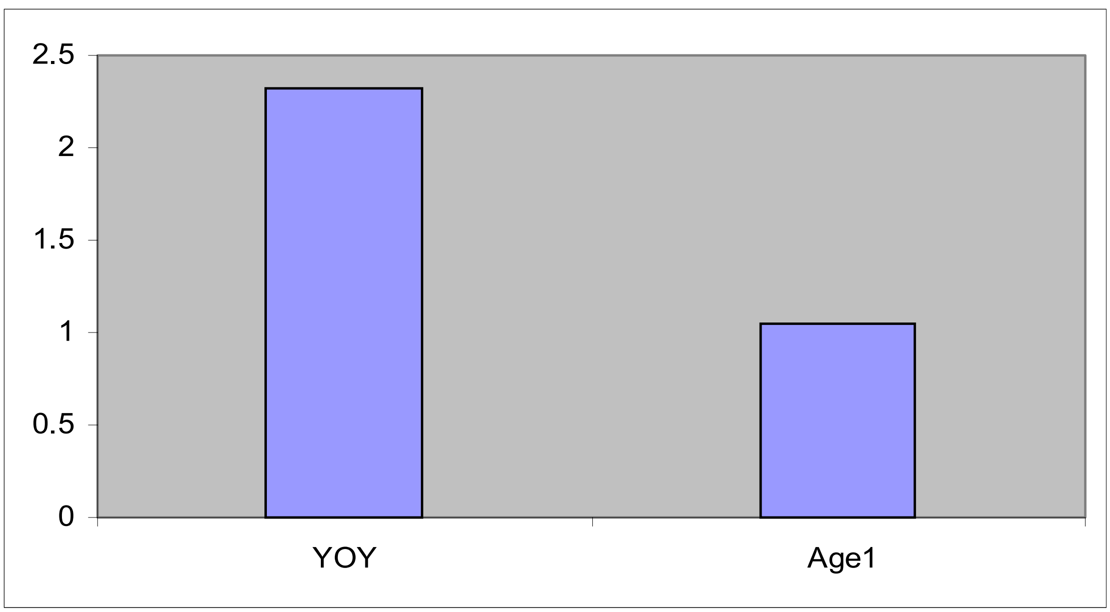


Figure 13. Abundance of steelhead in Sanchez Fork (Fish/10m)

South Fork Snorkel Survey

Snorkel surveys were conducted on the South Fork on two days: December 20th and 22nd. Throughout the South Fork, snorkelling was hampered and excluded from entire stretches by very dense vegetation covering the creek, in-stream woody debris and low water levels. The South Fork snorkel survey covered 152m of the creek, just under 17% of the length surveyed during the habitat assessment.

Again, the size and relatively low flows on the South Fork enabled units to be discrete, and in terms of size were easy to survey. Many of the units that were snorkeled in the South Fork were classified as plunge pools. These pools had much lower visibility than any other similar units due to the bubble curtain and turbulence created by the plunging water at the head of the pools. Since fish in such units use bubble curtains as cover, counts in these pools are more likely to be underestimates. The high level of silt and fine sediment throughout the South Fork also added to the visibility problems associated with the plunge pools, further reducing the accuracy of steelhead counts.

South Fork Steelhead Counts

All three age-classes of steelhead were observed in the South Fork as well as resident rainbow trout (Table 6; Figure 14). Following the pattern of the mainstem and Sanchez Fork, YOY steelhead were the most abundant age class seen on the South Fork; almost 2 YOY observed for every 10m of creek. This was higher than the abundance of

YOY steelhead observed on the mainstem, and very similar to that of Sanchez Fork. The South Fork had the lowest abundance of Age 1 steelhead out of all four tributaries; only 0.26 Age 1 steelhead observed for every 10m of creek. Age 2 steelhead were also observed in low numbers, 0.2 fish spotted every 10m (Figure 14). This was lower than the density of Age 2 steelhead observed on the mainstem however (Figure 10). Resident trout on the South Fork actually had the highest abundance of any tributary surveyed with 0.13 residents observed for every 10m of creek surveyed. (Figure 14).

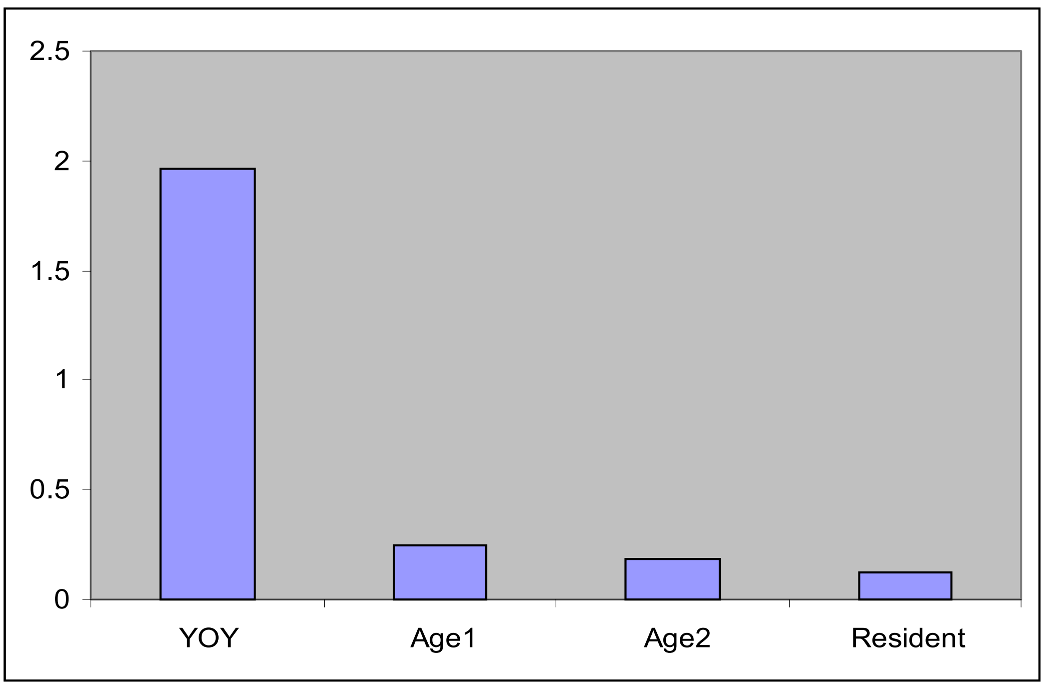


Figure 14. Abundance of steelhead in South Fork (Fish/10m)

Spatial distribution of Steelhead throughout the South Fork

The distribution of steelhead throughout the lower reaches of the South Fork, determined by snorkel observations, was relatively uniform (Figure 15). Interestingly, there were no steelhead of any age-class observed above unit # 54 (590m upstream) - approximately two thirds of the distance up the surveyed creek (Figure 15). Natural looking weirs above this point may have prevented spawning from taking place any higher in the South Fork. Age 1 and Age 2 steelhead were not observed in great enough numbers to notice any distinct pattern in distribution throughout the South Fork. 4 out of the 5 older fish were spotted in the lower 370m however.

Distribution of 'Young of year' steelhead

A total of 32 YOY steelhead were observed throughout the South Fork. These YOY fish were distributed fairly uniformly throughout the lower reaches of the South Fork, and were quite abundant; 16 out of the 19 lower units contained such fish, and were observed in pool, flatwater and riffle units. The highest abundance of YOY steelhead observed in a single unit was 4 individuals - spotted in a region of flatwater, sandwiched between two pools. Additionally, the compact nature of this flatwater unit resulted with this unit having the highest density of the South Fork with 0.533 fish/m^2. Average YOY density throughout the South Fork (0.144 fish/m^2) was much higher than the mainstem but less than Sanchez Fork (Table 9).

	YOY Steelhead	Age 1 Steelhead	Age 2 Steelhead	Resident Trout
Unit Average	0.144	0.015	0.013	0.011
Maximum Unit Density	0.533	0.122	0.154	0.132

Table 9. Steelhead density (fish/m2) throughout South Fork.

Distribution of Age 1 and Age 2 steelhead

The older age-classes of steelhead were seen in very low numbers; only four Age 1 and three Age 2 fish were observed throughout the entire South Fork. These older, larger fish were only spotted in pool habitats. The low count estimates may be an artifact of the South Fork's silty conditions, thereby reducing the effectiveness of the visual surveys. Alternatively, perhaps the South Fork has limited habitat for larger steelhead, most fish descending to the mainstem when they reach a certain size.

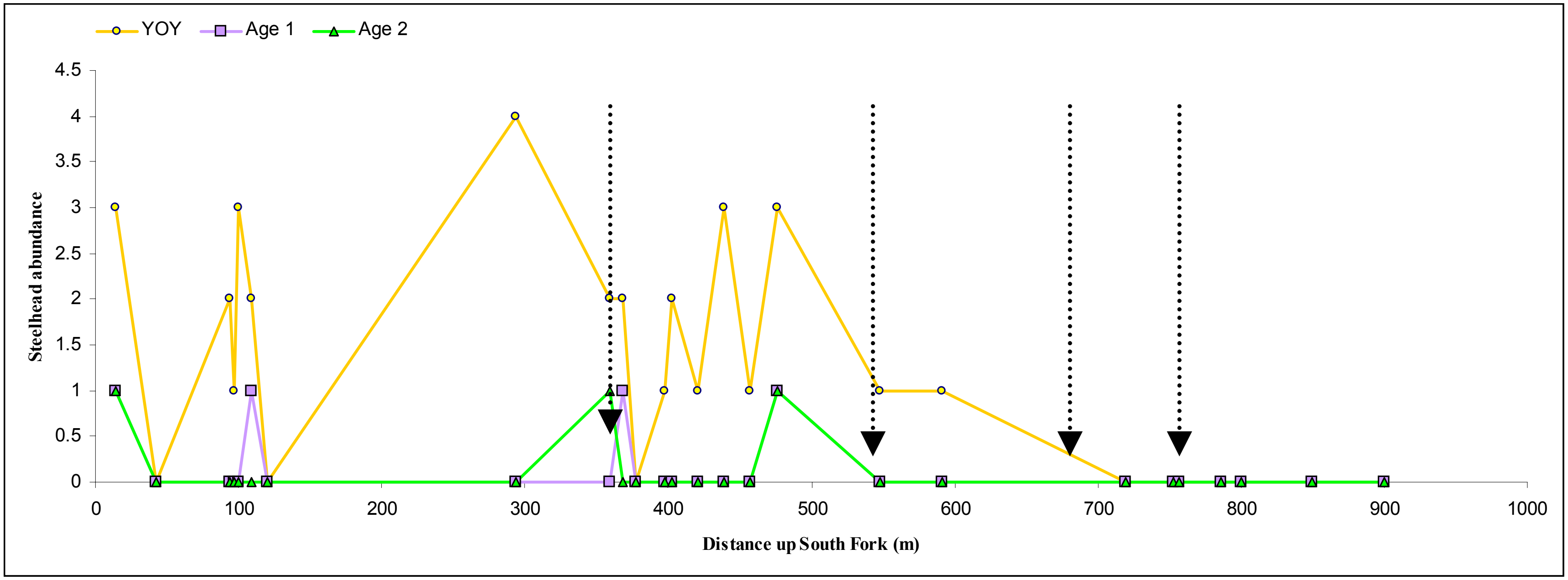


Figure 15. Spatial distribution of steelhead age-classes throughout San Pedro Creek's South Fork. Arrows indicate natural weirs/small waterfalls.

Middle Fork Snorkel Survey

Snorkel surveys were conducted on the Middle Fork on two days: December 13th and December 20th. The Middle Fork was similar to the South Fork in that very dense vegetation, shallow water depth and large jams of woody debris prevented snorkelling along parts of its length. Because of this, the snorkel survey, like the habitat assessment, was surveyed in two sections. The first section, starting at the confluence with the South Fork, continued 800m upstream when dense vegetation stopped the survey from this 800m stretch, 144.5m of creek were snorkeled. The second section resumed 70m below the Weiler Ranch road bridge and continued for approximately 220m upstream. 57m of this second section were actually snorkeled. The Middle Fork snorkel survey covered 201.5m of the creek, just over 17.5% of the length surveyed during the habitat assessment.

The Middle Fork had very low flow during the survey, often isolating fish to single pools. This allowed units to be surveyed accurately, with very little chance of inter-unit fish movement. Unlike the South Fork, the Middle Fork did not seem to have any problems with excess silt or other fine sediments, further helping underwater visibility and enhancing the survey accuracy.

Middle Fork Steelhead counts

All three age-classes of steelhead and a single resident trout were observed in the Middle Fork (Table 6; Figure 16). The Middle Fork had very high counts of YOY and Age 1 steelhead. As in the other tributaries, YOY steelhead were the most abundant age-class. In the Middle Fork however they were extremely abundant: almost 7 YOY observed for every 10m of creek, the highest abundance of the entire survey. Age 1 fish were the next most numerous; 1.3 fish were observed for every 10m of creek, the highest abundance of Age 1 steelhead in the entire survey. Age 2 fish were the least abundant age-class; only 1 fish for every 50m of survey, similar in abundance to the South Fork but lower than the mainstem. The fairly compact units present throughout the Middle Fork, combined with the high counts of young fish led to high average fish densities for YOY and Age 1 steelhead (Table 10).

	YOY Steelhead	Age 1 Steelhead	Age 2 Steelhead	Resident Trout
Total Number Observed	133	26	4	1
Unit Average	0.40	0.075	0.011	0.002
Maximum Unit Density	1.39	0.297	0.148	0.058

Table 10. Steelhead density (fish/m2) throughout Middle Fork.

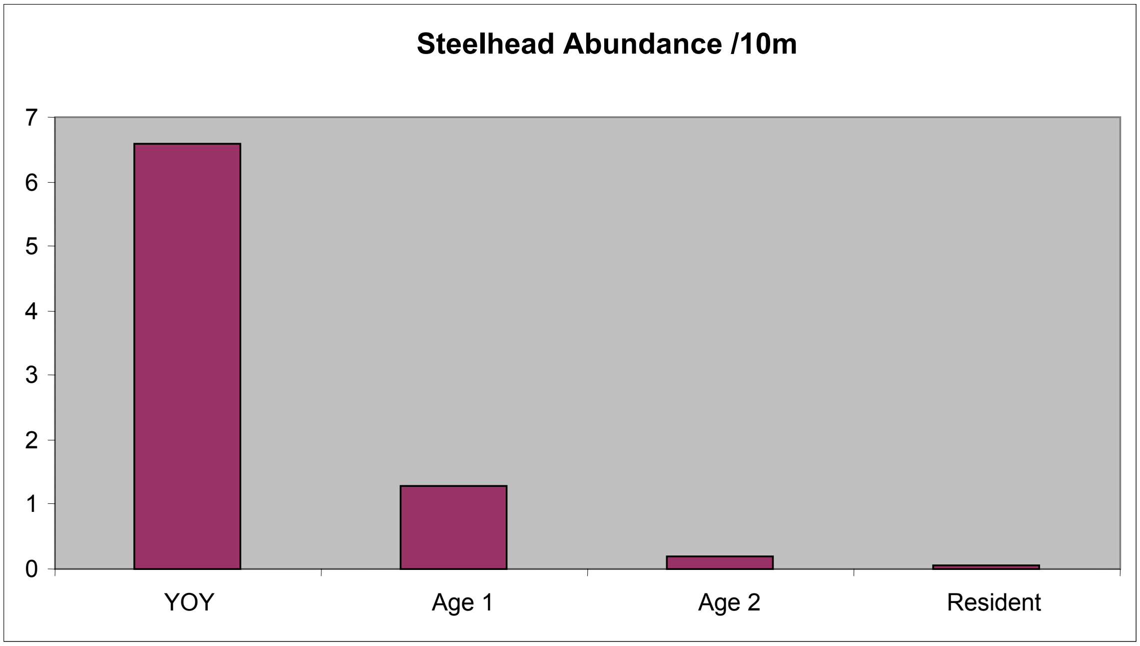


Figure 16. Abundance of steelhead in the Middle Fork (Fish/10m)

Spatial distribution of Steelhead throughout the Middle Fork.

The distribution of steelhead throughout the Middle Fork, determined by snorkel observations, was relatively uniform. Some large pools, however, suitable for rearing small fish, in the lower and middle reaches caused large productive 'spikes' (Figure 17). Unlike the South Fork, steelhead were found throughout the entire survey reach, indicating that adults were able to ascend and spawn high into the Middle Fork during last winter/spring.

Distribution of 'Young of year' steelhead throughout the Middle Fork.

YOY steelhead were found to be very abundant throughout the entire Middle Fork with a total of 133 observations (Table 6) and were observed in both pools and flatwater units. Their distribution throughout the lower reaches was fairly uniform; mainly due to the abundance of pools throughout this stretch of the creek. Unique to the lower reach of the Middle Fork was that every unit surveyed along the lower 800m of the Middle Fork contained YOY fish (Figure 17). This is reflected in the Middle Fork's unit average density of YOY fish (0.40 fish/m^2) (Table 10) – nearly twice as high as Sanchez Fork and almost three times greater than the South Fork. The highest abundance of YOY steelhead observed in a single unit was 20 individuals (1.28 fish/m^2), and were inhabiting a relatively large, deep, corner pool - located about 500m up the creek (Figure 17). The highest density of YOY observed on the Middle Fork however, was 1.39 fish/m^2 (12 individuals), and was observed in a narrow scour pool, which had clearly been enhanced by a large rootwad. The upper reach of the Middle Fork had reduced flow and was therefore much narrower. This region was also less productive than the lower reach where steelhead were observed in six out of the ten units snorkeled.

Distribution of Age 1 and Age 2 steelhead

A total of 26 Age 1 steelhead were observed throughout the Middle Fork. All but 3 of these fish were observed in the lower reach (Figure 17) and with the exception of a single fish, were observed exclusively in pools. The Middle Fork's highest abundance of Age 1 fish actually occurred in two separate units; both with 6 individuals. The first of these units was the plunge pool, downstream of the Middle Fork's only culvert, in the very lower part of the Middle Fork. The second unit was a corner pool/alcove, approximately 715m from the creek's mouth. This unit also had the highest density of Age 1 steelhead (0.4 fish/m^2) on the Middle Fork.

Only four Age 2 steelhead were spotted in the Middle Fork. All four fish were observed in the middle of the survey reach, between 715-760m from the mouth (Figure 17), residing in relatively large, deep pools. Two Age 2 fish were observed together in the same pool – one of the deepest and most productive pools on the Middle Fork.

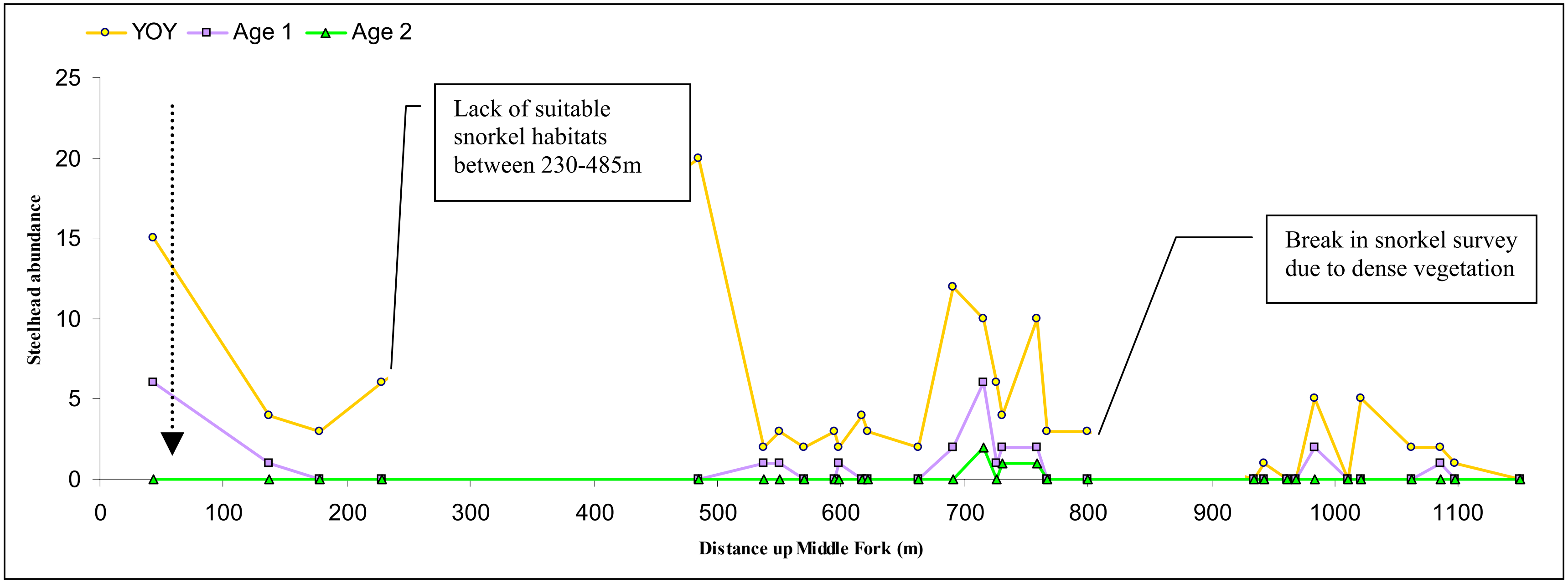


Figure 17. Spatial distribution of steelhead age-classes throughout the Middle Fork. Arrow indicates location of culvert.

Effect of habitat type on steelhead abundance

For the following analysis, snorkeled habitats were divided into three groups: pool, flatwater, and flatwater/pool habitat. Units were classified as pools if they were deeper than 30cm. Units less than 30cm at their deepest point were classified as flatwater. Flatwater/pools were units which could not simply be split into a respective pool and flatwater habitat for the purpose of snorkelling and thus contained attributes of both habitat types. The calculation of unit average fish densities ensures the standardization of fish numbers and prevents bias from highly abundant units. For this analysis the mainstem was partitioned into four separate reaches, each 1km long (Figure 5) (Tables 11-14). The Middle Fork, South Fork and Sanchez Fork were all treated as single reaches (Tables 15 – 17).

	Pools	FW/Pools	Flatwater	Total
Habitat Abundance	11	8	3	22
YOY	0	2	0	2
YOY Density	**0**	**0.001**	**0**	
Age 1 Steelhead	1	0	0	1
Age 1 Steelhead Density	**0.003**	**0**	**0**	
Age 2 Steelhead	3	1	1	5
Age 2 Steelhead Density	**0.001**	**0.001**	**0.004**	

Table 11. Snorkeled units, fish counts and average fish densities (fish/m2) throughout reach 1 of mainstem.

	Pools	FW/Pools	Flatwater	Total
Habitat Abundance	22	0	5	27
YOY	8		2	10
YOY Density	**0.008**		**0.004**	
Age 1 Steelhead	33		0	33
Age 1 Steelhead Density	**0.031**		**0**	
Age 2 Steelhead	33		2	35
Age 2 Steelhead Density	**0.036**		**0.006**	

Table 12. Snorkeled units, fish counts and average fish densities (fish/m2) throughout reach 2 of mainstem.

	Pools	FW/Pools	Flatwater	Total
Habitat Abundance	21	9	7	37
YOY	17	5	2	24
YOY Density	**0.017**	**0.010**	**0.005**	
Age 1 Steelhead	98	12	3	113
Age 1 Steelhead Density	**0.091**	**0.025**	**0.011**	
Age 2 Steelhead	40	4	2	46
Age 2 Steelhead Density	**0.033**	**0.008**	**0.007**	

Table 13. Snorkeled units, fish counts and average fish densities (fish/m2) throughout reach 3 of mainstem.

	Pools	FW/Pools	Flatwater	Total
Habitat Abundance	23	4	5	32
YOY	114	35	31	180
YOY Density	**0.295**	**0.093**	**0.077**	
Age 1 Steelhead	51	9	1	61
Age 1 Steelhead Density	**0.112**	**0.040**	**0.001**	
Age 2 Steelhead	10	1	0	11
Age 2 Steelhead Density	**0.020**	**0.004**	**0**	

Table 14. Snorkeled units, fish counts and average fish densities (fish/m2) throughout reach 4 of mainstem.

	Pools	FW/Pools	Flatwater	Total
Habitat Abundance	20	5	5	30
YOY	109	10	14	133
YOY Density	**0.494**	**0.247**	**0.146**	
Age 1 Steelhead	25	0	1	26
Age 1 Steelhead Density	**0.115**	**0**	**0.010**	
Age 2 Steelhead	4	0	0	4
Age 2 Steelhead Density	**0.017**	**0**	**0**	

Table 15. Snorkeled units, fish counts and average fish densities (fish/m2) throughout Middle Fork.

	Pools	FW/Pools	Flatwater	Total
Habitat Abundance	16	1	6	23
YOY	22	2	8	32
YOY Density	**0.149**	**0.257**	**0.111**	
Age 1 Steelhead	4	0	0	4
Age 1 Steelhead Density	**0.022**	**0**	**0**	
Age 2 Steelhead	3	0	0	3
Age 2 Steelhead Density	**0.014**	**0**	**0**	

Table 16. Snorkeled units, fish counts and average fish densities (fish/m2) throughout South Fork.

	Pools	FW/Pools	Flatwater	Total
Habitat Abundance	4	3	2	9
YOY	5	3	3	11
YOY Density	**0.163**	**0.118**	**0.186**	
Age 1 Steelhead	2	2	1	5
Age 1 Steelhead Density	**0.043**	**0.078**	**0.100**	
Age 2 Steelhead	0	0	0	0
Age 2 Steelhead Density	**0**	**0**	**0**	

Table 17. Snorkeled units, fish counts and average fish densities (fish/m2) throughout Sanchez Fork.

To test for habitat preference among YOY and age 1 steelhead, the individual unit densities of YOY and age 1 steelhead in different habitats for the upper two mainstem reaches, the Middle Fork, the South Fork, but excluding Sanchez Fork, were first transformed Log (x+1), in order to smooth out the variances to allow for the units without fish, and then analyzed as separate year classes using a Kruskal-Wallis non-parametric test. The lower two reaches of the mainstem were not used in the analysis because of very low YOY counts in this area. Factors other than ‘habitat type’ must have resulted in the low YOY densities observed throughout these regions. Sanchez Fork was excluded from the analysis because of its very small sample size. To test for habitat preference among age 2 steelhead, the individual unit densities of age 2 steelhead in different habitats for all four mainstem reaches, the Middle Fork, the South Fork, but excluding Sanchez Fork, were first transformed Log (density + 1), in order to smooth out the variances to allow for the units without fish, and then analyzed as separate year classes using a Kruskal-Wallis non-parametric test.

YOY steelhead were observed in all three habitat types throughout San Pedro Creek. (Tables 11-17). YOY were found to significantly prefer pool habitat: $\chi^2 = 8.058$, p = 0.018 (Tables 18 & 19).

	Habitat Type	N	Mean	Median	Mean Rank
Log (Density+1)	Pool	80	0.247	0.133	67.41
	Pool/Flatwater	19	0.152	0.023	48.79
	Flatwater	22	0.090	0.032	48.25
	Total	121			

Table 18. YOY steelhead density ranking among three habitats throughout San Pedro Creek.

	Log (Density+1)
Chi-Square	8.058
df	2
Significance	**0.018***

Table 19. Kruskal-Wallis Test for habitat preference (YOY).

Age 1 steelhead showed a highly significant preference for pools over flatwater units: $\chi^2 = 15.997$, $p = 0.000$ (Tables 20 & 21). Age 2 steelhead demonstrated a significant pool preference: $\chi^2 = 8.508$, $p = 0.014$ (Tables 22 & 23). These habitat preferences can be seen graphically in Figure 18.

	Habitat Type	N	Mean	Median	Mean Rank
Log (Density+1)	Pool	80	0.085	0.041	68.99
	Pool/Flatwater	19	0.016	0	53.11
	Flatwater	22	0.005	0	38.77
	Total	121			

Table 20. Age 1 steelhead density ranking among three habitats throughout San Pedro Creek.

	Log (Density+1)
Chi-Square	15.997
df	2
Significance	**0.000*** **

Table 21. Kruskal-Wallis Test for habitat preference (Age 1 steelhead).

	Habitat Type	N	Mean	Median	Mean Rank
Log (Density+1)	Pool	113	0.024	0	91.52
	Pool/Flatwater	27	0.003	0	74.09
	Flatwater	30	0.003	0	73.10
	Total	170			

Table 22. Age 2 steelhead density ranking among three habitats throughout San Pedro Creek.

	Log (Density+1)
Chi-Square	8.508
df	2
Significance	**0.014***

Table 23. Kruskal-Wallis Test for habitat preference (Age 2 steelhead).

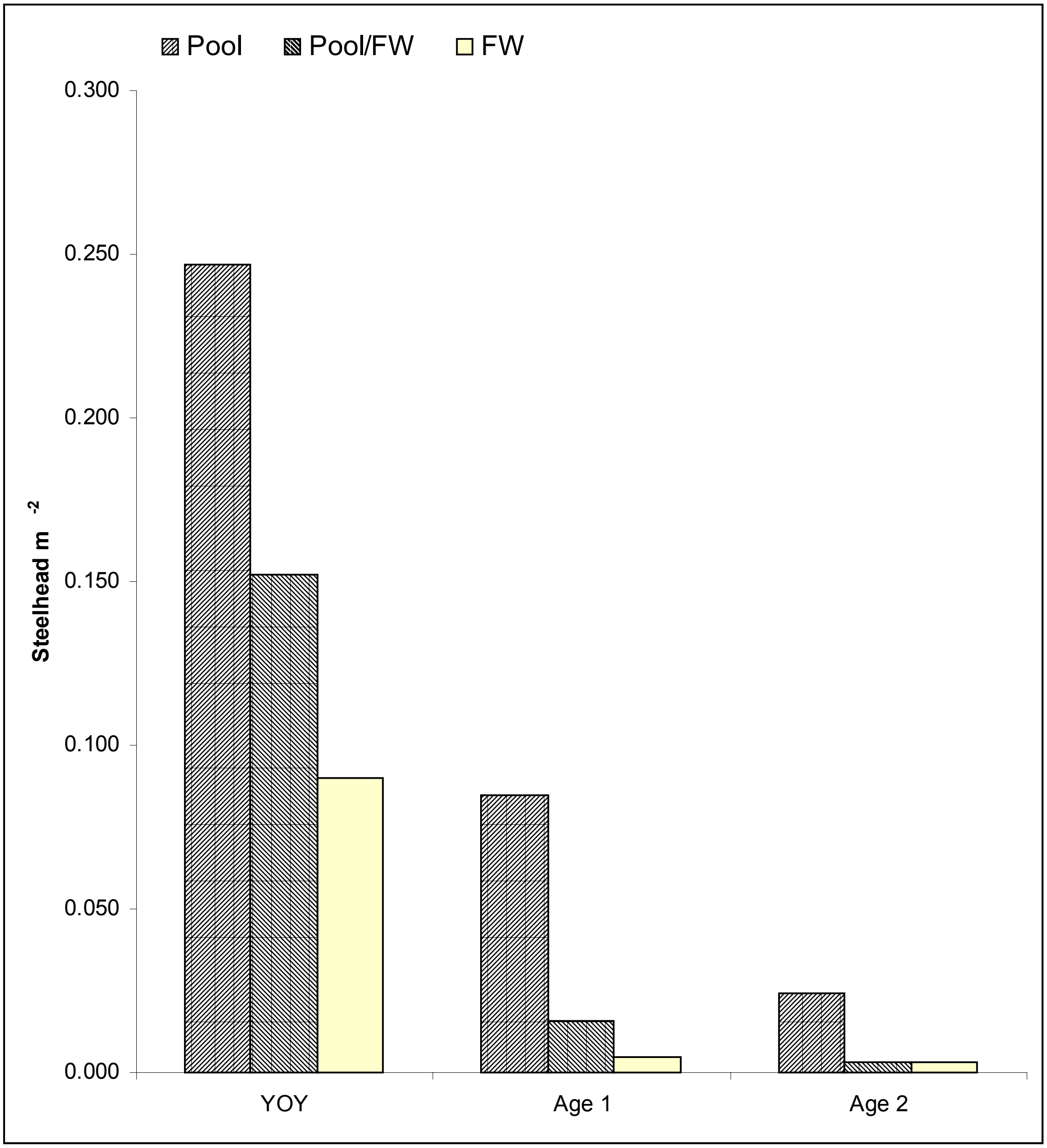


Figure 18. Steelhead age-class average densities in three habitat types throughout San Pedro Creek.

Effect of depth on steelhead abundance

I also examined the relationship between depth of habitat and steelhead abundance for all three age-classes. Steelhead abundance was compared between units ranging from 20cm to over 1m in depth - as snorkel surveys were restricted to units of depth greater than 20cm. Interestingly, YOY steelhead demonstrated no significant relationship to unit depth throughout San Pedro Creek: $r = 0.029$, $p = 0.699$ (Figure 19.) The two older steelhead age-classes, however showed positive relationships – their abundances increasing with unit depth: Age 1 steelhead $r = 0.451$, $p < 0.001$ (Figure 20), Age 2 steelhead $r = 0.472$, $p < 0.001$ (Figure 21.).

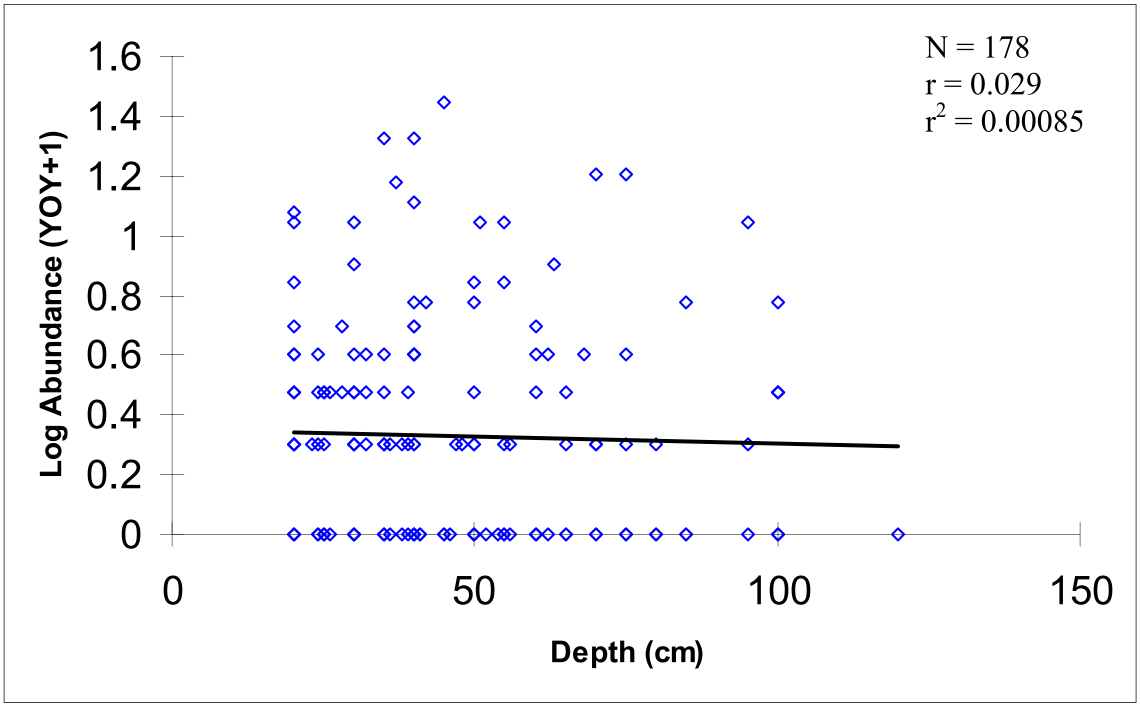


Figure 19. Log + 1 of YOY abundance versus unit depth throughout San Pedro Creek.

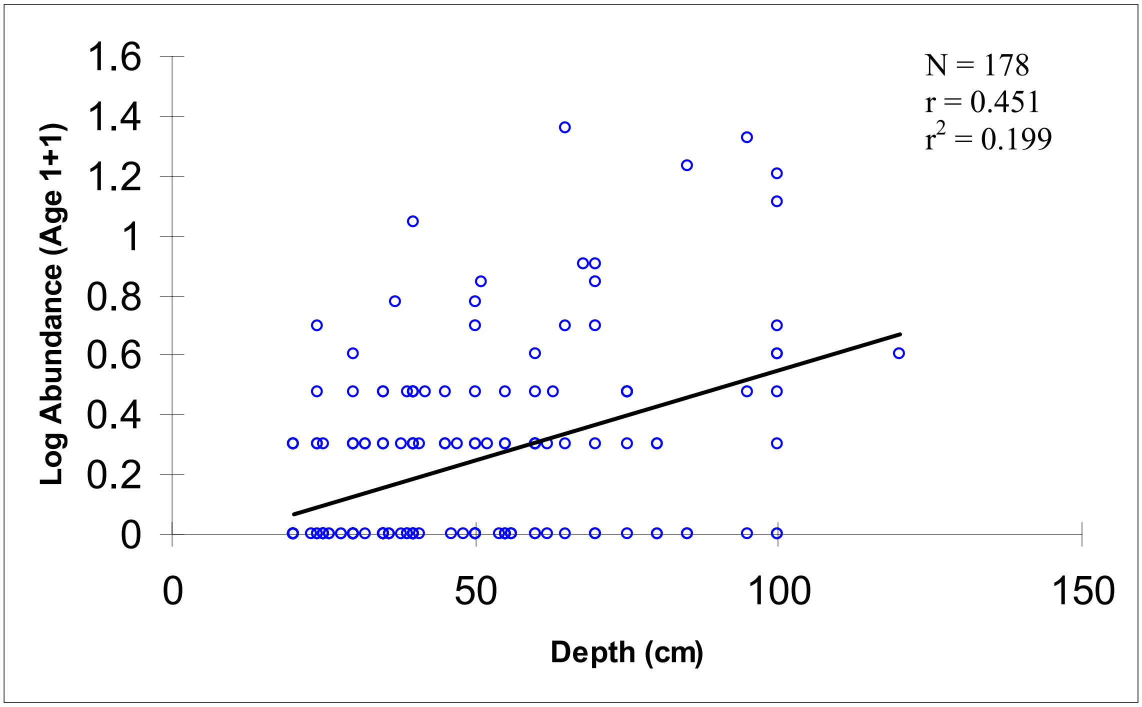


Figure 20. Log +1 of Age 1 steelhead abundance versus unit depth throughout San Pedro Creek.

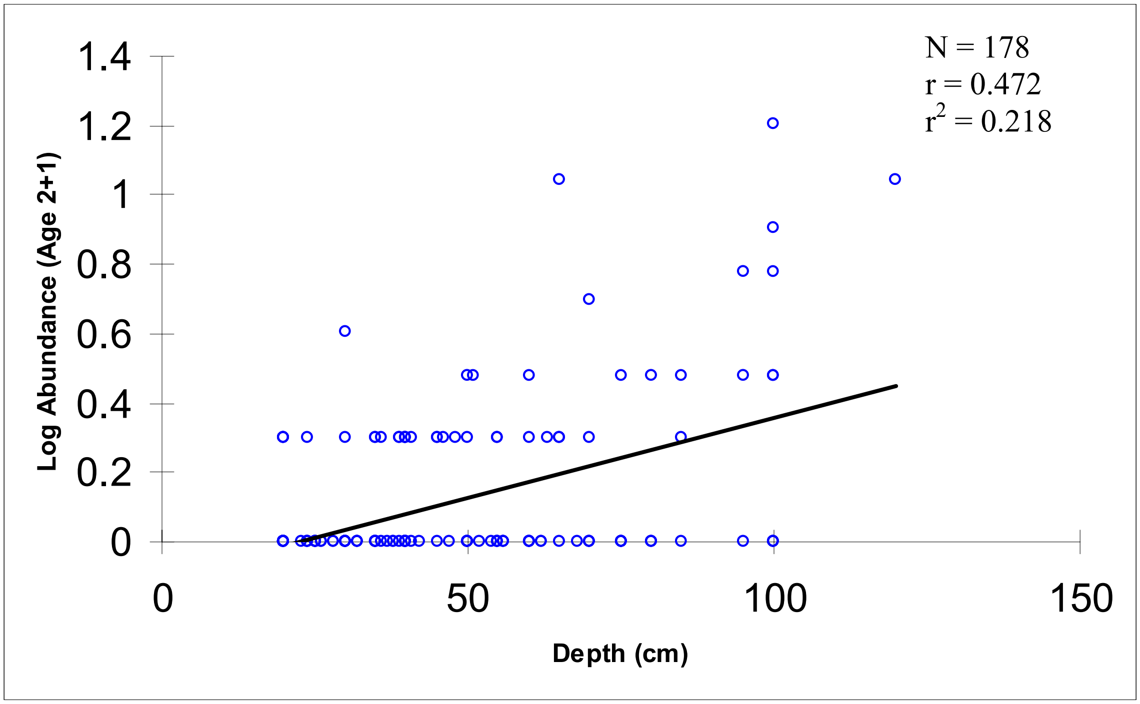


Figure 21. Log + 1 of Age 2 steelhead abundance versus unit depth throughout San Pedro Creek.

Effect of overhead cover on steelhead abundance

The effect of the overhead cover density on all three age-classes was examined. Overhead cover was estimated for each snorkeled unit as percentage of the unit covered. Based on the percentage values, six categories were assigned - and units were grouped accordingly into their category (Table 24).

	Category #					
	0	1	2	3	4	5
% OH Cover	0%	1-10%	15-30%	35-50%	55-70%	75-100%
# of classified units	8	21	15	24	15	30

Table 24. Categories assigned for overhead riparian cover values.

YOY steelhead showed a distinct preference for regions of the creek that had a reasonably dense canopy; very few fish were spotted in stretches lacking riparian cover. Average abundance of YOY steelhead demonstrated a strong positive relationship with increasing canopy density, a polynomial trend line was added to highlight the relationship: $r^2 = 0.796$ (Figure 22). Like the youngest fish, the older steelhead age-classes showed an aversion to very open units although, unlike YOY steelhead, they were most abundant in units with moderate overhead cover; their mean numbers decreased among units with a very dense canopy. r^2= 0.328 and 0.164 for Age 1 and Age 2 steelhead respectively (Figure 23; Figure 24).

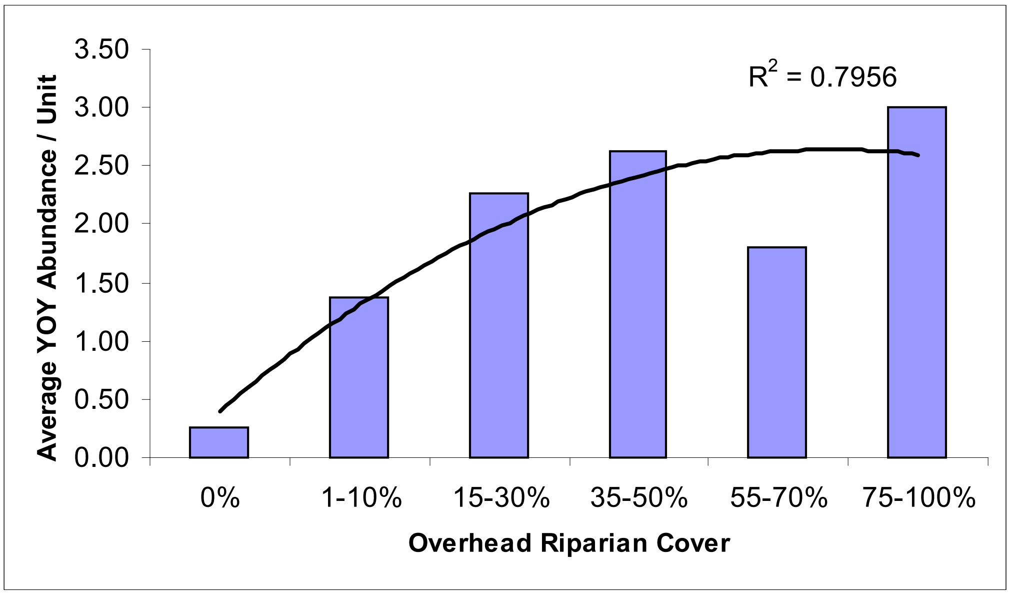


Figure 22. Average abundance of YOY steelhead versus density of overhead riparian cover throughout San Pedro Creek. N=245.

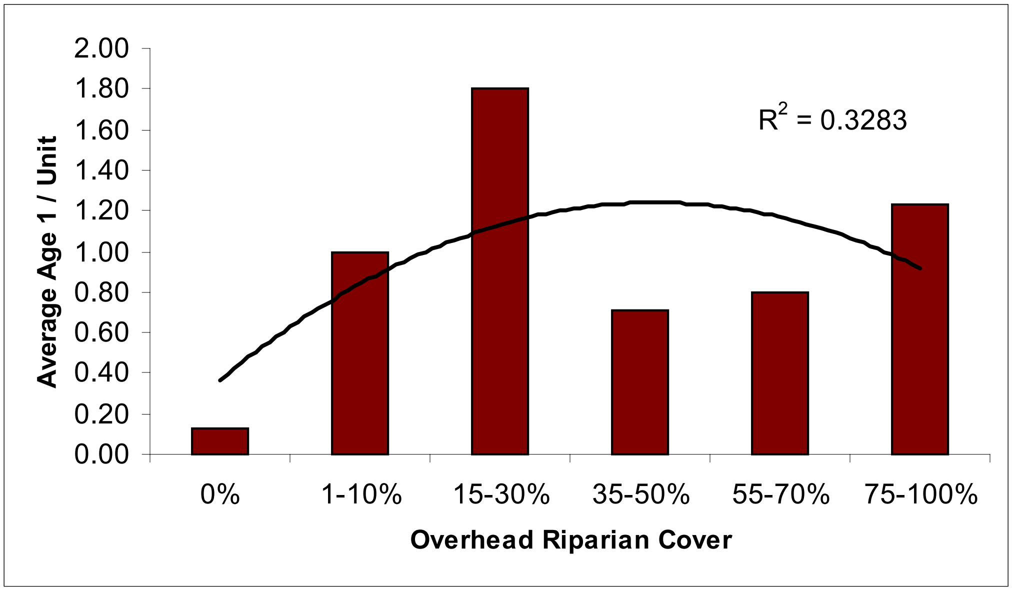


Figure 23. Average abundance of Age 1 steelhead versus density of overhead riparian cover throughout San Pedro Creek. N=115.

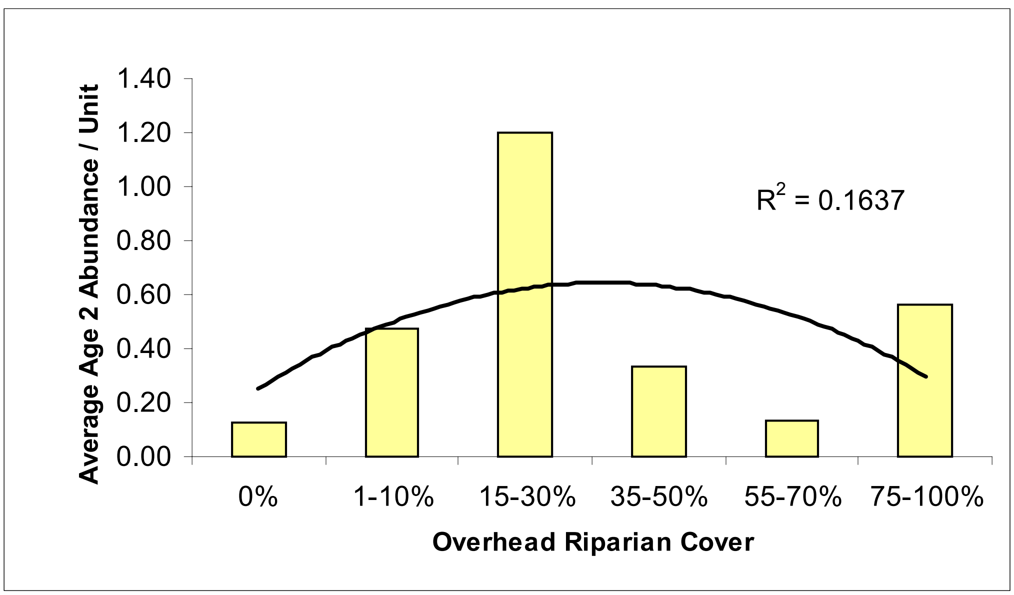


Figure 24. Average abundance of Age 2 steelhead versus density of overhead riparian cover throughout San Pedro Creek. N=56.

Effect of understory cover on steelhead abundance

The influence of understory density on all three age-classes was examined. Understory cover was defined as overhanging bank-side vegetative cover, undercut banks, roots, bedrock ledges, or any other low-lying vegetation or structure available as cover for fish use, except woody debris which was analyzed separately. The amount of understory cover was estimated for each snorkeled unit as percentage of the unit covered. Based on the percentage values, six categories were assigned, and units grouped according to their category (Table 25).

	Category #					
	0	1	2	3	4	5
% US Cover	0%	1-4%	5-10%	11-15%	16-25%	26-100%
# of classified units	7	6	53	16	18	13

Table 25. Categories assigned for the values of understory cover.

YOY steelhead were observed in all cover categories, but were most abundant in units with low to moderate understory cover. A polynomial trend line was added to highlight the relationship: $r^2 = 0.774$ (Figure 25). Age 1 steelhead were totally absent from units lacking cover, but were distributed fairly evenly throughout the other cover categories, $r^2 = 0.779$ (Figure 26). Age 2 steelhead were observed in all cover categories but there was a strong positive relationship between abundance and % cover, $r^2 = 0.996$ (Figure 27).

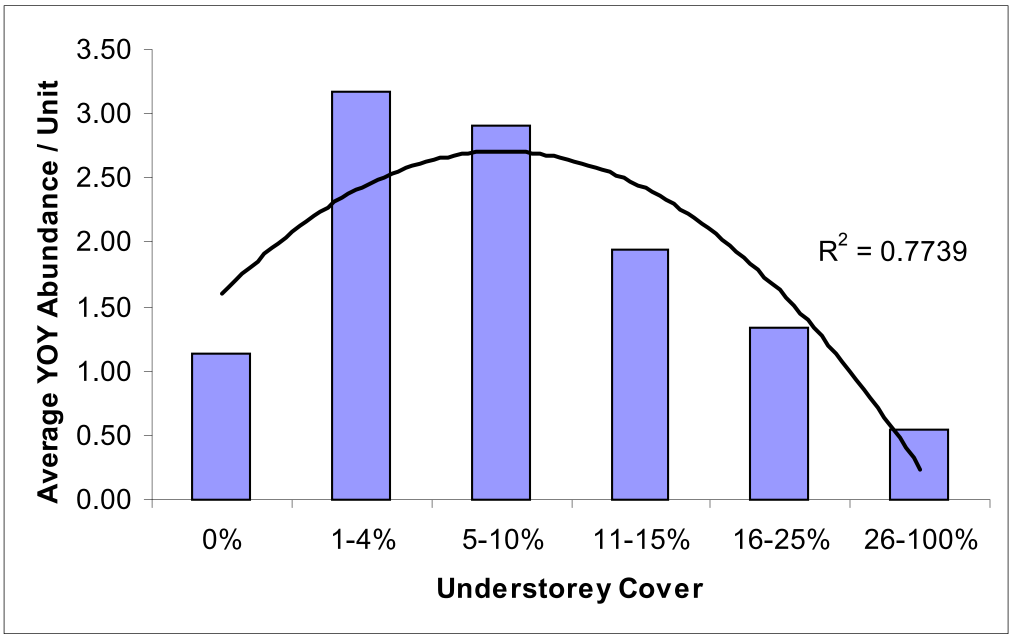


Figure 25. Average abundance of YOY steelhead versus density of understory cover throughout San Pedro Creek. N=243.

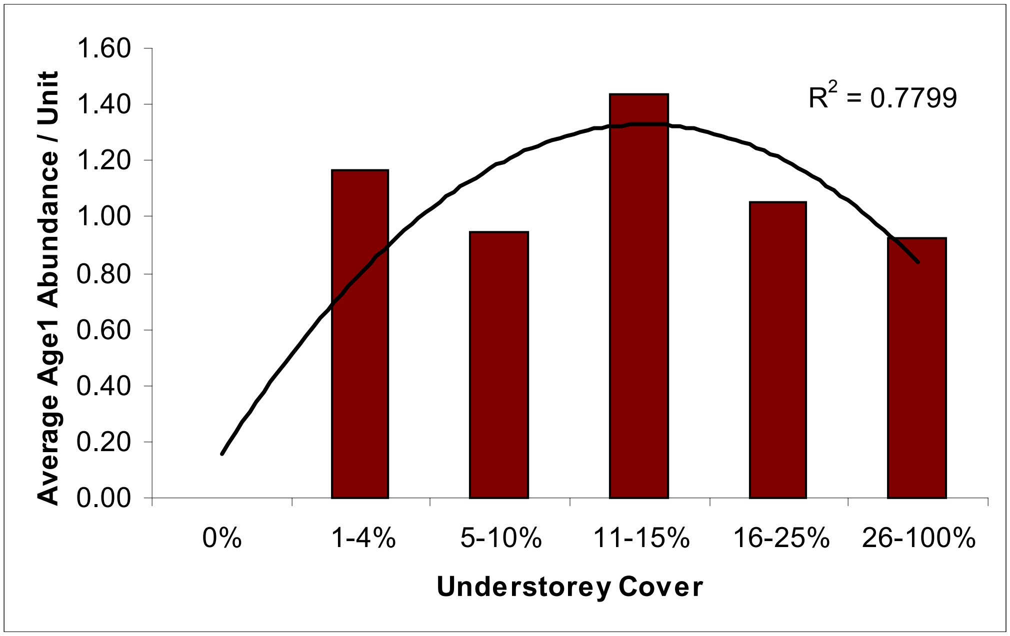


Figure 26. Average abundance of Age 1 steelhead versus density of understory cover throughout San Pedro Creek. N=111.

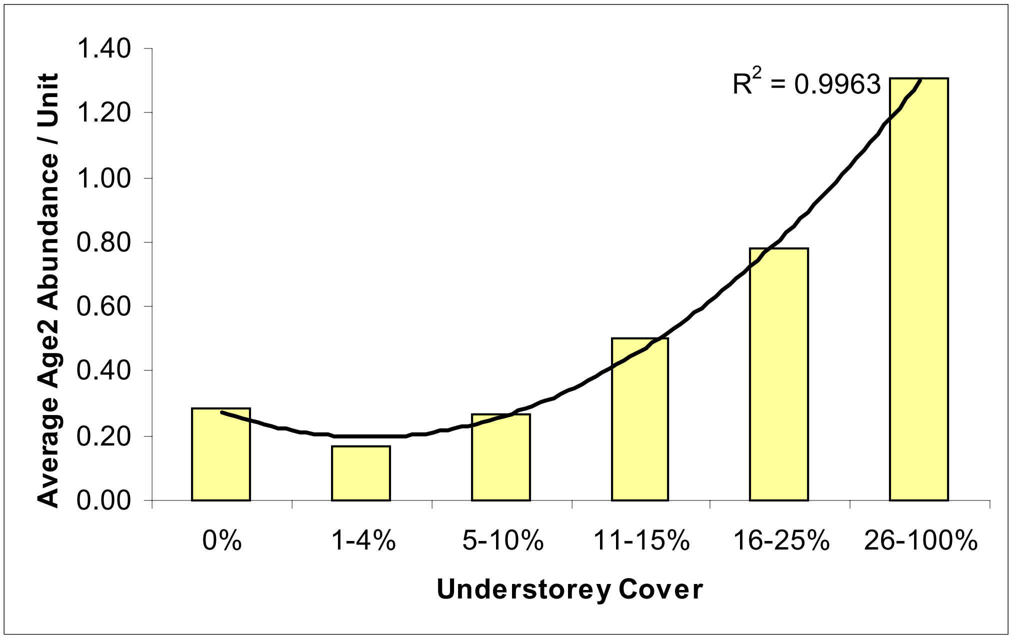


Figure 27. Average abundance of Age 2 steelhead versus density of understory cover throughout San Pedro Creek. N=56.

Effect of woody debris on steelhead abundance

The influence of in-stream woody debris on all three age-classes was examined. Woody debris was recorded qualitatively throughout all snorkeled units, but no quantitative measurements were made. On average, YOY steelhead were observed in much higher abundance in units with woody debris. Both older steelhead age-classes were less abundant on average in units with in-stream woody debris (Figure 28).

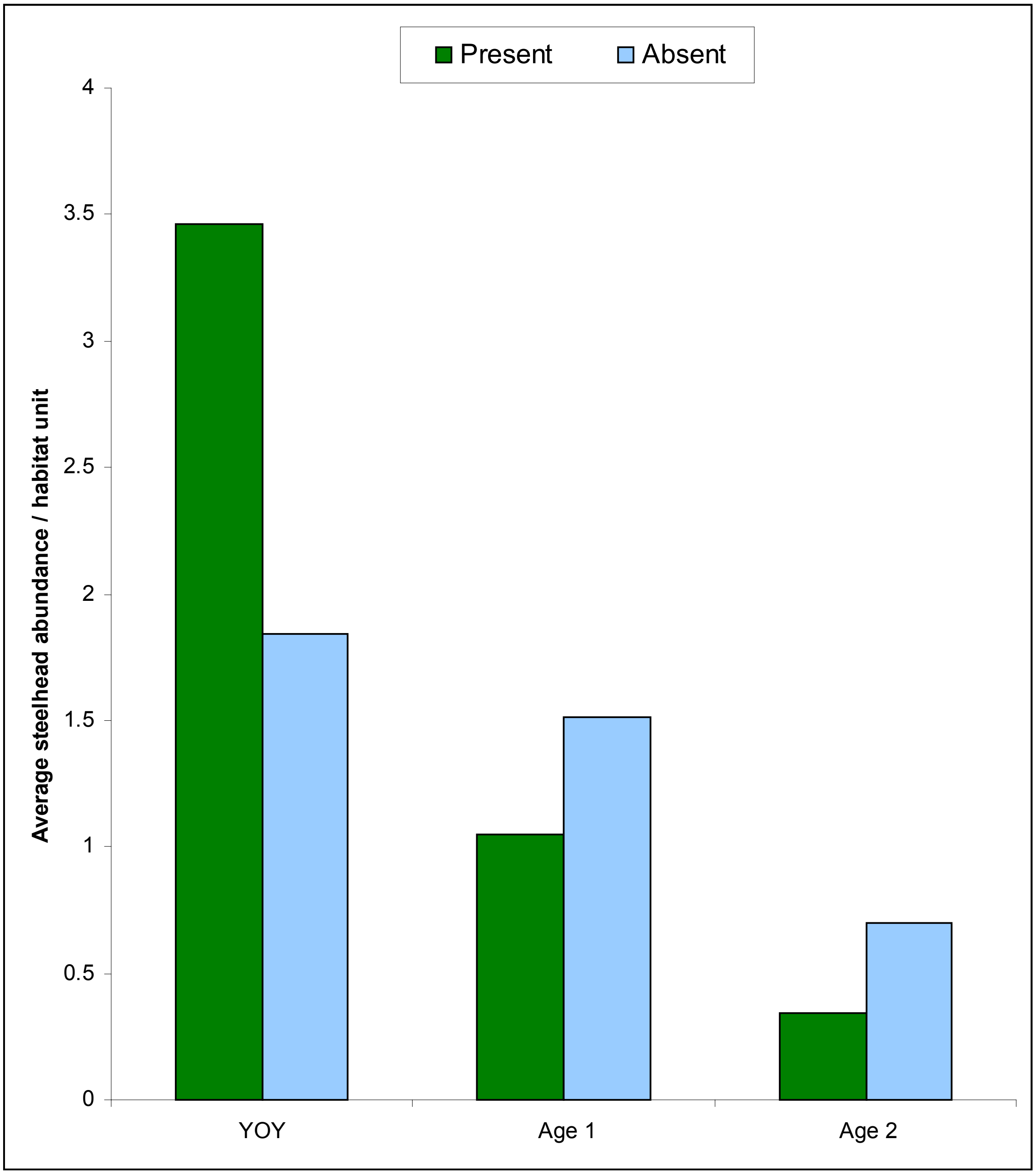


Figure 28. Presence of in-stream woody debris and its influence on all three steelhead age-classes throughout San Pedro Creek.

Discussion

Habitat

I found that, in terms of length, San Pedro Creek was dominated by flatwater habitat. Pools were the second most dominant feature of the creek, and riffle habitat the least common. Flatwater dominance held true for all survey sections. However, only the mainstem had riffle habitat forming the minority of its length - in all other sections, riffles dominated over available pool habitat. These findings, for all survey reaches, agree with Hagar's (2001) study, suggesting that the general habitat complexity of San Pedro Creek has not experienced any significant change over the last 3 years. One area that has experienced a major change since Hagar's survey was the FCP (completed late 2002). This lower section of the mainstem will need several years before its riparian habitat and in-stream habitat matures to effectively support steelhead. Some regions of suitable spawning gravel did exist in the project area, although there was a distinct lack of juveniles observed in this section of the creek: Perhaps with time, as the riparian zones mature further and habitat improves, steelhead may utilize the project area for spawning. During the summer survey, this lower part of the creek had extensive growth of aquatic vegetation - sometimes completely covering the creek. Such vegetation may provide critical cover for juveniles, especially during April and May as juveniles undergoing smoltification congregate in large numbers in these lower parts of San Pedro Creek.

In general, for streams less than 15m wide, a stream reach is rated as high quality habitat if it contains greater than 30% pools by length (The Washington State Fish and Wildlife Commission, 1997). San Pedro's creek-wide average was 29.7% pools by length. In comparison, pool habitat surface area in an undisturbed Washington coastal stream was found to be 81% of the total stream surface area (Grette, 1985) while Pennington stream (San Luis Obispo county), a coastal stream which also supports a steelhead population had 32% of its total area devoted to pool habitat (anon, 2002). Therefore, pool habitat throughout San Pedro Creek appeared to be more than reasonable for its suburban setting, but efforts should be made to increase pool abundance throughout particular areas of the creek, especially those currently dominated by uniform flatwater regions, such as the concrete sided channel located upstream of Capistrano Bridge.

It is important to note that unlike other pacific salmonids such as coho salmon, juvenile steelhead are not restricted to pool habitat, but are able to make use of flatwater and riffle zones (Roni & Quinn, 2001; Pauley *et al*., 1986; Lau, 1984). Therefore, steelhead habitat throughout San Pedro Creek may be of a higher quality than suggested by the pool length versus creek length method.

Deep pools (greater than one meter in depth), recorded on the mainstem, provide essential habitat for resident rainbow trout and older steelhead age-classes, especially during the summer and periods of low flow. Such deep pools are also essential for returning adult steelhead who require deep pools spaced along the length of the creek, which are used for resting as they slowly ascend the creek to the headwaters to spawn (Harvey & Nakamoto, 1997; Keeley & Slaney, 1996; Chen, 1992; Everest & Chapman, 1972). A total of 14 pools greater than one meter deep were counted in San Pedro Creek - all situated on the mainstem. Interestingly, Hagar's 2001 study only counted 7 such pools, again all on the mainstem. This may be explained by the slightly shorter survey length in the Hagar survey (3733m) when compared to this subsequent study (4020.5m). However, Hagar did not observe any deep pools in the upper reaches of the mainstem. This study located a deep plunge pool approximately 80m upstream from Oddstad Bridge - therefore probably a recent formation, and quite likely to be an important resting stop for adult pre-spawners to complete sexual maturation before spawning in the headwaters.

The abundance of riffle habitat was limited on the lower reaches of the mainstem but increased upstream (Figure 5) and was widespread throughout the Middle Fork (Figure 7) and the lower reaches of the South Fork (Figure 8). Successful spawning sites are often situated at the interface of the tail of a pool and the head of a riffle (Barnhart, 1986). The limited number of riffles on the mainstem may, therefore, limit the availability of successful spawning locations, with adult spawners required to ascend farther, and spawn in the upper reaches of the mainstem and upper tributaries, historically containing the most prolific spawning sites. For adult steelhead to spawn in these headwaters, they must first reach them. Because they must be unrestricted as they ascend the mainstem, alterations to the creek such as stream channelization or the diversion of flow through culverts may hamper or totally inhibit fish passage.

Stream culverts

I observed a total of 8 artificial culverts throughout San Pedro Creek: 4 on the mainstem (Adobe, Capistrano, Linda Mar & Oddstad), 3 on Sanchez Fork, and 1 on the lower Middle Fork. Artificial culverts, often due to poor design, may cause the loss or alteration of stream habitat and significantly modify stream discharge. Culverts can present total barriers to fish migration. Delay migration. Or limit fish migration to a short period when conditions allow, subjecting returning adults to increased levels of physical injury, stress and predation (Larinier, 2000). Badly designed culverts can therefore take a more significant toll on endangered and threatened fish than previously thought (NMFS, 2001). High water velocity, often observed in culverts during times of high flow, can seriously hamper or prevent adult salmonids from reaching favorable spawning habitat. Water velocity within a culvert is determined primarily by culvert length, width, gradient and roughness. If the culvert gradient is too steep, or the culvert width is narrower than the streambed width, the water velocity will be increased within the culvert. Even very slight changes in the slope of the culvert or substrate roughness within the structure may significantly change the culvert velocity (Clifford & Kellett, 2004).

The Adobe Road Culvert forces the creek to flow through a basic concrete box-culvert, 2.2 metres wide and 15.5 metres long. At the culvert's downstream mouth there was a 30cm raised-step from the pool below Adobe Bridge. Wooden beams have been anchored to the culvert base, designed to help fish passage. Unfortunately this culvert falls short of the guidelines for culvert design by the National Marine Fisheries Service (NMFS) and California Department of Fish and Game (CDFG) in the following respects:
The culvert was too narrow. NMFS (2001) and CDFG (2002) call for the culvert width to be a minimum of 1.5 times greater than the active channel width. The pools above and below the Adobe Bridge at the time of survey were 5m and 6.5m wide respectively.
The culvert had too high a gradient. NMFS (2001) recommend that the culvert should not exceed a 0.5% gradient. The gradient of Adobe was measured to be 1.1% (Davis, 2005).
The culvert was not embedded. In cases where physical conditions preclude embedment, NMFS (2001) recommend a maximum hydraulic drop of 30cm for adults and 15cm for juveniles. Adobe actually sat 30cm above the lower pool. Apart from the wooden baffles attached to the culvert base, the base was too smooth and lacked natural stream substrate.
Water depth inside culvert was too low. For non-embedded culverts, guidelines state that a minimum water depth of 30cm is required for adult steelhead passage and 15cm for the

passage of juveniles. At the time of this study, water depth in Adobe was slightly less than 15cm. In failing to meet up to these specifications Adobe Bridge culvert clearly presents a problem to fish passage, especially for juvenile steelhead and trout, the 30cm high culvert step acting as a barrier to juvenile upstream movement during the summer and fall.

The culvert at Capistrano Road Bridge, with its hydraulic drop of one meter, greatly exceeds the NMFS (2001) and CDFG (2002) recommendations and presents a major problem for the upstream migration of adult steelhead, and an impassable barrier for upstream movement of juveniles. Directly above the Capistrano Road Bridge, the creek has been channelized into a straight concrete ditch which stretches for 200m upstream. During times of high flow this narrow channel has extremely high water velocities. This, coupled with the lack of suitable resting areas available, makes it unsuitable for steelhead during high flow events and will clearly hamper adult migration.

The mainstem's third obstacle is formed by the culvert below the Linda Mar Bridge. The culvert was 23 meters long, about 5 meters wide with a step raised about 15cm above the downstream pool. The wide, smooth, culvert base results in very shallow flow during summer and fall periods much lower than the NMFS & CDFG's 15cm depth guideline. The 1.3% gradient of this culvert (Davis, 2005) also exceeds the 0.5%

recommended by the NMFS for non-embedded culverts. The culvert at Linda Mar Bridge therefore presents an obstacle to upstream migration by both adult and juvenile steelhead, and would form a complete barrier to the upstream movement of juveniles during periods of low flow, especially the summer and fall.

Oddstad Bridge with its shallow water depth and 30cm step again does not meet NMFS's suggested criteria. This culvert seems to bar movement of juvenile steelhead in both directions because of the low flow spread over a fairly wide, flat base of the left-hand box. The right-hand box had no flow during the summer or fall but obviously receives high flow during the winter months due to the accumulation of sediment and gravel and boulders along its base. This sediment creates a more natural culvert base and will act to reduce flow velocity during times of heavy discharge, thus reducing the barrier to adult migration.

Sanchez Fork's steelhead spawning potential has been hugely impacted since the construction of the corrugated metal culvert sited less than 280m from its confluence with the mainstem. This culvert acts as a total barrier to adult and juvenile migration, effectively depriving steelhead of suitable spawning and rearing habitat upstream.

The two concrete culvert sections observed on Sanchez Fork may pose as temporary barriers to fish migration. During low flow, water depth over these culverts was too shallow to allow unrestricted fish movement. During times of high flow, water velocities through these culverts would be very high and may therefore act as barriers to adult steelhead and the upstream movement of juveniles

The Middle Fork's single remaining culvert in San Pedro County Park again falls short of current culvert guidelines: Very shallow water depth during time of survey prevented juvenile migration while its smooth base lacking stream substrate will promote high flow velocities in the winter thus hampering the upstream migration of adult steelhead, although the culvert's design - incorporating a 45˚ bend half way along, may help to mollify the effects of high water velocity.

Steelhead presence high in the Middle Fork and South Fork, above the culverts mentioned, indicates that, except for Sanchez Fork's corrugated metal culvert and the South Fork's water diversion structure, there are no complete barriers to adult steelhead ascending San Pedro Creek. This does not mean that they have no impact on adult migration however and would likely act as temporary barriers, upstream migration only possible during certain periods of optimum flow rates.

Steelhead observations

A total of 749 steelhead were counted throughout San Pedro Creek during Fall 2004. The age composition of fish counted was: 392 YOY steelhead; 243 Age 1 steelhead; 104 Age 2 Steelhead; and 10 resident Rainbow trout (Figure 29). Table 6 in the results section provides a detailed breakdown among tributaries.

Hagar's study performed counts of steelhead which were differentiated into individuals less than 100mm TL (Total Length), which I interpret to be YOY, and individuals greater than 100mm TL, assumed to be Age 1+ steelhead. Using the 'above water' observation method, Hagar counted a total of 729 steelhead during the Fall 2001 survey. The age composition of Hagar's count was: 678 YOY steelhead; and 51 Age 1+ steelhead.

Interestingly, Hagar observed huge numbers of YOY throughout the lower reaches of the mainstem; the present study recorded very few throughout this stretch (Figure 30). Both studies have similar counts for YOY abundance throughout the upper reaches of the mainstem and throughout the Middle Fork and Sanchez Fork. Therefore, the huge difference in abundance in the lower mainstem seems quite odd. During the snorkel survey, hundreds of Three-spined stickleback (*Gasterosteus aculeatus*) were seen throughout the lower reaches of San Pedro Creek, presumably because of the important spawning and rearing areas in the vicinity (Sullivan, 1990b). From a distance, or, viewed from the bank, such small fish could be confused with YOY steelhead. Hagar's 'above water' visual counts, known to be a less accurate method, may have confused some of these stickleback individuals for YOY steelhead. However, since Hagar is an experienced steelhead biologist this explanation may not apply. Alternatively there may have been a 'mass exodus' of YOY from the lower reaches of the mainstem during the months before the present survey: Sullivan's 1989 snorkel survey through the mainstem, from the mouth upstream to the Peralta Road Bridge, provided abundance information for five separate survey dates. The five surveys between May 3rd and September 11th showed a mass exodus among both the Age 1 and Age 2 classes. Very abundant throughout the reach during the end of May through July, they suddenly almost all disappeared when the final survey was undertaken on September 11th. On the other hand, YOY were still abundant in September, although markedly less so than during July. The present study surveyed the lower reaches of the mainstem on October 22nd. Perhaps, like Sullivan's experience with yearling and Age 2 steelhead, YOY underwent a mass migration upstream, providing a possible explanation for my extremely low counts. This seems unlikely however, given that Capistrano Bridge fish ladder is a complete barrier to upstream juvenile migration, and the greatest concentrations of YOY steelhead were all upstream of this point. In September and October of 2002, in preparation for the flood control project, the lower reach of the mainstem, downstream of the Peralta road bridge, was surveyed using seine nets to transplant steelhead and other fish to the new stream. A total of 180 steelhead were recorded over 3 days of netting. Interestingly, only 33 of these fish were small enough to be classed as YOY fish - much lower than Hagar's count of about 200 but much higher than the 2 YOY observed throughout the lower reaches during this study.

Hagar's counts of older steelhead (Age 1+) were considerably lower throughout all reaches than those of the present survey (Figure 31). Larger fish, more likely to use available cover such as undercut banks and woody debris (Personal observations, 2003 & 2004), would be much harder – if not impossible to see when conducting bank or other 'above water' observations. It is not surprising therefore to see the much higher counts of older steelhead recorded from an underwater survey method like the present study and Sullivan's previous study.

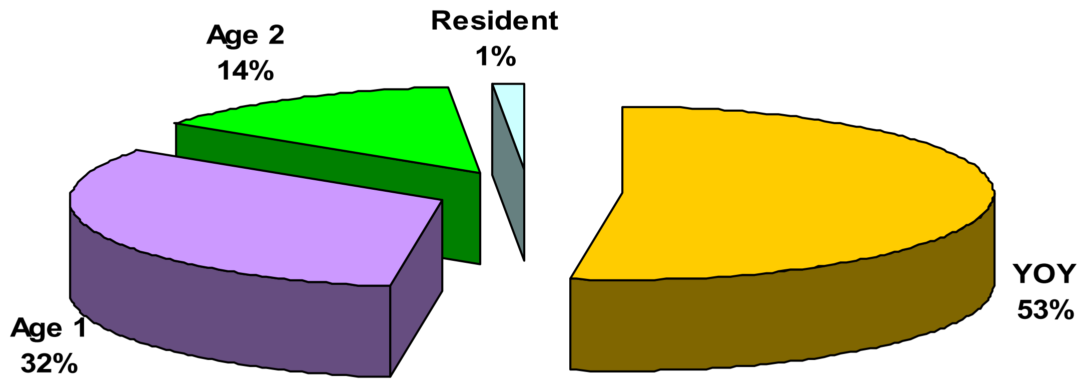


Figure 29. Age composition of the San Pedro Creek steelhead population surveyed during fall 2004.

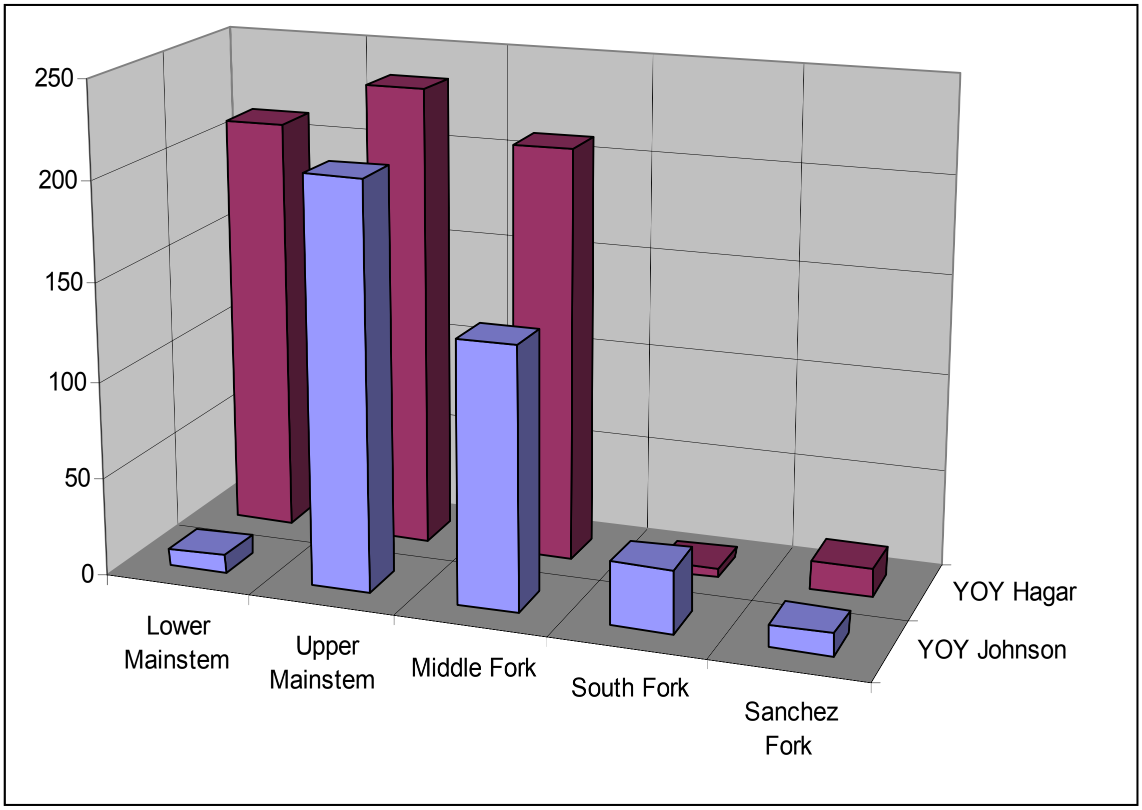


Figure 30. Distribution of the YOY steelhead counts between Hagar (2001) and my study.

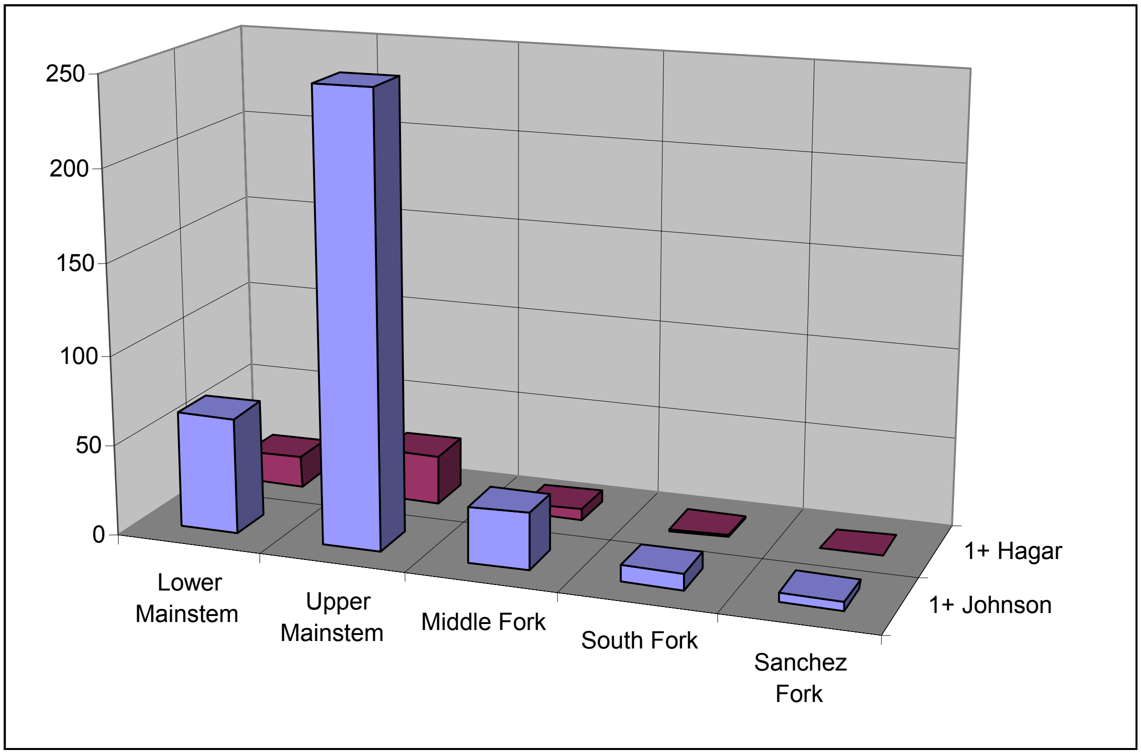


Figure 31. Distribution of the Age 1+ steelhead counts between Hagar (2002) and my study *.

*(Age 1+ category includes Age1, Age 2, and Resident steelhead categories in this study).

Steelhead densities

With the exception of the Middle Fork, the average densities calculated for all YOY steelhead in San Pedro Creek during this study seem low (Table 26) – all below Oregon Department of Fish and Wildlife's goal of 0.5 fish/m^2 for steelhead YOY during late summer and fall (Satterthwaite, 2002). With this survey taking place late in the season (October-December), however, we would expect lower densities of YOY than summer surveys due to the high natural mortality rates experienced by salmonids residing in such small streams during the summer and fall, caused primarily by extremely low flows and habitat shrinkage (Lau, 1984). To support a high density of steelhead, a creek must have the following characteristics: Relatively easy access for adult spawners, good quality spawning gravel with low levels of silt and other fine sediment, and suitable juvenile rearing habitat with high availability of food to reduce the effects of intraspecific competition.

The Middle Fork's relatively high YOY density of 0.4 fish/m^2 is just below ODFW's 0.5 fish/m^2 'Healthy Population Goal', and is similar to those calculated for other streams: Lau (1984) calculated the average YOY density throughout Caspar Creek (Mendocino County, CA) as 0.5 fish/m^2 during September; a density of 0.45 fish/m^2 was observed in Soldier Creek, a tributary of the Trinity River (KRIS Information System, 2001); a density of 0.5 fish/m^2 was observed during 1999 and 2000 in the Ten Mile River (KRIS Information System, 2000); and was much greater than some apparently healthy streams: Flebbe (1999) calculated average trout density in pools to be 0.14 fish/m^2 in Wine Spring Creek, NC; while Chapman (1988) determined the density of YOY steelhead as 0.1 fish/m^2 during October for the Wenatchee River, WA. Other published values range widely but usually range between 0.2 and 0.5 fish/m^2 (Satterthwaite, 2002).

	Mainstem	Sanchez Fork	South Fork	Middle Fork
YOY	0.069	0.270	0.144	0.400
Age 1+	0.069	0.170	0.039	0.088
Total Density	**0.144**	**0.440**	**0.183**	**0.488**

Table 26. Average steelhead densities (fish m^{-2}) throughout San Pedro Creek's major tributaries.

Unfortunately, steelhead densities (fish/m^2) were not calculated for the two previous studies on San Pedro; although Hagar's counts, similar to the present study, excluding the lower mainstem, indicate similar low-density estimates. Sullivan's (1990) much higher YOY counts throughout the mainstem suggest much higher densities in this region, perhaps due to a very successful spawning season the preceding winter/spring. This is quite possible as stream specific salmonid densities demonstrate natural cycles and fluctuations, and have been shown to be highly variable over both annual and decadal time-scales (Crisp, 1993).

Densities of Age 1+ steelhead for all tributaries, except Sanchez Fork, were below the Oregon Department of Fish and Wildlife's goal of 0.1 fish /m^2 for Age 1+ steelhead (Satterthwaite, 2002). The South Fork's very low Age 1+ density reflects the tributary's lack of large, pool habitat and thus low 'carrying capacity' for older steelhead. The high value recorded for Sanchez Fork is more an artifact born from the small survey area for the stream and not that it has the best rearing habitat for older steelhead age-classes. The Middle Fork however, with relatively high Age 1+ density as well as high YOY density demonstrates that its habitat is suitable for multiple age-classes of steelhead, and is therefore very important to San Pedro Creek's steelhead population - not only because of its suitable spawning habitat and capacity for juvenile rearing, but also for the successful rearing of older and larger steelhead.

Steelhead age classes and spatial distribution

Three age-classes of steelhead were observed throughout San Pedro Creek. These findings correspond to Sullivan's observations on the lower mainstem and with studies on other creeks in the San Francisco Bay region (Leidy, 2003). As expected, the youngest age-class (YOY) had the greatest abundance, with older age-classes decreasing in frequency (Figure 29). While it is not clear whether this pattern illustrates the variation in the duration of freshwater residence or natural mortality rates among steelhead over time, it is likely to be a combination of both factors.

The majority (89%) of YOY steelhead were concentrated in the upper reaches of the mainstem and the Middle Fork (Figure 32). Both of these areas are important spawning grounds during the winter and spring (Sullivan, 1990a). Site fidelity thus seems high among YOY steelhead, although culverts located on the upper mainstem and the lower middle fork will prevent major dispersal events, acting to keep YOY in such concentrated pockets. Hagar's findings agree with these except for this study's lack of YOY fish observed in the lower mainstem. The high YOY densities recorded in the upper reaches of San Pedro Creek indicate that at least some adult spawners were able to reach spawning grounds high in the watershed, and were therefore able to successfully navigate through the Capistrano fish ladder and the other culverts.

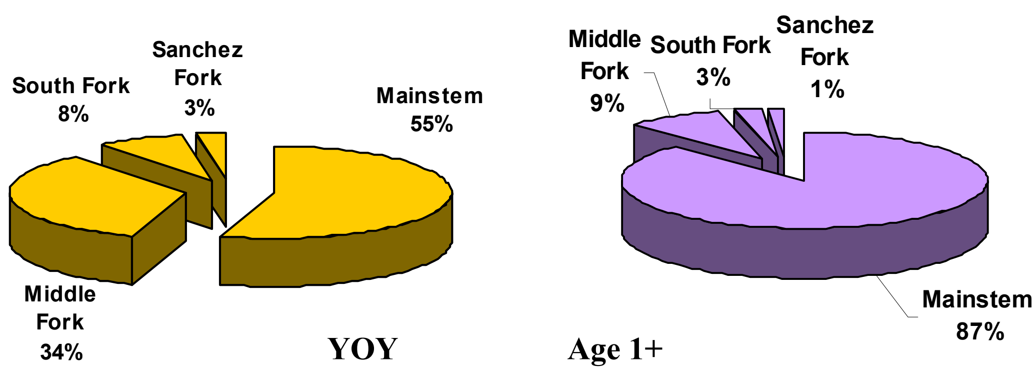


Figure 32. YOY and Age 1+ steelhead distribution throughout San Pedro Creek's tributaries.

The mainstem also had the majority of the older steelhead age-classes (87%) (Figure 32). These findings agree strongly with Hagar who observed 44 out of 51 (86.3%) Age 1+ fish on the mainstem, indicating habitat selectivity by older fish (Sullivan, 1990b; Hagar, 2002). During the high flows of winter and spring, rates of dispersal, both active and passive, are likely to be much greater. Culverts do not prevent downstream dispersal during such high flow events, thus allowing fish to descend from the headwaters to the mainstem, and from the mainstem's upper reaches down to its lower reaches. The greater number of deep pools throughout the mainstem, coupled with the higher flows, makes it suitable for rearing older, larger fish, preferring such habitats.

Influence of habitat type on steelhead abundance

This survey showed that habitat type was a significant factor in determining steelhead abundance, especially older age-classes, throughout San Pedro Creek. It is apparent in this study that as pool habitat increases, so does the abundance of older steelhead. Previous studies have observed steelhead inhabiting all habitat types in similar abundances with no apparent preference (Lau, 1984) or demonstrating clear preference for riffles and runs with high water velocity over pools (Young, 2001; Higgins, 1994; Chapman, 1988). It is important to note however, that these studies involved streams with resident coho salmon. Coho are known to prefer low velocity pool-habitat, avoiding riffles and shallow run habitat (personal observation, 2003; Young, 2001; Lau, 1984). In such streams, coho and steelhead which are both highly territorial may be in direct competition for space and food. In such instances, habitat displacement occurs, and steelhead locate themselves in areas of higher flow velocity avoided by coho (Roni & Quinn, 2001; Young, 2001). This study shows that when coho do not influence the habitat choice of steelhead, steelhead generally prefer slow-flowing, energetically favorable pool habitats where juveniles have the highest growth rates (Young, 2001).

Influence of habitat depth on steelhead abundance and age distribution

Deep pools provide essential habitat for older and larger steelhead (Harvey & Nakamoto, 1997; Keeley & Slaney, 1996; Ozaki, 1994; Everest & Chapman, 1972), especially in small coastal streams like San Pedro Creek. Generally food availability, and the level of protection from predators, is considered to be greater with deeper habitats (Harvey & Nakamoto, 1997). Larger fish have higher individual food requirements, are less efficient at foraging in shallow water, and although predator-prey relationships among fishes generally favor larger individuals, large fish can experience greater risk of predation from piscivorous birds and mammals (Harvey & Nakamoto, 1997). Everest & Chapman (1972) found that spatial segregation by body size is common among salmonids. Agonistic interactions between steelhead size classes may contribute to such segregation. Therefore, larger steelhead are more likely to inhabit pools and thereby force smaller fish into shallower habitats – a pattern supported by the results of this study.

Influence of overhead cover on steelhead abundance and age distribution

Riparian cover is an important component for a healthy and natural stream ecosystem (Thompson & Larsen, 2004; English *et al*, 2000). One of the functions of a riparian zone is to provide a canopy, or overhead cover to a creek or stream. Such overhead cover directly influences creek water temperature by insulating against extreme hot or cold conditions (Craven *et al*, 1996), can provide juvenile steelhead excellent cover from piscivorous birds (Thompson & Larsen, 2004) and is a source of terrestrial insects (Craven *et al*, 1996), an important food source for stream fish like steelhead.

YOY steelhead throughout San Pedro Creek demonstrated the strongest positive relationship with overhead cover. They were found in greatest abundance in units with good to excellent coverage. YOY steelhead are often situated in shallow, flatwater habitats such as runs and glides, so overhead cover provides essential shelter which such shallow habitats cannot provide. Older age-classes, which seemed to demonstrate preference for moderate overhead cover, are much more likely to be found in deeper pool habitat, protection in itself, and thus may not need such dense overhead cover. Additionally, such older fish are more likely to associate with in-stream cover such as large woody debris or submerged rootwads (Personal observation, 2003; Olsen & West, (1991) in KRISweb, 2005) thus decreasing their dependency on canopy cover.

Influence of understory cover on steelhead abundance and age distribution

Riparian cover, not restricted to the canopy, may also include low lying bank-side shrubbery and root complexes that provide direct cover to steelhead, especially along bank margins. Undercut banks and bedrock ledges also allow excellent cover for steelhead and may provide shelter from strong currents. Such habitat features are not only important for juveniles but also adult steelhead. After migrating from the ocean into their natal streams, adults often spend several months before the onset of spawning in order to allow their bodies to fully prepare, and allow them to produce healthy, and in the case of females, well provisioned, gametes. Creek conditions, much different from those of the open ocean, often subject adult migrants to increased levels of stress. Stress related to lack of water depth and cover may reduce fecundity and success of spawning (KRISweb, 2005). Roff (1982) discovered that stress during the maturation of female salmonids considerably reduced the number of eggs produced and is always associated with reduced egg performance (Schreck *et al*., 2001). Therefore, adult steelhead producing the maximum number of high quality gametes requires good quality habitat in the form of deep pools and creek channels with good riparian cover.

In this study, YOY steelhead were observed the least in units with high abundance of understory cover. This may be a factor of competition with the older age-classes, which were abundant in well-covered units. YOY also have the advantage of being small, allowing them to utilize interstitial spaces within the gravel substrate to provide cover (KRISweb, 2005; Personal Observations, 2004), unavailable to larger fish. Age 2 steelhead demonstrated an extremely strong positive relationship with understory cover. This highlights the dependence of larger fish on complex habitat throughout San Pedro Creek. Maintaining a healthy creek ecosystem with great habitat diversity, will therefore bolster the age structure of San Pedro Creek's steelhead population, important for its survival through years of adverse environmental conditions and the future perseverance of the population.

Influence of woody debris on steelhead abundance and age distribution

In-stream woody debris is an essential player in the formation and maintenance of suitable stream habitat for salmonids (Thompson & Larsen, 2004; Roni & Quinn, 2001; English *et al*, 2000; Solazzi *et al*., 2000; Flebbe, 1998; Nakamoto, 1998; Urabe & Nakano, 1998; Keeley & Slaney, 1996). Removal of woody debris often has a negative impact on the local habitat for salmonids. Several studies have demonstrated higher winter fish numbers, associated with increased abundance and area of winter rearing habitat, from the placement of large woody debris (Roni & Quinn, 2001; Solazzi *et al*., 2000). As a result, many recent projects have concentrated on the artificial planting of woody debris in creeks lacking natural recruitment, with efforts to improve local habitats and maximize the watersheds' potential to support salmonids (Roni & Quinn, 2001; Solazzi *et al*., 2000; House *et al*., 1989). Often salmonids, especially coho, are found in highest densities in regions containing woody debris. However, some studies have demonstrated that summer steelhead densities are sometimes unaffected or even negatively effected by placement of large woody debris. Roni & Quinn (2001) found that steelhead densities were negatively correlated with the presence of large woody debris in the summer, but winter and spring densities were higher in pools with woody debris present (Roni & Quinn, 2001; Solazzi *et al*., 2000). Solazzi *et al.* (2000) also noted increased numbers of steelhead smolts during spring from areas with additional structures of large woody debris.

YOY steelhead throughout San Pedro were observed in higher abundance within units containing woody debris, whereas 1+ steelhead were found to be less abundant. The increase in YOY abundance was unexpected, but House *et al.* (1989) reported similar increases associated with the placement of large woody debris. These findings are in opposition to Olsen & West's (1991 in KRISweb, 2005) observations on Klamath River tributaries: Age 1+ steelhead strongly preferred units containing log covers and excluded YOY steelhead from such areas. Perhaps the low counts of Age 1+ steelhead associated with woody debris in this study may be a factor of fish visibility. Pools containing woody debris structures are often much more complex than those without. Counts in these units may therefore be an underestimate of the fish number.

Conclusions

The lower reaches of San Pedro Creek were characterized by deep pools, long stretches of flatwater and limited riffle habitat. Riffles became more common but pools were less abundant in the upper reaches. The lower reaches of San Pedro Creek are therefore more suitable for older steelhead and resident trout while the upper reaches of the Creek have better potential for adult spawning and YOY habitat.

Steelhead were not distributed randomly throughout San Pedro Creek but instead exhibited distinct aggregations in seemingly ‘productive’ areas - allowing me to accept my original hypothesis. Different age-classes also demonstrated their highest densities in separate regions of San Pedro Creek: Most of the Age 2 steelhead were observed in the lower reaches of the mainstem, while age 1 steelhead were present throughout the mainstem and into the basin’s upper reaches. YOY steelhead numbers were extremely sparse in the lower reaches, increasing dramatically throughout the mainstem’s upper reaches and the headwaters of San Pedro Creek. The Middle Fork’s high densities of YOY and age 1 steelhead indicate that it provides essential habitat for spawning and the successful rearing of juvenile steelhead. It is likely that the Middle Fork now provides the only major spawning ground throughout the entire watershed, downstream areas of the creek benefiting from ‘seeding’ events from the dispersal of juveniles, originating in the productive Middle Fork, during periods of high flow. Therefore, care must be taken to protect the Middle Fork in order for San Pedro Creek to continue to support steelhead.

Habitat selection by steelhead in San Pedro Creek was influenced by the size of the individual, itself an indicator of the individuals age. Differences in habitat utilization between steelhead age-classes were clearly apparent: All three age-classes of steelhead demonstrated significant preferences for pool habitat indicating that when closely related competing species like coho salmon are absent, steelhead prefer deeper, more energetically favorable habitats.

The presence of YOY steelhead throughout the upper reaches of the mainstem and the South Fork indicate that culverts on the mainstem were not total barriers to adult migration. Likewise, YOY steelhead abundance in the upper reaches of the Middle Fork indicate that the culvert in San Pedro County Park was not barring further ascension by adults. Further studies of the culverts during the adult spawning season will be important to evaluate the conditions needed for adults to ascend and pass through these structures and for how long and how often those conditions are expected to occur during the season. This will help to determine the absolute impact of each culvert on San Pedro Creek's steelhead population and enable prioritization of restoration projects to target those with the shortest passable periods first (Hagar, 2002). As previously mentioned, two complete barriers to adult migration and juvenile upstream movements exist in San Pedro Creek.

Removing these barriers will help to provide increased spawning habitat and juvenile rearing habitat and may increase the carrying capacity of San Pedro Creek for steelhead.

The role of the San Pedro Creek Watershed Coalition (SPCWC) in protecting San Pedro Creek and the wildlife it supports cannot be overemphasized. Although much restoration and rehabilitation work has been completed, there remains a huge amount for future projects. A long-term steelhead monitoring program would detect changes in the health of the population which itself reflects the overall health of the creek itself. This coupled with the replacement or removal of culverts and habitat improvements to degraded sections of the creek, made possible by the dedication and tireless efforts of the SPCWC, will set the foundations to ensure that steelhead trout continue to return and thrive in San Pedro Creek.

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Appendix 1. Habitat survey data.

San Pedro Creek - Habitat Survey															
Mainstem															
		Cover				Width									
Habitat #	Type	OH	US	AQ	Length	DS	M	US	Substrate	Max. Depth	Woody Debris	W.Temp	Flag	Distance up Creek (m)	
1	LSL	5	2	35	20	6.5		5.2(.8)	SAND	>100		17	*	20	
2	MCP	5	2	10	26	5.2(.8)	5.7	5.8(.65)	SILT	70	YES	17	*	46	
3	MCP	10	5	20	17.5	5.8(.65)	3.1	2.7	SILT, G50	55		17	*	63.5	
4	LGR	2	5	5	19	2.7	2.5	3.5	G80	16		17	*	82.5	
4.1	LSP	0	0	70	4	1.3	1.3	1	G50	40		17	*	86.5	
5	LSP	50	40	0	5	2.5	1.6	1.5	G50	60		17	*	91.5	
6	GLD	10	10	55	29	1.5	4.4	5.5	G60	30		17	*	120.5	
7	GLD/LSP	10	10	35	17	3.5	3	2.5	SILT	54		15	*	137.5	
8	GLD/LSL	0	2	40	60	4.5	5	6.5	SAND	56	YES	15	*	197.5	
9	GLD	2	15	15	19	4.5	4	4	SAND	39		15	*	216.5	
10	LSL	10	20	25	8.5	4.5	4	3	SAND, G5	53	YES	15	*	225	
11	GLD/LSL	2	10	15	35	3	4	3.5	SAND	46	YES	15	*	260	
12	LGR	2	2	5	13	2.5	2.5	2	G15, C85	20		15	*	273	
13	GLD/LSP	5	15	25	47	3.5	3	2.5	SAND, G15	40		15	*	320	
14	MCP	0	2	20	23.5	2.5	3	3	SAND, SILT	41		15	*	343.5	
15	HGR	0	5	5	2.5	3	3.2	3.2	G80, C120	5		14	*	346	
16	GLD/LSP	2	5	10	61	3.4	3	1.8	SAND, G40	36		14	*	407	
17	GLD/LSL	2	5	15	53	3.3	2.5	5	SAND, G50	54	YES (LOG BANK)	14	*	460	
18	GLD/LSP	0	2	55	55	4	7	5.5	SAND, ALGAE, G60	56		14	*	515	
19	LSL	0	0	5	9	6.5	5.5	5	SAND, ALGAE	>100	50% LOG COVER	14	*	524	
20	GLD/LGR	0	0	8	32	4	4	4	G80, C120, ALGAE	25		14	*	556	
21	LSR	50	10	2	20	4	8	6	SILT, ALGAE	>100	YES	14	*	576	
22	LSC	10	15	0	5.5	1.8	1.5	1.7	SAND, G20	34		15	*	581.5	
23	LGR/FW	-	-	-	29							15		610.5	
24	FW	80	10	0	17.5	2.8	2.9	3	SILT, G50	24		15	*	628	

25	LGR				2.5							15		630.5	
26	FW	15	30	5	11	3.8	3	4	SILT, G50	28		15		641.5	
27	LSC	10	20	0	15.5	4.5	5	2	SAND, SILT	50		15		657	
28	LGR/FW				19					24		15		676	
29	MCP	90	25	0	9.5	3.1	3.9	2.8	SAND, SILT	70		15		685.5	
30	LSC	90	40	0	14.5	2.5	2	2	SAND, G20	41		15	*	700	
31	LSC	75	30	0	11.5	1.8	2.8	2.2	SILT, SAND	60	YES	15		711.5	
32	FW/LGR				11							15		722.5	
33	LSC	90	40	0	6.5	3	2.5	2.5	SILT, SAND	50		15	*	729	
34	LSC				9							15		738	
35	HGR				22							15		760	
36	MCP	40	20	0	15	3	3.5	4	SILT,SAND,G50	62		15		775	
37	LSC	5	15	0	14	3	3	2	SILT, SAND, G10G50	33		15		789	
38	HGR				5.5							15		794.5	
39	MCP/LSC	30	2	0	19	3.5	3.2	1.5	SILT, G50	36		15		813.5	
40	FW	75	5	0	13	4	3.3	3.5	G5	30		15		826.5	
41	LGR				14.5	2.5						15		841	
42	FW	2	5	2	11	3.5	3.3	2.2	G50, C70	25		15	*	852	
43	LGR				14							15		866	
44	FW/LSC	15	10	5	29	4	3.2	3.5	SAND, G50	65	ROOTMASS	15		895	
45	LGR				11							15		906	
46	FW/LSC	10	10	0	29.5	3.5	3.7	2.3	SILT, SAND, G20	38		15	*	935.5	
47	LSC	60	40	0	34	1.7	2.2	2.5	SILT, G50	55		15		969.5	
48	FW/LGR	10	25	0	15	2.5	2.2	2	G50, C120	18		15		984.5	
49	CAS				8.5				BOULDERS			15		993	
50	LSB	50	5	0	8	3	1.8	3.5	SILT, SAND, G50	40		15	*	1001	Reach 1 End
51	CAS				9							15		1010	Reach 2 Start
52	LSC/MCP	0	15	5	16.5	2	2.5	4	G50, C70	50		15		1026.5	
53	LGR/FW				8.5							15		1035	
54	LSC	50	10	0	6.5	4	2.3	1.4	SILT, SAND	55		15	*	1041.5	
55	HGR				5.5							15		1047	

56	FW	15	5	2	20	2.7	2.3	2.3	G50,C100	20		15		1067	
57	LSC	65	15	0	11	3.4	4	3.2	SILT,SAND,G50	24		15		1078	
58	LSC	40	10	0	12.5	3.7	4	3	SILT, SAND, G50	60		15		1090.5	
59	HGR				16							15		1106.5	
60	FW/LSC				15.5							15		1122	
61	LGR				6							15		1128	
62	LSC/MCP	40	35	0	18.5	2.6	7.5	6.5	SILT, SAND, G10	95		15		1146.5	
63	ADOBE				15.5							15		1162	
64	LSB	10	50	0	5	5	3	1.5	SILT, SAND	78		15		1167	
65	LGR/FW				15							15		1182	
66	LSC	10	35	0	13.5	3	3.6	3	G50, C70	40		15		1195.5	
67	LGR				7.5							15		1203	
68	LSC	30	20	5	23	1.8	4	3	SILT, SAND, G40	55		15	*	1226	
69	LGR/FW				12							15		1238	
70	LSC	50	30	0	9.5	4.5	4	2.3	SILT, SAND	80	ROOTMASS	14	*	1247.5	
71	LGR				7.5							14		1255	
72	LSC	2	35	0	11.5	4	3.8	3.5	SILT, SAND, G10	100+	UNDERCUT	14		1266.5	
73	FW/LGR				18							14		1284.5	
74	CRP	90	25	0	8	3.8	3	3	SILT, G30,G50	70	YES, UC	14	*	1292.5	
75	LGR				4							14		1296.5	
76	CRP	0	0	0	8.5					55		14		1305	
77	LGR/FW				27.5							14		1332.5	
78	MCP/LSC	40	40		16.5					50	ROOTMASS	14		1349	
79	LGR				19							14		1368	
80	MCP	70	10	0	5	3.2	3.8	2.2	SILT, SAND, G60	50		14	*	1373	
81	LGR/FW				44.5							14		1417.5	
82	LSB	30	15	0	14	4	3	4	G10, G50, BOULDER	100		14		1431.5	
83	FW/CAS	60	10	6	21	4	2.5	2	BOULDER, BR	30		14	*	1452.5	
84	LSB/MCP	80	40	5	14	2	4	2.8	SILT, SAND, BR	>100		14	*	1466.5	
85	LGR/FW	10	10		25.5					20		14		1492	
86	MCP	20	15	0	17	4.8	4	3.5	SILT, SAND, BR	50		14	*	1509	
87	FW/LGR	10	10		37					20		14		1546	

88	CRP	15	20	0	11.5	5.5	6	6	SILT, SAND	>100		14		1557.5	
89	LSC	0	10	2	12.5	5	3.5	2.8	SILT, SAND	60	UC	14		1570	
90	LGR/FW	10	10		24					20		14		1594	
91	MCP/LSC	80	20	0	8.5	2.2	2	1.4	SILT, SAND	85	ROOTMASS, UC	14	*	1602.5	
92	LGR/FW	10	10		20.5					20		14		1623	
93	LSB	20	15	0	13	4	3	2.5	SILT, SAND	50		14		1636	
94	LGR/FW				32							14		1668	
95	LSC/LGR	75	75	0	22				SILT, SAND	70		14		1690	
96	LGR/FW				24					24	bedrock	14		1714	
97	FW/LSC				21				SILT, SAND	>100		14		1735	
98	LGR				10							14		1745	
99	LSB	30	10	0	11.5	4.5	3.5	4	SILT, BR	65	BR LEDGE	14	*	1756.5	
100	LGR/FW				22							14		1778.5	
101	LSC	60	20	1	13.5	3.8	4	2.5	SILT, SAND	55	ROOTMASS	14		1792	
102	FW/LGR				10							14		1802	
103	FW/LSB				26.5					55		14		1828.5	
104	CRP	40	5	0	10.5	3	4	2	SILT, SAND	95	BR LEDGE, UC	14	*	1839	
105	FW/LGR				10							14		1849	
106	CRP				8				SILT, SAND, G50	80		14		1857	
107	FW/LGR				12							14		1869	
108	LSB	20	40	0	11	4	3.5	3.5	SILT, SAND, C100	61		14		1880	
109	LGR/FW				32							14		1912	
110	MCP	25	2	0	15	5	5	4	SILT	65	SWD	14		1927	
111	PLUNGE	30	35	0	12.5	5	5	4.5	SILT, BOULDERS	85		14	*	1939.5	
112	LSC/FW				30							14		1969.5	
113	FW				35							14		2004.5	Reach 2 End
114	FW/LSC				16					52	WEIR	15		2020.5	Reach 3 Start
115	FW/LSR	90	5	0	6.5	3	2.5	1.5	SILT,SAND, G5, G50	35	R00TMASS	15	*	2027	
116	CAS/HGR				13					60		15		2040	
117	FW/MCP/LSC				28					60		15		2068	
118	LGR				2.5							15		2070.5	

119	MCP/LSC				35					65		15		2105.5	
120	LGR				8							15		2113.5	
121	FW/LSC				10.5					40		15		2124	
122	LGR				5							15		2129	
123	LSC				15.5					>100	SANCHEZ FORK ENTERS	15		2144.5	
124	LGR				3.5							15		2148	
125	FW/LSC				13.5					35		15		2161.5	
126	LGR				5							15		2166.5	
127	LSC	50	5	0	14.5	4.5	3	3.25	SILT, SAND	55	ROOTMASS	15	*	2181	
128	HGR				11							15		2192	
129	FW/MCP	15	15		16					30	RM	15		2208	
130	CRP/LSB	65	10	0	12.5	4	4	2.8	SILT, SAND, BOULDER, G50, C100	75		15	*	2220.5	
131	FW/CAS				22							15		2242.5	
132	MCP	80	5	0	18.5	5	5	2	SILT, SAND, BDRK, C100	75		15		2261	
133	LSC				18					85		15		2279	
134	HGR				4							15		2283	
135	FW				9.5							15		2292.5	
136	FW/HGR				16.5							15		2309	
137	FW				15.5							15		2324.5	
138	TRP				20					>100		15		2344.5	
139	FW/LSC				23							15		2367.5	
140	CRP				4.5					50	SWD	15		2372	
141	HGR				9							15		2381	
142	CRP	75	25	0	19.5	3	3	3	SILT, SAND, BLDERS	70	ROOTMASS,UC	15	*	2400.5	
143	FW/LGR				11							15		2411.5	
144	CRP/LSR				24					60		15		2435.5	
145	CRP				9				CLAY	95		15		2444.5	
146	CAS				16					20		15		2460.5	
147	FW				13					24		15		2473.5	
148	MCP				15					70		15		2488.5	

149	LGR				2.5							15		2491	
150	FW/HGR				22.5							15		2513.5	
151	LSC/FW				24							15		2537.5	
152	CAS				25					20		15		2562.5	
153	MCP				18.5					40		15		2581	
154	LSC	35	20	0	7.5	3	3	2.5	SAND, G50, BOULDER	30		15	*	2588.5	
155	CAS				16					20		15		2604.5	
156	MCP/LSC				21					45		15		2625.5	
157	HGR				7.5							15		2633	
158	FW				37.5							15		2670.5	
159	MCP/CAS				36					40		15		2706.5	
160	PLUNGE	70	10	5	12.5	3.5	5	4	BLDR	60		15		2719	
161	CAPISTRANO BRIDGE				23.5					80		15		2742.5	
162	FW				63					20		15		2805.5	
163	MCP/LSC				15					40		15	*	2820.5	
164	FW/MCP				22					40		15		2842.5	
165	RUN				11.5							15		2854	
166	HGR				8							15		2862	
167	MCP				7					45		15		2869	
168	LGR/FW				45.5							15		2914.5	
169	LSC				11					>100	SWD	15		2925.5	
170	HGR				5.5							15		2931	
171	MCP	40	50	1	10	2	3.3	3.3	SILT, C70	65		15	*	2941	
172	LGR				5							15		2946	
173	LSC				15					50	ROOTMASS	15		2961	
174	FW				11.5					24		15		2972.5	
175	CRP				7					75		15		2979.5	
176	LGR				10							15		2989.5	
177	LSC				16					45		15		3005.5	Reach 3 End
178	FW/LGR				27							15		3032.5	Reach 4 Start
179	FW/LGR				23							15		3055.5	

180	MCP				7					35		15		3062.5	
181	FW/LGR				7.5							15		3070	
182	LSB				13					70		15		3083	
183	LGR				6							15		3089	
184	LSB	0	25	35	15.5	4.5	3.5	2	SILT,SAND, G10	100		15	*	3104.5	
185	HGR				4.5							15		3109	
186	CRP				16.5					80		15		3125.5	
187	LGR/LSC				29					75		15		3154.5	
188	FW/MCP	5	15	10	19	3.5	4	4.5	SILT, SAND	68		15	*	3173.5	
189	FW				11							15		3184.5	
190	MCP				10					50		15		3194.5	
191	LGR				8							15		3202.5	
192	LSR	85	15	0	9.5	3	4	3	SILT, SAND, GRAVEL	75	LWD,UC,ROOTMASS	15		3212	
193	FW/LGR				40					30		15		3252	
194	FW/LSC/LGR				29					45		15		3281	
195	HGR				11.5							15		3292.5	
196	PLUNGE				16					95	LINDAMAR	15		3308.5	
197	LINDAMAR BRIDGE				23							15		3331.5	
198	LSR/MCP				14					>100		15		3345.5	
199	HGR				5.5							15		3351	
200	FW/LGR				29					20		15		3380	
201	LSC	50	15	0	6.5	2.2	3.2	2.2	SILT, BOULDERS, C120	40		15	*	3386.5	
202	FW/RUN				33				BOULDERS			15		3419.5	
203	FW/LGR				30							15		3449.5	
204	LSC	50	5	0	11	4	4	2	SILT, SAND, C120	63	ROOTMASS	15	*	3460.5	
205	HGR				6						STREAM SPLIT (North Fork)	15		3466.5	
206	CCP				10					50		10		3476.5	
207	HGR				6.5							10		3483	
208	MCP	40	25	0	8	2.5	2.5	2	SILT, SAND, G60	50		10	*	3491	
209	HGR				13.5						"NIKKO" BRIDGE	10		3504.5	
210	FW/LGR				25					20		10		3529.5	

211	CRP	80	2	0	8	1	2.2	2.5	SILT, G60, C90	37		10	*	3537.5	
212	FW/HGR				113.5					20		10		3651	
213	MCP	10	15	2	6.5	1.5	2	1.5	BLDR	35		10	*	3657.5	
214	HGR				8							10		3665.5	
215	FW				6.5					20		10		3672	
216	MCP	35	5	0	4.5	2	2.2	1	BLDR, SAND, G60, C120	35		10	*	3676.5	
217	HGR				9							10		3685.5	
218	MCP				4.5					40		10		3690	
219	HGR				4.5							10		3694.5	
220	PLP	10	2	0	4	3	4	3	BLDR, SAND, SILT	40		10		3698.5	
221	ODDSTAD				18.5							10		3717	
222	FW/LGR				16						UC	10		3733	
223	MCP	100	5	0	5.5	1.6	2	0.8	BLDR, SAND, G60, C100	30		10	*	3738.5	
224	HGR				3							10		3741.5	
225	FW/LGR				38.5							10		3780	
226	PLP				3.5				SILT, SAND	45		10		3783.5	
227	FW/LGR				16.5					20		10		3800	
228	PLP				4.5					>100	DEEP, UC, ROOT	10		3804.5	
229	LGR				3							10		3807.5	
230	LSC	50	15	0	7	2	3	2	SILT, CLAY	48	UC, SWD	10		3814.5	
231	LSC	40	0	0	8	2.5	2.5	1	BEDROCK, C70, Boulders	55	UC, bubble curtain	10	*	3822.5	
232	FW/LSC				8					30		10		3830.5	
233	FW/LGR				23							10		3853.5	
234	CRP				6.5					80	SWD/LWD	10		3860	
235	LGR				4.5							10		3864.5	
236	LSC	60	5	0	7.5	2.5	3.5	2.5	g50, bedrock	55	UC, bubble curtain, SWD	10		3872	
237	LGR/FW				11							10		3883	
238	MCP	100	0	0	5	1.2	2.3	1	SAND, C100, G50	47	SWD, ROOT	10	*	3888	
239	FW/ LGR				25.5							10		3913.5	
240	PLP	75	5	0	7	5	4	2.5	SILT	70	SWD/LWD, bubble curtain	10		3920.5	
241	LGR				6							10		3926.5	

242	MCP/LSC	80	10	0	5.5	3.5	4	2	sand, gravel	62		10		3932	
243	FW/LGR				26.5							10		3958.5	
244	LSC				9					40		10		3967.5	
245	LGR				5							10		3972.5	
246	LSC	90	2	0	5	1.7	2.5	1	SILT, G60, C90	60		10		3977.5	
247	LGR/FW				43							10		4020.5	Reach 4 End

Appendix 2. Snorkel survey data.

San Pedro Creek Snorkel Survey								
Main Stem								
Unit #	Unit Type	YOY	Age 1	Age 2	Resident	Other	Comments	Unit Length
3	MCP	0	0	0	0	STK		17.5
4.1	LSC	0	0	0	0	STK		4
5	LSC	0	0	0	0	STK		5
8	GLD/LSL	1	0	0	0	STK	Aquatic Veg. - great cover	60
9	GLD	0	0	1	0	STK	Utilizing LWD	19
11	GLD/LSC	0	0	1	0	STK		35
13	GLD/LSC	0	0	0	0	STK		47
14	MCP	0	0	0	0	STK		23.5
16	GLD/LSC	1	0	0	0	STK	good gravels	61
17	GLD/LSL	0	0	0	0	STK		53
18	GLD/LSC	0	0	0	0	STK, SCU		55
19	LSL	0	0	0	0	STK		9
20	GLD/LGR	0	0	0	0	SCU		32
29	MCP	0	0	0	0			9
30	LSC	0	1	1	0			14.5
33	LSC	0	0	1	0	STK, SCU		6.5
36	MCP	0	0	0	0	STK		15
39	MCP/LSC	0	0	1	0			19
42	FW	0	0	0	0			11
44	FW/LSC	0	0	0	0	STK		29
46	FW/LSC	0	0	0	0			29
50	LSB	0	0	0	0			8
54	LSC	0	0	0	1	SCU		6.5
57	LSC	0	4	1	0	STK		11

66	LSC	0	0	0	0				13.5
68	LSC	0	2	0	0		above adobe		23
70	LSC	0	1	0	0				9.5
72	LSC	0	3	5	1				11.5
74	CRP	1	0	0	0				8
76	CRP	1	0	1	0		plank over creek		8.5
78	MCP/LSC	1	2	2	0				16.5
80	MCP	0	0	0	0				5
82	LSB	2	1	2	0				14
83	FW/CAS	0	0	0	0				21
84	LSB	0	4	7	1				14
85	LGR/FW	1	0	0	0				25.5
86	MCP	0	5	0	0				17
87	FW/LGR	1	0	0	0				37
88	CRP	0	3	10	2		deep 'duck pond'		11.5
89	LSC	0	1	0	0				12.5
90	LGR/FW	0	0	1	0				24
91	MCP/LSC	0	0	2	0				8.5
92	LGR/FW	0	0	1	0				20.5
93	LSB	0	1	0	0				13
96	LSB	2	1	0	0				24
99	LSB	1	4	1	0				11.5
104	CRP	0	0	0	0				10.5
106	CRP	0	1	2	0				8
111	PLP	0	0	0	0		19th Nov		12.5
114	FW/LSC	0	1	0	0	STK!			16
115	FW/LSR	0	0	0	0	STK!			6.5
116	CAS	0	0	2	0				13
117	FW/MCP/LSC	0	3	0	0	STK!			28
119	MCP/LSC	2	22	10	0				35

121	FW/LSC	1	2	0	0				10.5
123	LSC	2	12	15	1		may be underestimate - large numbers of fish present!		15.5
125	FW/LSC	0	2	0	0				13.5
127	LSC	0	1	0	0		iron oxide seepage?		14.5
129	FW/MCP	2	3	3	0		Trout hiding in complex small root masses under right bank		16
130	CRP/LSB	0	2	0	0	Crayfish			12.5
132	MCP	0	2	2	0				18.5
133	LSC	5	16	1	0	Crayfish			18
138	TRP	2	15	2	0		Changed habitat type from fw/mcp		20
139	FW/LSC	1	0	0	0				23
140	CRP	0	4	0	0				4.5
142	CRP	1	7	1	0				19.5
145	CRP	1	2	2	0				9
146	CAS	1	0	0	0				16
147	FW	0	2	0	0				13
148	MCP	0	4	4	0				15
152	CAS	1	0	0	0				25
153	MCP	0	0	1	0				18.5
154	LSC	0	0	0	0				7.5
155	CAS	0	0	0	0				16
156	MCP/LSC	0	1	1	0				21
159	MCP/CAS	0	0	0	0	Sculpin			36
160	PLP	0	1	0	0				12.5
161	Capistrano	0	0	0	0		pool above lower fish ladder		23.5
162	FW	0	0	0	0				63
163	MCP/LSC	0	2	0	0				15
164	FW/MCP	1	1	1	0				22
169	LSC	2	3	0	0		good habitat under alder veg in water		11
171	MCP	0	1	1	0	Crayfish			10
173	LSC	1	0	0	0				15
174	FW	0	1	0	0				11.5

175	CRP	1	1	0	0				7
177	LSP	0	2	0	0				16
180	MCP	0	0	0	0				7
182-186							silty due to bank stabilization work		
187	LGR/LSC	3	0	0	0				29
188	FW/MCP	3	7	0	0				19
192	LSR	15	2	0	0				9.5
193	FW/LGR	7	0	0	0		surveyed areas deep enough		40
194	FW/LSC/LGR	27	1	1	0				29
196	PLP	10	20	5	0		big pool may be underestimate		16
198	LSR/MCP	2	2	0	0				14
200	FW/LSR	2	0	0	0				29
204	LSC	7	2	1	1				11
208	MCP	5	0	0	0	Crayfish			8
210	FW/LGR	11	0	0	0				25
211	CRP	14	5	0	0				8
212	FW/HGR	10	1	0	0				113.5
213	MCP	1	0	0	0		hard to survey - stuff in water		6.5
215	FW	2	0	0	0				6.5
216	MCP	1	2	1	0				4.5
218	MCP	3	1	0	0				4.5
220	PLP	20	10	1	0		may be underestimate		4
223	MCP	1	0	0	0		me by self (15th Dec)		5.5
227	FW/LGR	1	0	0	0				16.5
228	PLP	5	0	0	0	Crayfish			4.5
230	LSC	1	0	1	0				7
231	LSC	6	0	1	0		good uc, boulders, bubble curtain		8
232	FW/LSC	0	1	0	0				8
234	CRP	1	0	0	0		LWD		6.5
236	LSC	10	1	0	0		UC, Bubble curtain		7.5
238	MCP	1	1	0	0				5

240	PLP	1	1	0	0		bubble curtain, lwd	7
242	MCP/LSC	3	1	0	0			5.5
244	LSC	3	1	0	0			9
246	LSC	4	2	0	0			5
Middle Fork Counts								
Unit #	Unit Type	YOY	Age 1	Age 2	Resident	Other	Comments	Unit Length
2	PLP	15	6	0	0			5.5
8	MCP	4	1	0	0			7
10	MCP	3	0	0	0			4
12	LSC	6	0	0	0			5
35	CRP/LSC	20	0	0	0			9
37	LSR	2	1	0	0			3
39	MCP	3	1	0	0			3
40	FW/LGR	2	0	0	0			20
41	FW/LGR	3	0	0	0			25
42	LSL	2	1	0	0			3
44	FW/MCP	4	0	0	0			4
45	FW	3	0	0	0			4.5
50	CRP/FW	2	0	0	0			6
52	LSR	12	2	0	0			6.5
56	CRP/ALC	10	6	2	0			6
57	FW/LGR	6	1	0	0			10.5
58	LSC	4	2	1	0			4.5
60	MCP	10	2	1	1			8

62	LSC	3	0	0	0			5
66	FW/MCP	3	0	0	0			5
upper middle								
below wr bridge								
1	LSR	0	0	0	0			6
3	CRP	1	0	0	0			5
5	LSB	0	0	0	0			3
6	HGR/CAS	0	0	0	0			8
8	MCP/LSL	5	2	0	0			5.5
above wr bridge								
1	FW/MCP	0	0	0	0			7
2	STP	5	0	0	0			11
8	MCP/PLP	2	0	0	0			2.5
11	MCP	2	1	0	0			6
13	MCP/FW	1	0	0	0			3
South Fork Counts								
Unit #	Unit Type	YOY	Age 1	Age 2	Resident	Other	Comments	Unit Length
2	LSR	3	1	1	0			4.5
4	LSC	0	0	0	0			5
7	RUN/HGR	2	0	0	0			24.5
8	PLP	1	0	0	0			3.5
8.5	DAM	3	0	0	0			3
10	MCP	2	1	0	0			3.5
12	LSB	0	0	0	0			3
27	FW	4	0	0	0			3
30	LSB	2	0	1	0			3
32	MCP/TRP	2	1	0	0			6
34	PLP	0	0	0	0			3.5

35	CAS/RUN	1	0	0	0			20.5
36	FW/PLP	2	0	0	1		Borderline resident	4.5
38	MCP/PLP	1	0	0	0		Hard to see due to bubble curtain - common problem with PLP	4
41	PLP/MCP	3	0	0	0			6.5
43	MCP	1	0	0	1			3.5
45	MCP/LSC	3	1	1	0			5
69	STP	1?	0	0	0			6.5
71	FW/CAS	0	0	0	0			23
72	MCP	0	0	0	0			4.5
76	FW/CAS	0	0	0	0			11.5
Sanchez Fork Counts								
Unit #	Unit Type	YOY	Age 1	Age 2	Resident	Other	Comments	Unit Length
2	STP	1	0	0	0			5
3	FW/LSC	2	0	0	0			6
7	FW/LSC	0	1	0	0			5
8	FW/BPB	1	1	0	0			5
10	LSB	2	0	0	0			5
15	LSC	1	0	0	0			4
18	FW	1	1	0	0			2.5
20	FW	2	0	0	0			10
24	PLP/LSC	1	2	0	0			5