Central
Coast
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Studies

CCoWS

Fish Species Distribution and Habitat Quality for Selected Streams of the Salinas Watershed; Summer/Fall 2002

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Preface

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Cover Photo:

Rainbow trout (*Oncohynchus mykiss*) yearling (1+ yrs) in Arroyo Seco River near the Santa Lucia Creek confluence. (Photo: Joel Casagrande, 08 Aug 02)

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1 Introduction

1.1 Background

The Salinas Watershed is the largest in the Central Coast Region[1] of California and is host to an array of native fish, wildlife, and plant species. The Watershed once supported runs of anadromous salmonids including steelhead and possibly chinook salmon. It now only supports a small, probably declining run of steelhead. In August 1997, the South-Central Coast Steelhead Evolutionary Significant Unit (ESU), which extends from the Pajaro River in Santa Cruz County to the coastal streams of San Luis Obispo County, was federally listed as 'threatened' (NMFS 1997).

The Watershed has a unique assemblage of native stream fishes that are believed to have originated from the Sacramento / San Joaquin Watersheds (Snyder, 1913; Moyle, 2002). Currently, there is no migration link between the Salinas Watershed and the greater Sacramento / San Joaquin Watersheds.

South Central Coast steelhead and other native fish of the Salinas Watershed are unique because of the varying climatic conditions that they must face and to which they have evolved. Fish species not only must cope with inhabiting a region that poses harsh environmental conditions such as high water temperatures, non-perennial water, drought, and flooding, but must also survive the accompanying anthropogenic effects of population growth. During the past century, the Salinas Valley has been transformed by the draining of its wetlands, reduction of winter flows, conversion of natural lands to intensive agriculture, and increased urbanization. Stream alterations such as channelization and the construction of culverts, roads, bridges, and dams coupled with the loss of riparian habitat due to encroachment from a variety of land uses, introduction of non-native species, seasonal releases of dam water, and accelerated ground water pumping have impacted the aquatic system. The decline of salmonids is almost certainly due to the combined effects of these anthropogenic changes to the watershed.

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[1] State Water Resources Control Board Region 3

Nearly all of the possible beneficial uses outlined in the Central Coast Regional Water Quality Control Board Basin Plan (1994) apply to the watershed. These range from human recreation to protection of rare and endangered species. Beneficial uses of the Salinas River that relate to fish habitat include:

- Spawning, Reproduction, and/or Early Development (SPWN)
- Migration of Aquatic Organisms (MIGR)
- Rare, Threatened, or Endangered species (RARE)
- Cold Fresh Water Habitat (COLD)
- Warm Fresh Water Habitat (WARM)
- Commercial and Sport Fishing (COMM)

Water quality plays an important role in fish habitat. A number of the listed beneficial uses may be adversely affected by higher than natural pollutant levels or other stressors that occur within the Salinas Watershed.

Section 303(d) of the Federal Clean Water Act (1972) requires states to develop lists of impaired waters that do not meet water quality standards. The Salinas River is listed on the 2002 Clean Water Act Section 303(d) list as being adversely impacted by:

- Fecal Coliform (L)
- Nutrients (L)
- Pesticides (L, M)
- Salinity/TDS/Chlorides (L, M)
- Sedimentation/Siltation (L, M)
- Chloride (U)
- Sodium (U)

[L=lower, to Gonzales, M=middle, to Nacimiento R, U=upper, to Santa Margarita Res.]

Accordingly, the Central Coast Regional Water Quality Control Board (CCRWQCB) is required by law to develop and implement a Total Maximum Daily Load (TMDL) specification for each combination of pollutant/stressor and waterbody.

The present study provides technical assistance toward this effort, specifically examining the distribution freshwater fish of the Salinas Watershed, and relationships between fish distribution and aquatic habitat. Particular attention is paid to possible relationships between steelhead habitat and sediment load. At the outset, it is believed that reservoir construction and the reduction of winter flows are the dominant factors for steelhead decline in the Salinas Watershed. However, as demonstrated in more northerly regions, sedimentation of spawning habitat can also be an important factor. The potential role of sedimentation in limiting fish habitat in the Salinas Watershed is poorly understood.

1.2 Project Objectives

The primary objective of this project was to examine fish species distribution and to quantitatively evaluate physical habitat quality throughout the Salinas Watershed.

This objective was accomplished by completing the following tasks:

- Literature review and summary of life cycle characteristics and ecology of Salinas Watershed fish species
- Review of previous work to determine past and present abundance and distribution of fish
- Investigation of habitat quality accomplished by a 3-phased assessment:
    1. Reconnaissance survey
    2. Detailed habitat assessment
    3. Population assessment

2 Study Area

The Salinas River flows to the Monterey Bay National Marine Sanctuary from the southeast to the northwest over 283 km through a long, fertile valley (Fig. 2.1). The watershed drains approximately 11,700 km^2 (4,205 mi^2) of land consisting of several different land uses. In general, grazing and natural lands exist in the surrounding foothills and mountainous areas, while agricultural and urban development are found throughout the valley floor (Newman et al., in prep. 2003).

The river originates from springs found in the mountainous southern region of the Santa Lucia and La Panza Mountain Ranges east of Santa Maria. It has a broad, low-gradient channel with relatively uniform sandy substrate throughout. The sand and gravel that make up the river bottom are permeable, requiring several storms to initiate flow each season.

In most areas along the lower river, the channel has become incised to some degree, and the banks of the river have been lined with levees for flood control. Most stretches of the river are bordered with stands of mixed riparian vegetation. Some species include, Fremont cottonwood *(Populus fremontii)*, California sycamore *(Platanus racemosa)*, red alder *(Alnus rubra)*, Pacific dogwood *(Cornus nuttallii)*, and three species of willow (arroyo, red, and sandbar) *(Salix lasiopeis)*, (*S. laevigata*), (*S. exigua)*. *Arundo donax*, a giant non-native, invasive, perennial grass, has spread extensively throughout the riparian corridor. Its widespread distribution along the Salinas River has resulted in loss of habitat for native fish and wildlife (Oakins, 2001).

Within the Salinas Watershed there are several large sub-watersheds. On the eastern side, starting from the south, are the Huerhuero Creek, Estrella River, Big Sandy Creek, Pancho Rico Creek, San Lorenzo Creek, Chalone Creek and Chualar Creek watersheds. The Gabilan Creek watershed, which drains into Elkhorn Slough via the Old Salinas River channel, was also included in this report although it is a tributary to the Old Salinas River. The present day mouth of the Salinas River is at the Salinas Lagoon, but some flow still continues along the coast through the Old Salinas River Channel toward Elkhorn Slough. The climate of the eastern mountains, the Gabilan, Diablo and Temblor Ranges, is significantly drier than the mountains of the western side of the drainage. The eastern slopes are primarily covered with annual grasses and shrubs with oaks, gray pines and a variety of riparian species in the upper altitudes and canyons respectively. The streams on this side of the valley on average are much drier, with alternating reaches of perennial and non-perennial water.

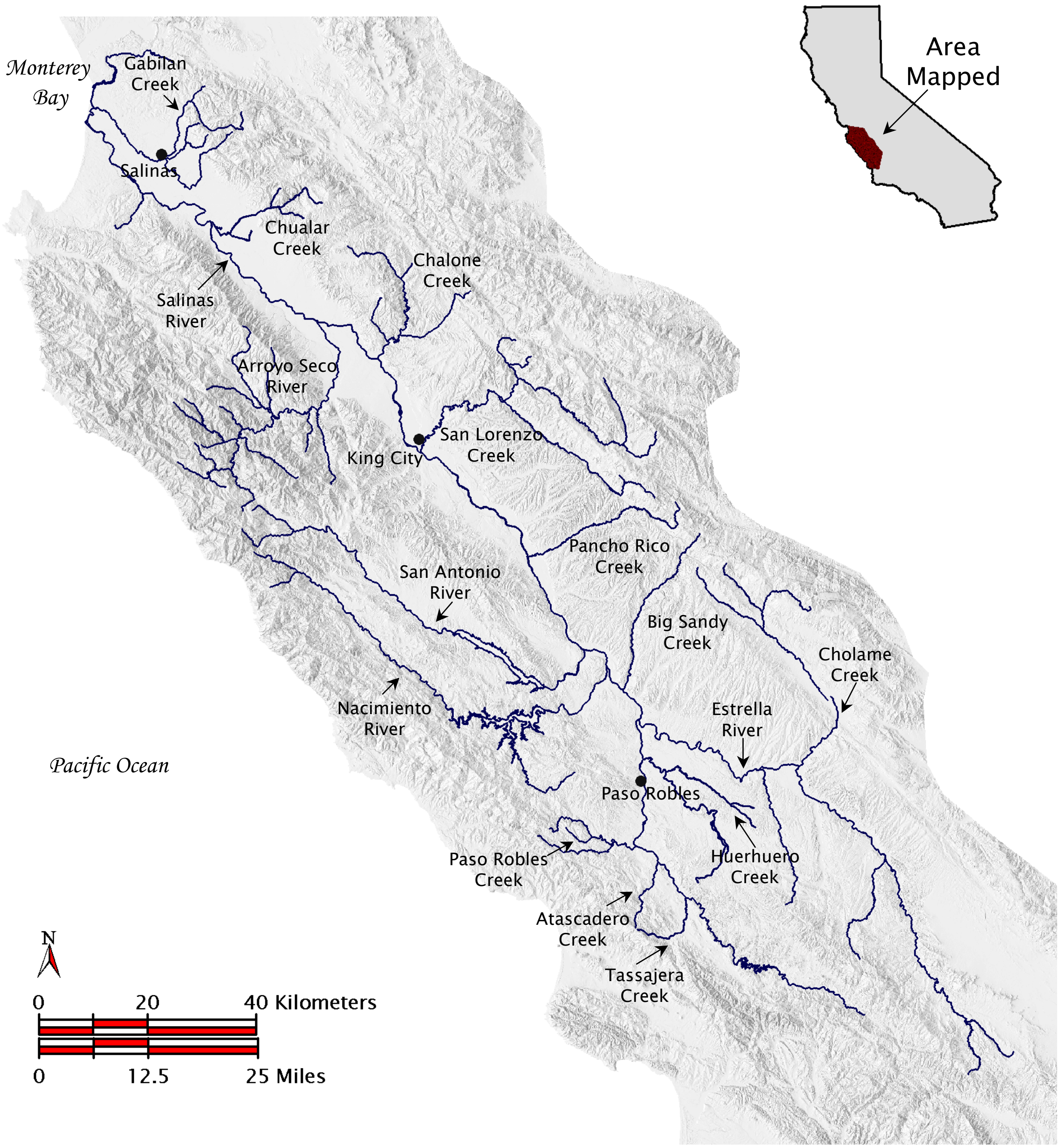

Figure 2.1 Major streams of the Salinas River Watershed.

The mountains to the west of the valley, the Santa Lucia Range and the Sierra de Salinas, provide most of the annual water supply to the Salinas River (Snyder, 1913; Barclay, 1975; Watson et al., 2003). Here the mountains are much more forested and perennial water is in greater abundance than the neighboring mountains to the east due to the orographic effect of the coastal mountains. Major sub-watersheds of the west side, starting from the south, are Santa Margarita Creek, Atascadero Creek, Paso Robles Creek, Nacimiento River, San Antonio River, Arroyo Seco River and El Toro Creek.

There are three major dams in the Salinas Watershed. The first built was the Salinas Dam (1942) which is across the main channel of the Salinas River near Santa Margarita. It was built to supply water to Camp San Luis during World War II and, secondarily, to supply water to the city of San Luis Obispo.

The Nacimiento Dam, built in 1956, is on the Nacimiento River located approximately 6 km (10 miles) from its confluence with the Salinas. Snyder (1913) and Titus (2001) both state that the Nacimiento River was historically one of, if not the largest, salmonid producing tributaries within the Salinas Watershed prior to the construction of the Dam. Both the Nacimiento and San Antonio rivers flow parallel to each other in a southeast direction (Fig. 2.1).

The San Antonio Dam (1965), on the San Antonio River, was also built close to the confluence with the Salinas River. These last two dams were built to mitigate flooding and as a way of ensuring a reliable water supply for agriculture and urban developments. Consequently, since their completion, the hydrology of the Salinas River Watershed and its anadromous, or ocean going, salmonid populations have been significantly altered. Snyder (1913) describes the Salinas River as it was before the construction of the dams:

"The Salinas itself is an erratic and torrential stream. During the dry season its feeble current shifts here and there over broad stretches of wind blown sand, entirely disappearing at times and again rising to the surface. After the advent of the winter rains, however, it presents a broad expanse of seething water which often threatens everything before it."

Currently, summer water releases are managed to ensure groundwater recharge throughout the valley. The major fresh water supply for all agricultural and urban/residential consumption within the Salinas Valley is groundwater.

3 Species Characteristics and Ecology

The definitive reference for California freshwater fish is the recently revised "*Inland Fishes of California*," by Peter Moyle (2002). The following section draws heavily from Moyle along with other pertinent references to describe and differentiate the native and non-native species of fish and their habitat preference in the Salinas Watershed.

3.1 Native Fish of the Salinas River Watershed

3.1.1 Rainbow Trout/Steelhead (Oncorhynchus mykiss irideus)

Rainbow trout are now widely distributed throughout North America. They can be migratory, resident, or a mixture of the two (Titus et al., 2001). Fish that are migratory can either be anadromous (sea-going) (Fig. 3.2), limnodramous (lake-run) (Fig. 3.1), or potadromous (in-river migrants) (Moyle, 2002). Steelhead is

Figure 3.1. Young rainbow trout, or young-of-the-year, in the upper Nacimiento River. The fish seen here may be of the limnodramous form, migrating down into Nacimiento Reservoir where they mature and return to the upper river to spawn. (Photo: Joel Casagrande, 13 Sep 02)

the name given to an adult rainbow trout that has returned to freshwater after migrating to the ocean. Purely resident rainbows will usually remain within the same few hundred meters of stream for their entire lives. Figure 3.3 illustrates the variety of life cycles exhibited by rainbow trout/steelhead in the Salinas Watershed.

Identification

Originally, rainbow trout were found from the coastal streams of Alaska down to streams of the Baja peninsula (Moyle, 2002). Currently, they are believed to be the only native salmonid remaining in the Salinas River Watershed[2]. Historic and current population details are described in Sections 4 (Historical Data) and 8 (Results: Population Assessment) respectively.

Figure 3.2. A 26-inch adult male steelhead from the Salinas River. Note the hook lower jaw, a physiological trait of sea-going male steelhead. (Photo Courtesy of Charlie Barr, *c.* late 1980's)

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[2] One chinook salmon was caught by Jeff Hagar in the Salinas Lagoon in 2002. This was believed to be a stray from either a hatchery in a nearby watershed or from the Sacramento River System. Franklin (1999) has several anecdotal references to chinook salmon in the Salinas River prior to the construction of the three dams.

Both the anadromous (steelhead trout) and the resident forms can co-exist in the same stream. Generally, resident rainbow trout exist above natural and man-made barriers whereas the anadromous and mixed forms exist below.

The anadromous trout move out to sea after spending their first 1-3 years in their natal stream. After spending as many as four years at sea (usually 1 to 2 years), they typically return to their natal stream to spawn (Shapovalov and Taft, 1954).

Rainbow trout and/or steelhead are usually silver in color with several small, black dots on their dorsal and adipose fins as well as their entire back (Moyle, 2002). The lateral line has an iridescent pink to red (depending on subspecies) band running from the cheeks to the base of the caudal fin. The back can be an iridescent blue to a brownish green and the belly is usually white or creamy-yellow. Young trout and steelhead have 5-13 well-defined oval shaped markings, called parr marks, along their lateral line (See Cover Photo).

Adult steelhead during their ocean phase have dark “steel blue” backs with silver-white bellies. Once they re-enter freshwater streams they begin to regain their pink “salmon” coloring in their lateral area and cheeks (Fig. 3.2). The fish seen in Figure 3.2 was caught just a few miles upstream from the ocean and had not completed its color transformation.

Both the California Department of Fish and Game (CDFG) and the Monterey Bay Salmon and Steelhead Project (MBSSP) have planted rainbow trout/steelhead in the Salinas Watershed (MCWRA and USACE, 2001). Table 3.1 indicates the date, stock of origin, number of fish planted and general locations of where plantings in the Salinas Watershed occurred. A total of 228,038 fish were planted between 1981 and 1996 by the two agencies. Further plantings were suspended after the South-Central Coast steelhead was listed as a threatened species under the Federal Endangered Species Act of 1972 (MCWRA and USACE, 2001). It is generally thought that transplants may have contaminated the genetic purity of steelhead in streams such as the Salinas River. However, a recent genetic study by Garza (2003) suggested that the genetic identity of steelhead in each Californian stream may have remained intact to a greater extent than was previously thought.

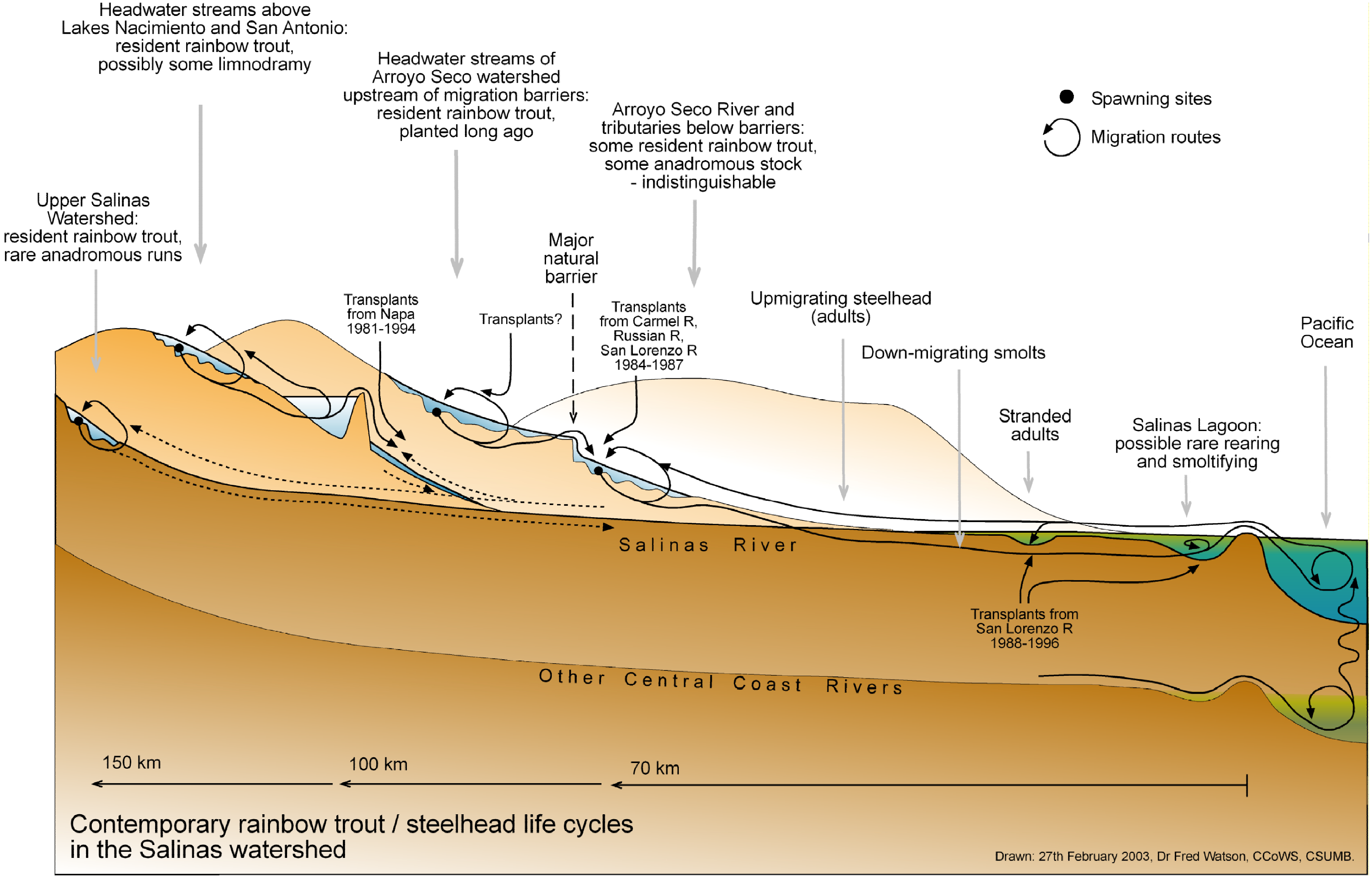

Figure 3.3 This diagram illustrates the many different spatial life cycles and possible migration patterns for rainbow trout/steelhead in the Salinas Watershed. Perennial freshwater is shown in blue. Brackish water and saltwater are shown in bluish green.

Table 3.1 Steelhead released in the Salinas Watershed by the California Department of Fish and Game and Monterey Bay Salmon and Trout Project. Data Source: MCWRA and USACE, 2001.

Date	Agency	Stock of Origin	Rearing Location	Number Released	Release Location
1981	CDFG	Silverado Hatchery (Napa)	–	17, 095	Nacimiento River (Below dam)
1984	CDFG	Silverado Hatchery (Napa)	–	16,145	Nacimiento River (Below dam)
March 1984	MBSSP	Carmel River	–	5700	Arroyo Seco River (Government Camp)
1985	CDFG	Silverado Hatchery (Napa)	–	17,570	Nacimiento River (Below dam)
March 7, 1985	MBSSP	Russian River	–	5,635	Arroyo Seco River (Government Camp)
1986	CDFG	Silverado Hatchery (Napa)	–	18,550	Nacimiento River (Below dam)
March 18, 1986	MBSSP	San Lorenzo River	Big Creek	12,500	Arroyo Seco River (Government Camp)
1987	CDFG	Silverado Hatchery (Napa)	–	17,290	Nacimiento River (Below dam)
March 11, 1987	MBSSP	San Lorenzo River	Big Creek	5,200	Arroyo Seco River (Government Camp)
1988	CDFG	Silverado Hatchery (Napa)	–	12,520	Nacimiento River (Below dam)
March 9, 1988	MBSSP	San Lorenzo River	Big Creek	4,500	Salinas River Lagoon @ slide gate
1989	CDFG	Silverado Hatchery (Napa)	–	16,050	Nacimiento River (Below dam)
1991	CDFG	Silverado Hatchery (Napa)	–	8,600	Nacimiento River (Below dam)
March 22, 1991	MBSSP	San Lorenzo River	Big Creek	7,425	Salinas River at Old Highway 1
March 26, 1991	MBSSP	San Lorenzo River	Big Creek	7,920	Salinas River at Old Highway 1
1992	CDFG	Silverado Hatchery (Napa)	–	10,560	Nacimiento River (Below dam)
April 14, 1992	MBSSP	San Lorenzo River	Salinas Pond	6,510	Salinas River/Lagoon @ Twin Bridges
April 17, 1992	MBSSP	San Lorenzo RIver	Salinas Pond	3,580	Salinas River/Lagoon @ Twin Bridges
1993	CDFG	Silverado Hatchery (Napa)	–	18,020	Nacimiento River (Below dam)
February 20, 1993	MBSSP	San Lorenzo River	Salinas Pond	8,028	Arroyo Seco
1994	CDFG	Silverado Hatchery (Napa)	–	11,500	Nacimiento River (Below dam)
March 15, 1994	MBSSP	San Lorenzo River	Salinas Pond	4,080	Salinas River @ Davis Road
1995	MBSSP	San Lorenzo River	Big Creek	6,175	Lower Salinas River
April 3, 1996	MBSSP	San Lorenzo River	Big Creek	3,980	Salinas River @ Twin Bridges
Total				228,038	Salinas Watershed

– Data not available.

Spawning and Life History

The physical nature of spawning is the same for both resident and the anadromous forms. The female digs a nest, or redd, by laying on her side using her tail in a violent flapping-like motion to scour out an oval shaped depression in the stream bottom (Shapovalov and Taft, 1954). The size of the pit usually depends on the size of the female. She then tests the size by maneuvering herself into the pit for fitting. Spawning usually occurs in a gravel-cobble (1-13 cm diameter) mixed substrate, located at the tail end of a pool or in a riffle. If too much silt is present, the fish will search for a different spawning location. Redds are usually constructed where water depths range from 10-150 cm and velocities range from 0.20-1.55 m/sec (Moyle, 2002). After the eggs have been laid and fertilized by the male, the female covers them using the same movements described above (Shapovalov and Taft, 1954). Once spawning is completed, some adults immediately begin their journey back downstream to the sea while others may remain. Some will die due to disease, stress, or exhaustion (Hagar, 1996).

Incubating eggs require redds that are free of excess fine sediment with a continuous supply of oxygen rich water. For the same reasons, stream flow must remain moderate to high in order to ensure a continued supply of oxygen to the eggs. Once the eggs have hatched, usually between two to four weeks, the fry move to the shallow areas, usually over gravel where they begin feeding immediately. As they grow, they seek refuge in deeper water and become more independent. Often they aggressively defend a territory they have previously claimed by swimming violently and sometimes biting the caudal area of an invading fish (Moyle, 2002).

Anadromous juveniles, or smolts, migrate downstream with receding high flows during the winter or early spring and begin rearing, or simply putting on weight, in the river's lagoon. However, for larger watersheds, such as the Salinas, where the river's lagoon is 70 km from the nearest known spawning tributary, rearing occurs in the tributary streams (MCWRA, 2001).

Before they can rear or go to the ocean, juvenile steelhead will begin a process called smoltification, which prepares them for adult life at sea (Alley, 1997). Again, for smaller watersheds, smolting usually occurs in the river's lagoon, but for watersheds such as the Salinas, it also occurs in the tributary streams.

During the smolting process, the fish will grow rapidly in length and change color. The tips of their fins turn black and their sides turn silvery (Alley, 1997). In the lagoon they acclimate to the salt found in the brackish waters.

When stream flows become large enough or mechanical breaching of the sandbars is induced (Casagrande et al., 2002), fish that are ready will migrate into the ocean where they will spend from one to three years. Upon their return, mature adults will wait offshore for the sandbar to breach again. Once the lagoon has breached, they migrate to their natal spawning gravel. Peak migration times for steelhead of the south central coast are usually between December and March (Moyle, 2002).

Habitat Characteristics

All rainbow trout, both anadromous and resident, prefer cold, clear, streams with swift velocities and year-round flow (Moyle, 2002). Juveniles will spend a great deal of their time in riffle habitats. Intermediate-sized fish will predominantly reside in run habitats and larger adult trout usually seek deep pools where temperatures remain low (Moyle, 2002). All sizes and lifestyles thrive in streams that have significant riparian cover, in-stream shelter (i.e. undercut banks, boulders, or large woody debris) and a diverse abundance of invertebrates for food. The metabolism for rainbow trout is directly correlated with water temperature. Rainbow trout can survive in temperatures ranging from 4-27°C, although the optimal temperature for fish growth is 15-18°C (Moyle, 2002). During periods of high temperatures, trout are most likely to be found in riffle environments (Smith, 1982). Here (Fig. 3.4), food is more easily accessible to trout as it becomes entrained from the bottom by the turbulent flows (Moyle, 2002; Smith, pers. comm.,2003).

Rainbow trout need near-saturated levels of dissolved oxygen for the high metabolic rates needed for growth (Moyle, 2002; Smith pers. comm., 2003). When temperatures are low, rainbow trout and steelhead can survive in waters with low dissolved oxygen concentrations, however their level of activity decreases.

Rainbow trout feed on both aquatic and terrestrial insects. Terrestrial insects are more active during dusk and dawn, therefore peak feeding times for rainbow trout also occur at dawn and dusk. Benthic macroinvertebrates are consumed when they are plucked from the substrate by the stream currents and become adrift. In the ocean, steelhead prey on crustaceans, such as krill, and small fish (Moyle, 2002).

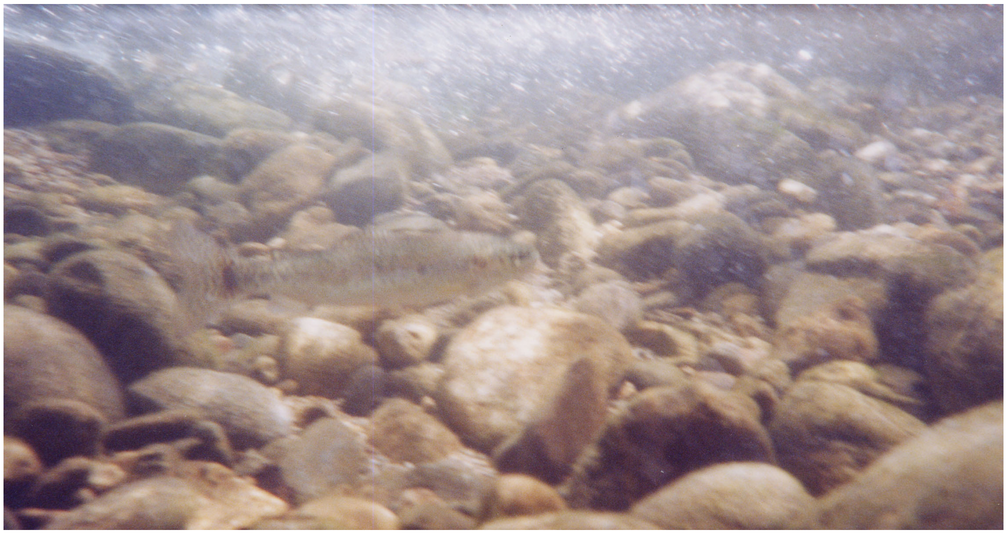

Figure 3.4 A mature rainbow trout seen in a riffle habitat in the Arroyo Seco River above the Santa Lucia Creek confluence. Water temperatures were 23°C, above their preferred limit. This fish was observed at this location on three different occasions over 7 hours during this day possibly indicating a strong preference for the faster water associated with the riffle habitat. Photo: Joel Casagrande, 07 Aug 02.

3.1.2 Sacramento Pikeminnow (Ptychocheilus grandis)

Identification

The Sacramento pikeminnow, formerly known as the Sacramento Squawfish, is a large piscivorous cyprinid[3] that is native to the Sacramento-San Joaquin drainage as well as other coastal drainages like Coyote Creek and the Pajaro and Salinas Rivers (Hubbs, 1947; Murphy, 1950; Smith, 1982; Harvey and Nakamoto, 1999). They can reach lengths of up to 1 meter (Moyle, 2002). They have dark

Figure 3.5 Sacramento pikeminnow in the Arroyo Seco River. (Photo: Joel Casagrande, 06 Aug 02)

brown to olive colored backs with a dark lateral band from their cheeks to the base of their tail. Their belly is usually white to gold-yellow and breeding adults have orange tainted fins (Fig. 3.5) (Moyle, 2002). Pikeminnows are very elongated and have a flattened, tapered head that is very similar to that of a Northern Pike (*Esox lucius*), hence its name.

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[3] Cyprinids are any fish belonging to the *Cyprinidae*, or minnow family.

Spawning and Life History

Sacramento pikeminnows are long-lived fish (Moyle, 2002). They become sexually mature around their third or fourth year with males generally maturing before females. During April and May, fish that are ready to spawn residing in large rivers or reservoirs migrate into their tributary spawning grounds (Harvey et al., 1999). However, pikeminnows that live year round in small streams may only move as far as the closest riffle. Spawning habitats are usually gravel riffles or shallow areas with flowing water at the base of pools (Taft and Murphy, 1950; Moyle, 2002). Water temperatures are cool usually ranging from 15-21°C.

Spawning is not well documented because it usually occurs at night (Moyle, 2002). In general, groups of males arrive at the spawning areas first. When a female arrives, several males then accompany her to an area she deems suitable. She drops her eggs which are simultaneously fertilized by the male(s). The eggs sink to the bottom and stick to the gravels where they remain for approximately 4-7 days (Taft and Murphy, 1950; Moyle, 2002). After the 4-7 days, the eggs hatch and the fry then move to shallow waters associated with pool edges and backwater areas (Moyle, 2002).

Habitat Characteristics

Adult pikeminnows thrive in bodies of water with minimal to moderate flows such as those found in large streams with deep pool and runs (Fig. 3.6). Younger pikeminnows remain in shallow water in order to avoid being preyed upon by adults and other larger species of fish such as rainbow trout/steelhead. As they grow into juveniles, they begin to school with other cyprinids (Taft and Murphy, 1950).

Pikeminnows tend to be abundant in rivers and creeks that are not chronically turbid or polluted. They can tolerate a wide range of temperatures but are usually found in warmer waters associated with California foothill streams where summer water temperatures can reach 32°C. However, pikeminnows usually prefer waters that range from 18-28°C during the summer (Moyle, 2002). They can also tolerate brackish environments. In the Salinas Lagoon, pikeminnows were caught in waters with salt concentrations of 4 ppt (Habitat Restoration Group et al. 1992).

Large adults will spend much of the day roaming deep pools for food, usually young fish (Fig. 3.6). Like many species of fish, pikeminnows use undercut banks, large woody debris (LWD), and overhanging vegetation for cover from predators and are usually found inhabiting waters with these shelter components. It is unusual to find a pikeminnow greater then 12 cm in length in pools shallower than 1 meter and with velocities less than 40cm/sec during the day (Moyle, 2002).

Pikeminnows are commonly found with Sacramento suckers and hardhead (*Mylopharodon conocephalus*), although hardhead were not observed during the present study. Their range also overlaps with rainbow trout and other salmonids in streams that contain both species. Studies have suggested due to their

Figure 3.6 Two large (> 2 ft) pikeminnows cruising in a deep in the lower reaches of The Arroyo Seco River. Note their long torpedo shaped bodies and deeply forked tails. (Photo: Joel Casagrande, 31 Oct 02)

aggressive and predatory behavior, pikeminnows may have a negative impact on salmonid survivability and population (Taft and Murphy, 1950). It has been well documented that pikeminnows will congregate below diversion dams, spillways, and other man made facilities to prey on out-migrating young salmonids. While studies on the impacts of pikeminnows below man-made obstructions such as the Red-Bluff diversion dam on the Sacramento River, do suggest that they can impact out-migrating juvenile salmonids, there is still a lack of evidence that suggests pikeminnows are the significant reason for population declines as opposed to human stream alterations such as the dams and diversion gates themselves. For example, Moyle (2002) states that once the gates at the Red Bluff diversion dam were left opened during the out-migration of young salmonids, their success in passing the pikeminnows waiting at the diversion structure improved significantly; even with pikeminnows in large numbers present (Moyle, 2002).

The presence of adult pikeminnows can change the choice of microhabitats used by rainbow trout as well as other native California stream fishes (Smith, 1982; Brown and Moyle, 1991). Smith (1982) noted that in streams of the Pajaro system threespine sticklebacks were rare or absent from pool habitats with the presence of juevenile and/or adult pikeminnow. Brown and Moyle (1991) concluded that the presence of introduced pikeminnow in the Eel River system caused juvenile rainbow trout to use riffle habitats exclusively and at one site on the South Fork Eel River, both juvenile trout and suckers were absent from pool habitats entirely.

3.1.3 Sacramento Sucker (Catostomus occidentalis)

Identification

Sacramento suckers are native to the Sacramento-San Joaquin River drainages, streams draining to Monterey Bay, and northern coastal streams such as the Eel River, Mad, Navarro, and Bear Rivers (Snyder, 1913; Hubbs, 1947; Barclay, 1975; Moyle, 2002). In addition, they have also been introduced to a variety of other water bodies, such as streams of the Morro Bay drainage, San Luis Obispo County, by way of water diversions (Barclay, 1975; Moyle, 2002). They are usually one of the more abundant species within their range.

Figure 3.7 An adult Sacramento sucker in the lower Arroyo Seco River. (Photo: Joel Casagrande, 31 Oct 01)

Sacramento suckers are large bottom feeders with sub-terminal mouths that are excellent for feeding on stream bottom detritus and algae. They can reach approximately 0.6 meters (2 ft) in length (Fig. 3.7). As adults, their backs are brownish-olive in color with large scales, while their undersides are gold-yellow to white (Moyle, 2002). Young suckers are usually grayish or creamy white with several (3-4) dark splotches on their sides (Moyle, 2002).

Spawning and Life History

Females can mature during their fourth, fifth, or even sixth year. Suckers generally spawn in late winter and spring (Moyle, 2002; Smith, 1982). They prefer to spawn in tributaries to large rivers or lakes. Gravel is generally the preferred substrate and water temperatures needed to initiate spawning range from 12-18°C (Moyle, 2002). Females are followed closely by as many as 7 males. When ready, the female and a couple of males begin to splash violently creating a depression in the stream bottom. She will then drop to the bottom (usually a depth of 30cm) with the accompanying males. Once hitting the bottom she will release the eggs while at the same time the males fertilize them. The eggs either attach directly to the underlying gravel or they are carried downstream until they are caught in a backwater eddy or debris (Moyle, 2002).

Figure 3.8 A dry pool in the lower portion of Arroyo Seco River with nearly a hundred dead Sacramento suckers. These fish may have migrated downstream and were trapped when streamflows between pools ceased leaving the pools to evaporate. (Photo: Joel Casagrande, 27 Sep 01)

The eggs hatch in 2-4 weeks. The young will quickly move to shallow water, usually flooded areas and pool edges. Juveniles move down to larger rivers after 2 or 3 years of living in their natal stream. During stream reconnaissance in the fall of 2001, nearly a hundred suckers were found dead in a large, dry pool in the Arroyo Seco River just upstream from the confluence of the Salinas River

(Fig. 3.8). It is presumed that these fish had migrated downstream in the spring and became isolated when the pool eventually dried up.

Habitat Characteristics

Sacramento suckers can be found in a large range of habitat types from fast-flowing shallow streams to deep pools or sloughs with little or no flow (Barclay, 1975; Leidy, 1984). They can tolerate salinity at low levels and are therefore found in many coastal estuaries like San Francisco Bay and the Salinas River lagoon (Habitat Restoration Group et al. 1992; MCWRA, 2001; Moyle, 2002). Their habitat preference is generally based on the size of the fish. Large adults prefer deep pools and runs or if in shallow water beneath undercut banks (Leidy, 1984; Moyle, 2002). Juveniles will remain in shallow water where they can feed without the fear of being preyed on by pikeminnows or other predators (Leidy, 1984; Moyle, 2002). In streams that are clear, large adult suckers will stay near the bottom of deep pools (Fig. 3.9) to avoid avian predators such as osprey and herons (Moyle, 2002). Their diet includes detritus, algae, and small benthic invertebrates (Moyle, 2002).

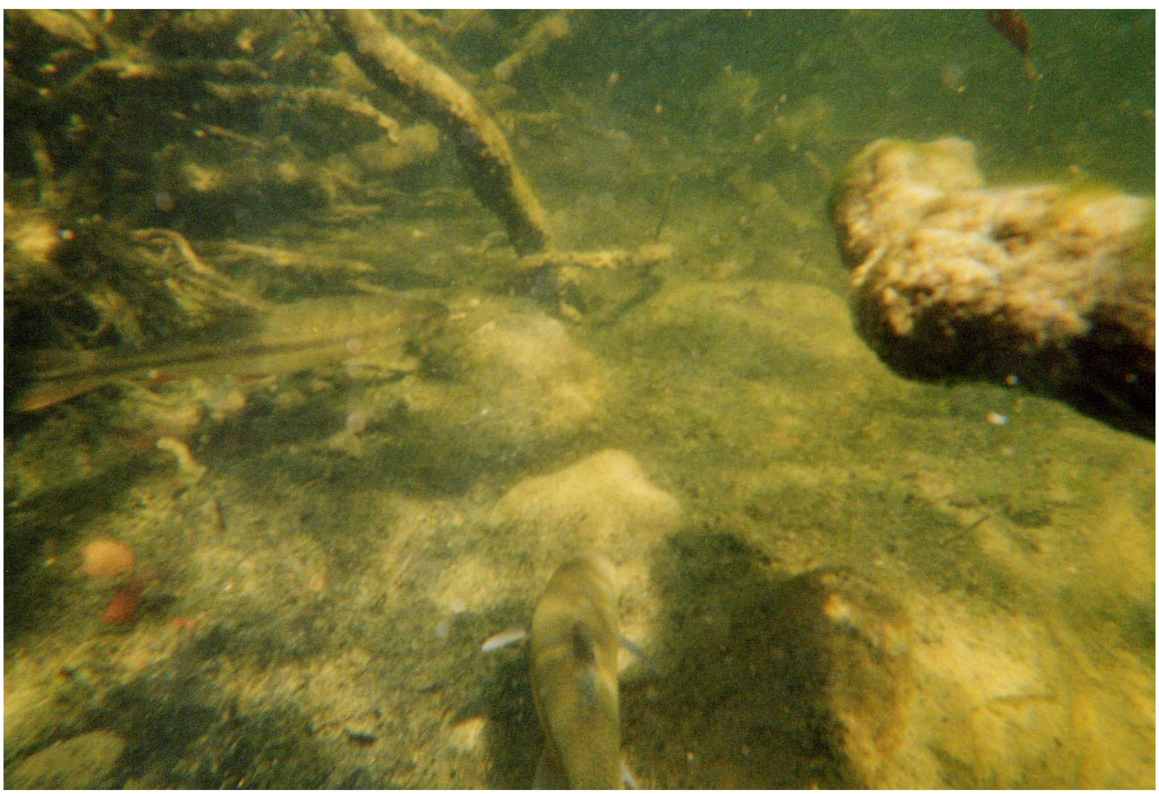


Figure 3.9 An adult sucker (lower center) and pikeminnow (center left) swimming amongst a root wad in a large pool of the lower Arroyo Seco River. (Photo: Joel Casagrande, 31 Oct 01)

3.1.4 Monterey Roach (Lavinia symmetricus subditus)

Identification

The California Roach is a native cyprinid to the Sacramento-San Joaquin river drainages, tributaries to Monterey Bay, tributaries of Tomales Bay and Pescadero Creek (San Mateo County) (Moyle, 2002). Snyder (1913, as cited in Moyle, 2002) designated the Monterey Roach under its own genus, *Hesperoleucus*, and went on to describe six species based on location and morphological differences. One of the species formed was the *H. subditus*, or the Monterey roach (Snyder, 1913; Moyle, 2002). However, because roach are so closely related to hitch the genus used for hitch, *Lavinia* (Girard 1854) is preferred to *Hesperoleucus* (Snyder, 1913). Furthermore, Moyle (2002) states that Girard (1854) has precedence over Snyder (1913).

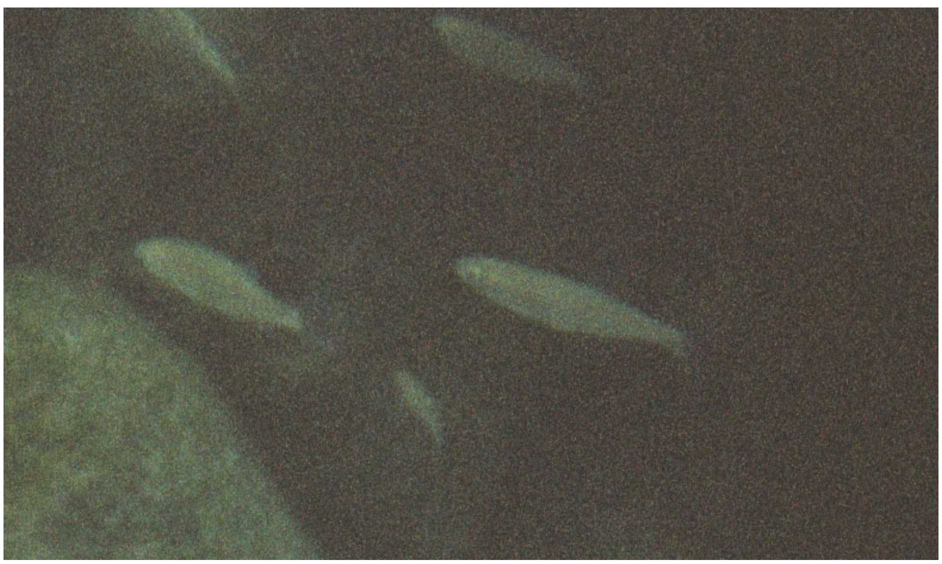


Figure 3.10 Monterey roach in the Salinas River near San Ardo. (Photo: Joel Casagrande, 31 Oct 02)

It is rare to find roach greater than 10 or 11 cm in length. Proportionally, their eyes and heads are large and they are commonly described as a “chunky” fish. Coloration of this species varies. The top (dorsal) half can range from dark gray, to gold or even steel blue. The lower half is usually a silver or dull gray (Fig. 3.10). During the spawning season, red/orange coloration will appear on their chin, operculum, and base of the paired and anal fins (Moyle, 2002). They have a dark caudal spot at the base of their caudal fin. Monterey roach can and do hybridize with hitch (Moyle, 2002).

Spawning and Life History

Spawning occurs in late March to early July, but only after water temperatures exceed 16°C. Roach mature between 2 and 3 years (Fry, 1936). Fish of both sexes move in large groups from the pools into shallow waters where rocks are 3-5cm in diameter. Females will drop their eggs in crevices between the rocks and following males immediately fertilize them (Fry, 1936). Like pikeminnows, the fertilized eggs are sticky and adhere to the gravels where they will remain for 2-3 days until they hatch (Fry, 1936; Moyle, 2002). The larval roach will stay in the side waters with dense emergent vegetation where they will feed on their yolk sac and eventually diatoms and crustaceans (Fry, 1936; Moyle, 2002). Usually they reach maximum length by their third summer, although growth is said to be highly seasonal (Fry, 1936; Moyle, 2002).

Habitat Characteristics

Roach are a warm water minnow found commonly in California's foothill streams and lowland coastal streams, except when in the presence of predatory piscivorous fish, especially those that are non-native (Brown and Moyle, 1991; Brown and Brasher, 1995; Moyle, 2002). Due to their tolerance of high temperatures and low dissolved oxygen levels, roach are well adapted to living conditions of intermittent streams and heavily altered habitats (Moyle, 2002; Smith, 1982). Thus, they are often the only species found in isolated pools during the summer months (Leidy, 1984; Moyle, 2002). In addition, roach can also be found in cold trout streams. In general, they are most associated with moderate grade streams with low flows, mild temperatures and abundant aquatic vegetation (Moyle, 2002). When roach are the only occupant of a pool they will swim out in the open, whereas when pikeminnows, bass, or other piscivorous fish are present, they remain along the outer edges of the pool or in shallower waters (Brown and Moyle, 1991; Brown and Brasher, 1995;Moyle, 2002;).

Roach are omnivores. They primarily feed off the bottom of streams but will also take drift organisms when they reach adulthood (Fry, 1936). Filamentous algae, aquatic insects and crustaceans are their preferred food, especially filamentous algae in warm streams (Fry, 1936; Moyle, 2002).

3.1.5 Hitch (Lavinia exilicauda harengus)

Identification

Hitch is a native cyprinid in the Salinas and Pajaro River watersheds (Snyder, 1913). Hitch are also a native of the Sacramento-San Joaquin drainages as well as the Clear Lake, Russian River, and most small drainages along the San Francisco Bay (Murphy, 1948; Smith, 1982; Moyle, 2002).

Hitch have deep and laterally compressed bodies that taper down to a narrow caudal peduncle (Fig. 3.11). Their heads are small with proportionally larger eyes and their tails are large and forked (Moyle, 2002). Young hitch have a black spot at the base of their tails, but this disappears as they grow. In addition,

Figure 3.11 This hitch was found dead in the Reclamation Ditch west of Salinas during a large fish kill in early July of 2002. (Photo: Joel Casagrande, 01 Jul 02)

young hitch are completely silver in color but as they grow their backs become darker, and eventually become a brownish-yellow as an adult (Moyle, 2002).

Spawning and Life History

Spawning occurs anywhere from March through May when there are late spring rains (Murphy, 1948). Murphy (1948) explains that people of the Clear Lake basin called these late spring rains, “hitch rains” because this was when hitch would move out of Clear Lake and crowd into low gradient tributaries to spawn.

Hitch are capable of spawning in rivers, sloughs, and lakes. In rivers, spawning takes place over clean medium sized gravel associated with riffle habitats. In lakes and reservoirs, spawning can occur in near shore gravel beds where wave action is abundant (Moyle, 2002). Their significant adaptability to altered habitats allows them to spawn in sloughs, drainage ditches and ponds. Preferred water temperature for spawning is 14-18°C. However, Smith (1982) witnessed hitch spawning at temperatures as high as 26°C during early summer months. Hitch splash violently while spawning. Each female is followed by 1-5 males, who immediately fertilize the eggs as soon as they are released. Unlike most other cyprinids, hitch’s eggs are not sticky. Instead, the eggs fall into crevices between the gravel particles and absorb water to increase their size, thus creating a tighter hold between the gravel (Murphy, 1948). The eggs hatch after 3-7 days at temperatures ranging between 15-22°C (Murphy, 1948; Swift, 1965). Larvae begin swimming in an additional 3-4 days (Murphy, 1948). Young hitch live in the littoral zone of lakes, reservoirs, and deep pools in rivers until they reach approximately 5 cm in length. At 5cm they begin moving into the open water where they begin foraging on plankton (Murphy, 1948).

Habitat Characteristics

Hitch prefer warm deep watered lakes, rivers, and sloughs, but they can also be found in low-gradient clear streams (Murphy, 1948; Moyle, 2002) and brackish environments such as lagoons (Habitat Restoration Group et al. 1992). In the Salinas Lagoon, hitch were caught in waters with salt concentrations of 9 ppt. (Habitat Restoration Group et al. 1992). In large rivers, young hitch are found in runs with abundant shelter such as large woody debris and overhanging vegetation. Adults are found in the deepest pools associated with dense cover. In lakes, the young stay near the shore for protection by emergent vegetation, while the adults are found in the open, deep waters (Moyle, 2002). Hitch can tolerate high water temperatures. This enables them to survive in urban or channelized streams with silty bottoms and poor water quality (Leidy, 1984).

Hitch are omnivores that feed on filamentous algae, aquatic insects, and terrestrial insects. Juvenile and adult hitch larger than 50mm feed on *Daphnia* (a water flea) and other zooplankton; aquatic insects are also taken from the surface. Juvenile hitch less than 50mm feed on the larvae and pupae of aquatic invertebrates as well as plantktonic crustaceans (Moyle, 2002). Hitch coexist with other native fish such as Sacrmento pikeminnows and suckers, Sacramento blackfish, threespine stickleback and roach in habitats that have not been altered severely. In more altered environments they are found with mosquitofish, catfish, bass and other introduced species (Leidy, 1984).

3.1.6 Speckled Dace (Rhinichthys osculus carringtoni)

Identification

Speckled dace are the most common minnow on the west coast from Canada to Mexico. There are several subspecies including the Sacramento speckled dace *R.o. carringtoni* (Moyle, 2002). Speckled dace are native to both the Salinas and Pajaro River basins (Snyder, 1913; Hubbs, 1947; Barclay, 1975). They are small fish with a thick caudal peduncle, pointed snout, and a small sub-terminal

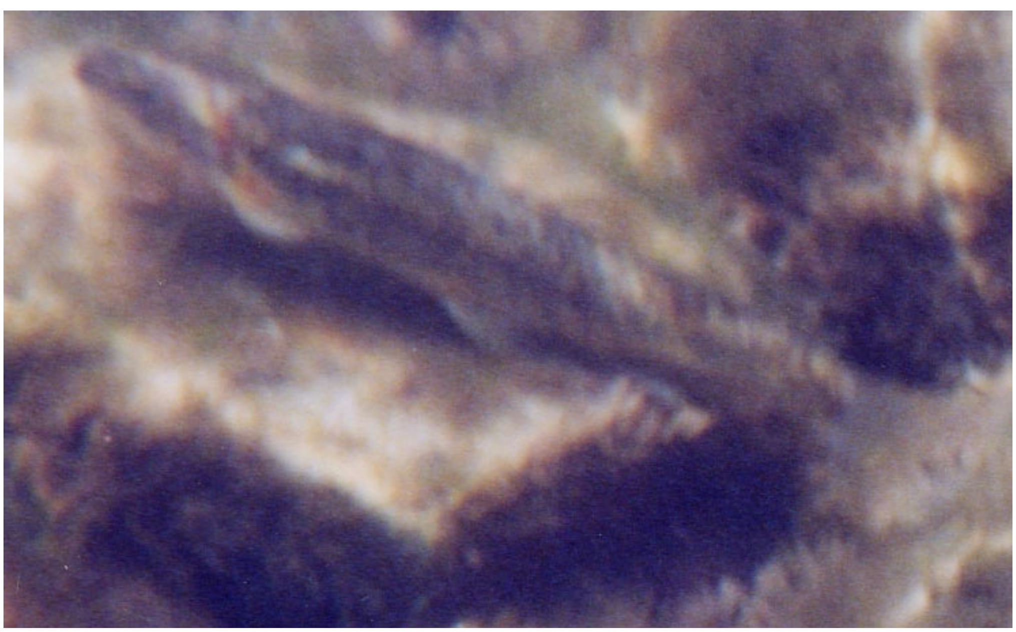


Figure 3.12 Speckled dace (~3-4 inches) in Arroyo Seco near the Santa Lucia Creek confluence. Note its thick caudal peduncle (lower right) and "speckled" coloring. (Photo: Joel Casagrande, 08 Aug 02)

mouth (Baltz et al., 1982; Moyle, 2002). The base of the dorsal fin is set far back from the base of the pelvic fins. Coloring for this species varies. Most fish greater than 3 cm have several dark markings "speckles" (Fig. 3.12) on their back and sides, an underlying dusky yellow or olive back and a milky-white or tan belly (Moyle, 2002). Also, they have a dark lateral line and a black spot at the base of the tail. During the breeding season, the bases of the fins for adults turns orange to red, and the males will often develop a red snout (Moyle, 2002).

Spawning and Life History

Speckled dace mature in their second summer and spawn throughout most of the summer months as water temperatures rise (Moyle, 2002). However, other studies in intermittent streams suggest that increased runoff from summer storms induced speckled dace to spawning (John, 1961).

Spawning usually occurs in riffles and in pools over clean gravel where males have previously removed any overlying detritus or algae (John, 1963; Moyle, 2002). The female dace dips the lower end of her body into the gravel and releases a few eggs, while at the same time the surrounding males fertilize them (John, 1963). The eggs sink into crevices between gravel particles. The eggs are sticky, which holds them in place between the particles (Moyle, 2002). Eggs hatch in approximately 6-8 days with water temperatures around 18-19°C (John, 1963). After another week the larval fish begin to leave the protection of the gravel and school in warm shallow water where rocks and emergent vegetation are present (Moyle, 2002).

Habitat Characteristics

Speckled dace are able to survive in a variety of environments ranging from small spring-fed streams, large rivers, isolated pools of intermittent streams and lakes (Moyle, 2002; Smith, 1982; John, 1963). Common habitat components are clear, well-oxygenated water, abundant cover such as rocks, overhanging vegetation, bubble curtains, and wave action (Moyle, 2002). Although Smith (1982) found that dace were inversely correlated with cover in streams of the Pajaro Watershed.

Dace generally prefer shallow riffle/run habitats with gravel and cobble as the dominant substrates where they feed by plucking invertebrates from the bottom

(Fig. 3.13) (Baltz et al., 1982; Smith, 1982). In lakes, they feed on a wide variety of food ranging from large flying insects to zooplankton (Moyle, 2002).

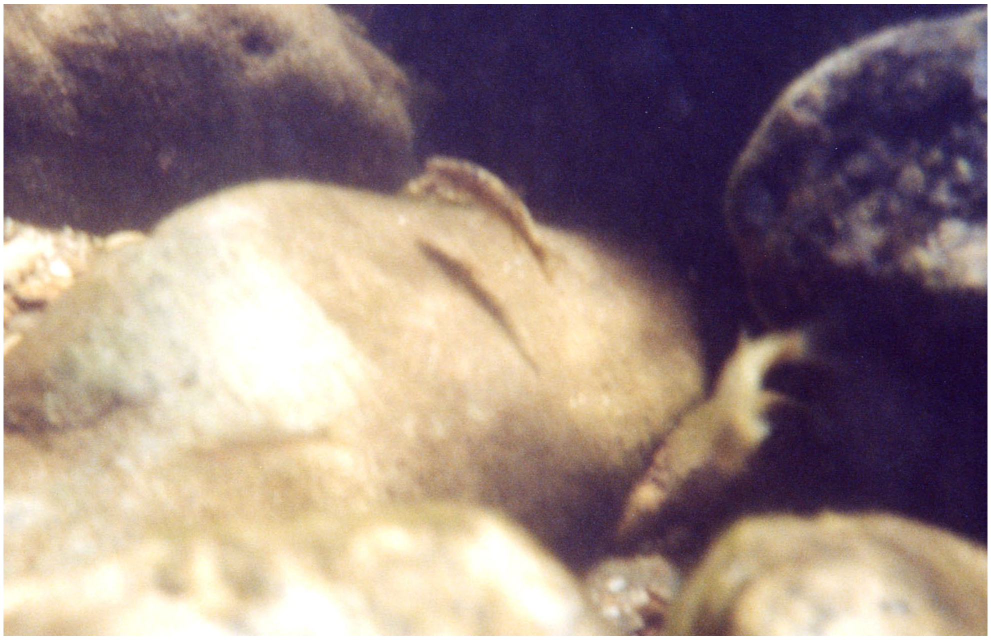


Figure 3.13 A speckled dace swimming over a mixture of boulder and gravel substrate in the Arroyo Seco River. (Photo: Joel Casagrande, 08 Aug 02)

3.1.7 Threespine Stickleback (Gasterosteus aculeatus)

Identification

Threespine sticklebacks are a small (rarely > 5cm) native species to the Sacramento-San Joaquin River drainages and most coastal watersheds of North America (Snyder, 1913; Hubbs, 1947; Greenbank et al., 1959; Smith, 1982; Moyle, 2002). They are also native to the Salinas watershed (Snyder 1913). Like the rainbow trout, threespine sticklebacks exists in two distinct lifestyles: resident *G. a. microcephalus* and anadromous *G. a. aculeatus*. Both the anadromous, and resident forms of this species exist and can coexist in the same watershed.

Sticklebacks are laterally compressed with narrow caudal peduncles and they have three well-defined spines in front of their dorsal fin (Fig. 3.14) (Greenbank et al., 1959). Their mouths are terminal with an upward slant and they have proportionally large eyes. Generally, adult fish, when in fresh water, have olive to dark green backs with a white or tan colored belly. During breeding season,

Figure 3.14 This threespine stickleback was found dead in a small pool in Sandy Creek. This species is presumed to be of the resident form due to the distance it was found from the sea. (Photo: Joel Casagrande, 23 Oct 02)

the undersides of the head and bellies of males turn red (Greenbank et al., 1959; Moyle, 2002).

Spawning and Life History

Sticklebacks generally complete their life cycle in 1 year and rarely exceed 2 or 3 years (Greenbank et al., 1959; Moyle, 2002). They can complete their entire life cycle in fresh, salty, or a combination of the two environments. During late spring and early to mid summer, water temperatures begin to increase. This induces sticklebacks to move into their preferred breeding areas. Vrat (1949) stated that the period of sexual activity for threespine sticklebacks of the central coast of California is between February and August.

Male sticklebacks will move into backwater areas where there is abundant emergent vegetation and begin to build a nest in its self-determined territory. The males take mouthfuls of sand, creating a depression, and then deposit the sand away from the depression (Vrat, 1949). In some cases the males will place pieces of vegetation and algae into the depression and bind them together with an adhesive kidney secretion – although Vrat (1949) did not observe the use of vegetation of any kind (Vrat, 1949; Moyle, 2002). Finally, once the nest is big enough, the male will begin to wiggle through it creating a tunnel (Greenbank et al. 1959; Moyle, 2002). The females are drawn to the nest by the males who coax them with a zig-zag courtship dance (Vrat, 1949; Moyle, 2002). If the female decides to follow the males to the nest, she will deposit her eggs in the nest. The males will immediately fertilize the eggs once the female exits through a hole made in the other side (Vrat, 1949).

After fertilizing the eggs, the males become the protective guardian of the nest. They ensure that the nest is protected from predators and also provide an essential current of water through nest by flapping their pectoral fins (Vrat, 1949). Generally, the eggs will hatch in 6-8 days and the fry will remain in the nest for another couple of days. The young fish will then join in a shoal of their own while the males return to shoals consisting primarily of adults (Moyle, 2002). Greenbank et al. (1959) indicated that sticklebacks that spawn after their second year would usually die within a few weeks of spawning. Greenbank continued that in late summer spawned sticklebacks are found along the shores either dead or in a extremely weak condition.

Habitat Characteristics

Both anadromous and non-anadromous threespine sticklebacks prefer slow, clear, well-vegetated and shallow waters overlying gravel, sand, and/or silt (Smith, 1982; Moyle, 2002). In the Pajaro River, they are found in slow, shallow and predator free waters or in large deep pools with abundant cover (Smith, 1982). Anadromous adults are typically pelagic and are usually found not far from shore. They prefer cool waters ($< 24°C$) and can tolerate a wide range of salt concentrations. Sticklebacks will concentrate into shoals when they are not breeding. This allows them to find food more easily. Non-anadromous sticklebacks feed primarily on aquatic organisms found on the bottom of streams or within the aquatic vegetation (Moyle, 2002). Anadromous forms adapted to an open water lifestyle, feed on aquatic organisms found in the water column along with some benthic organisms (Moyle, 2002).

The spines on their back evolved as a defense mechanism that would make swallowing of these fish difficult for predators. However, sticklebacks are commonly preyed on by large piscivors, including salmonids, as well as by birds (Moyle, 2002).

3.1.8 Pacific Lamprey (Lampetra tridentate)

Identification

The Pacific lamprey is an eel-like native fish of most coastal streams along the Pacific Rim (Baja California to Japan) (Fry, 1973). They have no paired fins or jaw and their body is cylindrical in form and slightly compressed towards the tail. Their mouths are round and they have three well-defined teeth in the upper tooth plate (Fry, 1973).

Lamprey can exist in two different forms: anadromous and non-anadromous (a dwarfed landlocked form). Moyle (2002) states that dwarfed landlocked forms exist in the upper Klamath River and Goose Lake, but may be distinct species themselves. Some landlocked populations are the result of a dam or barrier, such as in Clair Engle Reservoir on the Trinity River. However, Fry (1973) states that trapped or non-anadromous forms usually die out after a short existence.
As adults, they can exceed 40cm in length and are usually dark green/black on their backs and yellow/gold on their belly (Fry, 1973; Moyle, 2002). As

Figure 3.15 Pacific lamprey (ammocoete) swimming over algae covered rocks in the lower Arroyo Seco. This specimen was approximately 15cm in length. (Photo: Joel Casagrande 28 Aug 02)

juveniles, or ammocoetes, they are a much more pale brown or flesh-like color (Fig. 3.15) and are usually less than 20cm in length. When ammocoetes metamorphose, usually after 5-7 years, they develop large eyes, well-defined silver sides and dark blue backs. Like steelhead, they also changing internally in order to adapt to the abrupt transition to salt water (Moyle, 2002).

Spawning and Life History

Spawning adults typically begin their journey into tributary streams between March and late June, although some migrations begin as early as January (Moyle, 2002). Upstream movements usually occur at night during periods of high flow; although they have been known to migrate during a wide range of flows. Some lamprey will move in large bursts while others move consistently over a two to four month period (Moyle, 2002). When migrating, they can cover large distances and are blocked only by large impoundments such as giant dams, floodgates and large control structures. Lamprey can climb fish ladders, small dams and low waterfalls fairly easily. To conserve energy they attach themselves with their mouths to the bottom of the ladder, wall of a diversion gate or a rock in a fast current and rest until they are ready to continue (Fry, 1973).

After reaching their spawning area both sexes will construct a nest in the depression that results from removing any larger stones from a predominantly gravel substrate. Generally, stream flow is moderate to fast and water column depths range from 30-150 cm. Stones are removed when lamprey attach themselves to the rock on its downstream side and wiggling from side to side in reverse, which will usually move the rock downstream (Moyle, 2002).

Once the nest is completed females attach themselves to a rock upstream of the nest while the male attaches himself to the head of the female. Simultaneously, while intertwined and vibrating rapidly, the female releases her eggs and the male releases sperm. The fertilized eggs fall into the nest and usually adhere to the gravels at the downstream edge of the nest (Fry, 1973). After spawning, the adult lampreys disturb the upstream substrate to create a silt, sand and gravel plume that covers the eggs (Moyle, 2002). Some lamprey will continue to spawn until they are spent. Few lamprey survive to spawn the following year (Fry, 1973; Moyle, 2002).

Embryos hatch in approximately 19 days when water temperatures are near 15°C (Moyle, 2002). The newly hatched ammocoetes stay protected in the

Figure 3.16 A lamprey ammocoete (center) hovering over its preferred habitat of fine to moderate sized sediments and an abundance of algae and rotting detritus in Paso Robles Creek. Note the blue coloration starting to come in at the left end (head) of the lamprey. (Photo: Fred Watson, 20 Sep 02)

gravels for a few days but eventually swim or drift downstream to an area of mud, silt, or sand. Here they burrow into the bottom, tail first, where they begin to feed on algae and other organic matter (Moyle, 2002). Ammocoetes move around filter feeding off the stream bottom until they begin to morph into adults. Once mature they become parasitic predators using their mouths to attach to large fish.

Habitat Characteristics

Lamprey ammocoetes spend their entire time in streams where detritus, algae and fine to moderate sized stream bottom sediments are abundant (Fig. 3.16). As adults, they spend a great deal of their time in the ocean attached to a variety of large fish including salmon, sharks and a various species of flatfishes

(Moyle, 2002). Landlocked lamprey, trapped in reservoirs and lakes, spend most of their time attached to large fish such as suckers. Pacific lamprey are preyed on in large numbers by seals and sea lions and at one time were a popular food source for coastal Native American tribes (Moyle, 2002).

3.2 Non-native Fish of the Salinas River Watershed

Several non-native species of fish have been introduced into the Salinas River watershed over the last century. California Department of Fish and Game (CDFG) introduced many game species into the Nacimiento, San Antonio and Salinas Reservoirs almost immediately after the dams were completed (Barclay, 1975, MCWRA and USACE, 2001). However, some species were introduced from sources other than CDFG. In the Salinas Watershed some introduced species include: mosquitofish, white and channel catfish, white and black crappie, largemouth, smallmouth and white bass, threadfin shad, redear and green sunfish, and carp (MCWRA and USACE, 2001). Many have escaped the reservoirs and entered the valley's streams and lagoon, where some are still found today. However, Moyle and Light (1996) concluded that in California streams the success of an invasion by a non-native species is dictated by the species and its adaptability to the ambient hydrologic regime. Furthermore, the effects of biotic interactions are less important except for when the non-native population is small.

In general, non-native fish can have negative impacts on natural food webs, native species distributions and interactions, as well as overall habitat quality (Moyle, 2002).

The following are short descriptions of a few non-native species and their impacts on native fish and their habitats. These species were observed in the Salinas River Watershed during surveys conducted by *CCoWS* in the fall of 2002.

3.2.1 Common Carp (Cyprinus carpio)

Identification and Habitat Characteristics

Carp are large bottom dwelling cyprinids found in nearly every state in the country. They were introduced to California in the late 19th century as a potential public food source due to their popularity and success in Europe. However, this industry was short lived, and no further plantings were made by government agencies (Moyle, 2002).

Carp have large barbells on their upper lips and large scales throughout their torso. They also have a distinct long dorsal fin starting from the middle of their back down to the caudal peduncle. Carp are adaptable, surviving in waters that range from 4-24°C and thriving in eutrophic lakes, reservoirs and large rivers. In water bodies with low dissolved oxygen concentrations, carp can take oxygen in by “gulping” air at the surface and then pumping a mixture of air and water across their gills (Moyle, 2002). Carp also have the ability to withstand salinities as high as 16 ppt, which allows them to survive in estuarine habitats (Moyle, 2002).

Implications to native species and their habitat

Carp feed along the bottom by sifting through the silts for aquatic insect larvae and emergent vegetation. The disruption of the silt and emergent vegetation in small and shallow water bodies increases the turbidity of the water, thus raising water temperatures and limiting plant growth. Furthermore, Moyle states that by removing the emergent vegetation they eliminate cover for native fish species as well as important waterfowl habitat. Carp also feed on fish eggs found on stream bottoms, thus altering the reproductive success of native species.

3.2.2 Western Mosquitofish (Gambusia affinis)

Identification and Habitat Characteristics

Figure 3.17 Mosquitofish found in a drying pool in Paso Robles Creek. (Photo: Fred Watson, 20 Sep 02)

Western mosquitofish were introduced throughout the western United States to help control mosquitoes and associated diseases (Moyle, 2002). They are small fish, rarely reaching lengths greater than 6cm (Fig. 3.17). They are usually gray to olive green on their backs and lighter gray on their bellies. However, the fish seen in Figure 3.17 does appear to have a dark blue coloring on its back. Common characteristics are the large black eyes, small upturned mouth, thick caudle peduncle and a round tail, or caudal fin (Moyle, 2002).

The Western mosquitofish is well adapted to a variety of warm water environments including large rivers, warm ponds and lakes, sloughs, brackish estuaries and flooded rice fields. In lakes and other large bodies of water, mosquitofish stay on the outer edges where there are no predatory fish and temperatures are high (Moyle, 2002). They can tolerate a large temperature range from 0.5 to 40°C, but they are usually found where temperatures remain between 10 and 35°C. Their tolerance for saline waters is just as broad, 0 to 58 ppt, but they prefer salinities under 25 ppt (Moyle, 2002). Because of their small heads and bodies mosquitofish are capable of surviving in extremely shallow pools (<5cm). Low dissolved oxygen (<4mg/L) is overcome by remaining in upper most millimeters of the water column were oxygen diffuses easily (Moyle, 2002).

Implications to native species and their habitat

Mosquitofish as a biological control for mosquitoes is currently very popular throughout California and much of the west. Moyle (2002) states that when used properly such as in isolated ponds, contained rice fields and agricultural ditches they can be a benefit if native fish and invertebrates that prey on mosquitoes are absent. When mosquitofish become the dominant species in a habitat where they coexist with similar sized native fish, competition and predatory interactions can be detrimental. In addition, mosquitofish will irritate spawning fish of other species to the point where spawning will cease. They are also problematic for amphibians such as newts and frogs whose eggs are consumed by mosquitofish (Moyle, 2002).

3.2.3 Bass (Morone spp and Micropterus spp)

Identification and Habitat Characteristics

Bass are large predatory piscivores that are currently found in most lowland drainages of California, as well as throughout the United States. There are several species of bass-four of which are found in the Salinas River watershed. They are: white bass (*Monrone chysops*), striped bass (*Morone saxatilis*), largemouth bass (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieu*). All of these species were planted by CDFG into the Nacimiento and San Antonio reservoirs to create a new sport fishery in the area (MCWRA et al., 2002).

Most species of bass prefer large bodies of water such as lakes, reservoirs, and large rivers where clear to moderately cloudy, warm water persists (Moyle, 2002). Smallmouth bass (Fig. 3.18) found in reservoirs or lakes tend to stay near the confluences with incoming streams where the water and abundant cover in the form of rock ledges and large woody debris is present. Conversely, largemouth and white bass prefer the stagnant and slightly cloudier waters with beds of aquatic plants. This type of habitat is commonly found in low elevation lakes, reservoirs and large sloughs.

Implications to native species and their habitat

All species of bass feed on small fish and amphibians. Native minnows, young-of-the-year salmonids and amphibians are especially vulnerable. With the exception to striped bass, the remaining species tend to be more successful in altered habitats such as dredged sloughs, reservoirs and sections of river below dams where flows are maintained (Moyle, 2002).

Figure 3.18 A northern smallmouth bass from a lake in Minnesota. (Photo: Fred Watson, 2002).

Native fish can out compete bass only during normal or above normal runoff years when native fish are able to spawn before their competitors. Native species associated with bass will spawn a few months before most bass species, especially smallmouth bass. This gives the native fry a few months to grow large enough to feed on bass larvae, thus lowering or temporarily eliminating this non-native species (Baltz and Moyle, 1993; Moyle, 2002).

3.3 Fish Assemblages of the Salinas River Watershed

Barclay (1975) categorized three unique fish assemblages, for the Salinas River Watershed. The names used for these assemblages were derived from Murphy (1941) and Hopkirk (1967) for foothill streams of the Sacramento River Watershed and by Moyle and Nichols (1973) for foothill streams of the San Joaquin River Watershed.

Water temperature, velocity, and stream gradient are all habitat characteristics used to segregate, or zone, these assemblages. However, two assemblages, or even a particular species, can overlap into two different habitat zones (Moyle, 2002). The overlapping of two assembages is dependent on seasonal climate (i.e. annual precipitation or stream flow, and water temperature) and a variety of human induced impacts such as the presence or absence of barriers, pollution, or water diversions.

The following are habitat conditions and species most commonly found within the three fish assemblages. For the Salinas River drainage, Barclay used:

1) The Sucker, Stickleback and Pikeminnow Assemblage,
2) The California Roach Assemblage, and
3) The Rainbow Trout-Speckled Dace Assemblage.

In Section 9, species presence/absence data collected during the present study was compared to the assemblage results Barclay documented.

3.3.1 The Sucker, Stickleback and Pikeminnow Assemblage

Like Barclay (1975), this assemblage was the most encountered assemblage during observations made in the summer and fall of 2002—see Section 9. Fish found in this assemblage are Sacramento suckers and pikeminnows, threespine stickleback, hitch, Monterey roach as well as a few non-native species such as redear and green sunfish, bluegill, and bass.

Common habitat characteristics for this fish assemblage are larger rivers, or reservoirs, warm water temperatures, clear water, sand or bedrock substrate and limited or no overhead cover. Algae are usually abundant as a result of the limited shade cover. Such conditions are common in areas of the Salinas River main stem and larger tributaries that have perennial water such as the lower Arroyo Seco and Nacimiento Rivers (Barclay, 1975). Reservoirs, such as Lake Nacimiento and Lake San Antonio, also contain many species from this assemblage as well as abundant non-native species due to the popularity of sport fishing in the area.

3.3.2 The California Roach Assemblage

The California roach Assemblage is commonly found in smaller tributary streams that are usually intermittent during the summer season. Stream channel characteristics are low to moderate grade with gravel, boulder, and or bedrock substrate (Barclay, 1975). Pools are well shaded and bank vegetation is moderately abundant. Water temperature and dissolved oxygen concentrations can vary greatly in the summer. As a result, it is not uncommon for Monterey roach to be the only native fish found in these streams due to their tolerance for high temperatures and low dissolved oxygen levels. During winter, Sacramento pikeminnows and suckers may use these streams for spawning if flows are large enough. In addition, if residual pools are large and deep, young-of-the-year for these two species, and possibly others can survive until the following winter (Moyle, 2002).

3.3.3 The Rainbow Trout-Speckled Dace Assemblage

Habitat conditions most commonly found are steep, cold, clear water streams with gravel, cobble, boulder and occasionally bedrock substrate (Barclay, 1975). Streams are generally small in size (first and second order streams) and, in some cases, may be spring-fed streams that only have water present for a few hundred meters. Generally, riffles are more abundant than pools. Another important characteristic is the abundance of in-stream shelter (i.e. root wads, large woody debris, and undercut banks) and a healthy riparian corridor (Moyle, 2002). Species encountered in these areas were rainbow trout, speckled dace and threespine stickleback. Young-of-the-year pikeminnows and suckers may occasionally be found in this assemblage as well. Riffle sculpin (*Cottus gulosus*) are also commonly found in these habitat conditions; however no sculpin were observed during this study.

4 Historical Data and Other Work

The major comprehensive reports to date on the status of fish in the Salinas Watershed are: Snyder (1913), Barclay (1975), Titus et al., (2001), and a section of the Draft EIR/EIS for the Salinas Valley Water Project (MCWRA and USACE, 2001). The Titus report provides a status report on steelhead in the Salinas drainage and a useful overview of previous work, most of which is contained in the following list. The most extensive collection of anecdotal evidence pertaining to historic steelhead and salmon migrations in the Salinas Watershed is provided in Franklin (1999).

The following is a list of the major existing data sources on stream and habitat health in the Salinas Watershed from various agencies, citizen groups, and anecdotal accounts; most are included in Titus et al. (2001). Following this list is brief summary and timeline of extensive studies conducted in the Salinas Watershed based on available literature. Figure 4.1 summarizes the general locations of where stream habitat health and population surveys have been conducted in the past by different agencies.

Table 4.1 This table contains codes for the super-script number following the date for each of the listed references below. Most of the presented documents are unpublished and were only summarized by Titus et al., 2001.

Code Number	Reference Location
1	Unpublished reference in Titus et al., 2001
2	Published Reference in Titus et al., 2001
3	Not referred to in Titus et al., 2001
4	Reference acquired by *CCoWS*
5	Citation given in references of this document
6	Personal Communication

- **California Department of Fish and Game**
    - CDFG (1930's) [1]: surveyed 10 kilometers of Arroyo Seco headwater tributaries
    - CDFG (1930's) [1]: surveyed San Antonio River, Trout, and Tassajera Creek
    - CDFG (1945) [1]: surveyed Tassajara Creek

- CDFG (1950–1951) [1]: unpublished field notes on steelhead status in Nacimiento River
- Evans (1950) [1]: unpublished reports on steelhead status in Old Negro Creek
- CDFG (1951) [1]: field notes on status of steelhead in San Antonio River
- Evans (1951) [1]: field notes on status of steelhead in Tassajera Creek
- Best (1954) [1]: unpublished reports on catch censuses and electrofishing surveys along the Arroyo Seco
- Pelgen and Fisk (1955) [2]: report on fish, wildlife, and recreation in Salinas River basin
- CDFG (1957) [1]: surveys along Paso Robles, Arroyo Seco, Willow, and Higgins Creek
- Smedley (1958) [1]: unpublished field notes on upper San Antonio River
- Evans (1958) [1]: unpublished report on status of steelhead in San Antonio River
- Day (1959) [1,4,5]: habitat inventory of Gabilan Creek
- CDFG (1959) [1]: surveyed lower San Antonio River
- CDFG (1960) [1]: report on survey of Paso Robles, Santa Rita, and Jack Creek
- Schreiber (1960) & Hinton (1962) [1]: unpublished reports on surveys of upper Nacimiento River
- CDFG (1961) [1]: surveys of Nacimiento River
- Moore (1961) [1]: report on surveys along San Antonio River
- Hansen (1963) [1]: unpublished report on survey of Willow Creek
- Hansen (1964) [1]: unpublished report on survey of Willow Creek
- CDFG (1965) [1]: Salmon, Steelhead, and marine resource inventory
- Johnson (1965) [1]: unpublished report on juvenile steelhead density in Willow Creek and entire San Anotonio River system
- CDFG (1966) [1]: surveys along Las Tablas Creek
- CDFG (1966) [1]: angling surveys along Higgins and Lost Valley Creek
- Azbill (1968) [1]: unpublished report on steelhead rescues on lower Arroyo Seco
- Puckett (1971) [1]: survey of steelhead between San Francisco and San Luis Obispo
- CDFG (1973) [1]: electrofishing survey of Jack and Santa Rita Creek
- Barclay (1975) [2,4,5]: fishery survey of Salinas River drainage
- Johnson (1978) [1]: unpublished document on Arroyo Seco as viable fishery
- Chappell (1979): unpublished document on surveys in 1978 of Lost Valley and Zigzag Creek[1]
- Benthin (1981) [1]: unpublished report on steelhead in lower San Antonio River

- Barton (1983) [1]: unpublished document on steelhead catches on lower Arroyo Seco
- Johnson (1984) [1]: unpublished document on steelhead catches on Arroyo Seco
- CDFG (1986 & 1988) [1]: environmental impact documents
- The Habitat Restoration Group et al., (1992) [3,4,5]. Salinas Lagoon Management and Enhancement Plan: Volume 2 Technical Appendicies
- Murphy (1992) [1]: electrofishing survey of four sections of Old Negro Creek
- Murphy (1992) [1]: electrofishing survey of nine sections of upper Nacimiento River
- Murphy (1992) [1]: electrofishing survey of five sections of Arroyo Seco
- Murphy (1993) [1]: electrofishing survey of four sections of Old Negro Creek
- Murphy (1993) [1]: electrofishing survey of four sections of Arroyo Seco
- Nelson (1992-1993) [1]: observations of adult steelhead in the Arroyo Seco
- Page, L.M. (1995) [3]: Aquatic faunal survey of Camp Roberts National Guard Training Site and Camp San Luis Obispo National Guard Training Site, California with emphasis on rare species.
- Nelson and Highland (2000) [4,5]: Atascadero Creek survey report
- Gilroy (2000) [6]: habitat inventory of Gabilan Creek
- Titus, Erman, and Snider (in prep) [4,5]: report on history and status of steelhead in California coastal drainages south of San Francisco Bay; interviews and a detailed review of literature and agency reports were conducted and used to develop drainage-by-drainage status reports

- **Bulletin of the Bureau of Fisheries**
  - Snyder (1913) [2,4,5]: report on fishes of streams tributary to Monterey Bay

- **United States Forest Service**
  - USFS (1981) [1]: surveys in headwaters of Arroyo Seco
  - USFS & Department of Agriculture (2000) [3,4,5]: Arroyo Seco Watershed Analysis

- **Coastal Watershed Council and Ventana Wilderness Alliance**
  - CWC (1999) [3,4,5]: data report for monitoring on Tassajara Creek and Arroyo Seco as part of Clean Streams Program

- **Upper Salinas Watershed Coalition and Las Tablas RCD**
  - USLTRCD (2002) [3,4,5]: watershed fisheries report and case study for upper Salinas River and tributaries; includes monitoring on Atascadero Creek, Little Cholame, Rinconada Creek, Tassajara Creek, Trout Creek, Santa

Margarita Creek, Graves Creek, Paso Robles Creek, and several sites along the Salinas River

- **Hagar Environmental Science**
  - Hagar(1995) [3,4,5]: report on steelhead spawning in Salinas River tributaries prepared for Monterey County Water Resources Agency
  - Hagar (1996) [3,4,5]: report on steelhead status in Salinas River prepared for Monterey County Water Resources Agency

- **Monterey County Resources Agency and US Army Corps of Engineers**
  - MCWRA & US Army Corps of Engineeers (2001) [3,4,5]: Draft EIR/EIS for the Salinas Valley Water Project containing section on fish biology and fisheries resources of the Salinas Watershed

- **Anecdotal Accounts from local residents**
  - Franklin (1999) [3,4,5]: Anecdotal report on steelhead and salmon migrations in the Salinas River

- **Hubbs, Clark**
  - Hubbs (1947) [2,4,5]: Mixture of marine and fresh-water fishes in the lower Salinas River, California

4.1 Literature Review

The first major fisheries study in the Salinas Watershed was conducted by Snyder (1913). In his study, Snyder examined the Salinas River and several of its major tributary streams. Snyder lists 12 native species of fish that he observed during his research. Of these twelve species, 11 still are present today in the Salinas Watershed. Snyder did not observe Sacramento pikeminnow in the Salinas Watershed but did observe them in the nearby Coyote Creek and Pajaro River systems. It is thought that the Salinas and Pajaro River fish species are decedents of the Coyote Creek watershed, a tributary to the San Francisco Bay, resulting in similar species composition found in the greater Sacramento River Watershed. It is presumed that Coyote Creek once changed its course and began flowing into the Pajaro River, thus extending the Sacramento River fish communities (Moyle, 2002). Tectonic processes have since redirected Coyote Creek back to the San Francisco Bay leaving isolated remnants of the Sacramento River fish communities in the Pajaro and Salinas Watersheds.

Since 1913, pikeminnow have been found in abundance throughout the watershed (Hubbs, 1947; Barclay, 1975). Conversely, Snyder frequently observed tule perch *(Hysterocarpus traskt),* in the Salinas and Pajaro River watersheds. However they have since become extinct in both watersheds. Another species native to the Salinas, Pajaro and Sacramento/San Joaquin Watersheds but not observed by Snyder (1913) was thicktail chub *(Gila crassicauda)*. The bones of this species were commonly found in archeological sites throughout the Salinas and Pajaro Watersheds (MCWRA and USACE, 2001). This species is now entirely extinct presumably due to extensive alterations to lowland aquatic habitats throughout its native range (MCWRA and USACE, 2001; Moyle, 2002).

Between the 1930's and the present, the California Department of Fish and Game (CDFG) has conducted stream habitat and salmonid population assessments for several streams in the Salinas Watershed - most of which are referred to and summarized by Titus et al., (2001). All of this work was done in tributary streams on the western side of the Salinas Valley. The associated reports include field survey notes, stream fisheries surveys, and electroshocking surveys for salmonid species. A significant amount of these surveys were conducted prior to the construction of the Nacimiento and San Antonio Dams. Population surveys conducted by CDFG after the construction of these dams indicated that anadromous salmonid populations began to decline.

Hubbs (1947) surveyed the fishes present in the waters located near the interface between the Salinas River Lagoon and the lower portions of the Salinas River. In this study, Hubbs found three freshwater species that had not yet been encountered in the Salinas Watershed: tidewater goby *(Eucyclogobius newberryi),* Sacramento perch *(Archoplites interruptus)* and carp. The latter two are non-native species to the watershed, although Sacramento perch are native to other California drainages. Tidewater goby was listed as an endangered species in 1994 and have been absent from the Salinas River Lagoon for some time.

Barclay (1975) conducted an extensive survey of stream fishes in the Upper Salinas River (upstream of the Nacimiento River confluence) and its southern tributaries in the Santa Lucia Range as well six coastal streams in San Luis Obispo County. This study recorded species distributions, abundances, and overall structure of fish communities, or assemblages in the Upper Salinas River with the intent of detecting the existence of rare and endangered species. His report is the first to thoroughly inventory fishes of the Upper Salinas River drainage and he noted that most studies done in that region to date were short-term, preliminary surveys that targeted trout and their habitat conditions. Barclay noted the presence of several non-native species in the Upper Salinas River main stem, including white catfish, brown bullhead, channel catfish, mosquitofish, green sunfish, bluegill, and black crappie.

In the early 1980's the Untied States Forest Service conducted an extensive survey of the Arroyo Seco River and its headwater tributaries. This study focused primarily on the distribution and density of rainbow and brown trout. The results of this work are also summarized by Titus et al. (2001).

In 1992, The Habitat Restoration Group, Philip Williams & Associates and Wetlands Research Associates completed a management and enhancement plan for the Salinas River Lagoon. This study contains a significant amount of water quality data for 1987, 1990, 1991, and 1992, as well as fish species presence and abundance for the Salinas Lagoon during 1990 and 1991.

Hagar (1995) conducted a survey of steelhead spawning in the Salinas Watershed. This study focused primarily on redd and underwater snorkel surveys in the Arroyo Seco and lower Nacimiento Rivers. No redds were observed in the lower Nacimiento River and only a few were observed in the Arroyo Seco River.

Hagar (1996) assessed the current status of steelhead in the Salinas Watershed with an emphasis on the flow requirements needed to for successful migration through the broad and sandy lower reaches of the Salinas River main stem and the lower reaches of the Arroyo Seco River.

MCWRA and USACE (2001) compiled an extensive review of fisheries biology in the Salinas Watershed as part of an Environmental Impact Report for the proposed Salinas Valley Water Project (involving an inflatable dam just upstream of the lagoon, and increased spillway heights on the upstream dams). This document is one of the most comprehensive recent accounts of the Salinas River fishery and includes historical information, existing fish and aquatic resources and the possible effects of a variety of alternatives for increasing water supplies for Monterey County on aquatic resources and rare species. The review also includes current fish species lists for major water bodies of the Salinas Watershed.

In summary, the existing body of work in the Salinas Watershed describes a unique assemblage of native fish exist in the Salinas Watershed, including steelhead, which have historically used the tributaries of the Salinas River for spawning and rearing. The Salinas River has served and continues to serve as a migration corridor for steelhead. In the past, steelhead and possibly chinook salmon (Franklin, 1999) used the Salinas in greater numbers. The Nacimiento and San Antonio Rivers were the most important rivers for steelhead spawning and rearing and once may have supported a significant run of steelhead (Snyder, 1913; Titus et al., 2001). Other important areas for steelhead spawning and rearing included the Arroyo Seco drainage, the Paso Robles Creek drainage, Santa Margarita Creek drainage, and the Atascadero Creek drainage. Figure 4.2 is a map of reaches in the Salinas Watershed known to have supported anadromous salmonids based on anecdotal evidence documented in Franklin (1999) and Titus (2001). Today the best remaining habitat for anadromous salmonids is in the Arroyo Seco Watershed. Recent anecdotal sightings in the Arroyo Seco Watershed and in the Salinas River mainstem, suggest that migrating steelhead are presently using this system (Table 4.2). One witness described the numerous steelhead in Vaqueros Creek during the winter of 1998 as the last significant run seen in the recent past. This may be attributed to the lack of significant and timely runoff in the Salinas Watershed over the last four winters.

Table 4.2 Recent reports of adult steelhead sightings of in the Salinas Watershed. These reports were reported to the authors of this report either directly form the source or through a second hand party (noted).

Date (approximate)	Location	Species	Anecdote	Source
winter 2001-2002	Davis Rd. near Salinas	Steelhead	Caught and measured an 18" steelhead at Davis Rd. Bridge, which was released. This steelhead was trapped in a large pool due to low flow conditions in the Salinas River.	Resident of Salinas
Winter 1998	Vaqueros Creek (tributary to the Arroyo Seco)	Steelhead	Witnessed several "steelhead" in Vaqueros Creek. It was also mentioned that this was the last year of such an abundant run in Vaqueros Creek.	Resident of Vaqueros Creek (2rd hand information)
mid-late 1990's	Piney Creek and the Arroyo Seco River	Steelhead	Witnessed steelhead at night jumping up passable migration barriers (road crossings) in Arroyo Seco and estimated up to 50 "steelhead" throughout the winter in a pool on Piney Creek.	Lifelong Resident of the Arroyo Seco Watershed

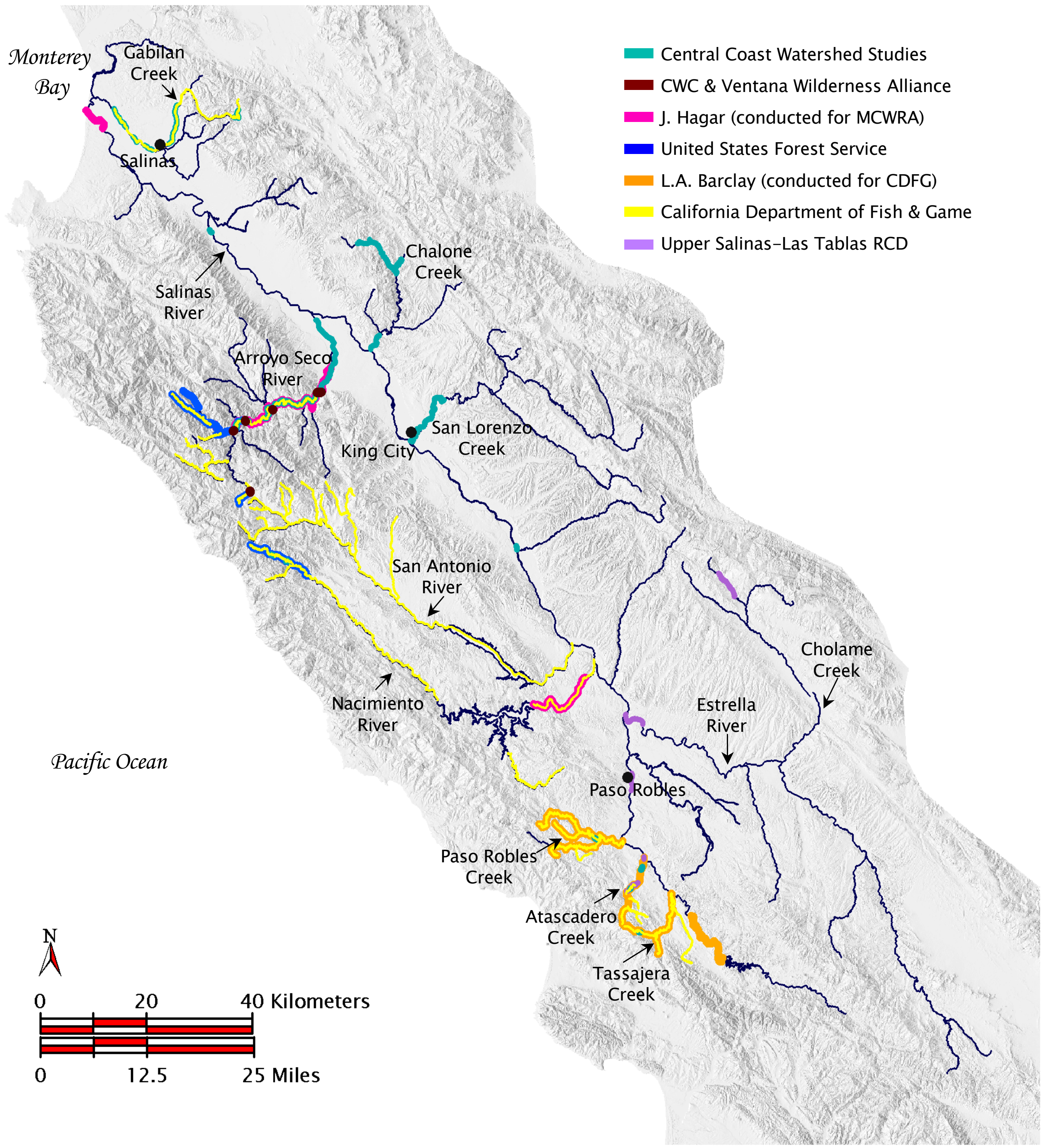


Figure 4.1 Locations were data on stream habitat and population studies/observations were collected in the Salinas River Watershed by various agencies.

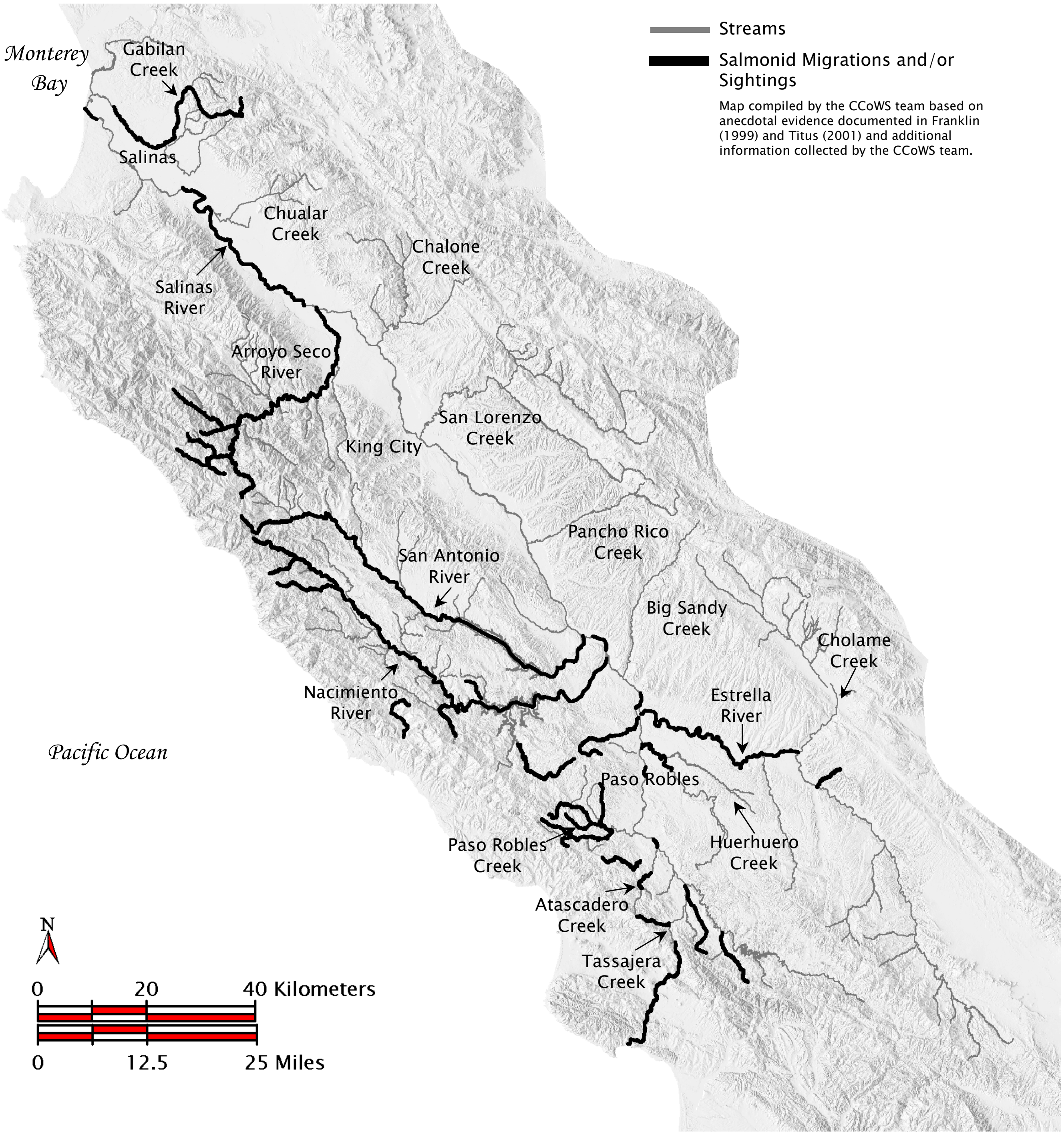


Figure 4.2 Historic distributions of salmonids in the Salinas Watershed based on anecdotal evidence provided in Franklin (1999) and Titus (2001) and additional information collected by the CCoWS Team.

5 Survey and Assessment Methods

As stated in Section 1.2, the primary objective of this project was to examine fish species distribution and to quantitatively evaluate physical habitat quality throughout the Salinas Watershed. The work was situated within the context of determining total maximum daily sediment loads for the Salinas Watershed, and so special attention was given to quantifying impacts on fish habitat that may be due to sediment loading. The work was completed in three phases:

1. Reconnaissance Survey
2. Detailed Habitat Assessment
3. Population Assessment

The reconnaissance survey was intended to map easily measured stream attributes along as many streams as possible. Such attributes included the presence of water, riparian vegetation, and channel substrates. The reconnaissance work provided the basis for selecting a smaller number of sites for detailed, quantitative habitat assessment. In an effort to characterize aquatic ecosystems under most-limiting conditions, sites for detailed assessment were generally limited to reaches of perennial water surveyed during fall.

For detailed habitat assessment, two approaches were tested, ultimately resulting in an objective method based on simple measurements made within a series of fifty transects spaced 10 meters apart along 500 meter stream reaches. the method strongly emphasizes objectivity, in order to provide a repeatable framework for application of Clean Water Act mandates in relation to total maximum daily loads of sediment. Measurement sites were selected within an objective along-stream grid pattern comprising 500 points aligned within 50 transects. further, only objective measurements are made at each site (e.g. depth, velocity, temperature, direct-overhead cover). Subjective measurements (e.g. "fish cover quality") are excluded. The exception is that a subjective judgment is made as to whether each transects falls within a pool, riffle, or run. To offset this exception, parameters were measured that could lead to objective characterization of whether a transect was in a pool or not. these include flow velocity and depth, and change in stream width from transect to transect.

It should be noted that the methods for the 3 phases of the study evolved as the project progressed. The methods were continuously updated as the lead technicians and student assistants became more knowledgeable about fish species identification and habitat characteristics. The streams of the Salinas Watershed vary spatially, requiring that the methods be adapted as streams with different habitat and flow regimes were encountered. Access, timing of the rainy season, and timing of funding were other issues that governed the methods of this project.

5.1 Reconnaissance Survey

After reviewing previous work it was concluded that most stream habitat assessment studies done in the Salinas Watershed occurred in the western tributaries, thus there was a lack of information on stream health for tributaries in the eastern half of the watershed. Due to this lack of knowledge, streams in the eastern portion of the watershed were first targeted for stream reconnaissance and assessment. However, finding access locations to many of these streams was difficult. Not only did the eastern tributaries have a lack of habitat information, information on the presence/absence of perennial water was also of interest. These streams included Gabilan Creek, Chalone Creek, Sandy Creek, and San Lorenzo Creek. Reconnaissance surveys were performed in each of these areas first followed by an extensive reconnaissance in the Arroyo Seco River.

The main objectives of the reconnaissance surveys were to locate perennial water and any obstructions that may prevent fish migration. The surveys involved walking and mapping portions of the stream using GPS, while collecting general information on stream characteristics and habitat. This information was then used to stratify streams into bio-geomorphic provinces.

Reconnaissance involved first determining which portions of the stream were accessible. Once the portion of the creek to be surveyed was located and adjacent land ownership was identified, the landowner was contacted in order to gain permission for access. The length of stream surveyed was dependent on land ownership and access. The reconnaissance survey was then conducted during the summer and fall of 2001 as follows.

First, necessary field equipment, listed in Table 5.1, was assembled into field kits. Teams, usually of two, then conducted the survey. Selected stream reaches were walked and mapped using GPS. Detailed notes were taken throughout the survey and included descriptions of creek pattern (for example meandering, braided, or straightened), creek profile, and roughness. Estimates of Rosgen stream type classification were also made (Rosgen, 1998). In addition, total channel width and depth were measured using an optical rangefinder and/or measuring tape. Surface substrate composition (i.e. boulder, cobble, gravel, sand, or silt) within each section was determined by visual estimation. Estimates for average percent overhead cover were also made and all major plant species observed were noted. If perennial water was present, low flow width and depth were measured using a measuring tape. Surface velocity (m/s) was measured using a 2-meter measuring tape, stopwatch, and dowel. Water temperatures were taken periodically throughout the survey. For major pools encountered, length, width, and depth measurements were also taken. For each reach, pools and large woody debris counts were made. Important features such as large pools, areas with unstable bank conditions or visible erosion, invasive plant species, obstructions, road crossings, pollution sources, and all fish, amphibian, reptile, crustacean, and mammal species encountered were

CCoWS Reconnaissance Data Sheet

Reach #:_____ **Stream Name:**____

Start Location:__________________________________ **Team:**____

Date:_________________ **Start Time:**_____________ **Slope:**_____________ **Water Present:** (Y/N)

Water Temp:________ (°C) **Surface Velocity:**_________ (m/s) **Avg. Water Depth**:______(m)

Rosgen Stream Type: _________ **Stream Type Notes**:____

Estimated Channel Width:___________ (m) **Estimated Channel Depth**:______________(m)

Measured Low Flow Width:___________ (m) **Measured Low Flow Depth**:_____________ (m)

Small Pool Count (length < 4m):____

Medium Pool Count (length 4 to 10m):____

Large Pool Count (length >10m):____

LWD Count: ____

Surface Substrate Composition: Gravel________ (%)

Bedrock ________ (%) Sand ________(%)

Boulder ________ (%) Silt ________(%)

Cobble ________ (%) Clay ________(%)

Overhead Cover: ________ (%) ***check all plant species on back

Land Use: Left_______________________________ Right________________________________

Bank Erosion: Left (Y/N) Right (Y/N) **Litter**: Left (Y/N) Right (Y/N) Channel (Y/N)

Rip-Rap: Left (Y/N) Right (Y/N) **Ag/Urban Drains**: Left (Y/N) Right (Y/N)

Fish: (Y/N) list species ____

Reptiles: (Y/N) list species____

Amphibians: (Y/N) list species ____

Mammals: (Y/N) list species ____

Crustaceans: (Y/N) list species ____

GPS Points and Descriptions: ____

Figure 5.1 Stream Reconnaissance Sheet

Plant Species List

_____Alder
_____Anise
_____Arundo
_____Burmuda grass
_____Buckeye
_____Buckwheat
_____Cape ivy
_____Cat tail
_____Cocklebur
_____Cottonwood
_____Coyote brush
_____Cypress
_____Dogwood
_____Eucalyptus
_____Ferns
_____Grasses
_____Gray pine
_____Hemlock
_____Jimson weed
_____Madrone
_____Manzanita
_____Maple
_____Mint
_____Monterey pine
_____Mugwort
_____Mule fat
_____Mustard
_____Nettle
_____Oak
_____Oat
_____Pampas grass
_____Pepper tree
_____Pineapple weed
_____Poison Oak
_____Rushes/Reeds
_____Rush rose
_____Sage
_____Salt bush
_____Sedges
_____Seep Willow
_____Sword grass
_____Sycamore
_____Tamarix
_____Thistle
_____Tree tobacco
_____Watercress
_____Wild berry
_____Willow
_____Yerba

Other species:____

Dominant Species (List 1):____

Write all additional notes in field book.

Figure 5.1 Cont.

noted and marked with GPS. A sample field sheet and additional notes for completing the survey are shown in Figure 5.1.

Table 5.1 Field equipment used during stream reconnaissance

Field Equipment	
GPS: *Garmin eTrex Summit*	Optical range finder
Reconnaissance data sheets	Reel measuring tape
Digital Camera	2-meter measuring tape
Topographic maps	Ruler and grain size card
Plant and fish guides	Thermometer
Waterproof field book	Stopwatch
Boots and waders	Small dowels

5.2 Habitat Assessment

5.2.1 Previous methods

Traditional methods of stream habitat assessment are often subjective and qualitative (e.g. WPN, 1999; Dettman & Kelley, 1986). This is inappropriate within the context of TMDL determinations, which require that numeric targets are set for factors such as physical habitat quality, and that these numeric targets can be monitored in the field over decades without observer bias.

For example, many habitat characterizations rely on observers to identify 'pools' from 'riffles', 'runs', and 'glides'. While descriptive guidelines exist, supported by limited quantitative measurements, this is a highly subjective process. Differences commonly occur between observers, and even within the same observer's experience depending on the context of the surrounding river, or rivers that have been visited in the recent past. We seek wholly objective means of defining these basic habitat types.

Secondly, habitat characterizations often involve qualitative descriptions, such as "in-stream cover is good, medium, or poor". Field interpretation of such descriptors is context dependent, with no obvious fixed baseline for comparison. Habitat that appears to offer "good" cover in a uniform, channelized ditch may be described as "poor" cover in a pristine mountain stream. Quantitative descriptors are sought, such as the maximum diameter of the largest piece of woody debris that is underwater.

5.2.2 Objective method

We have developed a method for physical habitat assessment that emphasizes objective quantification of the physical stream environment. It centers on a spatial sampling design that does not rely overly on observer decisions as to where to measure habitat; and a small set of objectively measurable parameters. This approach necessarily involves the exclusion of certain commonly, but subjectively measured parameters, such as cobble embeddedness.

The advantages of this style of approach are:

- Results do not depend on observer
- Results do not depend on irrelevant context
- Measurements are repeatable many years later with high precision
- Minimal training required – not limited to a small number of experts with limited ability to survey every stream in a region
- Quantitative results are amenable to quantitative habitat-biota analysis
- Results provide good basis for TMDL numeric targets

5.2.3 Spatial sampling design

A hierarchical spatial sampling design is employed. Streams are first surveyed using the reconnaissance methods described in Section 5.1 above, or using knowledge gained from aerial photographs or previous work. Streams are then subjectively divided into provinces, where each province contains reaches of a generally similar habitat type – e.g. non-perennial sand-bed river; or steep perennial mountain bedrock stream. A number of 500-meter reaches are selected from each province, either randomly, or subjectively based on access limitations. The end-points of the 500 m reaches are accurately mapped using GPS. The reaches are then surveyed as a sequence of 50 transects from left-bank to right-bank. Each transect is sampled at between 9 and 11 evenly spaced points. Thus, each 500 m reach is sampled at 500 point-locations, with minimal observer bias in determining the location of any point.

The locations of the reaches surveyed during the present study are presented in Table 7.2.

5.2.4 Measured parameters

The following parameters are measured once per transect (50 per reach):

- Water temperature (°C)
- Surface velocity (m/s)
- Wetted channel width (m)
- Percent overhead vegetative cover
- In-stream shelter complexity (0–3; 3 = excellent).

The following three parameters are measured at each of the 500 points within each 500 m reach:

- Particle size (mm)
- Water depth (cm)
- Fine sediment accumulation (cm)

Water temperature is one of the principal determinants of fish habitat type (Baltz et al, 1987). Most species are described as either cold-water or warm-water species. Different life stages of a given species usually have different water-temperature tolerances. As fish are poikilothermic (cold-blooded) organisms, water temperature determines their basal metabolic rate, and thus their activity levels, and the rate at which they must consume food in order to grow.

Water velocity is both a direct and indirect indicator of fish habitat. For example, trout often feed by stationing themselves beside high velocity areas, from which they can pluck food passing by at a higher rate than in lower velocity flow (Smith and Li, 1983). Indirectly, high velocity water has a greater capacity to transport sediment, and thus leads to coarser substrates where fine sediment particles are washed away.

Particle size determines the feasibility of processes such as burying of eggs during spawning, and the amount of habitat available for organisms such as benthic macroinvertebrates, upon which many fish feed.

Water depth is primarily an indicator of the total volume of freshwater habitat in a stream. Variation in water depth is an indicator of habitat diversity, manifested as sequences of geomorphic features such as pools and riffles.

Likewise, wetted channel width is primarily a measure of the total size of a stream.

Fine sediment accumulation refers to the amount of fine material overlying some preceding, coarser substrate. It is an indicator of recent disturbance in the watershed upstream. Perhaps the most effective way of measuring fine sediment accumulation is using what is now known as a V* Rod (Vee Star Rod), after Hilton et al., 1993. This is simply a 2 m long stainless steel rod that is forcibly driven into the streambed. The rod penetrates unconsolidated fines, and stops when it reaches coarse sediment, or older, consolidated fines. The depth of fine sediments as well as the total depth of water and sediment is read directly off the graduated rod. At each of the transects, 10 sediment accumulation measurements were taken for a total of 500 per reach[4]. The results are presented as reach average sediment accumulation (RASA) – See Section 7.2.

Overhead vegetative cover determines both solar shading, and thus temperature, and the opportunity for carbon inputs to the stream both as fine litter, and large woody debris. Vegetative cover also influences insect availability.

In-stream shelter complexity is a qualitative measure of habitat quality and diversity. It includes relatively objective counts favorable features such as the number of boulders and large woody objects.

Each of these habitat characteristics is measured for each transect, or for each point within each transect as described in the following box. A sample field sheet is also shown in Fig 5.2.

---

[4] Note that not all reaches had 50 transects due to lack of perennial water, private property and dense poison oak.

CCOWS Stream Habitat Assessment Method (CSHAM)

- Each stream was first stratified into biogeomorphic provinces, based on information gathered from the stream reconnaissance, such as presence or absence of perennial water, major breaks in stream class, temperature, and density of riparian vegetation.
- A random reach or pair of reaches was identified within each province. Each reach contained 500 meters of stream, which is considered long enough for the reach to be representative of its province.
- GPS coordinates were taken at the beginning and end of each 500-meter reach.
- Each 500-meter reach was sampled along 50 lateral transects spaced 10 meters apart. Progressive 10-meter intervals were determined using either a measuring tape or 10-meter rope.
- All habitat assessment data was entered into the CCoWS *Microsoft Access* database.

    - Each 10-meter transect extended across the wetted stream channel.
    - All measurements were made within the boundaries of the wetted area and all data was recorded on a *CCoWS Habitat Assessment Data Sheet* Fig 5.2.
    - If the entire transect was dry, no measurements were made and the field sheet entry was "dry".
    - A subjective determination of habitat type (pool, glide, run, or riffle) was noted.
    - In-stream shelter complexity was rated between 0 to 3 (0 = none, 3 = excellent) for the wetted area including 5 meters upstream and 5 meters downstream using the California Department of Fish and Game method (Flosi et al., 1998).
    - The wetted width of the transect was measured and recorded.
    - Within the transect, the surface temperature at the thalweg was measured.
    - The surface velocity (m/s) at the thalweg was measured using a stopwatch, 2-meter measuring tape, and dowel. The field sheet entry for water velocity was 0.01 m/s if measured velocity was less than or equal to 0.01 m/s. This was used only if there measurements were collected in a flowing river. Measurements taken in pools with no stream flow coming in or exiting were given a 0 (m/s) as opposed to a 0.01 m/s value.
    - The transect was divided into approximately 9 evenly spaced points.
        - At each point, the overhead vegetative cover was measured and recorded using a densitometer. A densitometer is a reflective viewing device including a mirror and spirit level used to detect the presence of vegetation directly overhead of the observer when held parallel to the ground at eye level. Data was recorded as "yes" or "no".
        - At each point, the depth of water was measured and recorded using a stainless steel graduated rod. If water was too deep to be measured with a graduated rod, a weighted measuring tape was used. If a point was dry, it was recorded as "0".
        - At each point, the amount of fine sediment accumulation overlying the coarser substrate was measured by forcibly driving the rod until a change in resistance was observed as the rod contacted coarse material. Total depth (water depth plus fine sediment accumulation depth) was recorded. If total depth was greater than the length of the graduated rod, then measurement was recorded as ">180cm". If a point is dry, it was record as "0" (Hilton et al., 1993).
        - At each point, one sediment particle was randomly selected and measured along the intermediate axis using a ruler or grain size card. If substrate was bedrock, it was recorded as "999". If the substrate was LWD or a root mass, it was recorded as "0".

CCoWS Habitat Assessment Data Sheet

Stream:____
Location:____
Province ID:__________________________Reach ID:_____________________________________
Team:____
Date:_________________Start time:________________End time:__________________________
Start GPS ID:_________________________End GPS ID:___________________________________
Observations:____
____

Transect ID:___________________________Start time:_________________________________
Habitat type:____(Pool, Glide, Run, Riffle)
If pool, downstream riffle crest thalweg water depth:______________________(cm)
Thalweg Surface Water Temp:__________(°C) Thalweg Surface Velocity:____________(m/s)
Transect Width:________________________(m)
Fish Sightings:____

Point ID (#)	Particle Size (mm)	Overhead Veg. Cover (yes/no)	Water Depth (cm)	Total Depth (cm)
Thalweg				
1				
2				
3				
4				
5				
6				
7				
8				
9				

Instream Shelter Components:

____1 to 5 boulders	____>6 boulders	____root mass
____single root wad	____LWD >12"diam, 6'long	____SWD <12" diam
____LWD + SWD	____undercut bank <12in.	____undercut bank >12in.
____bedrock ledge	____bubble curtain	____branches near water

____limited submersed vegetation	____extensive submersed vegetation
____undercut bank <12in. + root mass	____LWD + boulders + root wads
____≥3 LWD + SWD	____≥3 boulders + LWD + SWD
____undercut bank >12" + root mass or LWD	____b. curtain + LWD or boulders

Figure 5.2 Stream habitat assessment field sheet

Table 5.2 Field equipment used for detailed habitat assessment

Field Equipment	
GPS unit-*Garmin eTrex Summit*	Ruler and grain size card
Habitat assessment data sheets	Pin flags
Boots or waders	V* rod
Optical range finder	*Raytek* laser thermometer
Reel measuring tape or 10-meter rope	Stakes and clamps
2-meter measuring tape	Digital camera
Stopwatch	Random number chart
Small fluorescent dowels	Densitometer

5.3 Gabilan Creek (Dettman and Kelley Habitat Assessment Methodology)

Prior to development of the CCoWS method for detailed habitat assessment, an alternative method was used in Gabilan Creek. A method developed by D.W. Kelley and David Dettman, a fishery biologist from Monterey Peninsula Water Management District, was used to assess habitat as part of a student's thesis at California State University Monterey Bay (Hager, 2001). This method, Rearing Index for Young-of-the-Year Program, RIYOYP, (Dettman and Kelley, 1986) measures the quality and quantity of rearing habitat in order to calculate a rearing index for young-of-the-year steelhead and is summarized in (Hager 2001). RIYOYP can then be used to predict steelhead young-of-the-year population density per unit length of stream.

The method is unique in that it has been correlated with steelhead population data. However, it is somewhat subjective often requiring a professional/experienced judgment and therefore this method was not fully used.

The software for the original RIYOYP was revised and updated by Dr. Fred Watson, Adjunct Faculty at California State University Monterey Bay. The new program is operated using *Microsoft Access* Software. It was tested by entering data provided and previously analzyed by Dave Dettman using the older method. The results of the updated version were comparable to the original Dettman/Kelley program with less than 3% error.

Reaches along Gabilan Creek were selected based on their suitability for rearing, determined by the reconnaissance phase of this study. Each reach was delineated according to character type (pool, glide, riffle, or run). Each character was then divided into homogenous sections, or patches, based on factors such as apparent depth, velocity, and dominant substrate. For each section, length and width measurements were taken. Five depth measurements were then taken for each section. The surface water velocity was measured using a stopwatch, a dowel, and a 2-meter measuring stick. Next, percent embeddedness of the section was measured for five randomly chosen cobbles. Abundance of cobbles was determined by estimating the percent of cobbles per total substrate. Roughness and cover were rated from 0 to 3 (0-poor, 3-excellent).

The data were then entered into the updated RIYOYP, which calculated a rearing index for each reach. The rearing capacity, number of young-of-the-year per unit length of stream, was also determined.

Results for this section are in Section 7.2.1.

5.4 Population Assessment

The original plan for the population assessment was to estimate fish distribution and population density by electrofishing and/or netting in the reaches where habitat assessment was performed. However, the application status for the National Marine Fisheries Service Section 10 Permit, which is required to conduct this type of study in a steelhead stream, is still pending as of February 2003 although the application was submitted October 2000.

An alternative method of assessment was developed and provided information on species composition, distribution, and estimated abundance for a given reach of stream. Population assessment involved stream bank and snorkel-based underwater fish observations and counts (an adaptation of California Department of Fish and Game method, Flosi et. al 1998) in the reaches where habitat assessment was performed. Figure 5.3 is the field sheet used during the populations assessment surveys. Table 5.3 lists the field equipment needed to conduct the population assessment, which was performed as follows:

- Assessment began at the start location of the 500-meter reach in which habitat assessment was performed (pin flag or GPS coordinates were located).
- 1 or 2 divers, depending on width of stream, surveyed the entire reach of stream either by snorkel or a combination of snorkel and visual stream bank observation either with polarized glasses or *Aqua-Vu* underwater viewing system (Nature Vision Inc).
- Starting at the downstream end of the reach, diver(s) swam/crawled in an upstream direction and recorded # and species of fish observed within a given habitat type (i.e. riffle, run, or pool) on an underwater writing slate.
- If 2 divers were required, divers swam side by side while each observed fish on either the left or right half of the stream channel.
- If sections of the reach were too shallow to snorkel (depth less than 10 inches or from chin to top of head), observations were made above the water either from within the channel or along the stream bank using polarized glasses or *Aqua-Vu* underwater viewing system.
- The entire reach was surveyed in this manner.
- Any observations of fish behavior and habitat utilization, as well as a brief summary of the assessment was recorded in the notes section of the *CCoWS Population Assessment Data Sheet* (Fig. 5.3)
- All population assessment data was entered into the CCoWS *Microsoft Access* database.
- Fish were counted as follows:

- Only fish $\geq$ 4 inches were counted except for the following:
    - Rainbow Trout/Steelhead
- Smaller species that were easily identified when isolated (i.e. speckled dace, sculpins, and threespine stickleback) were also counted
- Size classes for Rainbow Trout/Steelhead were recorded as follows:
    - <3 inches (estimated length) = young-of-the-year (0+)
    - 3-6 inches (estimated length) = yearling (1+ yr)
    - >6 inches (estimated length) = yearling (2+ yr)

Table 5.3 Field equipment used for population assessment

Field Equipment	
Snorkel	Pencil
Dive mask	Thermometer
Slate board	Wet suit and booties
Waterproof camera	Polarized sunglasses

CCoWS Population Assessment Data Sheet

(Stream Bank or Underwater Observations)

Stream:____
Location:____
Province ID:________________________Reach ID:__________________________
Team:____
Date:________________Start time:_______________End time:________________
Observation Method: _____Stream Bank _____Underwater _____Combination
Surface Water Temperature:_____________________ (°C)

Species Code	Size Class	Count

Notes:____
____
____
____
____
____

Figure 5.3 CCoWS population assessment field sheet.

Salinas River Basin Fish List & Codes

Code	Common Name	Scientific Name
LP	Pacific lamprey	*Lampetra tridentate*
RCH	Monterey roach	*Lavinia symmetricus*
HCH	Hitch	*Lavinia exilicauda*
BLK	Sacramento blackfish	*Orthodon microlepidotus*
PM-S	Sacramento pikeminnow	*Ptychocheilus grandis*
DC	Speckled dace	*Rhinichthys osculus*
SKR-S	Sacramento sucker	*Catostomus occidentalis*
RT	Rainbow trout/steelhead	*Oncorhynchus mykiss*
STB	Threespine stickleback	*Gasterosteus aculeatus*
PSCP	Prickly sculpin	*Cottus asper*
CSCP	Coastrange sculpin	*Cottus aleuticus*
RSCP	Riffle sculpin	*Cottus gulosus*
TP	Tule perch	*Hysterocarpus traski*
GSH	Goldfish	*Carassius auratus*
CP	Carp	*Cyprinus carpio*
BLB	Black bullhead	*Ameirus melas*
GAM	Mosquitofish	*Gambusia affinis*
WHB	White bass	*Morone chrysops*
GSF	Green sunfish	*Lepomis cyanellus*
BG	Bluegill	*Lepomis macrochirus*
LMB	Largemouth bass	*Micropterus salmoides*
BCR	Black crappie	*Pomoxis nigromaculatus*

Figure 5.3 Cont. CCoWS Population assessment field sheet.

6 Results: Stream Reconnaissance

Stream reconnaissance was conducted during the summer and fall of 2000 and 2001. The main objective of the reconnaissance work was to become more familiar with the streams and their respective watersheds. Secondly, it was critical to stratify the streams into provinces, as defined in the methods section, and to locate perennial water (Fig. 6.1) and migration barriers. Much of the data has been incorporated into a watershed scale map. A second map of the Arroyo Seco Watershed has also been completed and illustrates, in more detail, longitudinal trends along the main stem of the Arroyo Seco from its confluence with the Salinas to the gorge waterfall, a large natural barrier. All reconnaissance data has been entered into a database and is available on the web. A map illustrating the results of this field campaign is shown in Figure 6.2[5].

The following section describes each of the major sub-watersheds where reconnaissance was conducted during the 2000 and 2001 monitoring seasons.

Results are discussed in Section 7.

[5] A full scale version of this poster (36” x 44”) is available at the following web address: http://science.csumb.edu/~ccows/

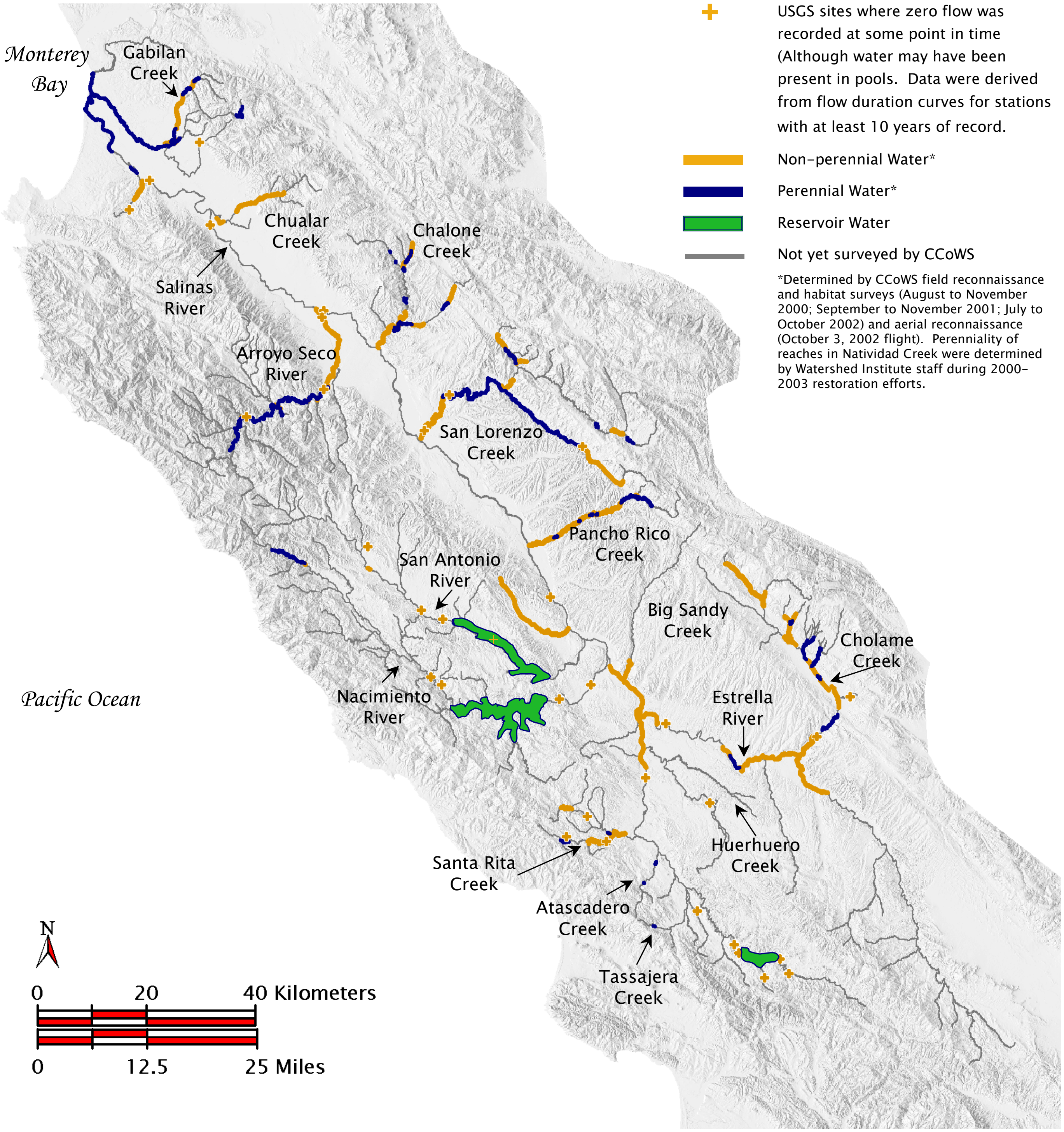


Figure 6.1 Perennial water in the Salinas Watershed. Data used to make this map were collected during field reconnaissance (summer and fall 2000-01), aerial observations (03 Sep 02), and habitat assessments (fall 2002). The 2002 water year was considered to be the second of two consecutive dry years. Long time residents of the Arroyo Seco watershed stated that they had not seen the river at such low levels in decades. With this type of information, it was inferred that any stream with water flowing during the fall of 2002, would in fact be perennial.

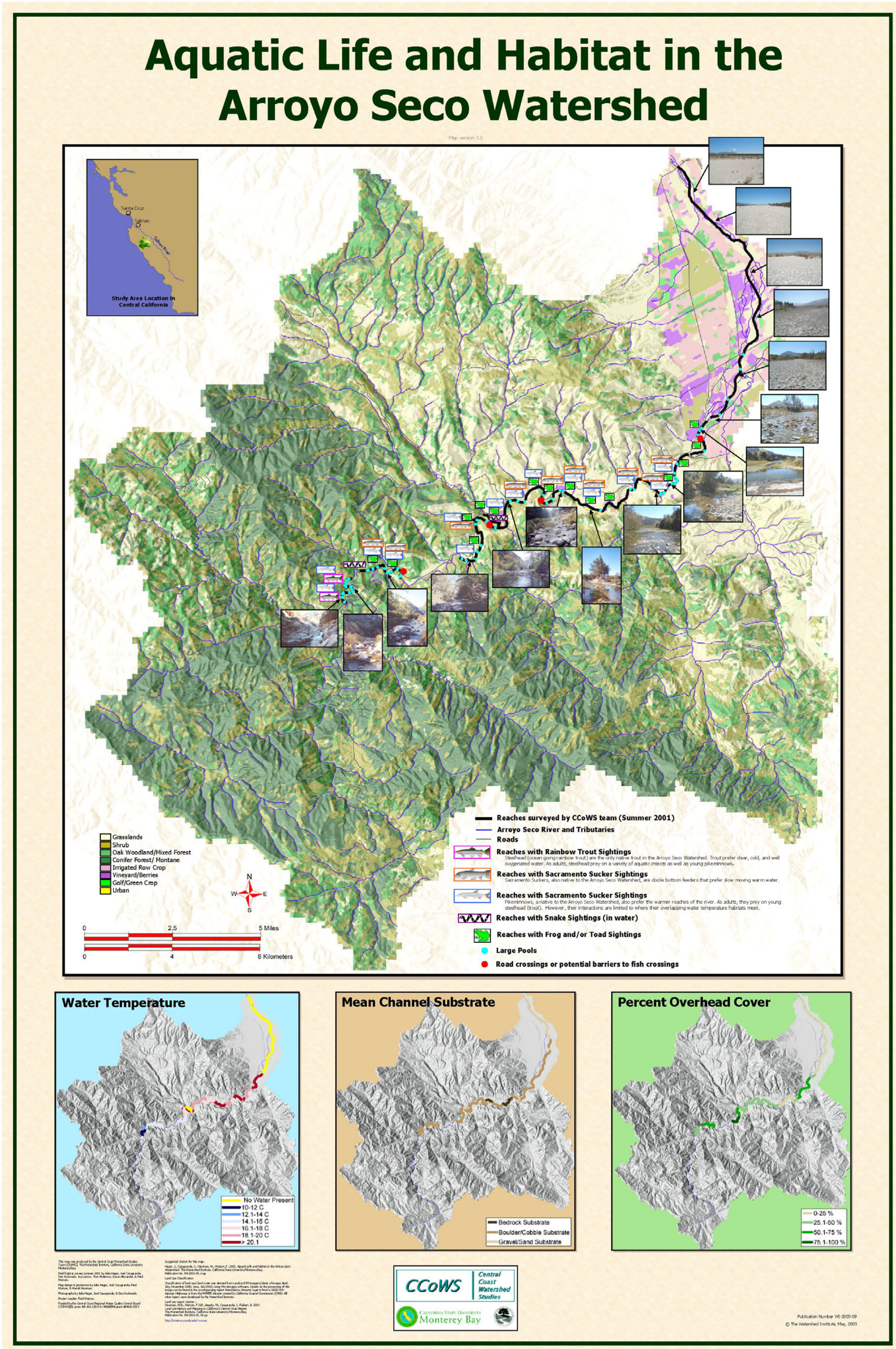


Figure 6.2 Aquatic life and habitat in the Arroyo Seco Watershed assessed during summer and fall of 2001. An actual poster-sized (42"x50") copy of this image is available at: http://science.csumb.edu/~ccows

6.1 Western Tributaries

6.1.1 Arroyo Seco River

The Arroyo Seco River is located west of Greenfield and drains a portion of the eastern half of the Santa Lucia Range. The river flows towards the northeast through a deep canyon finally disappearing into a broad alluvial fan. The river is perennial down to the Elm Street Bridge. The lower portion of the river (Fig. 6.3) is a dry sandy wash, on the Arroyo Seco River Cone, which is similar to the Salinas River in size and permeability. This reach lacks a consistent, mature riparian corridor and is controlled with levees on both sides. Neighboring land use in this area is predominantly row-crop agriculture and vineyards. At the canyon/valley bottom interface there is a large water diversion facility, the Clark Colony Water Diversion, which extracts surface water during winter for local agricultural usage. Fish screens are present at this facility to protect out-migrating juvenile steelhead, however Hagar (1996) states that some fish still become entrained into the diversion channel. Further downstream at Thorne

Figure 6.3 The lower reaches of the Arroyo Seco River near the Salinas River confluence. Here, the channel substrate is sandy and there is a lack of an obvious low flow channel. (Photo: Joel Casagrande, 25 Sep 01)

Road there is an old fish ladder that is often full of debris and sediment. The ladder is easily accessible and the poaching of steelhead has been documented (MCWRA and USACE, 2001; Hagar, 1996).

Further up the watershed, near the Sycamore Flats community, the channel substrate increases in size to gravel/cobble while the width of the channel becomes narrower. Bedrock formations are also found in large sections of the stream channel bottom (Fig. 6.4). Long runs and pools characterize the river throughout this reach during low flow. A mixed riparian corridor exists, and neighboring land use is low intensity residential mixed with limited ranching and vineyards.

The upper third of the watershed, above the Government Camp, is part of the Los Padres National Forest. In this section, cobbles and boulders are the dominant channel substrate (Fig. 6.5), and there is a healthy mixed riparian corridor. Red alder, Fremont cottonwood, California sycamore, and a variety of willow speices are common and abundant. The channel type is an alternating step run/pool and riffle/pool sequence. At times, the channel can be as narrow as 1 meter and as deep as 15 meters. Some areas are well shaded, but not by a

Figure 6.4 Low flow conditions near Sycamore Flats. Here bedrock is the dominant substrate. (Photo: Joel Casagrande, 28 Aug 02)

dense overhanging riparian corridor. Instead, tall canyon walls provide shade throughout most of the day (Fig. 6.6).

Figure 6.5 The Arroyo Seco River in Los Padres National Forest near Santa Lucia Creek. (Photo: Joel Casagrande 08 Aug 02)

Figure 6.6 Narrow granitic walls create shade and deep water in the upper Arroyo Seco. (Photo: Joel Casagrande, 03 Oct 02)

6.1.2 Nacimiento River (upper)

The Nacimiento River flows parallel to the Salinas River for much of its length, but in the opposite direction. The confluence of these two rivers is near the Monterey and San Luis Obispo County line. The Nacimiento Dam divides the watershed into its upper and lower sections. The dam is located approximately 10 km upstream of the confluence with the Salinas River. Above the dam there are two distinct provinces: the lush, steep, and perennial headwaters and the dry, intermittent section leading into artificial Lake Nacimiento.

The channel in the headwaters section of the river is steep characterized by a step/pool sequences with gravel/cobble substrate. Here the river runs through steep canyons well shaded by a dense riparian corridor of tan oak (*Lithocarpus densiflorus*), California bay (*Umbellularia californica*), red alder, California sycamore, and big leaf maple (*Acer macrophyllum*) (Figs 6.7 & 6.8). Logjams and large woody debris are abundant. Figure 6.7 illustrates the abundance of large woody debris and overhead shelter found along the upper reaches of the Nacimiento River. Microclimatic conditions throughout this reach are cool and

Figure 6.7 Shade created by overhanging large woody debris is a common feature in the upper Nacimiento River. (Photo: Joel Casagrande, 12 Sep 02)

damp, even in the summer. Perennial water found in the upper reaches of the Nacimiento River is provided by springs high in the Santa Lucias.

Figure 6.8 Perennial water shaded by dense overhanging vegetation in the upper Nacimiento River. (Photo: Tim Ellis, 06 Sep 02)

6.1.3 Paso Robles Creek

Paso Robles Creek enters the Salinas River approximately 3 km (5 miles) south of the city of Paso Robles. The watershed is small in comparison to Arroyo Seco and Nacimiento. There are three main tributaries to Paso Robles Creek, Willow Creek, Jack Creek and Santa Rita Creek. Springs in the upper most portion of this watershed keep some parts of the headwaters perennial. Access for this study was only obtained for the lower reaches of Paso Robles Creek and at the few public bridges that exist. Monitoring of this creek during this summer revealed only isolated stagnant pools (Figs 6.8& 6.9) as a refuge for trapped fish.

The lower section of the watershed has, at times, a mixed riparian corridor of Fremont cottonwoods, California sycamores, red alders, and willows. Some areas have been cleared for development and pasture lands. Cattle ranching is the dominant land use in this part of the watershed. Channel substrate in the lower reaches alternates between fine sediment in the pool bottoms to gravels and small cobbles in the riffles and runs.

Figure 6.8 A drying pool in the lower Paso Robles Creek created by a beaver dam (center). Here streamside vegetation is limited. (Photo: Joel Casagrande, 20 Sep 02)

Figure 6.9 Paso Robles Creek with extensive riparian vegetation just a few hundred meters downstream from Figure 6.8. (Photo: Fred Watson, 20 Sep02)

6.1.4 Atascadero Creek

Atascadero Creek runs west to east along Highway 41 through the City of Atascadero in northern San Luis Obispo County. The lower reaches of this Salinas tributary have been heavily urbanized (Fig. 6.10) over the last few decades (Funk et al., 2002). Still, a majority of the upper and middle reaches of the watershed are relatively healthy (Nelson, J. et al, 2000). Its two main tributaries, Eagle Creek and Hale Creek, are small perennial headwater streams.

In the lower reaches of Atascadero Creek, dense groves of willow, Fremont cottonwood and Eucalyptus (*Eucalyptus spp.*) are common along the banks in areas that have not been urbanized (Fig. 6.11). In most years, the downstream reaches of Atascadero Creek are perennial due to resurfacing of the creek through the alluvium, small tributaries that have been culverted into the creek,

Figure 6.10 Atascadero Creek under US 101. Note the presence of water in the channel. This picture was taken in September of 2002, a dry year. (Photo: Joel Casagrande, 24 Oct 02)

groundwater, and possible discharge from Atascadero Lake (a small reservoir on an unnamed tributary to Atascadero Creek) (J. Patterson, pers. comm.). The City was built on a large area of wetlands near the Atascadero and Salinas confluence (D. Funk pers. comm. 2002). In fact, the name "Atascadero" means, "stuck in the mud" in Spanish. Now, the paved over land drains into the heavily incised lower reaches of Atascadero Creek. However, these perennial reaches continue to provide habitat for native species such as Monterey roach, *(Lavinia symmetricus)* and Sacramento sucker, *(Castosomus occidentalis)* .

Figure 6.11 Atascadero Creek approximately 200 m upstream of U.S. 101. Here dense vegetation and perennial water are present. (Photo: Joel Casagrande 24 Oct 02)

6.1.5 Tassajera Creek

Tassajera Creek is a small perennial tributary to Santa Margarita Creek, which joins the Salinas River south of Atascadero. The creek's headwaters are in the Los Padres National Forest at the southern end of the Santa Lucia Range. The reach of stream surveyed during the present study was narrow with dense vegetation on both banks (Fig. 6.12). Riparian species include California sycamore, red alder, Fremont cottonwood, poison oak and nettle. Stream substrate is predominantly gravel/cobble with boulders and bedrock. Adjacent types of land use are natural forestlands in the headwaters followed by low-density residential and grazing in its downstream portion.

Figure 6.12 Tassajera Creek near the Los Padres National Forest boundary. (Photo: Joel Casagrande, 04 Jul 02)

6.2 Eastern Tributaries

6.2.1 San Lorenzo Creek

The upper portion of San Lorenzo Creek flows parallel to the Salinas River on the eastern side of the Gabilan Range (Peach Tree Valley). The creek then turns west and cuts through the Gabilan Range and near King City it merges with the Salinas River. Some sections of this creek are perennial, especially near the point where the creek cuts through the southern end of the Gabilan Range. The present study only assessed a small section of the creek from its confluence with the Salinas up to the USGS gage along Bitterwater Rd (approximately 6 km east of King City). The remaining upstream portions are on private land. Near the USGS gage, the stream is of moderate grade with gravel/cobble substrate. Here adjacent land use is primarily grazing in addition to an active gravel mine located just upstream from the gage.

Closer to King City, the stream exits the hills through a narrow canyon and winds through a broad alluvial fan. At this point, the stream is predominantly a low gradient sandy/gravel channel with little riparian vegetation (Fig. 6.13).

Figure 6.13. San Lorenzo Creek near King City looking east (upstream) towards the Gabilan Range. (Photo: Fred Watson, 30 Oct 00)

Major riparian species are Fremont Cottonwood, sandbar and arroyo willows and a few California sycamores. Channel and bank degradation due to off road vehicle (ORV) use and vegetation removal, as well as illegal dumping, are common within the lower reaches.

6.2.2 Chalone Creek

Chalone Creek is the next major watershed on the east side of the valley north of San Lorenzo Creek. The headwaters are located in the Pinnacles National Monument east of the city of Gonzales. Topo Creek, a large, primarily dry tributary to Chalone Creek, drains an area just southeast of the National Monument.

Figure 6.14 Chalone Creek, looking downstream in Pinnacles National Park. (Photo: Joel Casagrande, 03 Oct 00)

In the Pinnacles National Monument, the channel is of moderate grade with a mixture of cobbles and boulders as the dominant substrate (Fig. 6.14). Riparian vegetation is moderately dense in some areas and scarce in others. Some species include sandbar and arroyo willows, California sycamore, and gray pine (*Pinus sabiniana*). Perennial water exists in the uppermost reaches of this watershed and near the confluence of Chalone and Topo Creeks.

The lower reaches have been heavily impacted by mining (Fig. 6.15). Chalone joins the Salinas River just north of the city of Greenfield.

Figure 6.15 Lower Chalone Creek just upstream (looking downstream) from a large in-stream gravel mine. Note large channel width, lack of low flow channel and mature riparian vegetation. (Photo: Fred Watson, 29 Oct 00)

6.2.3 Sandy Creek

Sandy Creek is a small tributary to Chalone Creek located outside the east entrance of the Pinnacles National Monument. During the summer and early fall there was approximately a 1500-meter reach of perennial water located near the tributary's mid-section, while the sections above and below were dry. We hypothesize that this stretch of perennial water is the result of water perched above a thick sub-surface clay layer that was detected using a rod to measure sediment accumulation (Section 7.2). The dominant land use is natural (campground, National Monument) and grazing upstream and downstream of the perennial water.

During the present study, only the small perennial section of Sandy Creek was assessed. Channel substrate in this reach was predominantly sand mixed with some small gravel. However, there is a thin overlying layer of fine silt and clays throughout most of the run habitats. Several areas along the stream bank showed evidence of wild pig disturbance such as large wallows and tracks. Riparian vegetation and cover is dense throughout (Fig. 6.16). Common species are Fremont cottonwood and willow.

Figure 6.16 Sandy Creek inside the Pinnacles Campground (private). (Photo: Joel Casagrande, 23 Oct 02)

6.3 The Salinas River

6.3.1 Salinas River near Chualar

The main stem of the Salinas River near Chualar (38 river kilometers from the ocean) is characteristic of much of the Salinas River channel. The channel is wide, often exceeding 100 meters, and relatively flat throughout. A small low flow channel migrates through the main channel except in areas where bulldozing has been done to prevent flooding. The dominant substrate is coarse sand with some small gravels (Fig. 6.17).

Figure 6.17 The Salinas River, looking downstream, near Chualar. (Photo: Joel Casagrande, 03 Nov. 01)

Riparian vegetation is abundant in some areas and scarce in others. Stream banks are armored by riprap in several locations, and *Arundo donax* is widespread throughout much of this area. The Salinas River is non-perennial. However, in most years, annual summertime dam releases from Nacimiento and San Antonio dams allow water to remain in the channel through October and rarely through the whole year. In winter, a minimum release of 25 cfs from Nacimiento Reservoir and 3 cfs from Lake San Antonio usually dries up before reaching Greenfield. This leaves the Salinas River near Chualar dry until several winter rains can resume stream flow in the lower Salinas River.

6.3.2 Salinas River near San Ardo

Figure 6.18 The Salinas River, looking downstream, near San Ardo. (Photo: Joel Casagrande, 31 Oct 02)

The Salinas River near San Ardo is nearly 133 river kilometers from the Pacific Ocean. Here the channel widths are narrower than at Chualar. There is an increase in the abundance of gravel substrate; however, sand is still the dominant particle size throughout most of the channel. The riparian corridor is larger and in-stream vegetation and mature bank vegetation are more abundant. The most common tree species seen here are Fremont cottonwood, arroyo, red and sandbar willows and the occasional California sycamore. The river is less incised here and this allows the lower branches to overhang the water surface (Fig. 6.18). While no major pools were observed in this section of the river, overhanging branches captures debris and form temporary depressions in the stream channel (Fig. 6.19). Here, the river is also non-perennial. However, the presence of water is common due to releases from the Nacimiento and San Antonio Dams.

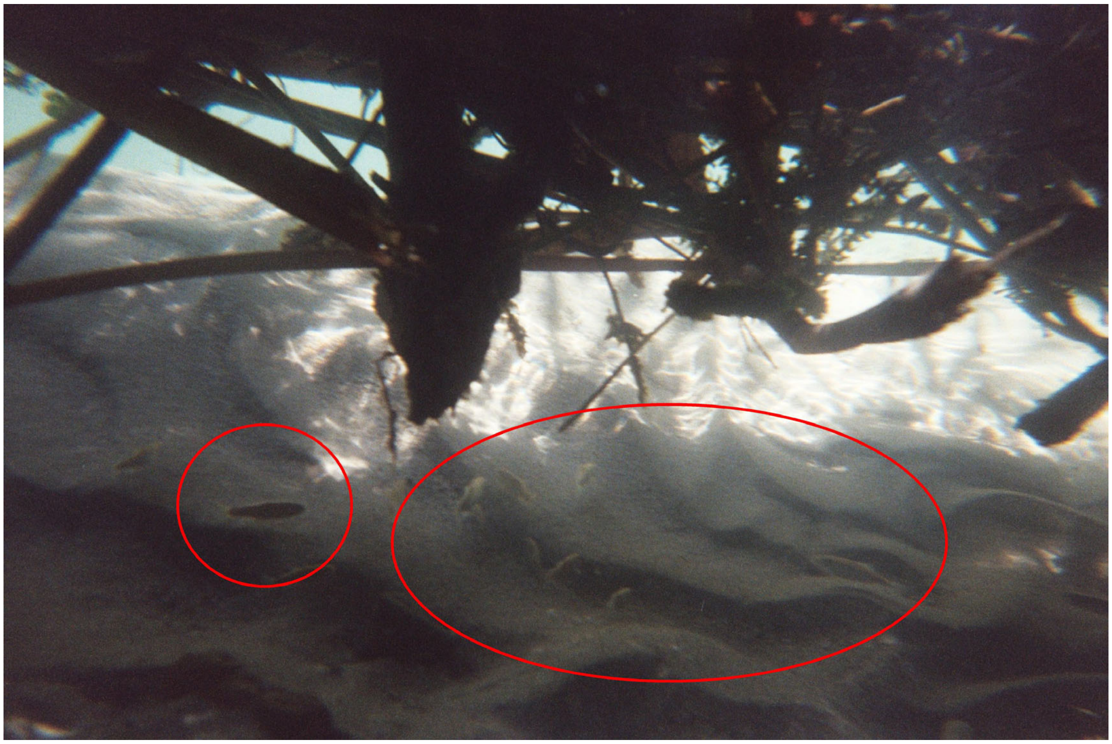


Figure 6.19 This underwater photo was taken along the waters edge in the Salinas River near San Ardo. Here small woody debris has accumulated (top of picture) within this overhanging branch at the river's surface. The result is a depression in the river's sandy bottom due to scour processes underneath the debris. The combination of the two provides shelter for fish (circled in red). Photo: Joel Casagrande, 31 Oct. 02).

6.4 Gabilan Creek

Gabilan Creek flows through the City of Salinas and exits through the Old Salinas River Channel into Moss Landing Harbor at the mouth of Elkhorn Slough. Its watershed is 316 km^2 from its confluence with Tembladero Slough near Highway 183 to its headwaters beneath Fremont Peak in the Gabilan Range (Hager, 2001; Casagrande, 2001). Two major tributaries, Natividad Creek and Alisal Creek, join Gabilan Creek in Carr Lake, which is located in the center of the City of Salinas.

In its headwaters, Gabilan Creek is a perennial stream that flows through steep canyons of maple and sycamore (Fig. 6.20). There is an abundance of downed trees, undercut banks, and other in-stream shelter features. Dominant channel substrate is cobble/boulder. The dominant land use type in the headwaters is natural land with some grazing.

Once the creek enters the valley bottom, strawberry and row crop agriculture become more prevalent. Here willow, cottonwood and sycamore become the dominant riparian species, where vegetation exists (Fig. 6.21). The channel substrate is coarse sand and in some locations, the channel is incised.

The lower reaches, better known as the Reclamation Ditch, are bordered by intensive row crop agriculture and urban development. Here the creek is heavily incised throughout and the banks are commonly lined with rip-rap (Fig. 6.22). The 13-mile system of ditches and shallow lakes that make up the Reclamation Ditch was created in 1917 to drain the swampy marshlands west of the City of Salinas. Now they are used to drain runoff and flood waters that originate in the city of Salinas (RDIPAC, 2001).

Figure 6.20 Gabilan Creek, in its headwaters, at low flow near Fremont Peak. (Photo: Joel Casagrande, 03 Nov 00)

Figure 6.21 Gabilan Creek during moderate flow at the entrance to valley bottom at Crazy Horse Canyon Road. (Photo: Fred Watson Oct 2000)

Figure 6.22 The Reclamation Ditch at San Jon Road near the City of Salinas. (Photo: Joel Casagrnade, Oct 2000)

7 Results: Stream Habitat Assessment

Prior to developing an objective habitat assessment protocol that was used throughout much of the present study, a pre-existing method, created by Dettman and Kelley (1986), was used in various streams during the fall and early winter of 2000 (Hager, 2001). In this section, the results from the two different methodologies are presented separately; first, results from streams assessed using the derived objective method followed by the streams assessed using the Dettman and Kelley Method. During this year's monitoring, several of the streams surveyed in 2000 using the Dettman and Kelley Method were resurveyed using the objective method.

Stream habitat assessment, using the objective method, began in late June 2002 and was completed in late October 2002, with a total of 17 reaches surveyed with a total of 7,138 data points representing streams from a wide range of habitats in 12 different bio-geographic provinces (Figs 7.1 & 7.2 and Tables 7.2 & 7.1). The goal was to assess 500 meters of stream in each reach. However many reaches contained fewer transects due to the absence of water as well as various accessibility issues such as private property and dense poison oak (Table 7.2). The absence of water was noted and is listed in Table 7.3. The time of year was chosen to represent the most limiting conditions for fish. It was the first fall season following back-to-back low rainy years and water levels were naturally at their lowest levels. A final map was created illustrating the primary habitat values, perennial water and fish species distributions for the Salinas Watershed (Fig. 7.3). Data included in this map are:

- Land Cover Classification
- Perennial water
- Fish species present
- Reach Average Water Temperature
- Reach Average Percent Overhead Vegetative Cover
- Reach Average Substrate d_{50}
- Reach Average In-Stream shelter, and
- Reach Average Percent Sediment Filled (Pool Habitats)

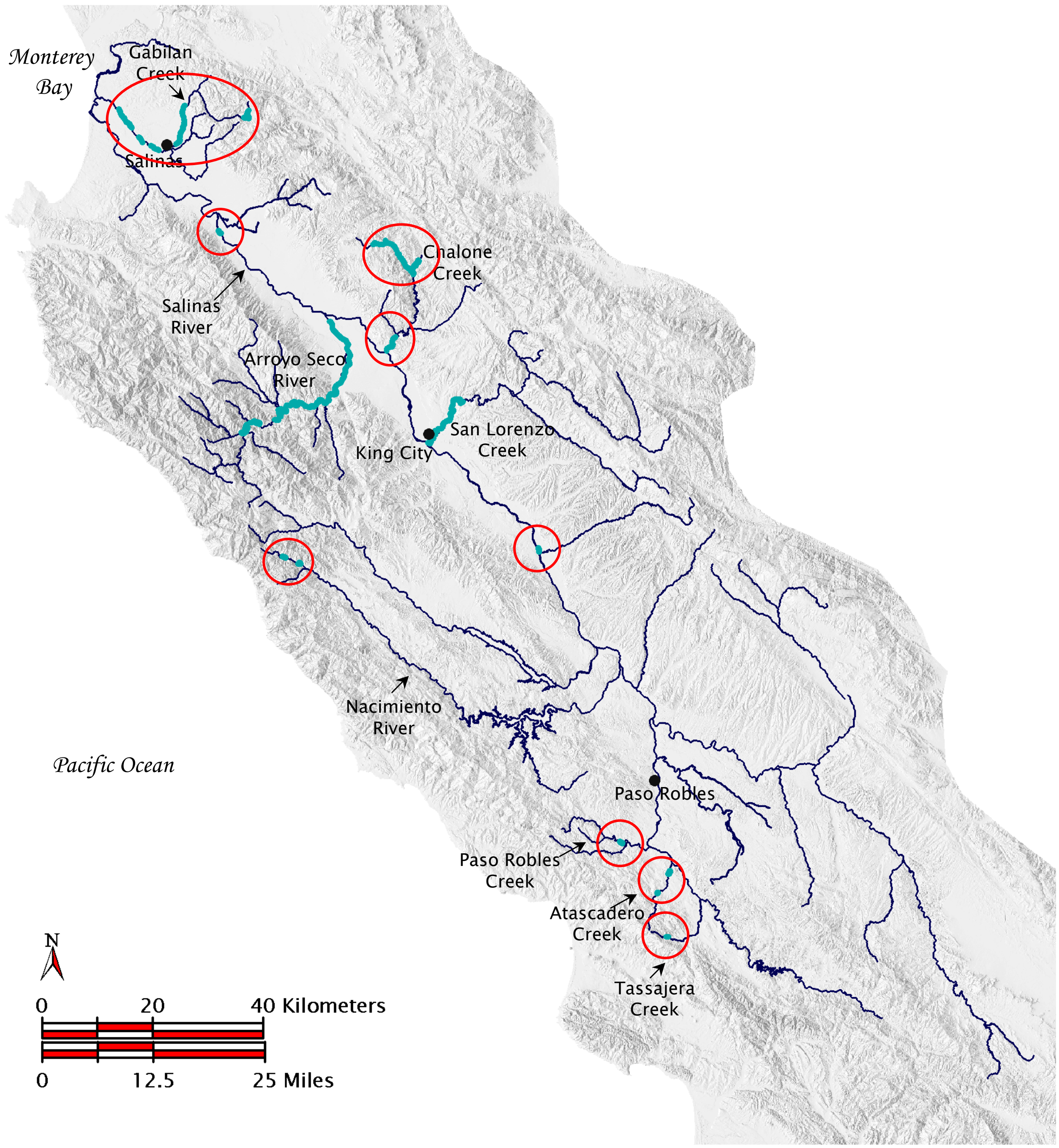


Figure 7.1 Streams surveyed during the present study (light blue); less obvious reaches are highlighted with a red circle. Surveys included a combination of field reconnaissance and/or habitat assessment and/or population assessment.

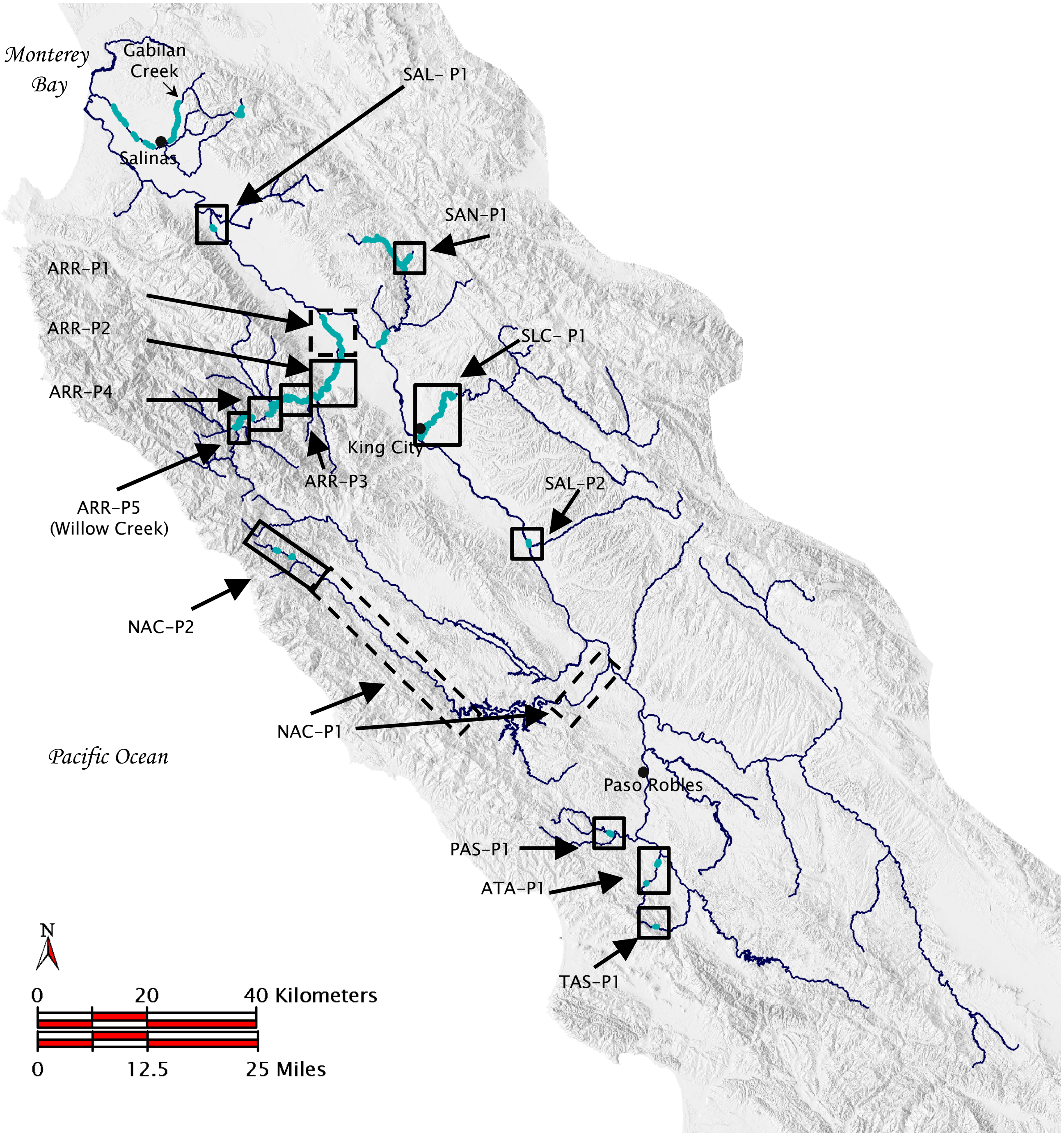


Figure 7.2 This map shows the locations of each bio-geographic province assessed during the present study. Areas outlined with a dashed box were not assessed during the present study.

Table 7.1 The following are descriptions of each of the bio-geographic provinces assessed during the present study.

Province Name	Province Code	General Location/Description
Arroyo Seco River Province 1	ARR-P1	Dry non-perennial reaches downstream of the Clark Colony Water diversion.
Arroyo Seco River Province 2	ARR-P2	Intermittent reaches between the Clark Colony Water diversion and Sycamore Flats.
Arroyo Seco River Province 3	ARR-P3	Perennial reaches between Sycamore Flats and the Government Camp.
Arroyo Seco River Province 4	ARR-P4	Perennial reaches upstream of the Government Camp to the gorge area.
Arroyo Seco River Province 5	ARR-P5	Headwater tributary (Willow Creek)
Nacimiento River Province 1	NAC-P1	Non-perennial reaches both above and below Nacimiento Reservoir.
Nacimiento River Province 2	NAC-P2	Perennial reaches in the headwater areas of the river.
Paso Robles Creek Province 1	PAS-P1	Hidden Valley Ranch
Atascadero Creek Province 1	ATA-P1	In the town of Atascadero.
Tassajera Creek Province 1	TAS-P1	Just downstream of the Los Padres National Forest eastern boundary.
Sandy Creek Province 1	SAN-P1	Perennial reach near Pinnicles Nat. Mon.
Salinas River Province 1	SAL-P1	Lower river near Chualar.
Salinas River Province 2	SAL-P2	Middle section of the river near San Ardo.

Figure 7.3 This map contains the primary data used to assess stream habitat quality as well as fish species distributions in the Salinas Watershed. A poster-sized (42"x50") format of this map is available at: http://science.csumb.edu~ccows

Table 7.2 Date and location of stream reaches surveyed for both habitat and population assessments.

Stream	Province	Reach	# of Transects	Date	Location (See Fig. 7.1
Arroyo Seco River	2	1	49	25 Jul 2002	Downstream of Elm St. bridge
Arroyo Seco River	2	2	49	27 Aug 2002	Downstream of Sycamore Flats
Arroyo Seco River	3	1	50	19 Jul 2002	Near Govt. Campground
Arroyo Seco River	3	2	50	04 Sep 2002	Upstream of Miller's Lodge
Arroyo Seco River	4	1	50	22 Jul 2002	Upstream of Rocky Creek confluence
Arroyo Seco River	4	2	50	07 Aug 2002	Upstream of Santa Lucia confluence
Willow Creek (tributary to Arroyo Seco River)	5	1	50	21 Aug 2002	Near confluence with the Arroyo Seco River
Nacimiento River (Upper)	2	1	50	06 Sep 2002	Near summit ranger station
Nacimiento River (Upper)	2	2	50	11 Sep 2002	Near Nacimiento Campground
Paso Robles Creek	1	1	50	19 Sep 2002	Hidden Valley Ranch
Atascadero Creek	1	1	11	03 Jul 2002	Near HWY 41 crossing
Atascadero Creek	1	2	43	18 Oct 2002	Near US HWY 101 Crossing
Tassajera Creek	1	1	18	05 Aug 2002	Near Los Padres National Forest East Boundary
Sandy Creek	1	1	50	03 Oct 2002	Pinnacles Campground (private) south end
Sandy Creek	1	2	50	11 Oct 2002	Pinnacles Campground (private) north end
Salinas River @ Chualar	1	1	50	26 Sep 2002	At Chualar River Rd.
Salinas River @ San Ardo	2	1	50	24 Oct 2002	Near San Ardo Bridge

7.1 Non-sediment Habitat Variables

7.1.1 Overhead Vegetative Cover

In general, streams with a high percentage of overhead-vegetative cover resulted in lower stream water temperatures (i.e. Nacimiento River and Sandy Creek) (Fig. 7.4). However, some reaches did not follow this correlation due to various human induced factors, such as concrete overpasses, Dam release water, and naturally low water levels in streams where flow ceased or almost ceased. For instance, at Atascadero Creek (Reach 1-2), a significant amount of the transects were measured under two broad highway overpasses, thus being shaded throughout the day. Concrete overpasses, buildings and other non-vegetative forms of cover were not recorded as "Overhead Vegetative Cover", although they do provide a source of shade for the stream. Instead, they were noted as concrete or bridge. Besides moderating temperature, vegetative cover provides several other benefits to an aquatic ecosystem such as, a source for terrestrial insects and leaf litter detritus, both of which fall into the stream and become important resources for fish and benthic macro-invertebrates.

In the Salinas River, similar cool water temperatures (Table 7.3) at San Ardo and at Chualar were the result of Dam releases. Water from both Lake Nacimiento and Lake San Antonio is released from the bottom of the reservoir where water temperatures stay cold year round. Temperatures remained cool even with limited shade cover.

Scatter towards the left end of Figure 7.4 may be attributed to the temporal variation for temperature readings.

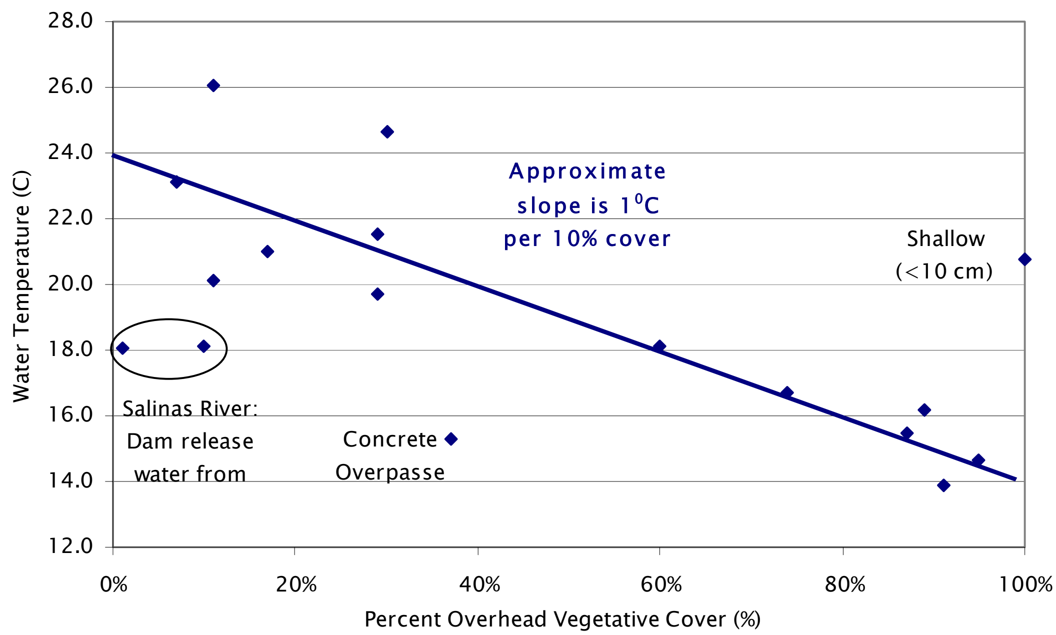


Figure 7.4 Reach average percent overhead vegetative cover versus reach average water temperature.

7.1.2 Channel Width

Another habitat factor that may influence temperature and percent overhead vegetative cover is channel width. Figure **Error! Reference source not found.**, suggests that both water temperature and overhead vegetative cover are dependent on channel width. For example, in Figure 2.9 the Salinas River's width (~ 30 m) is too large for mature riparian vegetation to cover more than 10-15 % of its width at low water levels. This means that 85-90% of the river is exposed to the solar heating, thus raising the water temperature. This is also true for the lower reaches of the Arroyo Seco River.

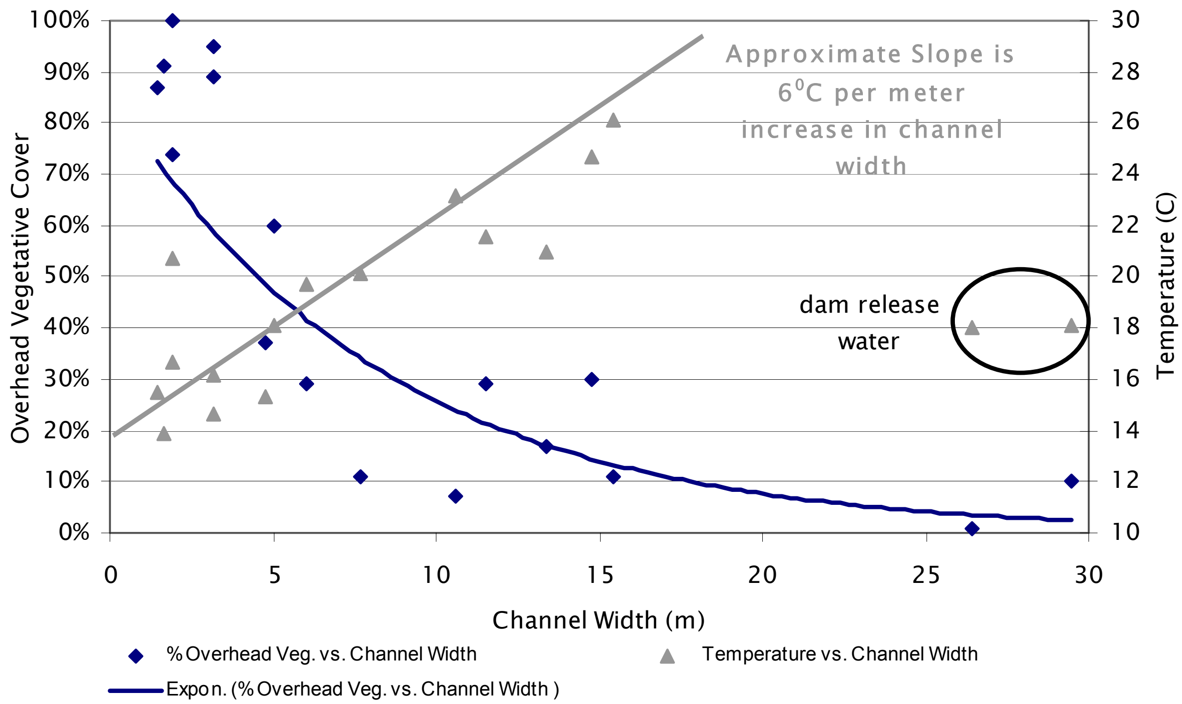


Figure 7.5 Percentage overhead vegetative cover and reach average temperature (°C) vs. channel width (m).

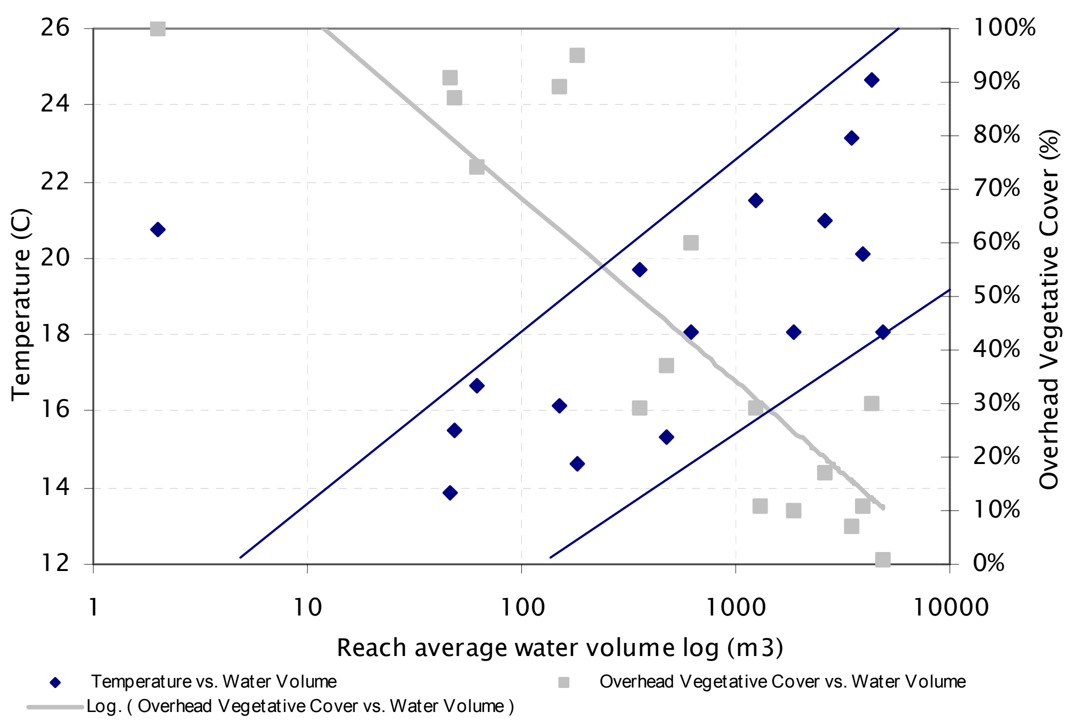


Figure 7.6 Reach average temperature and percent-vegetated overhead cover vs. reach average water volume.

7.1.3 Water Temperature

Water temperature was only measured in the thalweg at the surface. However, subsurface waters, especially in deep pools, were cooler. The mean water volume for each reach was estimated using mean transect widths and depths (Table 7.3). Figure 7.6 suggests that a positive correlation exists between reach average water temperature and water volume and a negative correlation between percent overhead vegetative cover and reach water volume.

In summary, wide stream reaches with higher water volumes during low flow conditions are warmer and less covered by overhead vegetation. Conversely, narrow stream/river reaches with smaller water volumes during low flow are cooler and significantly more shaded by overhead vegetation.

7.1.4 In-stream Shelter

In-stream shelter values for each reach represent the average of all transects surveyed within a particular reach. At each transect, the presence of any and all of the following habitat characteristics or combinations were noted:

- large woody debris (≥ 12 in diameter and ≥ 6ft in length)
- boulders
- bubble curtains
- undercut banks
- braches near the water
- root wads
- root balls
- bedrock ledges
- submersed vegetation

All reaches of stream surveyed contained moderate to good levels of in-stream shelter (Table 7.3). In-stream shelter values ranged from 1.5 (max. is 3) in the upper reach of Atascadero Creek to a 2.04 in the Arroyo Seco River near the Campground Day Use Area.

Table 7.3 Reach average values for all non-sediment related habitat attributes for Salinas Watershed streams surveyed during a dry period (Fall 2002).

Stream	Province – Reach	Reach Length (m)	# of Transects Assessed	Wetted Reach Width (m)	Reach average volume (m^3)	% Of Transects in riffle habitat (%)	% Of Transects in pool habitat (%)	% of Transects in run habitat (%)	% of Transects in glide habitat (%)	% of Transects in cascade habitat (%)	% Of Transects Dry (%)	Temp (°C)	Mean Water Depth (m)	Maximum Water Depth (m)	Thalweg Velocity (m/s)	Overhead Vegetation Cover (%)	Avg. In-Stream Shelter Value (0–3; 0=none, 3=excellent)
Arroyo Seco	2–1	490	49	15.4	1309	42.9	4.1	53.1	0.0	0.0	0.0	26.1	0.18	0.60	0.087	11	2.00
Arroyo Seco	2–2	490	49	13.4	2617	8.2	65.3	24.5	2.0	0.0	0.0	21.0	0.33	1.90	0.056	17	2.00
Arroyo Seco	3–1	500	50	14.8	4299	14.0	46.0	38.0	0.0	0.0	0.0	24.7	0.45	1.75	0.167	30	2.04
Arroyo Seco	3–2	500	50	11.5	1239	20.0	16.0	56.0	8.0	0.0	0.0	21.5	0.19	1.41	0.132	29	2.02
Arroyo Seco	4–1	470	47	10.6	3486	19.2	55.3	21.3	4.3	0.0	0.0	23.1	0.64	1.85	0.180	7	1.96
Arroyo Seco	4–2	500	50	7.7	3910	30.0	54.0	12.0	2.0	0.0	0.0	20.1	0.91	5.54	0.171	11	1.85
Willow Creek	5–1	500	50	5.0	619	36.0	24.0	26.0	12.0	0.0	0.0	18.1	0.23	0.82	0.27	60	2.00
Nacimiento River (upper)	2–1	500	50	3.2	182	40.0	24.0	36.0	0.0	0.0	0.0	14.6	0.12	0.55	0.252	95	1.86
Nacimiento River (upper)	2–2	500	50	3.1	149	22.0	18.0	46.0	10.0	0.0	0.0	16.2	0.10	0.80	0.187	89	2.00
Paso Robles Creek	1–1	500	50	6.0	353	0.0	38.0	0.0	0.0	0.0	62.0	19.7	0.26	0.95	0.00	29	1.74
Atascadero Creek	1–1	110	11	1.91	2.0	27.0	18.0	0.0	0.0	0.0	55.0	20.8	0.04	0.15	0.000	100	1.50
Atascadero Creek	1–2	430	43	4.8	475	14.0	51.2	27.9	7.0	0.0	0.0	15.3	0.21	1.10	0.096	37	1.93
Tassajera Creek	1–1	180	18	1.88	61.4	16.7	22.2	55.6	0.0	5.6	0.0	16.7	0.13	0.85	0.176	74	1.88
Sandy Creek	1–1	500	500	1.65	46.8	32.0	14.0	52.0	2.0	0.0	0.0	13.9	0.06	0.20	0.156	91	1.98
Sandy Creek	1–2	500	500	1.47	48.7	36.0	18.0	46.0	0.0	0.0	0.0	15.5	0.06	0.28	0.125	87	2.00
Salinas River @ Chualar	1–1	500	500	26.5	4876	0.0	0.0	100	0.0	0.0	0.0	18.0	0.39	1.20	0.545	1	1.94
Salinas River @ San Ardo	2–1	500	500	29.5	1855	10.0	0.0	90.0	0.0	0.0	0.0	18.1	0.13	0.67	0.487	10	1.91

Table 7.4 Reach average values for sediment related habitat attributes for Salinas Watershed streams surveyed during a dry period (Fall 2002). Sandy Creek and Salinas River data are shown as NA because the method is inapplicable for streams with no underlying hard layer.

Stream	Province – Reach	Reach Length (m)	# of Transects Assessed	Wetted Reach Width (m)	Bottom Substrate d_{50}	Reach Average sediment accumulation (cm)	Reach Average % sediment filled	Avg. sediment accumulation in riffles habitat (cm)	Average % sediment filled riffle habitat	Avg. sediment accumulation in pool habitat (cm)	Average % sediment filled pool habitat	Avg. sediment accumulation in run habitat (cm)	Average % sediment filled run habitat	Avg. sediment accumulation in glide habitat (cm)	Average % sediment filled glide habitat
Arroyo Seco	2–1	490	49	15.4	Gravel	2.7	14.8	2.34	19.7	2.15	5.0	2.95	11.6	–	–
Arroyo Seco	2–2	490	49	13.4	Gravel	4.8	13.1	0.93	9.9	6.34	13.2	2.10	13.9	2.40	15.9
Arroyo Seco	3–1	500	50	14.8	Gravel	1.1	9.4	1.68	12.4	6.63	7.7	2.71	10.5	–	–
Arroyo Seco	3–2	500	50	11.5	Gravel	3.6	16.4	2.08	22.6	8.04	15.7	2.98	14.8	3.35	14.7
Arroyo Seco	4–1	470	47	10.6	Cobble	5.9	7.3	0.91	5.1	9.71	9.0	1.00	3.0	5.89	16.8
Arroyo Seco	4–2	500	50	7.7	Cobble	3.6	5.3	1.14	5.6	5.78	5.0	1.66	5.4	2.40	8.4
Willow Creek	5–1		50	5.0	Gravel	2.8	10.1	1.63	9.7	5.18	12.2	2.32	8.7	2.53	10.2
Nacimiento River (upper)	2–1	500	50	3.2	Gravel	3.9	22.6	2.30	23.8	8.78	24.5	2.43	20.0	–	–
Nacimiento River (upper)	2–2	500	50	3.1	Gravel	2.9	21.2	1.26	13.3	4.35	17.9	2.46	24.0	6.26	33.0
Paso Robles Creek	1–1	500	50	6.0	Gravel	12.8	36.4	–	–	12.84	36.4	–	–	–	–
Atascadero Creek	1–1	110	11	1.91	Cobble	3.9	44.3	5.00	50.0	3.30	41.5	–	–	–	–
Atascadero Creek	1–2	430	43	4.8	Gravel	10.8	28.7	3.38	33.3	16.06	31.8	6.11	24.0	5.60	15.2
Tassajera Creek	1–1	180	18	1.88	Gravel	3.2	20.0	4.70	42	5.37	13.1	2.15	18.0	–	–
Sandy Creek	1–1	500	500	1.65	Sand	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sandy Creek	1–2	500	500	1.47	Sand	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Salinas River @ Chualar	1–1	500	500	26.5	Sand	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Salinas River @ San Ardo	2–1	500	500	29.5	Sand	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

– No data available for this attribute

7.2 Streambed Sediment: d_{50}, Accumulation and Percent Filled

At each of ten points per transect, an objectively selected sediment particle size was measured along its intermediate axis. Reach average values for the median sediment particle size (d_{50}) were calculated and are listed by size category (e.g. sand, gravel, cobble, boulder or bedrock) in Table 7.4. Appendix B contains reach specific sediment size class distributions.

In general, sandy streams included the Salinas River and Sandy Creek. Gravel dominated streams or reaches included the lower reaches of the Arroyo Seco River near Elm Ave, both reaches in the Nacimiento River, Willow Creek, and the southern west side streams, Tassajera, Paso Robles and Atascadero Creeks. Cobble was the median substrate in the upper reaches of the Arroyo Seco River near the Santa Lucia Creek confluence and the upper reach of Atascadero Creek. Bedrock was common throughout the Arroyo Seco River especially near Sycamore Flats (Reach 2-2). Bedrock was also found in moderate quantities in lower Atascadero Creek (Reach 1-2), and Tassajera Creek-See Appendix B.

Both the Salinas River and Sandy Creek did not have detectable hard sub-surface sediment layers using the rod penetration technique. The Salinas River and Sandy Creek may have always had such thick layers of fine sized alluvium. Therefore, the “accumulation” of fine sediments from anthropogenic or natural sources, is not meaningfully indicated by sediment accumulation measurements.

In Figure 7.7 the reach average sediment accumulation (RASA) is highest when the reach average d_{50} is small. Figure 7.8 shows reach average sediment accumulation for each habitat type (e.g. riffle, pool, run etc.) for all streams except for the Salinas River and Sandy Creek. For most reaches, pool habitats had significantly higher accumulations than run, riffle, and glide habitats with the exception of the Arroyo Seco River downstream of the Elm Ave Bridge (Reach 2-1), which is located below an active in-stream mining operation. This reach had low sediment accumulation values for all habitat types.

RASA in pools (Fig. 7.9), excluding the Salinas River and Sandy Creek, ranged from 2 cm in the lower Arroyo Seco River to 16 cm in the upper reach of Atascadero Creek. RASA in riffle habitat ranged from less than 1 cm in the

Arroyo Seco River near the Rocky Creek confluence to 5 cm in the lower reach of Atascadero Creek. RASA in run habitat ranged from 1 cm in the Arroyo Seco River near the Santa Lucia confluence to 6.1 cm in the upper reach of Atascadero Creek. Glide habitat, had accumulations ranging from 2.4 cm in two reaches of the Arroyo Seco River (Table 7.4) to 6.3 cm in the Nacimiento River.

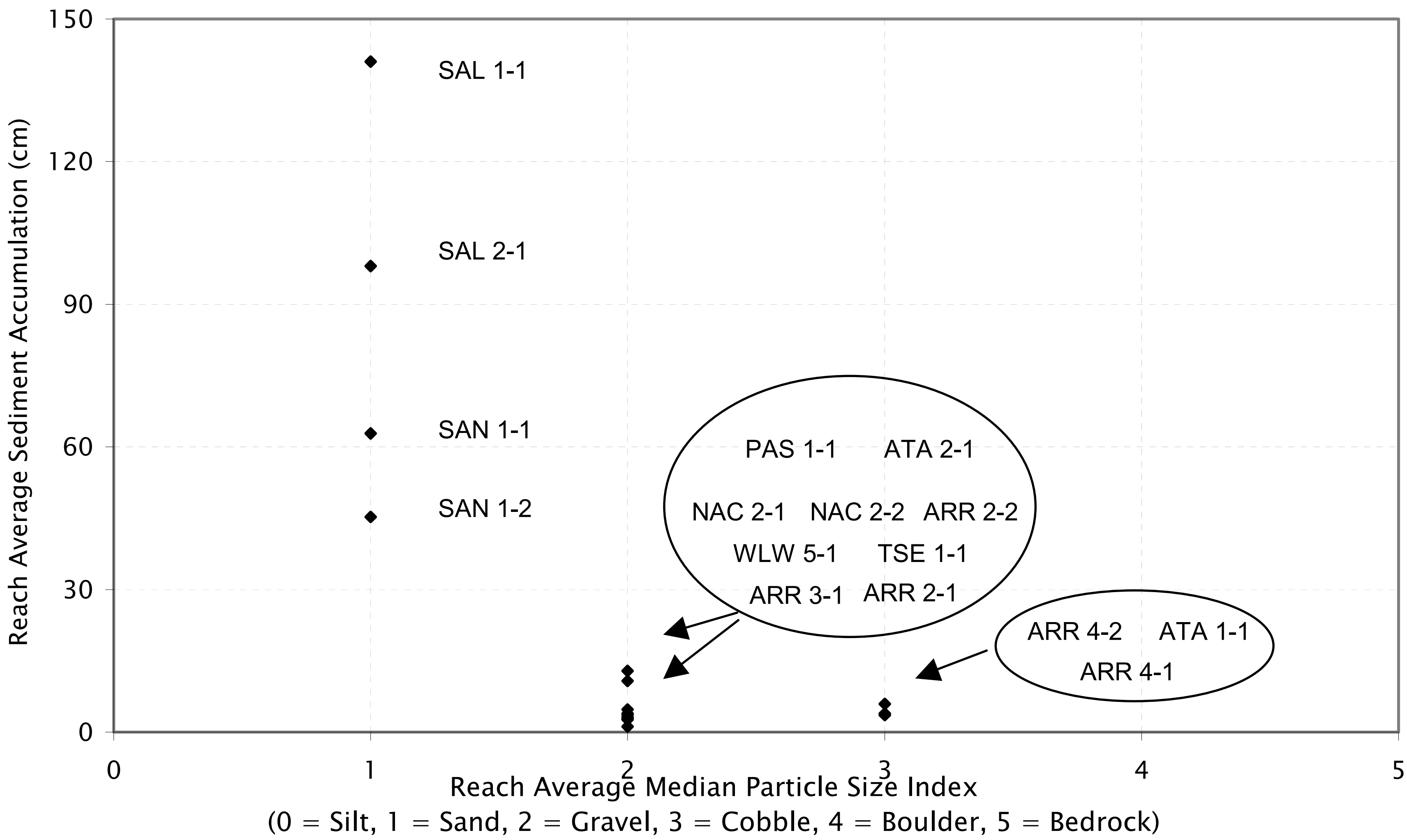


Figure 7.7 Average median particle size vs. the average sediment accumulation.

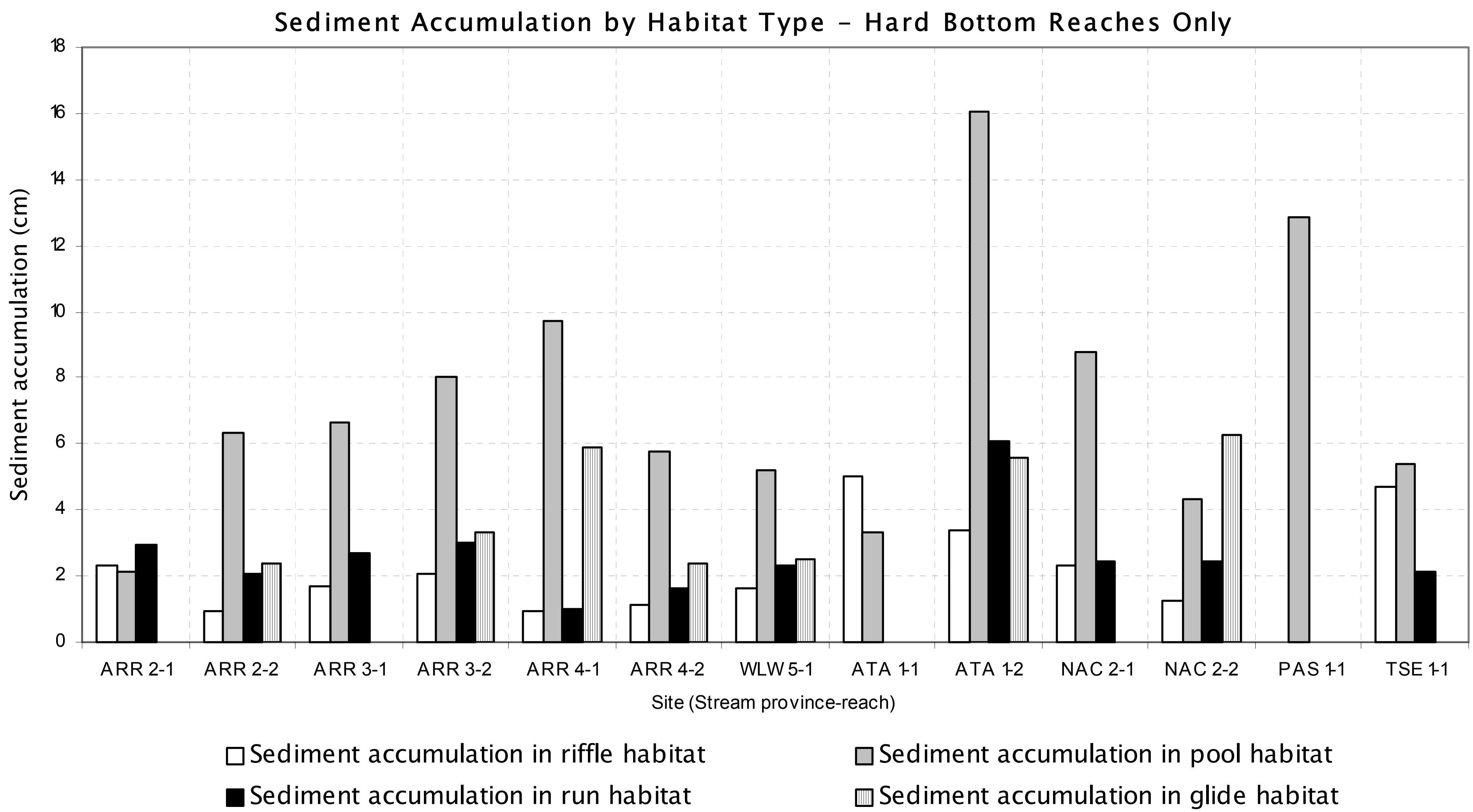


Figure 7.8 Average sediment accumulation for individual microhabitat types for all stream reaches assessed except for the Salinas River and Sandy Creek.

The degree of sedimentation of a site may be better quantified by the *percentage* of the total depth filled by fine sediment. Reach average percent filled (RAPF) was calculated as:

$$RAPF_r = \sum_{t=1}^{50}\sum_{p=1}^{10}\frac{S_{r,t,p}}{S_{r,t,p}+W_{r,t,p}}$$

Where $S_{r,t,p}$ is the depth of fine sediment at point p within transect t within reach r, and $W_{r,t,p}$ is the water depth at point p within transect t within reach r.

Figure 7.10 is the reach average percentage of the stream habitat type filled with sediments, or reach average percent filled. This is defined by dividing the sediment accumulation depths (top of sediments to hard bottom) by the total depth (surface of the water to the hard bottom). Several reaches measured had higher RAPF in riffle habitats (Fig. 7.10). This is because riffle habitats are shallow, thus the habitat volume available is smaller. For example, a riffle with a depth of 20 cm may only have an accumulation of 5 cm, thus resulting in a 20% fill.

In general, the highest percent accumulations were measured in low-gradient, shallow reaches. Reaches with low mean water depth (< 0.20 m) (Table 7.3) such as ARR 2-1, ARR 3-2, ATA 1-1, and TSE 1-1 all had moderate to high percent sediment filled in riffle habitats with respect to other habitat types (Fig. 7.10). Both reaches measured in the Nacimiento River had low mean water depths and moderate RAPF values in riffle habitats. However NAC 2-1 had slightly higher percentage filled in pool habitat and NAC 2-2 had higher RAPF values in all habitat types, especially glides.

In reaches where glide habitats were measured it was not uncommon to find that RAPF values were highest in this habitat type (i.e. ARR 2-2, ARR 4-1, ARR 4-2, and NAC 2-2) (Table 7.3 & Fig. 7.10). Glide habitats are generally found at the downstream edge of pools or deep runs where depths are generally shallower. Like riffles, high percentages of this habitat have accumulations of sediment. This is possibly a result of depositional processes associated with lower water velocities exiting pools and runs, where as with riffles it is more a function of shallow water depth. Glides where not measured in every reach, mainly because they often fell between transects.

Pool habitats, generally the deepest habitat type, had low to moderate RAPF values (Fig. 7.10). However, in most reaches this habitat type did have the highest RASA values (Fig. 7.8). Pools tend to be depositional environments, especially during times a receding streamflow. However, in most cases the larger depths can compensate for sediment accumulations. An example of this can be seen in Figure 7.9. This pool, in Willow Creek, has lost some of its residual volume to sediment accumulation – primarily sands and gravels.

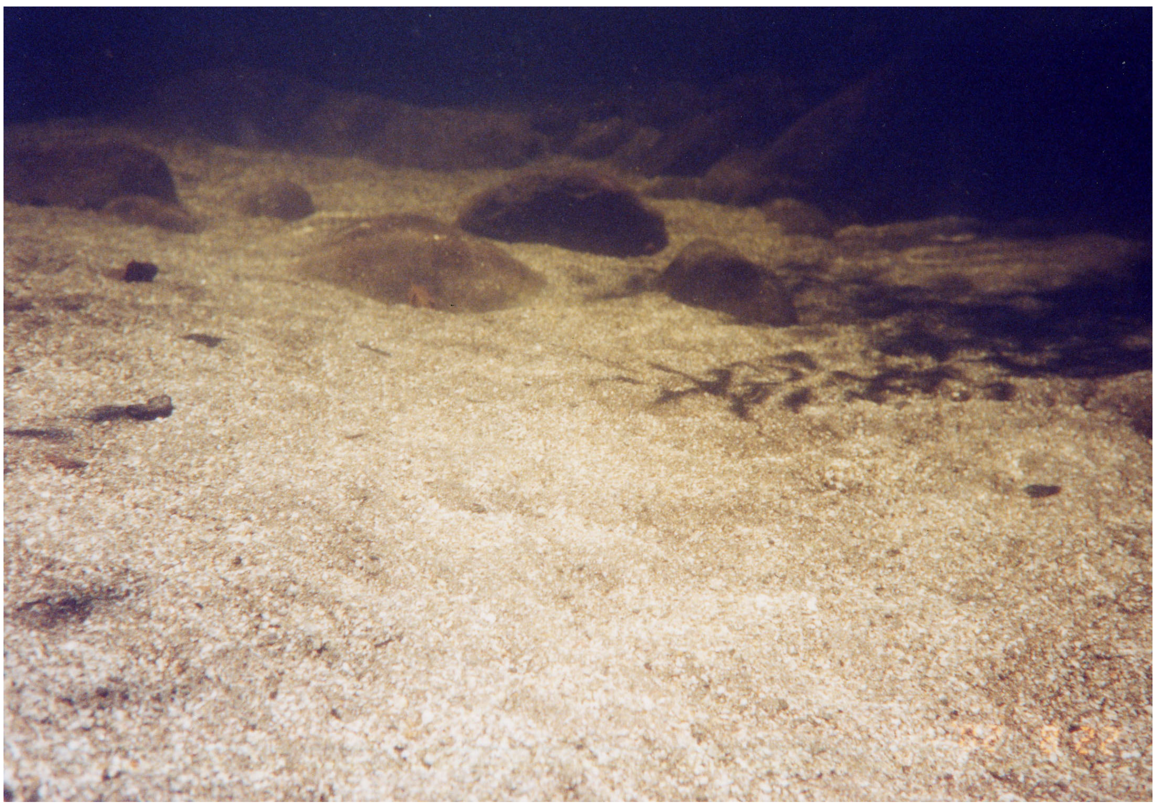


Figure 7.9 This underwater photo shows fine sediment accumulation in a pool in Willow Creek. Note the embedded boulders and cobbles in the background. (Photo: Joel Casagrande, 22 Aug 02)

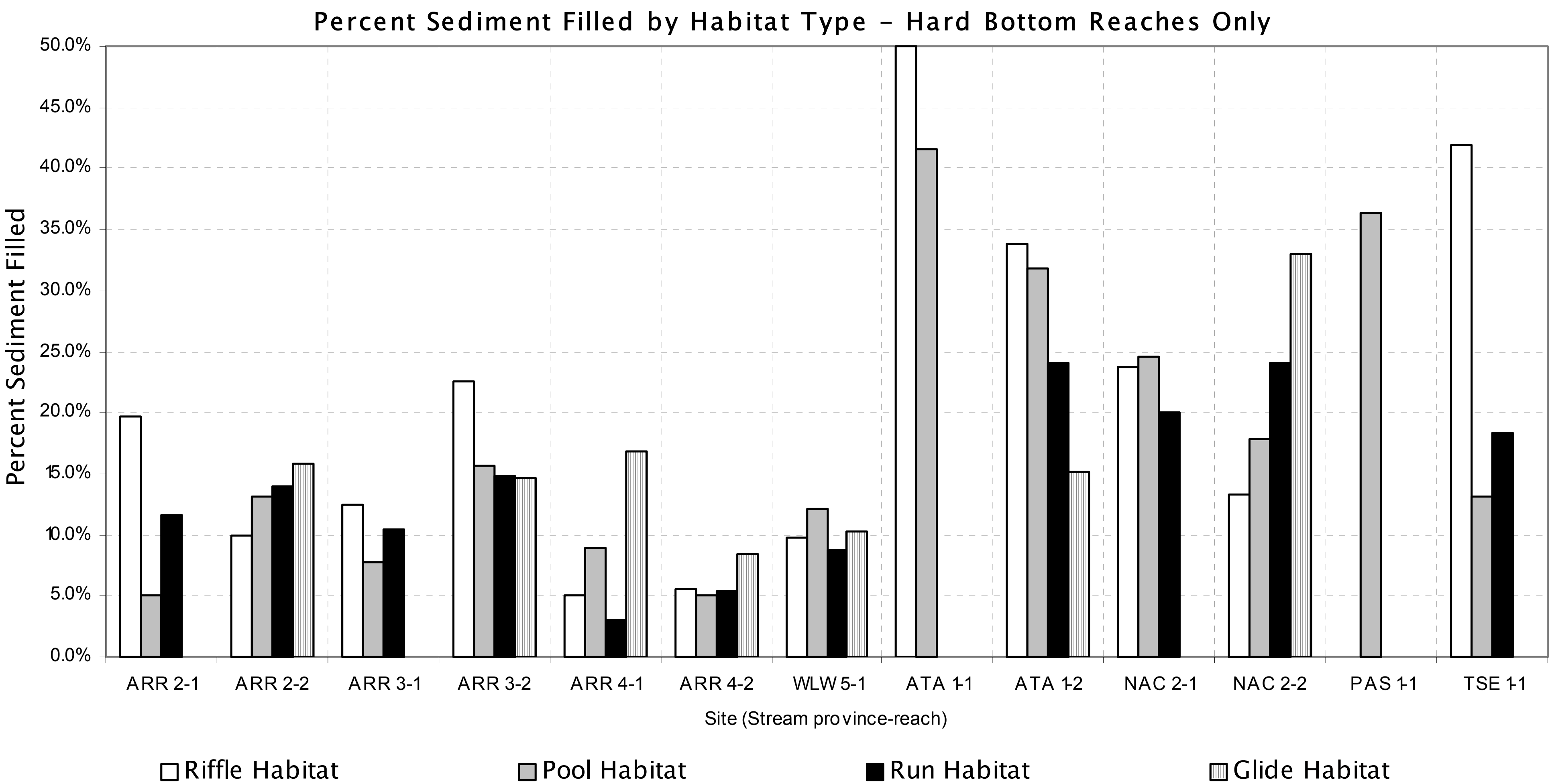


Figure 7.10 Reach average percent sediment filled by habitat type as defined by the measure of sediment accumulation or fill by the overall total depth (from the surface of the water to the bottom of the accumulated sediments).

7.3 Gabilan Creek (Dettman and Kelley Habitat Assessment)

From the reconnaissance work it was determined that the most appropriate location to perform Dettman and Kelley's habitat assessment was within the headwaters of Gabilan Creek. Five sites, containing a total of 46 patches, spanning a total 117 meters of stream length, were selected within the upper most reaches of the creek. Here, Gabilan Creek flows through a steep canyon surrounded by grazed grasslands.

Within each of the five locations, large woody debris, undercut banks, root wads, and abundant overhead canopy providing adequate shade and cover were present. Habitat assessment was conducted for these five sites using the RIYOYP (Dettman and Kelley 1986). The results for these five reaches are summarized in Table 7.5. Throughout all five of the sections, cover was abundant and received high ratings (usually 2 on a 0 to 3 scale). Roughness varied throughout the reaches depending on the amount of pools and riffles within each section. Pools generally received lower ratings, as they often lacked significant roughness. The average cobble abundance within the five habitats was 22%, and the average embeddedness was 26%. The average pool depth was 0.25 meters.

Unfortunately time did not permit the comparison of the two methodologies.

Table 7.5 Gabilan Creek Habitat Assessment Summary

Location	Reach Length (m)	Avg. Cobble Abundance	Avg. Cobble Embeddedness	Avg. Pool Depth (m)	Rearing Index (Computed Using Microsoft Access)	Estimated Density (# fish per meter)
Site 1	44.00	18%	21%	0.24	4182	1.58
Site 2	14.00	14%	30%	0.16	1767	2.02
Site 3	12.85	23%	35%	0.34	1121	1.47
Site 4	21.90	33%	26%	0.22	1300	1.08
Site 5	24.60	24%	18%	0.31	2525	1.72

7.4 Future changes to Habitat Assessment

A limitation with the habitat assessment method used during the present study was the length of reach measured and the spacing of transects for each stream. Individual habitat types (i.e. riffle, run, pool) may not have been measured in both large and small streams. For example, in the Salinas River, a single run habitat type may extend 500-600 meters in length; therefore a 500-meter reach may have not been practical for detecting different habitat types. Instead, a 1000-5000 meter reach with transects every 20-100 meters may be more ideal. For smaller, headwater streams, a 500-meter reach may be too much. In steeper and smaller streams, such as the upper Nacimiento River where habitat types change within a few meters, a 100-200 meter reach with transects spaced more closely together (i.e. 2-4 meters apart) may prove to be more useful.

One method that could be used would be to base the length of stream reach and the spacing of transects on the slope of the channel – channel A has a slope of S therefore the reach should be X meters long and spacing between transects shall be Y meters apart.

8 Results: Population Assessment

Stream population assessment was conducted in all 17 reaches. This resulted in the identification of 11 species (8 native and 3 non-native). Figure 8.1 lists the species observed in the Salinas Watershed and the total number of reaches (out of 17) in which they were found. Table 8.1 lists the species codes used in this report. Table 8.2 summarizes the native species observed in streams of the Salinas Watershed and Table 8.3 summarizes the observed non-native species. Figure 7.3 provides a spatial illustration of fish species distribution observed in the Salinas Watershed during the present study. Some species were encountered incidentally during other non-related monitoring and were also noted in these summaries as noted. Appendix A contains reach-specific population results.

The methodology used to determine the population for a given reach of stream employed using a combination of snorkel and bank-side observations. Due to the nature of the assessment not every species known to inhabit the Salinas Watershed was seen. These missing species may include riffle sculpin, Sacramento blackfish, as well as a variety of non-native species. There are limitations to what a diver can see underwater without the use of SCUBA equipment due to depth, temperature, and health precautions. Species identification was determined by using the descriptions stated in Section 3. Sizes categories, or fish length given for rainbow trout and Sacramento pikeminnow, were estimated by comparing objects of known length to the fish while underwater. The following values are to be used as population indexes or references and not as actual population totals.

Techniques that would improve the accuracy of the population assessment include:

- SCUBA
- Netting
- Electro-shocking

The latter two were precluded by National Marine Fisheries Service delays of over two years in obtaining the necessary permits.

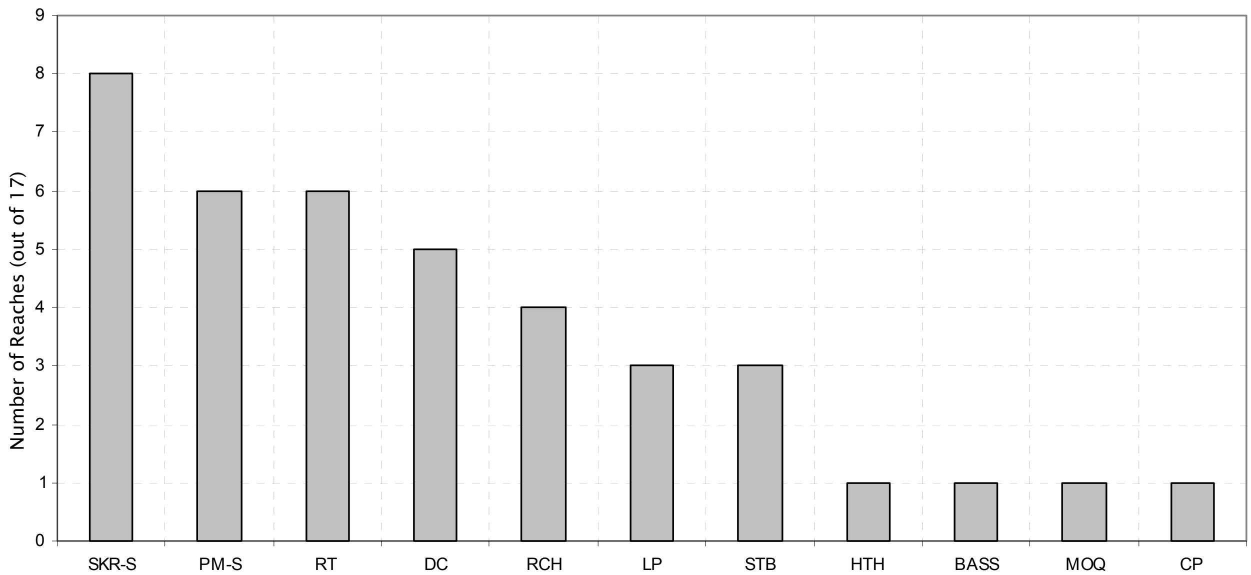


Figure 8.1 Number of reaches in which each species was observed in during population surveys from the summer and fall of 2002. This does not include incidental sightings.

Table 8.1 Species codes used for fish species observed in the Salinas Watershed.

Species Code	Species Common Name
SKR-S	Sacramento sucker
PM-S	Sacramento pikeminnow
RT	Rainbow trout
DC	Speckled dace
RCH	Monterey roach
LP	Pacific lamprey
STB	Threespine stickleback
HTH	Hitch
BASS	bass
MOQ	Mosquitofish
CP	Common Carp

Table 8.2 Native fish species observed in streams of the Salinas River Watershed during summer and fall of 2002.

Fish Species	Assemblage	Gabilan Creek/ Rec.Ditch	Arroyo Seco River	Nacimiento River (Upper)	Paso Robles Creek	Atascadero Creek	Tassajara Creek	Sandy Creek	Salinas River
Rainbow Trout	Trout-Dace	X*	X	X					
Sac. Pikeminnow	Pikeminnow -Sucker	X**	X						
Sac. Sucker	Pikeminnow -Sucker	X**	X			X			X
Monterey Roach	Roach	X*	X		X	X			X
Speckled Dace	Trout-Dace		X					X	
Hitch	Pikeminnow -Sucker	X**							X
Threespine Stickleback	Pikeminnow -Sucker		X**		X			X	X
Pacific Lamprey	All		X		X				X

X Observed during population assessment.
X* Observed alive but not during population assessment.
X** Observed dead not during population assessment.

Table 8.3 Non-native fish species observed in streams of the Salinas Watershed during summer and fall of 2002.

Fish Species	Assemblage	Gabilan Creek/ Rec.Ditch	Arroyo Seco River	Nacimiento River (Upper)	Paso Robles Creek	Atascadero Creek	Tassajara Creek	Sandy Creek	Salinas River
Bass	Non-Native (Trout-Dace)		X						
Mosquitofish	Non-Native (Roach)				X				
Carp	Non-Native (Roach)	X*/X**				X			

X Observed during population assessment.
X* Observed alive but not during population assessment.
X** Observed dead not during population assessment.

8.1 Rainbow Trout/ Steelhead

Rainbow trout were found in three streams surveyed during the course of this study – Arroyo Seco River, Willow Creek and the Nacimiento River above Lake Nacimiento. In both the Arroyo Seco and Nacimiento Rivers three different age classes were observed. No live steelhead were observed in any stream within the watershed. However, population assessments were made during the summer and fall, which are times of year when steelhead are not likely to be present. Although, an adult male salmonid skeleton was found in the dry sandy reach of the Arroyo Seco River during field reconnaissance of late summer of 2001 (Fig. 8.2).

Arroyo Seco River and Willow Creek

Rainbow trout were observed in the Arroyo Seco River from the Government Camp to the gorge near the Willow Creek confluence. Due to the large width and depth of Arroyo Seco River it is assumed that the majority of the trout present were not seen. However, 10 trout greater than 15 cm were observed in the upper reaches of the river with an additional 9 in Willow Creek. The majority of the trout, especially the larger ones, observed in the Arroyo Seco River were found in riffle habitat with abundant shelter in the form of large cobbles, boulders and or logs. Several younger and smaller trout were observed in small to medium sized pools where incoming riffles created bubble curtains as shelter. Trout densities were relatively low (Table 8.4) for all reaches of Arroyo Seco when compared to the upper Nacimiento River and the Carmel River. This difference may be real, or it may be biased by differences in the snorkeling survey.

Nacimiento River (upper)

Rainbow trout were abundant in the upper Nacimiento River and were the only species observed in two 500 m reaches of stream. A few of the larger pools contained approximately 40 young-of-the-year per pool. Significant trout densities were observed in the both reaches. Their densities were 38 and 33.4 trout/100 m respectively. These estimates compare well with estimates conducted in 1981 by the United States Forest Service (USFS) (Titus et al. 2000) which reported a visual estimate of 39 trout/100 m in the upper Nacimiento River. Only two trout greater than 15 cm in estimated length were observed in the Nacimiento River and most trout were less than 8 cm in estimated length.

Figure 8.2 A skeleton of an adult male salmonid, most likely a steelhead, found in the lower Arroyo Seco River between Thorne Rd. and Arroyo Seco River Rd. Note the hooked lower jaw (lower center), teeth and the overall size – all indicating that this fish had been to the sea. Total length was estimated at 26 inches. (Photo: Julie Hager, August 2001)

Table 8.4 Rainbow trout densities for all reaches where trout were observed. Sizes classes are estimated lengths.

Species	Stream	Reach	# of trout ≤ 3”	# of trout 3”–6”	# of trout ≥ 6”	Total Number	Density (# per 100 m)
 Rainbow Trout	Arroyo Seco River	3–1	0	3	0	**3**	0.6
	Arroyo Seco River	4–1	0	13	5	**18**	3.8
	Arroyo Seco River	4–2	0	4	5	**9**	1.8
	Willow Creek	5–1	0	1	9	**10**	2
	Nacimiento River	2–1	147	48	0	**190**	38
	Nacimiento River	2–2	150	15	2	**167**	33.4

(Photo: Joel Casagrande; 19 Jul 02)

Gabilan Creek (Dettman and Kelley Population Index Results)

Rainbow trout were the only species observed – although sightings were not required for the RIYOYP. The habitat data collected was entered into RIYOYP, which calculated a rearing index for each reach. The rearing indices were then used to determine the predicted rainbow trout/steelhead young-of-the-year population density per unit length of stream (Table 7.5 in Section 7.3).

The average potential population density for rainbow trout/steelhead young-of-the-year within the five surveyed sections was 1.6 fish per meter. The same RIYOYP has been conducted on several streams throughout the region. For instance, on the main stem of the Carmel River above the Los Padres dam, the average young-of-the-year rearing capacity was estimated as 5.7 fish per meter (Dettman and Kelley 1986).

8.2 Sacramento Pikeminnow

Arroyo Seco River and Willow Creek

Sacramento pikeminnows were only observed in the Arroyo Seco Watershed. They were found in all reaches from the confluence with Willow Creek to the last perennial water downstream from the Elm Ave. Bridge. Pikeminnow densities (Table 8.5) were highest in the middle reaches of the Arroyo Seco River and lower in Willow Creek and the shallow waters of the upper and lower-most reaches of the Arroyo Seco River. Several different age classes were observed

Table 8.5 Sacramento pikeminnow densities for all reaches where pikeminnow were observed.

Species	Stream	Reach	# of pikeminnow 4”-12”	# of pikeminnow ≥ 12”	Total Number	Density (# per 100 m)
 Sacramento Pikeminnow	Arroyo Seco River	2-1	55	0	**55**	11.2
	Arroyo Seco River	2-2	10	21	**31**	6.3
	Arroyo Seco River	3-1	106	1	**107**	21.4
	Arroyo Seco River	3-2	111	0	**111**	22.2
	Arroyo Seco River	4-1	169	3	**169**	36
	Arroyo Seco River	4-2	49	0	**49**	9.8
	Willow Creek	5-1	17	2	**19**	3.8

throughout the river (Table 8.5). Adults were most abundant in the lower reaches of the Arroyo Seco River and were usually observed in large pools with moderate to great cover. Juveniles were seen in both large and medium pools whereas young-of-the-year were usually found in riffle habitats.

8.3 Sacramento Sucker

Suckers were the most frequently encountered species during the present study. They were observed in the Arroyo Seco River, Willow Creek, Atascadero Creek, and the Salinas River. Densities were low compared to pikeminnows (Table 8.6).

Arroyo Seco River and Willow Creek

Sacramento suckers were found in all but one reach of the Arroyo Seco River and were found in Willow Creek as well. Adults were common in large pools. Young suckers were observed in riffle and shallow run habitats. Only juveniles and young-of-the-year suckers were found in Willow Creek. The highest densities (Table 8.6) were found in the upper-middle reaches of the river where water depths were great enough to support higher numbers of fish.

Table 8.6 Sacramento sucker densities for all reaches where suckers were observed.

Species	Stream	Reach	Number	Density (# per 100 m)
 Sacramento Sucker	Arroyo Seco River	2-1	32	6.5
	Arroyo Seco River	2-2	17	3.5
	Arroyo Seco River	3-1	3	0.6
	Arroyo Seco River	3-2	33	6.6
	Arroyo Seco River	4-2	25	5.0
	Willow Creek	5-1	8	1.6
	Atascadero Creek	1-2	5	1.2
	Salinas River	2-1	31	6.2

Atascadero Creek

Two large suckers were observed in a large, deep pool located adjacent to the southbound lane of HWY 101 near the bottom of the reach. Three juveniles were observed with Monterey roach in small upstream pools. Like Arroyo Seco, densities of suckers were low in Atascadero Creek.

Salinas River

Only 16 juvenile suckers were observed in a reach of the Salinas River near San Ardo. Water levels were very low and the only available habitat was a few pools that formed under tree branches along the waters edge. Other species sharing these pools were roach and hitch.

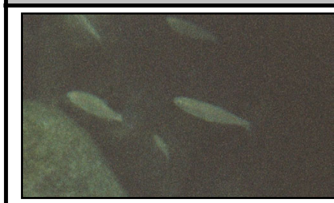
8.4 Monterey Roach

Monterey roach were observed in the Arroyo Seco River, Atascadero Creek, Paso Robles Creek, and the Salinas River (Table 8.7). Because roach interbreed with hitch, a species very similar to roach in appearance, identification is difficult when the two coexist. Some errors in identification are to be expected.

Arroyo Seco River and Willow Creek

Roach were not seen in abundance in Arroyo Seco. This is, in part, due to the difficulties of identifying roach in wide perennial streams using the snorkel technique. Roach are small fish that prefer to stay in pools with fish of comparable sizes, but only when predators are absent. This makes detection more difficult.

Table 8.7 Monterey roach densities for all reaches where roach were observed.

Species	Stream	Reach	Number	Density (# per 100 m)
	Arroyo Seco River	3-2	3	0.6
	Paso Robles Creek	1-1	600	120.0
	Atascadero Creek	1-2	440	102.3
Monterey Roach	Salinas River	3-2	21*	4.2
* Possible misidentification with Hitch				

Paso Robles Creek

The estimated population of roach was significantly higher in Paso Robles Creek (Table 8.7). Paso Robles was not flowing at this time and there were only a few scattered large pools less than or equal to 1.5 meters in depth. Despite shallow water depths, these pools supported high densities of Monterey Roach.

Atascadero Creek

Atascadero Creek, in Reach 1-2 near HWY 101, had similar high densities of roach. The dominant habitat type consisted of several large pools connected by short riffles with light streamflow (~5 cfs). In all pools vegetative cover, both aquatic and overhead, was abundant. Populations for this reach were estimated at 440 roach per 500 meters. This estimate was made using a small-infrared light underwater viewing system (Aqua Vu, Nature Vision Inc.) and bank observations. Snorkeling was avoided due to possible health risk. This may not have been as accurate as snorkel surveys.

Salinas River

The Salinas River had many fish that were less than 4 inches (10.2 cm). However, they were not easily identified and were therefore not counted. However, 21 roach that were larger in size (9-11 cm in length) were identified by characteristics described in Section 3.

8.5 Hitch

Salinas River

Hitch were found in found in similar abundances as roach in the Salinas near San Ardo (Table 8.8). Most hitch observed were 6-14 cm. Again, many fish smaller than 10 cm were observed but were unidentifiable. Shallow water at this reach limited habitat abundance.

Table 8.8 Hitch densities for the Salinas River near San Ardo where hitch were observed.

Species	Stream	Reach	Number	Density (# per 100 m)
 Hitch	Salinas River	3-2	23*	4.6
* Possible misidentification with Monterey Roach				

8.6 Speckled Dace

Speckled dace were observed in three reaches of the Arroyo Seco River, Willow Creek, and Sandy Creek.

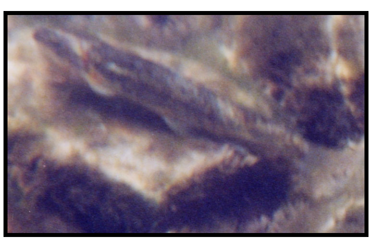
Arroyo Seco River

In Arroyo Seco, dace were not seen in abundance (Table 8.9), although this was likely due to the same difficulties experienced with estimating roach populations using snorkel surveys. Dace were observed at the head of small shallow pools where light incoming riffles were present. They were solitary, aggressive fish, rarely seen with any other species.

Sandy Creek

Large populations of speckled dace were observed in Sandy Creek. Most were confined to a few of the largest pools (~ 1 m in depth and 3 m wide) where densities may have been 30 fish to a pool. Here they shared limited space only with threespine stickleback. Most of this reach was characterized with shallow run and riffle habitats.

Table 8.9 Speckled dace densities for the streams where speckled dace were observed.

Species	Stream	Reach	Number	Density (# per 100 m)
 Speckled Dace	Arroyo Seco River	3-1	1	0.2
	Arroyo Seco River	3-2	3	0.6
	Arroyo Seco River	4-1	3	0.6
	Willow Creek	5-1	1	0.2
	Sandy Creek	1-2	97	19.4

8.7 Threespine Stickleback

Threespine sticklebacks were found in Paso Robles Creek, the Salinas River and Sandy Creek, although many of the fish encountered were dead. Sticklebacks have a short lifespan, and die after spawning in mid or late summer (Greenbank et al., 1959; Moyle, 2002). Sticklebacks are small skittish fish that are hard to detect in large volumes of water where emergent vegetation is abundant. Dead sticklebacks were observed in the lower Arroyo Seco River during field reconnaissance in 2001.

Paso Robles Creek

A small population of sticklebacks was counted in a small pool less than 10 cm deep. They were sharing this pool with mosquitofish, which were in much higher densities. Thirteen individual sticklebacks were counted in this pool (Table 8.10).

Table 8.10 Threespine stickleback densities for the streams where threespine stickleback was observed.

Species	Stream	Reach	Number	Density (# per 100 m)
 Threespine Stickleback	Paso Robles Creek	1-1	13	2.6
	Sandy Creek	1-2	8	1.6
	Salinas River	2-2	14	2.8

Salinas River

Threespine stickleback were observed in the Salinas River, usually alone and along the edges of the water. They were found with other small fish, most likely suckers, hitch and roach.

Sandy Creek

Only one pool contained sticklebacks in Sandy Creek. The eight counted in this pool were all dead. The lack of significant decomposition suggests that they had died recently.

8.8 Pacific Lamprey

Pacific lampreys were found in three locations during this study, the Arroyo Seco River, the Salinas River and Paso Robles Creek (Table 8.11). The specimens found in Arroyo Seco and Paso Robles were still in their ammocoetes phase. The specimen found in the Salinas River, later in the summer, had begun to metamorphose into a migrating juvenile. This was determined by the presence of its eyeball, dark blue coloration on its dorsal area and silvery to dull gray sides and belly.

Table 8.11 Pacific lamprey densities for the streams where Pacific lamprey were observed.

Species	Stream	Reach	Number	Density (# per 100 m)
 Pacific Lamprey	Arroyo Seco River	2-2	2	0.4
	Paso Robles Creek	1-1	2	0.4
	Salinas River	2-2	1	0.2

8.9 Mosquitofish

Mosquitofish were only observed in Paso Robles Creek where densities were high. Several pools contained an estimated 50-75 fish (Table 8.12). Several smaller groups of mosquitofish were found in small pools less than 5 cm in depth and with a circumference of approximately 1-meter. Mosquitofish are widely distributed/planted fish in California and have been found in other bodies of water in the local region, such as Watsonville Slough (Swanson, 2002) and Espinosa Lake near Salinas (local resident pers. comm.).

Table 8.12 Mosquitofish densities and population estimates for Paso Robles Creek.

Species	Stream	Reach	Number	Density (# per 100 m)
 Mosquitofish	Paso Robles Creek	1-1	250	50

8.10 Carp

Three carp were observed in a pool in the urban reach of Atascadero Creek (Table 8.13). One was a large adult and the other two were juveniles. Like mosquitofish, carp have been found in other water bodies in the local region, such as Tembladero Slough, the Reclamation Ditch, both Lakes Nacimiento and San Antonio, and the Salinas Lagoon (MCWRA and USACE, 2002). During July of 2002, a large fish kill occurred in the Tembladero Slough - Reclamation Ditch system. Carp, along with other species, were found dead near the Potrero Tide Gates (Fig. 8.3).

Table 8.13 Carp densities and population estimates for Atascadero Creek.

Species	Stream	Reach	Number	Density (# per 100 m)
Carp	Atascadero Creek	2-2	3	0.007

Figure 8.3 Dead carp in Tembladero Slough during a large fish kill on 02 Jul 02 (Photo: Joel Casagrande; 02 Jul 02)

8.11 Bass

One bass was observed in a middle reach of the Arroyo Seco River (Table 8.14). It is unknown whether or not it was a white, striped, smallmouth or largemouth bass. However, MCWRA and USACE (2002) state that the only species of bass found in the Salinas River main stem was largemouth bass. In that study, the authors presented a list of native and non-native fish for the Arroyo Seco River reported in collections done by Snyder (1913) and Page et al. (1995), as well as observations during redd surveys by Hagar (1995, 1996). In all studies, no bass were found in the Arroyo Seco River. It is still unknown whether or not a breeding population exists in the river.

Table 8.14 Bass densities and population estimates for the Arroyo Seco River near Govt. Camp.

Species	Stream	Reach	Number	Density (# per 100 m)
 Bass	The Arroyo Seco River	3-1	1	0.002

8.12 Changes to Population Assessment

The use of snorkel surveys as a means for estimating fish populations and presence/absence has limitations. As mentioned previously, the identification of young-of-the-year fish, when a mixture of similar looking species is present, can be challenging. Additionally, smaller and more elusive species may be missed entirely, such as riffle sculpin, threespine stickleback and speckled dace. It is certain that species population estimates and presence/absence would have been more accurate using an electoshocker and/or some type of netting (dip nets, seines, etc.) or a combination of the two.

The use of electroshocking, dip nets and seines would provide a more accurate estimate of species presence/absence and abundance.

9 Community Structure

In this section the use of species presence/absence data from all sites was used to investigate species interactions, more specifically assemblages and predator/prey and competition relationships. We revisit the fish assemblages, or associations, described by Barclay (1975) for the Upper Salinas River Watershed in Section 9.1. Then, Section 9.2 investigates co-occurrence of species within the present data set using Jaccard Similarity Coefficients, and compares this to Barclay's assemblages. Finally, Section 9.3 discusses observed predator-prey relations and inter-specific competition through data analysis.

9.1 Fish Assemblages - Barclay

Using the fish assemblages and the habitat characteristics defined by Barclay (1975) for the upper Salinas Watershed, species data collected during the present study were used to produce a map of current fish assemblages and their respective ranges (Fig. 9.1).

The Sucker, Pikeminnow and Stickleback Assemblage was found in the Salinas River main-stem, the lower reaches of the Arroyo Seco River and the lower Gabilan Creek just upstream of Carrr Lake in central Salinas. This assemblage covers the majority of the low-elevation reaches of the western and northern watershed (Fig. 9.1). Barclay (1975) stated that Sacramento suckers and sticklebacks were the numerically dominant species found in this assemblage, although pikeminnows were, at times, more dominant. Data collected during the present study agree with Barclay (1975). Pikeminnows were the numerically dominant species throughout most of the Arroyo Seco River. However, suckers were the dominant species in the Salinas River.

The California Roach Assemblage was commonly found in intermittent streams such as the lower reaches of Paso Robles Creek, Atascadero Creek and Gabilan Creek (Fig. 9.1). All three of these reaches had large to medium sized pools with little or no flow connecting them. Roach were the numerically dominant species in all three reaches. The California Roach Assemblage also inhabited the middle reaches of the Arroyo Seco River, even though roach were not the numerically dominant species. It is likely that roach were in greater numbers than counted in the Arroyo Seco River. Roach numbers were low due to the possible miss-identification with young pikeminnow and the lack of more accurate population assessment methods (i.e dip nets, electroshocking, etc.). Barclay (1975) states that California roach assemblages usually contain other species such as suckers, pikeminnows, and speckled dace. In the middle reaches of the Arroyo Seco River, roach were observed with these species. The summer and fall of 2002 was a low water year with presumably higher than normal water temperatures. This potentially allowed for greater expansion and overlap of the Sacramento sucker, pikeminnow and stickleback assemblage with both the California roach and Rainbow trout –speckled dace Assemblage.

The Trout-dace Assemblage was found in the headwater reaches of the Arroyo Seco River, Willow Creek, the Nacimiento River, Gabilan Creek, and Sandy Creek (Fig. 9.1). All three reaches had rainbow trout and/or speckled dace present. Sandy Creek supported only two species – speckled dace and threespine stickleback with speckled dace as the numerically dominant of the two. The Nacimiento River had significant populations of rainbow trout, but they were also the only species observed. Titus (2001) stated that trout also occur in the upper reaches of the San Antonio River. Nelson et al. (2000) stated that rainbow trout were found in the upper reaches of both Atascadero Creek and in Tassajera Creek during surveys performed in 1999. Access to these locations was not gained during the present study.

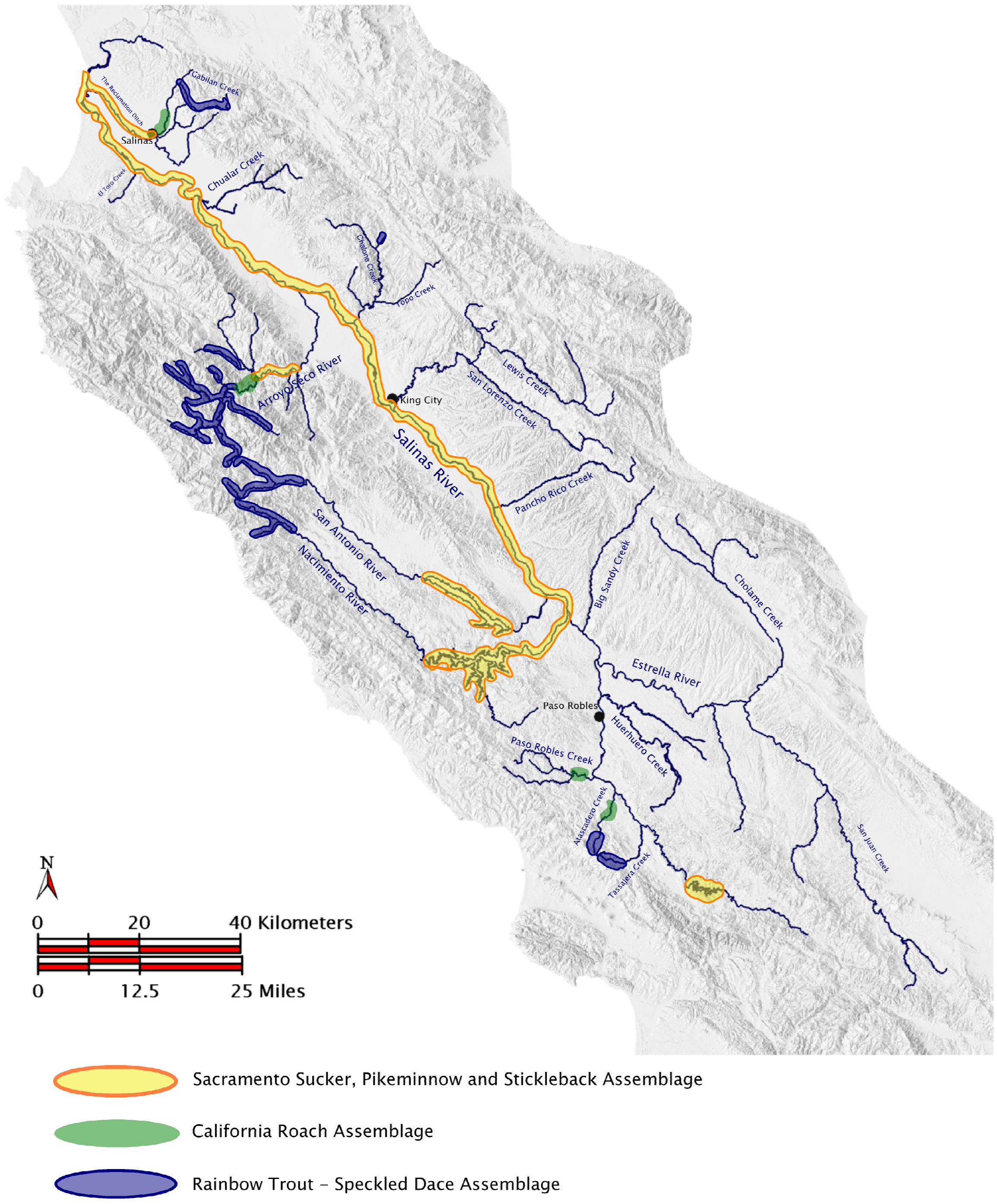


Figure 9.1 Distribution of the different fish assemblage based on population data collected during the present study. Assemblage compositions were defined by Barclay, (1975- adapted from Moyle and Nichols (1973) and Murphy (1941) and Hopkirk (1967)). This map is based on collected data and recent, well-documented sources. Note that streams with no color shading are either non-perennial or no fish species data exists to date. Assemblage shading was determined by the presence and/or abundance of typical species of each pre-determined assemblage as defined by Barclay (1975).

9.2 Species Occurrence Similarity Analysis

An underlying theme of the present project is to identify opportunities for objective characterization of fish distribution and habitat quality. As a result, we have explored objective and quantitative means of describing the tendency of species to occur within discrete assemblages. Matthews (1998) defines a fish assemblage as "fish that occur together in a single place, such that they have at least a reasonable opportunity for daily contact with each other."

The Jaccard similarity coefficient was computed as a means of quantifying the similarity of two species based on their co-occurrence at the same sites, and the similarity of two sites, based on the co-occurrence of the same fish species at these sites. The Jaccard similarity coefficient between two species X and Y is computed as (Krebs, 1999):

$$a / (a+b+c)$$

Where a is the number of sites where both X and Y were found, b is the number of sites where X was found but not Y, and c is the number of sites where Y was found but not X. Conversely, the similarity of two sites S and T is computed using the same equation, with a equaling the number of species occurring at both S and T, b equalling the number of species occurring only at site S, and c equaling the number of species occurring only at site T.

Figure 9.2 summarizes the presence/absence of species at sites, and presents two Jaccard similarity matrices (for sites, and for species). In simple terms, distinct groupings of high similarity values in these matrices indicate distinct groupings (i.e. assemblages) in nature. Statistical bootstrap techniques could be used to define similarity values that could be considered "high". For the present introductory analysis we simply define values higher than 0.3 as "high". With respect to species, some similarity is indicated between trout, dace, pikeminnows, and suckers – indicating some degree of assemblage of these species. Suckers and pikeminnows showed the highest degree of similarity (Fig. 9.2). There is also some similarity between lamprey, stickleback, roach, and to a lesser extent hitch and mosquitofish. For comparison, Barclay's assemblages are indicated at the top-left of the figure. Barclay's Trout-Dace Assemblage is confirmed by the data, but his Sucker-Pikeminnow-Stickleback Assemblage is not. Stickleback was only found with either of these two species at one site. This is most likely because threespine sticklebacks, often hiding in dense aquatic vegetation, are difficult to find without the use of a dip net or seine, which were not used during the present study. Dead threespine sticklebacks were observed in the Arroyo Seco River the previous year indicating they do exist with pikeminnow and suckers.

Turning to the Jaccard matrix of sites, a strong similarity is indicated between all western headwater sites. This is driven by the co-occurrence of trout in both the headwaters of the Nacimiento and Arroyo Seco. The Arroyo Seco River sites (including Willow Creek) form a stronger self-similar group because trout were found with speckled dace, pikeminnow, and sucker. There is also some evidence for grouping of lower sites such as on Atascadero Creek, Paso Robles Creek, the lower Arroyo Seco, and the Salinas River at San Ardo. This is based on co-occurrence of species such as roach, lamprey, and stickleback. Note that similarity coefficients involving the four sites where no fish were observed (Salinas River at Chualar and Tassajera Creek) are indicated as "000".

In summary, there is some evidence for discrete assemblages in the Salinas system, although these do not exactly correspond to more widely acknowledged assemblages. This could be simply because of small sample size, or indicative of an actual characteristic of the population. To clarify this, bootstrap techniques can be used to attach statistical significance to similarity coefficients. We have demonstrated this for benthic macro-invertebrate data (Gilmore, 2003).

The groups that are indicated are well defined with respect to species composition and geographic location. The trout-dace-sucker-pikeminnow group is well defined in western headwater sites, although speckled dace were found in abundance in Sandy Creek. A roach-lamprey-stickleback group occupies lower, warmer, shallower sites. Intermediate sites contain a disparate mix of species, often with sucker and pikeminnow.

Barclay's Assemblages

Barclay's Assemblages	RT	DC	PM-S	SKR-S	BASS	CP	RCH	HTH	LP	STB	MOQ
RT, DC	=	=	-	-						-	
SK-S, STB, PM-S			=	=	-		-	-		=	
RCH			-	-			=				

Presence / absence of species at sites

Sites	RT	DC	PM-S	SKR-S	BASS	CP	RCH	HTH	LP	STB	MOQ
NAC 2-1	Pres										
NAC 2-2	Pres										
ARR 4-1	Pres	Pres	Pres								
ARR 4-2	Pres		Pres	Pres							
ARR 3-2		Pres	Pres	Pres			Pres				
WLW 5-1	Pres	Pres	Pres	Pres							
ARR 3-1	Pres	Pres	Pres	Pres	Pres						
ARR 2-1			Pres	Pres							
ARR 2-2			Pres	Pres					Pres		
ATA 2-2				Pres		Pres	Pres				
SAL 2-1				Pres			Pres	Pres	Pres	Pres	
PAS 1-1							Pres		Pres	Pres	Pres
SAN 2-1		Pres								Pres	
ATA 2-1											
SAN 1-1											
SAL 1-1											
TSE 1-1											

Jaccard coefficients of site similarity (based on co-occurrence of fish species) (values below 0.3 not shown)

Sites	NAC 2-1	NAC 2-2	ARR 4-1	ARR 4-2	ARR 3-2	WLW 5-1	ARR 3-1	ARR 2-1	ARR 2-2	ATA 2-2	SAL 2-1	PAS 1-1	SAN 2-1	ATA 2-1	SAN 1-1	SAL 1-1	TSE 1-1
NAC 2-1	1																
NAC 2-2	1	1															
ARR 4-1	0.3	0.3	1														
ARR 4-2	0.3	0.3	0.5	1													
ARR 3-2			0.4	0.4	1												
WLW 5-1			0.8	0.8	0.6	1											
ARR 3-1			0.6	0.6	0.5	0.8	1										
ARR 2-1				0.7	0.5	0.5	0.4	1									
ARR 2-2				0.5	0.4	0.4	0.3	0.7	1								
ATA 2-2					0.4					1							
SAL 2-1									0.3	0.3	1						
PAS 1-1											0.5	1					
SAN 2-1													1				
ATA 2-1														000			
SAN 1-1														000	000		
SAL 1-1														000	000	000	
TSE 1-1														000	000	000	000

Jaccard coefficients of species similarity (based on co-occurrence at same

Fish species	RT	DC	PM-S	SKR-S	BASS	CP	RCH	HTH	LP	STB	MOQ
RT	1										
DC	0.4	1									
PM-S	0.4	0.5	1								
SKR-S		0.3	0.7	1							
BASS					1						
CP						1					
RCH				0.3			1				
HTH								1			
LP							0.4	0.3	1		
STB							0.4	0.3	0.5	1	
MOQ									0.3	0.3	1

Figure 9.2 Jaccard similarity matrix for species presence/absence and for sites (stream reaches).

9.3 Predator-Prey Relations and Inter-specific Competition

There is some evidence in the data for predator-prey relations and inter-specific competition. In Paso Robles and Atascadero Creeks, Monterey roach were in abundance while Sacramento pikeminnows, a major predator (Brown et al., 1995), were absent. Such densities of roach were not observed in the Arroyo Seco River in the presence of pikeminnows[6]. Likewise, the high densities of young rainbow trout were observed in the Upper Nacimiento River where pikeminnows were absent. In the upper reaches of the Arroyo Seco River where Sacramento pikeminnow are were present, trout appeared to be less abundant. Speckled dace, also observed in low numbers in the Arroyo Seco River, were very abundant in Sandy Creek where riffle sculpin were absent. Riffle sculpin, although not seen in the Arroyo Seco River during this study, will out-compete dace for benthic invertebrates and prime riffle habitats, thus reducing their abundance (Baltz et al., 1982). It is likely that riffle sculpin do exist in the Arroyo Seco River, although both Snyder (1913) and Hagar (1995) also did not see them during their surveys of the river (MCWRA and USACE, 2001).

[6] Note that it is highly likely that roach population estimates were under-estimated due to appearance similarities with young-of-the-year pikeminnow in most areas. However, the total number of possible miss-identifications would not have equaled the number of roach positively identified in other streams where they were the only species present (i.e. Paso Robles Creek and lower Atascadero Creek).

10 Species and Habitat Relations

The presence or absence and/or abundance of a fish species(s) can be affected by natural or man-made alterations to the quality, quantity and type of habitat for a given stream or water body and by the presence or absence of other fishes. For example, Figs 10.1& 10.2 are from an anonymous creek in the Salinas Valley. The dense riparian vegetation, visible in Figure 10.1, kept the water temperatures cool, and provided habitat, food and shelter for native fish species. However, one year later the vegetation was removed possibly in order to provide horse and cattle access to the stream's water. Now the stream bank is bare (Fig. 10.2), which may cause water temperatures to rise, erosion to increase and bank structure and complexity to decrease.

Larger examples of habitat alteration may include the loss of steelhead migration habitat due to the construction of Nacimiento and San Antonio Dams or the large sediment loads that resulted from the Marble Cone fires in the Arroyo Seco Watershed.

Fish species can also influence both the abundance and the presence/absence of other species, due to predator-prey relationships and competition for resources. For example, (Brown and Brasher, 1995) concluded that the presence of adult pikeminnow in pool habitats led to a decline in the number of juvenile rainbow trout and both juvenile and adult California roach in an artificial stream.

The methodology employed by the present study attempts to provide a basis for defining objective relationships between fish, their habitat and between different fish species. This methodology should facilitate the definition of habitat restoration or maintenance targets for conservation and improvement of the Salinas Watershed fisheries. The results are sufficient to indicate the future potential of this approach. At present the results can be used to make some preliminary interpretations.

This section attempts to relate the collected habitat data with observed fish species abundance and presence/absence. This may provide insight as to how current habitat conditions are currently shaping fish species distribution in the Salinas Watershed. Plots are given in terms of fish abundance and species diversity versus: shelter, cover, temperature, channel width, reach volume, etc.

Figure 10.1 This is an anonymous perennial cool water creek in the Salinas Valley. Note the mailbox in the upper right corner of the picture and the thick riparian vegetation in the background. (Photo: Thor Anderson, Mar. 2000)

Figure 10.2 Same creek as above only 1 year later. Note the same mailbox in the upper left corner and the removal of the riparian vegetation by heavy equipment. (Photo: Joel Casagrande, 21 May 2001)

10.1 In-Stream Shelter

Fish abundance and species diversity was greatest in streams with higher in-stream shelter values except for roach, which were found in great abundance in isolated deep pools with little or no cover (Fig. 10.3). Figs (10.4 & 10.5) show examples of trout utilizing large boulders, undercut ledges, and bubble curtains as in-stream shelter, or cover, in the Arroyo Seco River. Adult Sacramento pikeminnows and suckers were also observed in greater numbers using root wads and bedrock ledges (Fig. 3.9). Lamprey ammocoetes were observed buried in dense mats of submerged algae (Fig. 3.16). Hitch, Monterey roach, suckers, and threespined stickleback were observed in small scour pools underneath overhanging terrestrial vegetation in the Salinas River at San Ardo (Fig. 6.19).

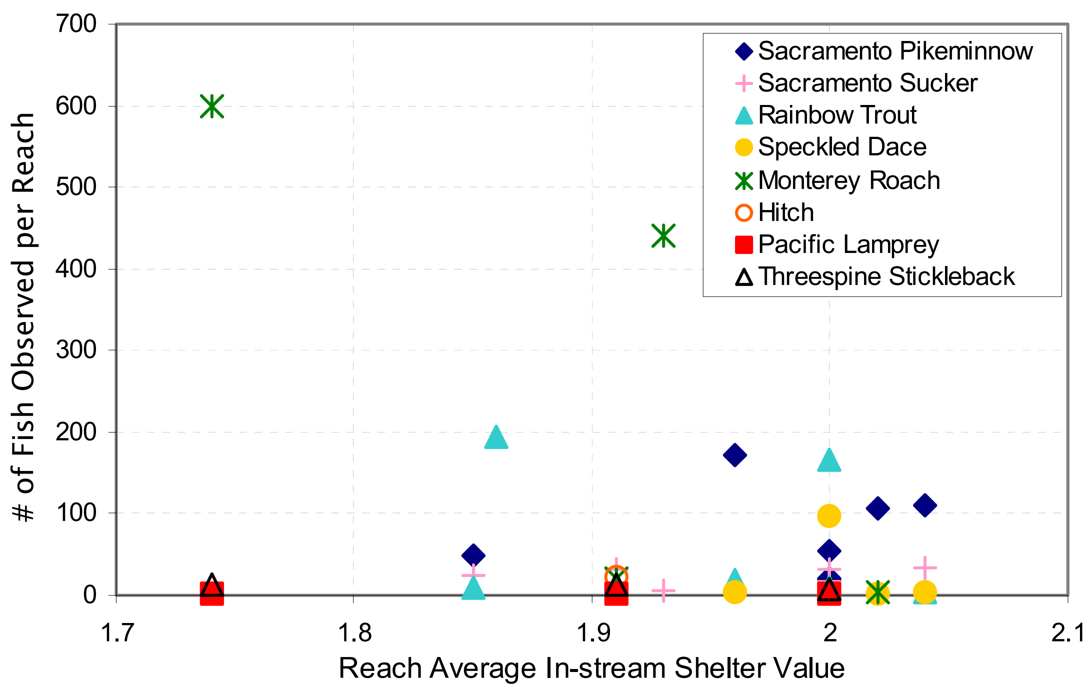


Figure 10.3 Reach average in-stream shelter values, where 0 is none and 3 is excellent, vs. # of fish observed per reach.

Figure 10.4 A rainbow trout under a large boulder in the Arroyo Seco River near the Santa Lucia Creek confluence. (Photo: Joel Casagrande, 08 Aug 02)

Figure 10.5 A rainbow trout (center and circled) utilizing boulders and a bubble curtain for shelter in Arroyo Seco near Willow Creek. (Photo: Joel Casagrande, 08 Aug 02)

10.2 Percent Overhead Vegetation

There was a weak positive correlation between streams that had high percentages of overhead vegetative cover and both rainbow trout and speckled dace (Fig. 10.6). Conversely, pikeminnows and suckers showed a weak negative correlation with an increase in the percentage of overhead vegetative cover (Fig. 10.6). Lamprey ammocoetes were observed in streams with less than 30% overhead vegetative cover. Ammocoetes prefer algae covered stream bottoms, which are prevalent under the high-sunlight conditions of streams with low cover.

Figure 7.5, in Section 7.1, suggests that narrower streams would be more likely to have higher percentages of overhead vegetative cover. Narrow streams were more frequently encountered in the headwater reaches where streams are steep and less developed. Higher percentages of cover create cooler water temperatures, which can highly influence which fish species and or assemblage(s) will be present – ultimately excluding warm-water fish.

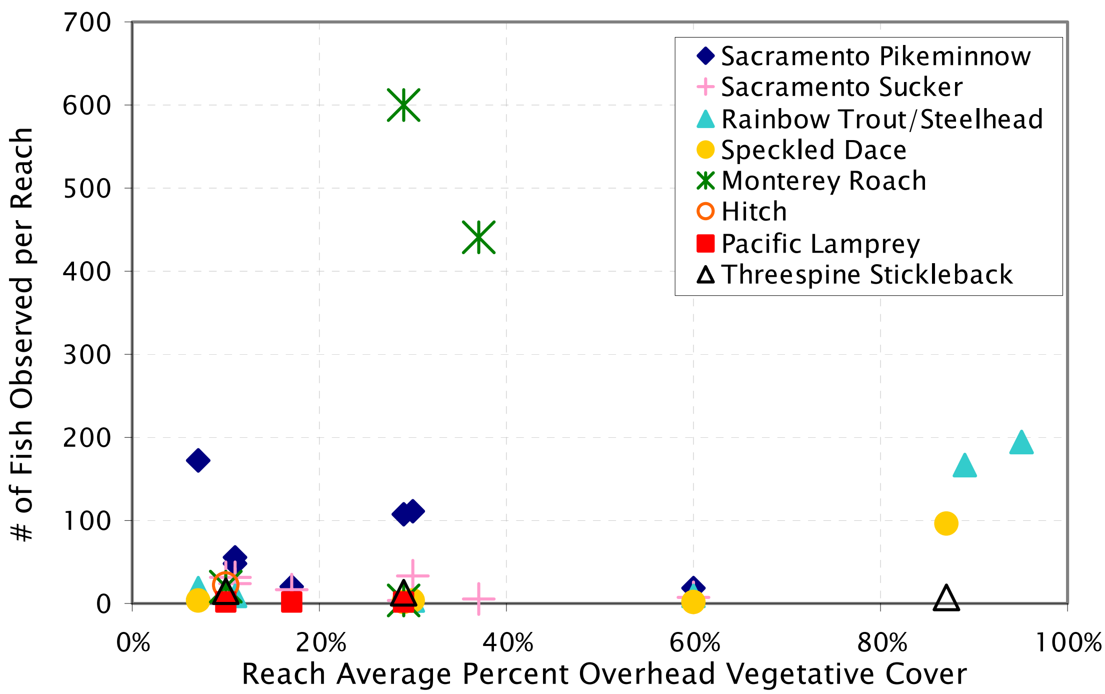


Figure 10.6 Reach average percent overhead vegetative cover vs. the # of fish observed per reach.

10.3 Temperature

Figure 10.7 suggests that trout and speckled dace, cool-water species, are less abundant in stream reaches that have warmer temperatures, although more accurate population data would improve this correlation. Trout were observed in temperatures near 25°C, which are near the lethal limit for this species. Reiser and Bjornn (1979) stated that the lethal temperatures for rearing trout are between 24 and 29.5°C, but that this is dependent on the amount oxygen available, size of the fish, exposure time and the amount of time for acclimation. Smith and Li (1983) suggest that juvenile steelhead can survive in high temperatures by shifting to riffle habitats where food is more easily available.

Water temperature can also affect the growth, distribution, habitat choice and interactions between two species. Reese and Harvey (2002) concluded that the growth of juvenile steelhead in the Eel River decreased by 50% when in waters between 20-23°C.

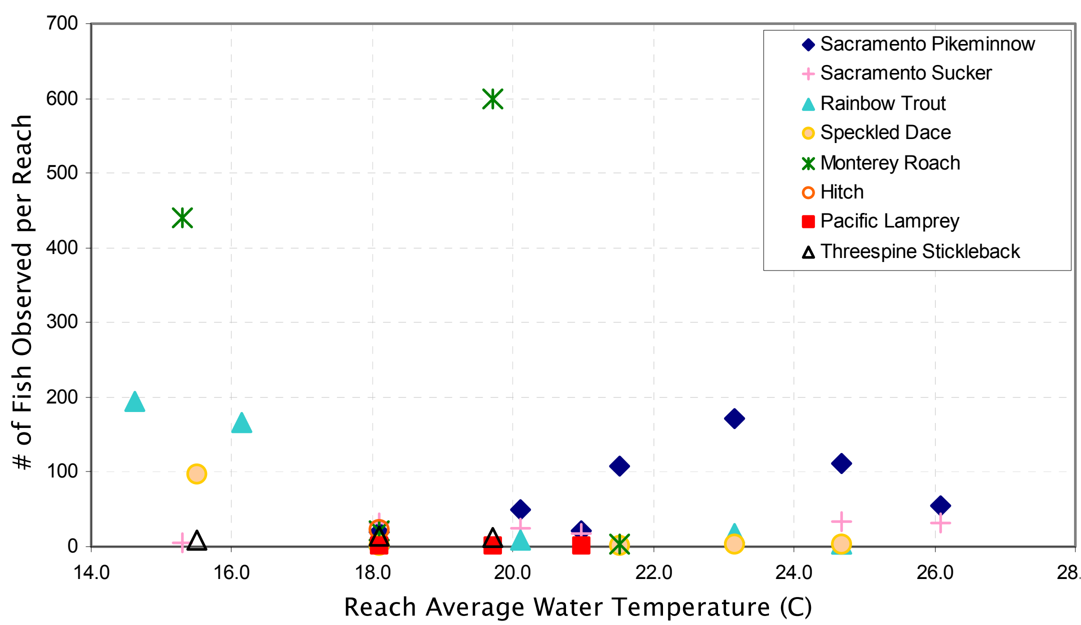


Figure 10.7 Reach average water temperature during daytime surveys vs. the # of fish observed per reach.

Pikeminnows and suckers, typically warm water fish, were both observed in the warmest water temperatures measured during this study. The highest densities of pikeminnows occurred in the middle section of the Arroyo Seco River where water temperatures averaged 23°C. Reese and Harvey (2002) also concluded that the presence of pikeminnows with juvenile steelhead caused a 50% reduction in steelhead growth when water temperature was between 20-23°C. In addition, they stated that behavioral interactions between the two species and initiated by the pikeminnow were 50% more frequent in warm water (20-23°C).

10.4 Water Volume

The abundance, or volume, of water present also can influence where one would find a particular species. Figure 10.8 suggests that some species were more commonly found in reaches where the volume of water was less than 500 m^3. Monterey roach were both present and abundant in Atascadero and Paso Robles Creeks, which had low water volumes.

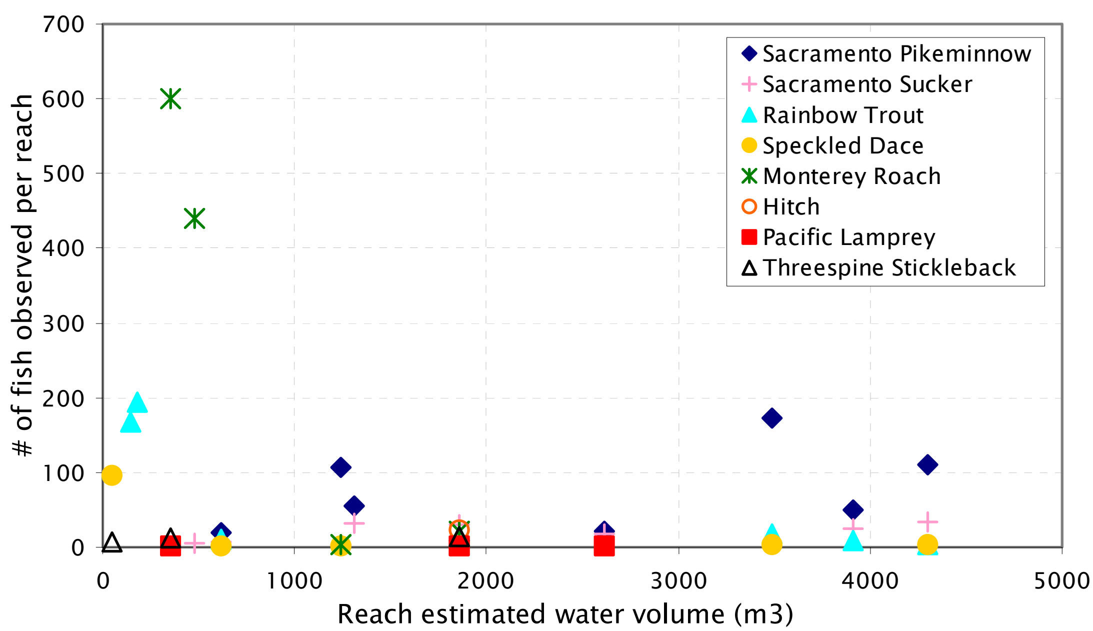


Figure 10.8 Number of fish observed per reach vs. reach estimated water volume.

Rainbow trout were most abundant in the upper Nacimiento River. In both reaches observed in the Nacimiento River, rainbow trout were the only species observed and the volumes of water were less than 500 m^3 (Fig. 10.8). The highest concentrations of speckled dace were found in Sandy Creek, which also had both low water volume and low species diversity. Conversely, fish species such as pikeminnow and suckers, which prefer larger volumes of water (large, deep pool) and that can tolerate a higher diversity of species, were more often found together in larger deep sections of the Arroyo Seco River. However, young-of-the-year pikeminnows and suckers were observed in the shallow, low volume, reaches where they were most likely born.

10.5 Reach Average Sediment Accumulation (RASA)

In Section 5.2.4 we defined reach average sediment accumulation, which is the average of all measured points within a reach.

Only two stream reaches had reach average sediment accumulations (RASA) greater than 6 cm (Fig. 10.9). Both of these reaches contained Monterey roach, which were abundant in pool habitats. Pacific lamprey, Sacramento sucker and threespine stickleback were the only other species observed in these reaches – all of which are tolerant of streams with moderate fine sediment accumulations.

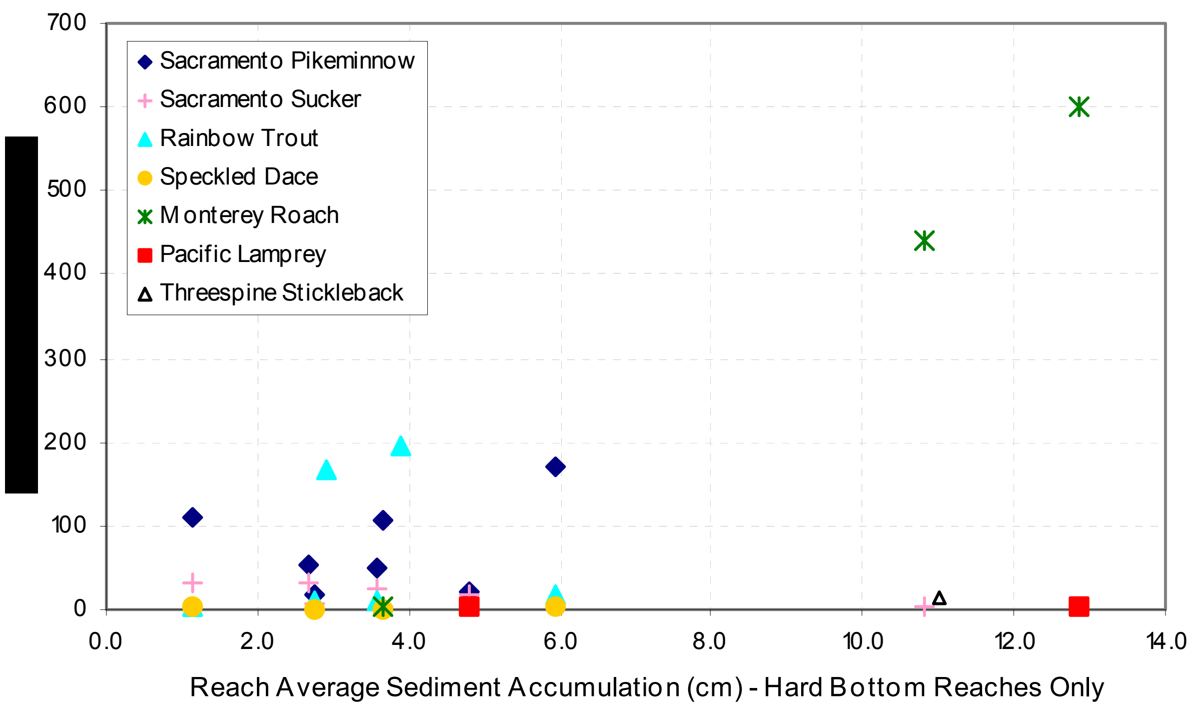


Figure 10.9 The number of fish for each species observed per reach with respect to average sediment accumulation. Data from the Salinas River and Sandy Creek are not present in this graph because it was determined that sediment accumulation measured using the V* rod is not a meaningful property of streams such as these, which flow over thick, sandy alluvial deposits.

Rainbow trout were predominantly observed in reaches with RASA less than 6 cm; most were observed in reaches with RASA less than 4 cm (Fig. 10.9).

10.6 Reach Average Percent Filled (RAPF)

In Section 7.2 we discussed that the percentage to which a reach, or habitat type, is filled with sediment may be better quantified by the average percent filled by fine sediment.

Three stream reaches had average percent sediment filled values greater than 25%, ATA 1-1, ATA 1-2, and PAS 1-1 (Table 7.4). Fish species observed in these reaches were Monterey roach, threespine stickleback, Pacific lamprey, and Sacramento sucker (Fig. 10.10). Two of these reaches (ATA 1-2 and PAS 1-1) contained predominantly larger pool habitat, especially PAS 1-1. Pikeminnow inhabited reaches with RAPF values less than 17 %. This species prefers larger pool habitat joined by flowing riffles. Large pools typically have a lower RAPF. With respect to our data set, rainbow trout were observed in a wide range of

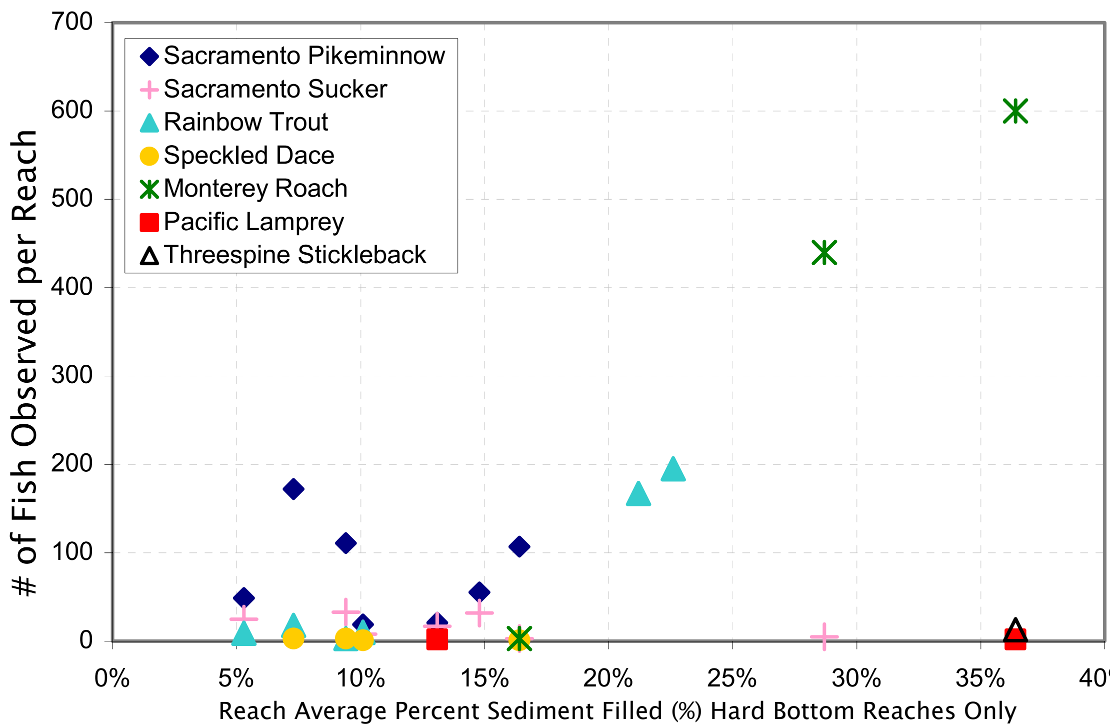


Figure 10.10 The number of fish observed per reach with respect to reach average percent filled (RAPF) with sediment. As above, data from the Salinas River and Sandy Creek are not present in this graph.

RAPF (5–23 %); although perhaps not when compared to other streams. However, the two reaches with the largest number of trout NAC 2-1 & NAC 2-2 were predominantly shallow, riffle habitats with small pools. Aside from these two reaches, trout were observed in the upper reaches of the Arroyo Seco River where accumulations with respect to depth were not significant (≤ 10%).

11 Possible Reasons for Species Declines

Based on descriptive estimates made by Snyder (1913) and Franklin (1999) steelhead numbers in the Salinas Watershed have declined significantly. There are a number of possible reasons for native fish species fragmentation and/or decline. Some of these include: large dams, groundwater pumping, stream barriers, suspended sediment and channel alterations. The following sections describe how these may be having an adverse effect on the distribution and existence of the fish species native to the Salinas Watershed.

11.1 Large Dams

Streamflow in two of the largest tributaries of the Salinas River (Nacimiento River and San Antonio River) as well as the main stem of the Salinas River above the Salinas Dam is managed so that during peak runoff periods (November-April), little or no water flows to the Salinas River. Moyle (2002) stated that the reduction of flood flows due to dams in the Salinas Watershed have resulted in "the upstream expansion of hitch; hybridization and competition with hitch have subsequently eliminated some roach populations." Furthermore, Moyle also stated[7] that many isolated populations of roach died during the droughts and were unable to re-colonize due to dams and other human-made barriers.

It is evident that there has been a reduction in the steelhead trout population from their numbers of the early 1900's, as described in Snyder (1913). The Arroyo Seco River still has a small run of steelhead, however, the large abundant runs on the Nacimiento and San Antonio Rivers are extinct as a result of the Dams[8]. Currently, no studies have been conducted to clearly define the causes(s) of the salmonid decline in the remainder of the Salinas Watershed (i.e. other streams besides Arroyo Seco, Nacimiento and San Antonio Rivers).

It is hypothesized that stream flow and the timing of high flows may be a primary cause of the decline in steelhead numbers. Figure 11.1 shows mean monthly stream flow for the Nacimiento River above and below the Nacimiento

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[7] Source: Jerry Smith, Professor of Aquatic Biology at California State University San Jose pers. comm., 1999 - as cited in Moyle 2002.

[8] Note: The trout populations upstream of the dams may be stranded remnants of these runs.

Dam. The flows required for successful out-migration of smolt steelhead occur during the late winter and early spring (Hagar, 1996). Fig 11.1 clearly shows that during most years a majority of the floodwaters are trapped in Lake Nacimiento. Releases from the reservoir (yellow) occur during periods when generally steelhead (June-October) do not migrate. While USGS flow records below the San Antonio Dam due not exist, one can assume that the same patterns are true for the San Antonio River. Funk and Morales (2002) conducted similar analyses for flows above and below the Salinas Dam, which yielded similar results. Together, the three dams truncate the 1 to 5 year flood events that are needed for up-migrating adults as well as out-migrating smolts. The construction of these dams has not only altered the natural flow regime of the Salinas Watershed, but they have also eliminated a significant portion of the best spawning habitat for steelhead.

Figure 11.1 Monthly average stream flow above and below Nacimiento Dam from Dec. 1982 through Nov. 1998.

11.2 Groundwater Pumping

Groundwater in areas such as the lower Arroyo Seco River and the lower Salinas River is pumped intensively (See Watson et al., 2003). Significant levels of groundwater pumping throughout the valley can alter viable habitat for both migratory and non-migratory species. In the spring and summer, when pumping rates increase, valuable pools and streamflow may experience further reduction (MCWRA and USACE, 2001). The pumping of groundwater also increases the time needed for the streambed to reach saturation during the early stages of winter runoff, thus altering the natural duration of streamflow.

11.3 Migration Obstructions

For in-stream migrating species such as pikeminnow, suckers and stickleback, human made obstructions such as the Thorne Road crossing and fish ladder eliminate possible seasonal migration routes. Pikeminnows and suckers both migrate to smaller tributaries for spawning and then return to the main streams for the remainder of the year. While ladders and small obstructions are passable for steelhead and lamprey, they are impassable to all other species. In Arroyo Seco, the occurrence of nearly one hundred dead adult suckers (Fig. 3.8) suggests that these fish either attempted to migrate up the Arroyo Seco River from the Salinas River and became trapped in the pool, or more likely, they migrated down the Arroyo Seco (past the Thorne Road crossing) and became trapped. Obstructions such as the Thorne Road Bridge can lead to species fragmentation and possibly localized extinctions (Moyle, 2002).

For steelhead, small fish ladders, such as the Thorne Road ladder on the Arroyo Seco River (Fig. 11.2), are easily accessible poaching sites (MCWRA and USACE, 2001; Hagar, 1996). This ladder is old, degraded and poorly maintained (Hagar, 1996). The ladder often becomes clogged with debris during periods of high runoff, which could block, or delay up-migrating adults (Hagar, 1996). Passable dams and other obstructions can also lead to unnecessary physical injury associated with navigating over the obstruction (NMFS, 1996). The ability of a steelhead to jump up and over obstacles is dependent on the depth of water from which they launch (Stuart, 1962 as cited in Reiser and Bjornn, 1979; Evans, 1974). Stuart suggested, based on laboratory experiments, that preferred jumping conditions exist when the ratio of height of falls to pool depth is 1:1.25.

In the Arroyo Seco River four in-stream, elevated road crossings and/or check dams may be impassable obstructions during periods of high or low streamflows. These are: the Clark Colony Water Diversion Facility (near the canyon entrance), a concrete crossing in the Sycamore Flats Residential area, a similar crossing at the Miller's Lodge area and another near the Arroyo Seco Resort at the Los Padres National Forest boundary (Figs 11.3, 11.4, & 11.5). The pools at the downstream end of the Clark Colony and Arroyo Seco Resort crossings are shallow, which may impede upward migration at low flows (Hagar, 1995; MCWRA and USACE, 2001). The crossing at Miller's Lodge has an adequate pool at the base of the crossing. At the Sycamore Flats crossing, the downstream pool is separated from the road by a wall of large riprap like boulders (Fig. 11.4) creating a more challenging jump. In general, higher flows are needed to pass these structures. The California Department of Fish and Game and Monterey County Public Works Department are currently working to remove and replace the Thorne Road structure with a 600-foot suspension bridge (M. Gingras, pers comm. 2003)[9]. There are also proposals in to remove and replace some of the road crossings in the Arroyo Seco River (M. Gingras, pers. comm. 2003) .

Figure 11.2 The Thorne Road crossing and fish ladder on the Arroyo Seco River. (Photo: Joel Casagrande, 29 Sep. 2001)

[9] Martin Gingras, California Department of Fish and Game, phone conversation May 28th 2003.

Figure 11.3 The check dam at the Clark Colony Water Diversion. Downstream is at right. (Photo: Joel Casagrande, 01 Oct 02)

Figure 11.4 A road crossing in the Arroyo Seco River near Sycamore Flats. (Photo: Joel Casagrande, 29 Aug 02)

Figure 11.5 Concrete road crossing in the Arroyo Seco River near the Arroyo Seco Resort. (Photo: Joel Casagrande, 02 Nov 01)

11.4 Suspended Sediment

Historically, streams in the Salinas Watershed have had high suspended sediment concentrations (Watson et al., 2003). In this study, it was concluded that suspended sediment concentrations have increased in the lower Salinas River (King City to the ocean); most likely related to row crop agricultural runoff. The current presence of native fish species/assemblages suggests that aquatic organisms of the Salinas Watershed have adapted to an environment with naturally high suspended sediment concentrations during winter runoff (Watson et al., 2003).

Several studies have demonstrated that suspended sediment can have adverse impacts on fish and other aquatic organisms. Bell (1984; as cited in Reiser and Bjornn, 1979) cited a study in which salmonids avoided streams with sediment concentrations greater than 4000 mg/L. Many other studies in which various sediment concentrations were known to have some adverse effect on steelhead/rainbow trout are summarized in Newcombe and Jensen (1996). In this report, symptoms ranged depending on concentration, duration time, and type of sediment. The symptoms themselves ranged from mortality to other complications such as, sub-lethal stress, blood cell count and blood chemistry change, gill abrasion, and excessive coughing. Note, however, that a majority of these studies were conducted on fish from watersheds much further to the north. Garza (2003) demonstrated that genetic differences do exist between coastal salmonids from different watersheds, which may support the theory that fish of the Salinas Watershed have adapted to more concentrated sediment regimes than what is typically listed for a rainbow trout or steelhead.

Recently, in the Salinas Watershed, suspended sediment concentrations were measured as high as 6,000 mg/L in tributary streams and 1,000 to 3,500 mg/L in the Salinas River (Watson et al., 2003; Casagrande, 2001). According to the concentration values cited in studies such as above, the concentrations measured in the Salinas River may be adversely affecting aquatic organisms. Although, recent observations (See Table 4.2) of steelhead in the Salinas Watershed may suggest that sediment concentrations during migration are not adversely affecting the fish.

11.5 Channel Alterations and Migration Flow Requirements

Channel Alterations

In most sandy streams in the Salinas Watershed, a defined low-flow channel usually exists. A low-flow channel is a smaller, deeper, and more sinuous channel migrating back and forth within a much larger and broader channel (Fig. 11.6). The low-flow channels often provide a more direct route for fish migrations. Alterations to channel morphology and streambank structure can negatively alter steelhead habitat (Bottom et al., 1985 as cited in NMFS, 1996). Channel activities such as bulldozing, use of all terrain vehicles (ATVs), and in-stream mining have altered many streams in the Salinas Valley. Figure (11.7) is the lower reaches of the Arroyo Seco River. In this reach, extensive ATV activity was evident in the fall of 2001 for several hundred meters. Reconnaissance of this stream revealed that a low-flow channel did existed throughout much of the river upstream of Figure 11.7. Stream channel conditions such as these can be difficult for migrating fish to navigate through.

Figure 11.6 The low flow channel in the lower Salinas River during low flow conditions. Note the bulldozing in the upper right hand corner. This was done under permit requiring that the low flow channel be left intact. (Photo: Thor Anderson, Fall 2000).

Figure 11.7 Channel degradation due to ATV in the lower Arroyo Seco River. (Photo: Joel Casagrande, 21 Sep. 2001)

In the Salinas River, in-stream channel grading has occurred in the recent past. After the 1995 floods, the Salinas River Channel Coalition (SRCC), a collective group of landowners along the Lower Salinas River, were permitted to grade in the Salinas River Channel to reduce the flood potential (MCEIR, 2002; Watson et al., 2003). In 2000, the low-flow channel was not bulldozed (Fig. 11.6). The five-year permit granted to the SRCC has since expired, and in 2002 channel no grading was permitted in the Lower Salinas River.

In smaller tributary streams, the low flow channels have also been disturbed. Figure 11.8 shows significant channel alterations in Gabilan Creek near Salinas. Here a bulldozer went up the center of the channel pushing sand toward the banks to create more room for expected winter runoff. If anadromous steelhead and or lamprey use this watershed, which is unknown at present, practices such as this could eliminate possible resting sites under the overhanging vegetation.

Figure 11.8 Channel bulldozing in Gabilan Creek near Salinas. (Photo: Joel Casagrande, 20 Oct 2000.)

Migration Flow Requirements

Due to a combination of factors (i.e. dams, diversions, groundwater extraction and channel alterations) available flow volumes for anadromous species migration has decreased. Hagar (1996) investigated migrational flow requirements and critical depths for migrating steelhead in the Salinas River (Soledad to the lagoon). Seven transects were selected in five different locations with potential passage problems. Each of the transects were surveyed in both January and May of 1996. Types of passage problems encountered were beaver dams, artificially widened channels (bulldozing), and naturally shallow shoals; especially channel widening.

Hagar (1996) concluded that transects with the highest volume of water needed for migration were upstream of Spreckels, mainly due to wider channel conditions and less vegetative confinement. Kelley and Dettman (1983; as cited in Hagar, 1996) suggested that a minimum of 200 cfs was needed for successful migration of adult steelhead through the lower Salinas River. However, Hagar concluded that the average discharge needed for migration at all transects below Spreckels was only 96 cfs and the average for all transects above Spreckels was 160 cfs.

12 Conclusion

The objective of this study was to examine the fish species distribution and evaluate habitat quality in the Salinas Watershed. In the summer and fall of both 2001 and 2002, field reconnaissance and habitat/population assessments were performed in several streams of the Salinas Watershed. Both 2001 and 2002 were considered dry water years with minimal summer/fall flow, which presented an opportunity to assess the aquatic organisms in their most limiting environmental condition.

Stream habitat in the mountainous headwater reaches is in good to excellent condition. Most of these reaches have little human development and many are protected within National Forest, parks and wilderness lands. Rainbow trout and speckled dace were observed in abundance in these upstream reaches.

Foothill stream reaches had warmer water temperatures, less riparian vegetation cover and an increase in the presence of warm water fish species. Sacramento pikeminnow, Sacramento sucker and Monterey roach were the most abundant species along with some rainbow trout and speckled dace. Monterey roach were very abundant in the southern and more intermittent streams where only pools and shallow riffles existed (i.e. Paso Robles and Atascadero Creeks).

In the lowland reaches, perennial water was scarce in the western tributaries and absent in those to the east. Water was present in the Salinas River due to water releases from the bottom of Nacimiento Reservoir. The only eastern tributary with accessible perennial water was Sandy Creek near the Pinnacles National Monument. Sandy Creek had perennial water in one relatively short reach near the Pinnacles. The water was shallow and cool with an abundant riparian canopy. Speckled dace and threespine stickleback were abundant in the upstream reach, which had more pool habitats for them to inhabit.

Sediment accumulations were low at all sites, however foothill stream reaches had slightly higher accumulations. Riffle habitats had the lowest average accumulation whereas pool habitats were often the highest. Sandy Creek and the Salinas River were probably always sandy bottom streams with no immediate hard layer beneath.

In general, most habitat alterations have occurred in the lowland stream reaches. Dams and reservoirs, channel modifications and pollution occur along the valley floor. Non-native fish species in the Salinas Watershed are primarily concentrated in the three reservoirs, but some escape during water releases. The Gabilan Creek/Reclamation Ditch had abundant carp populations. Many died during a large fish kill in July of 2002.

The Salinas Valley has experienced significant alterations in its hydrologic regime and land use (Watson et al., 2003; Newman et al., 2003), especially in the downstream end of the valley. One of the consequences has been the extirpation of four native fish species: the thicktail chub (*Gila crassicauda*), Sacramento perch (*Archoplites interruptus*), tule perch (*Hysterocarpus traski*), and the tidewater goby. All of these species were found in lowland water habitats such as sloughs, low elevation lakes, slow rivers, and estuaries (Moyle, 2002). Thicktail chub is extinct due to habitat loss and the introduction of non-native fish predators. Tule perch and Sacramento perch persist in isolated pockets throughout California, but were extirpated from most of their range due to habitat alteration, invasive predators, poor water quality and toxic pollution (Moyle, 2002). Tidewater goby is still present in other estuaries along the California coast but hasn't been observed in the Salinas Lagoon since 1946 (MCWRA and USACE, 2001). They thrive in quiet wetlands adjacent to lagoons. Draining and diking of quiet backwater refuges, artificial lagoon breaching, pollutants and non-native species such as largemouth bass, green sunfish and mosquitofish all have contributed to the decline of tidewater goby throughout California (Moyle, 2002). There is some anecdotal reports that Chinook salmon (*Oncorhynchus tshawytscha*) once inhabited the watershed (Franklin, 1999), but this has not been positively confirmed.

The aquatic fauna of the Salinas Watershed needs to be studied in greater detail. Sacramento perch, tule perch and tidewater goby could all possibly be reintroduced into the Salinas Watershed if their habitat requirements are improved, maintained and monitored.

13 Future Work

13.1 Wider Geographic Scope

During the present study, we tried to use objective methods to assess habitat conditions in the Salinas Watershed. While the methods themselves can be optimized further, the inclusion of streams representing a wider range of land uses and geographic settings would be useful. Most of the streams measured during the present study were western tributaries and were in predominantly natural or low intensity grazing and/or low-density residential areas. The following is a list of land use regimes and geographic locations where future habitat and popualtion assessments should occur.

- Streams draining the southern and more arid region of the watershed (Trout and Salsipuedes Creeks)
- Streams draining the eastern side of the valley
- Streams in purely grazing areas (Upper San Lorenzo, Upper Topo Creek, and Upper Cholame Creeks)
- Streams in purely low elevation agricultural areas (Lower Gabilan Creek/The Reclamation Ditch, and Chualar Creek)
- The lower Salinas River, its lagoon, and their adjacent sloughs and wetlands.

13.2 Other Future Work

Other studies that would benefit the overall understanding of aquatic habitat and organisms in the Salinas Watershed are:

- An assessment of aquatic invertebrates in the Salinas Watershed. This should expand on a recently conducted baseline study (Gilmore, 2003) and should include streams higher up in the watershed and extend as far downstream as the lagoon,

- implementation of a large woody debris (LWD) recruitment and inventory study for the Arroyo Seco River, which could then be compared to other nearby watersheds such as Carmel Watershed,

- monitoring habitat changes and fish species response in the Arroyo Seco River after the possible removal of the Arroyo Seco River road crossings and Thorne Road fish ladder,

- the monitoring of gravel recruitment downstream of the Clark Gravel Mine on the Arroyo Seco River,

- the creation of a fish species presence database for all streams in the California Central Coast region. This should integrate all previously known data into one common and web accessible database, and finally

- an investigation into salmonid distribution and physiology aimed at explaining the characteristics of resident and anadromous behaviors exhibited in the Salinas River system.

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15 Appendix

15.1 Appendix A: Stream Fish Species Population

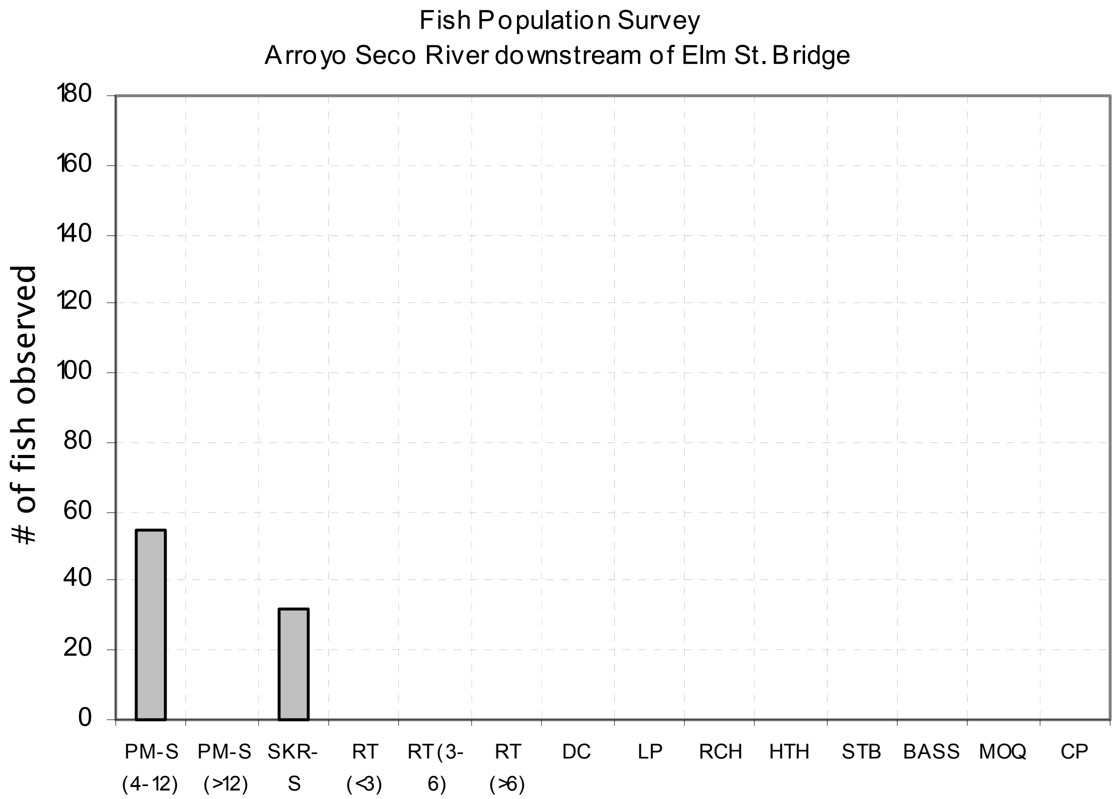
The following are graphs indicating reach specific species list, and their estimated populations. Table 15.1 is a list of species and their codes used in the following Figures. The figures are listed in order of furthest downstream first to furthest upstream, last (i.e. Arroyo Seco River). Table 15.2 lists the coordinates and datum for the beginning and ending of each reach assessed.

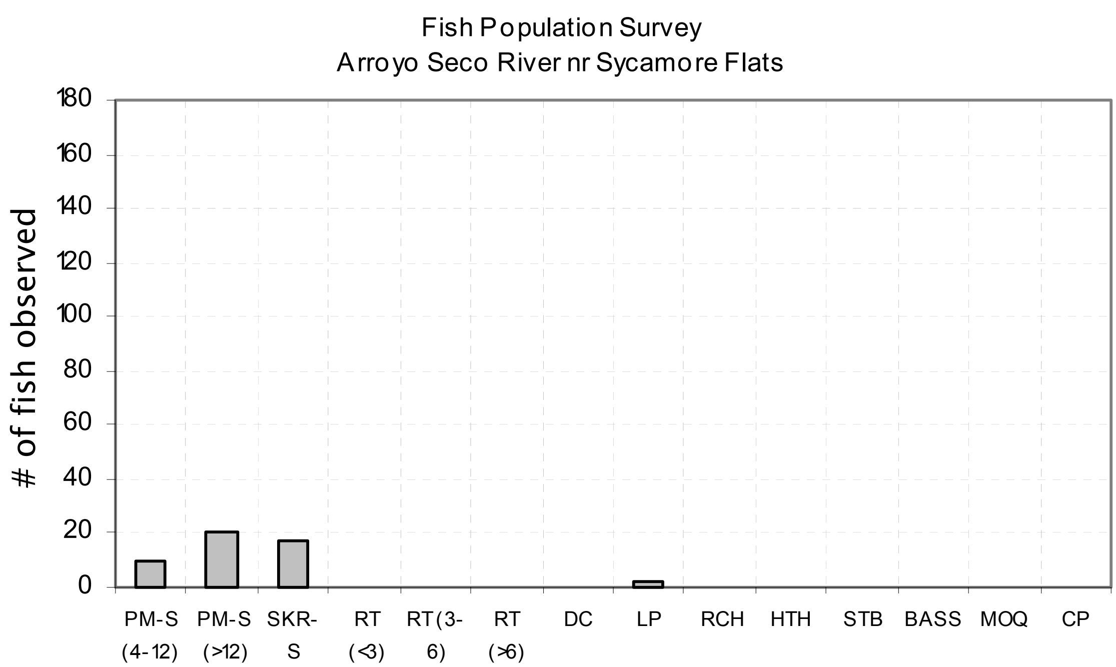
Table 15.1 Species initials and their translation

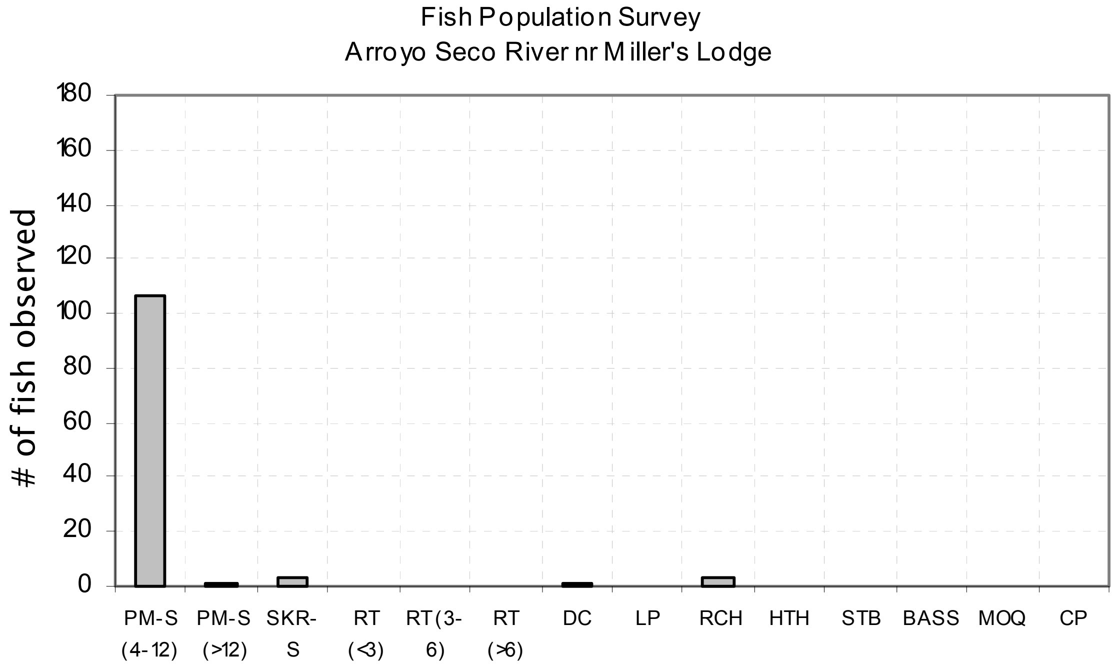
Species Code	Species Common Name
SKR-S	Sacramento sucker
PM-S (4-12)	Sacramento pikeminnow 4-12" estimated length
PM-S >12	Sacramento pikeminnow greater than 12"
RT <3	Rainbow trout 3" or less estimated length
RT 3-6	Rainbow trout 3-6 " estimated length
RT>6	Rainbow trout greater than 6" estimated length
DC	Speckled dace
RCH	Monterey roach
LP	Pacific lamprey
STB	Threespine stickleback
HTH	Hitch
BASS	bass
MOQ	Mosquitofish
CP	Common Carp

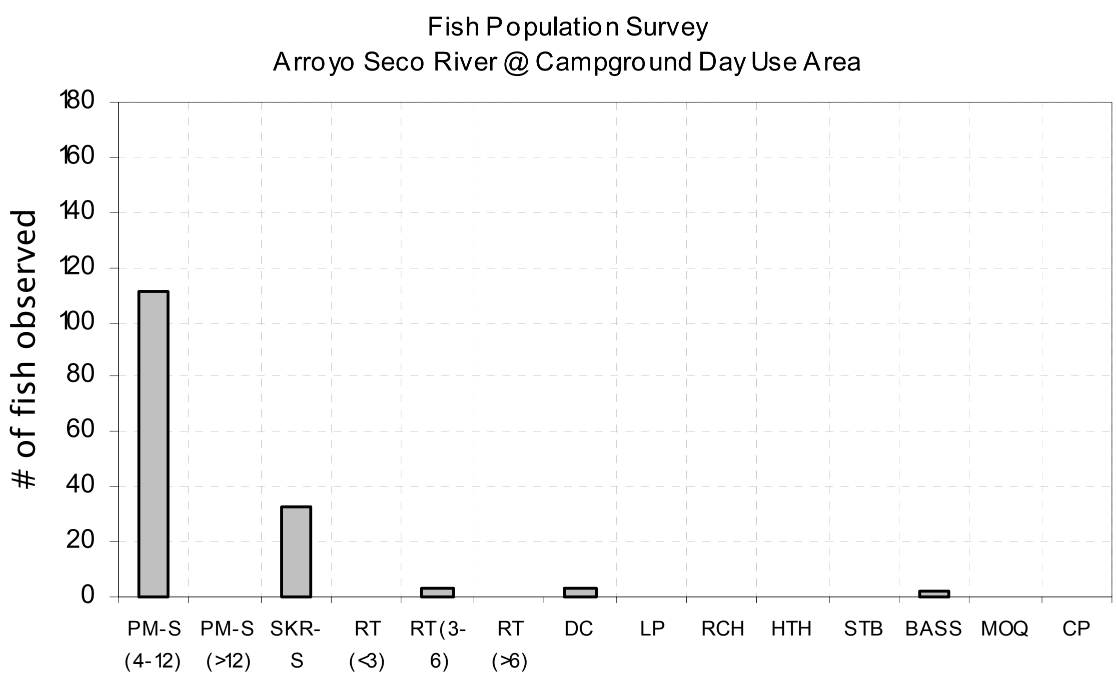
Table 15.2 Reach beginning and ending point GPS coordinates.

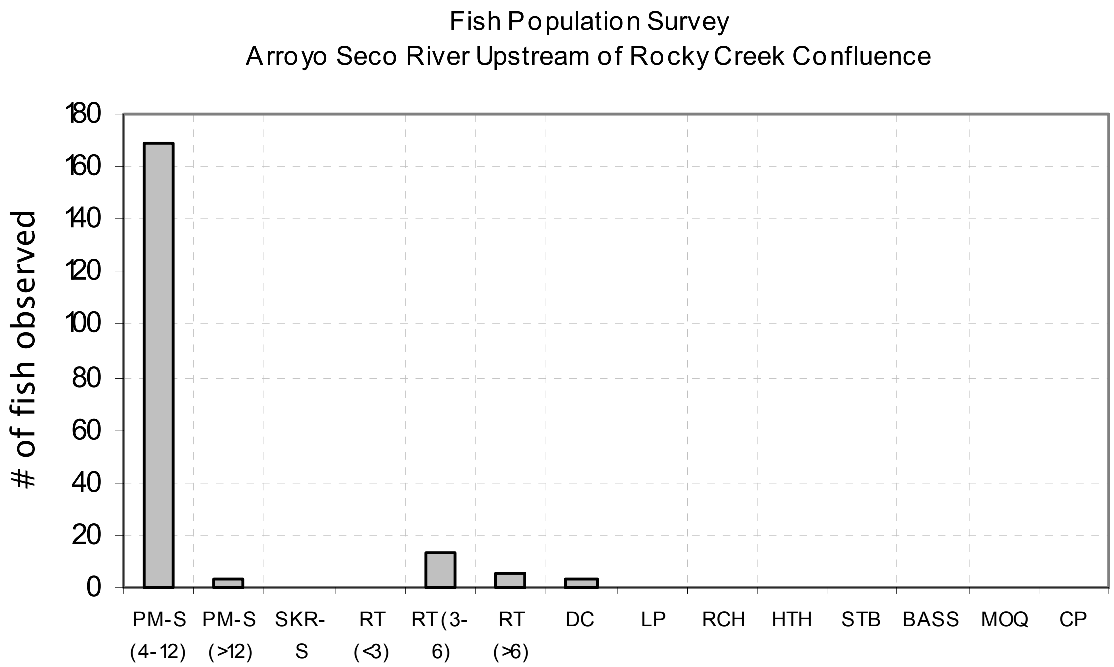
Reach	Beginning		End		Datum
	Easting	Northing	Easting	Northing	
ARR 2-1	651415	4016532	650970	4016283	NAD 83
ARR 2-2	645029	4014700	644551	4014701	NAD 83
ARR 3-1	636814	4011238	636464	4011193	NAD 83
ARR 3-2	641264	4012733	641216	4012288	NAD 83
ARR 4-1	634989	4010425	635533	4010188	NAD 83
ARR 4-2	635040	4009632	634648	4009395	NAD 83
WLW 5-1	634285	4009298	634677	4009379	NAD 83
NAC 2-1	642082	3986621	641637	3986825	NAD 83
NAC 2-2	644463	3985613	644887	3985566	NAD 83
PAS 1-1	702668	3935190	703120	3934927	NAD 83
ATA 1-1	709466	3925852	709505	3925969	NAD 83
ATA 1-2	711724	3929711	711479	3929336	NAD 83
TSE 1-1	711423	3918177	711255	3918231	NAD 83
SAN 1-1	665551	4039649	665860	4039911	NAD 83
SAN 1-2	666024	4040139	666244	4040509	NAD 83
SAL 1-1	630136	4045950	630514	4045543	NAD 83
SAL 2-1	687839	3988344	687928	3987849	NAD 83

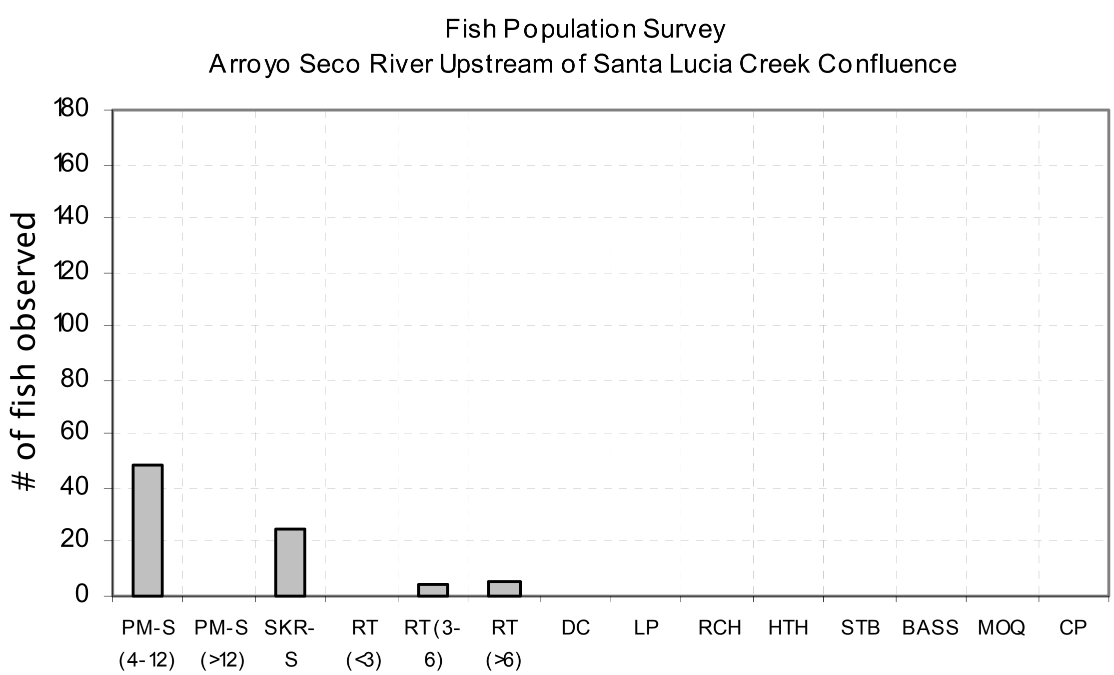

Fish Population Survey
Arroyo Seco River downstream of Elm St. Bridge
# of fish observed
0
20
40
60
80
100
120
140
160
180
PM-S (4-12)
PM-S (>12)
SKR-S
RT (<3)
RT (3-6)
RT (>6)
DC
LP
RCH
HTH
STB
BASS
MOQ
CP

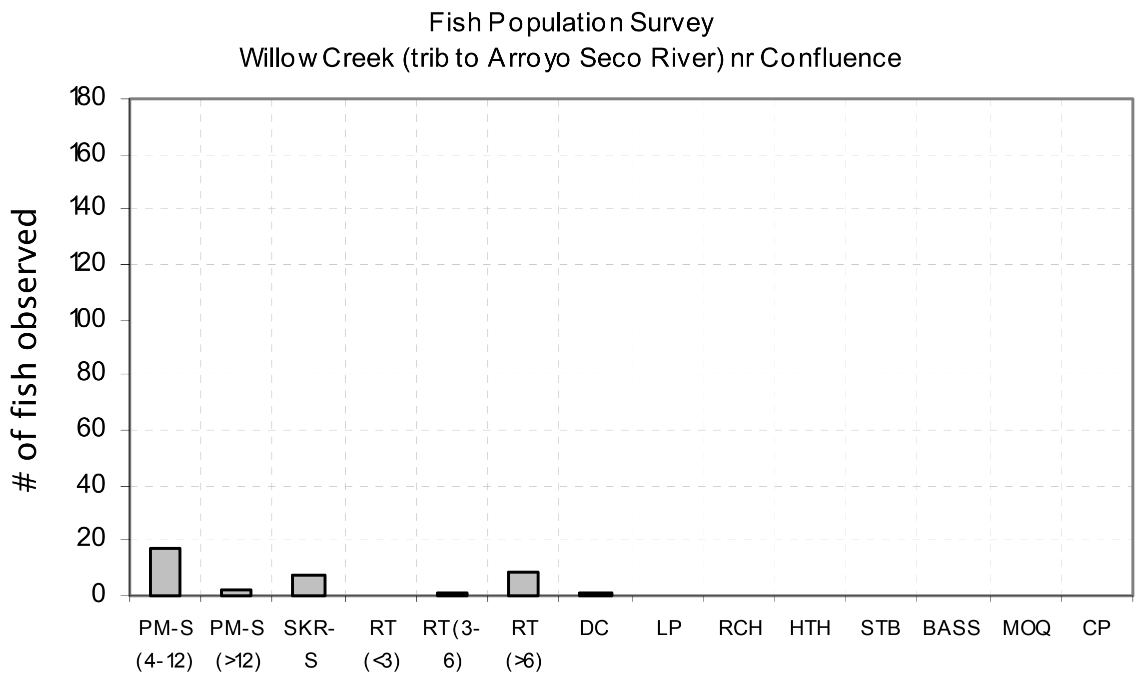

Fish Population Survey
Arroyo Seco River nr Sycamore Flats
# of fish observed
0
20
40
60
80
100
120
140
160
180
PM-S (4-12)
PM-S (>12)
SKR-S
RT (<3)
RT (3-6)
RT (>6)
DC
LP
RCH
HTH
STB
BASS
MOQ
CP


Fish Population Survey
Arroyo Seco River nr Miller's Lodge
# of fish observed
180
160
140
120
100
80
60
40
20
0
PM-S (4-12)
PM-S (>12)
SKR-S
RT (<3)
RT (3-6)
RT (>6)
DC
LP
RCH
HTH
STB
BASS
MOQ
CP

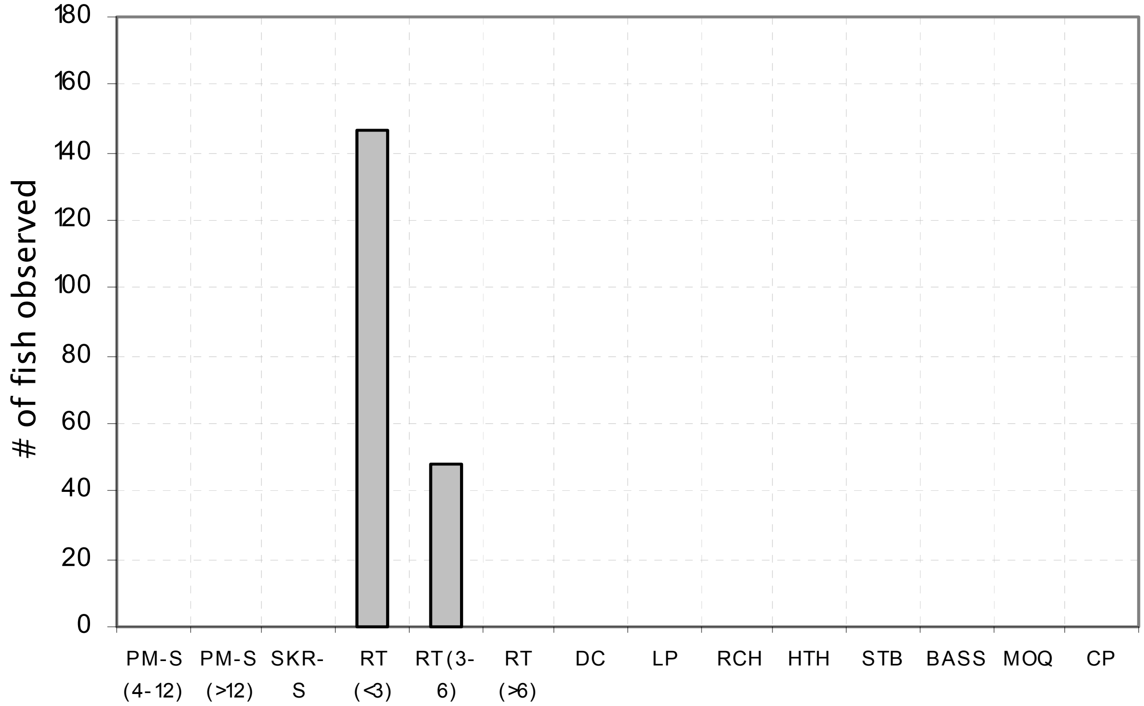

Fish Population Survey
Arroyo Seco River @ Campground Day Use Area
# of fish observed
180
160
140
120
100
80
60
40
20
0
PM-S (4-12)
PM-S (>12)
SKR-S
RT (<3)
RT (3-6)
RT (>6)
DC
LP
RCH
HTH
STB
BASS
MOQ
CP


Fish Population Survey
Arroyo Seco River Upstream of Rocky Creek Confluence
# of fish observed
0
20
40
60
80
100
120
140
160
180
PM-S (4-12)
PM-S (>12)
SKR-S
RT (<3)
RT (3-6)
RT (>6)
DC
LP
RCH
HTH
STB
BASS
MOQ
CP

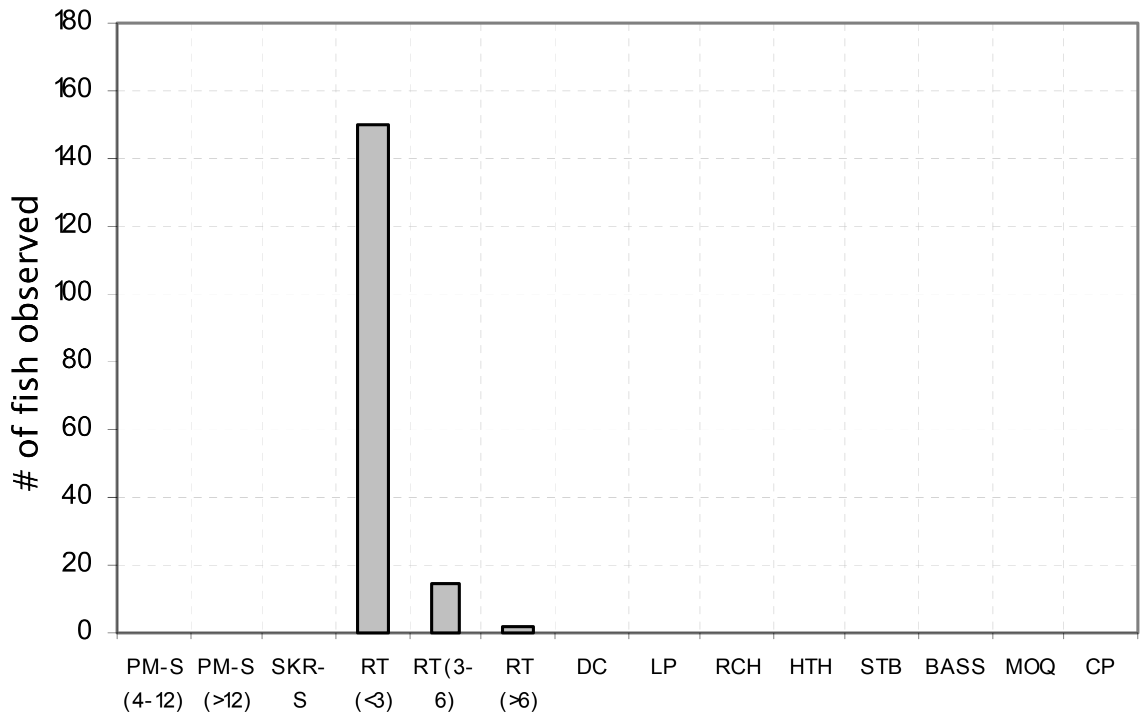

Fish Population Survey
Arroyo Seco River Upstream of Santa Lucia Creek Confluence
# of fish observed
0
20
40
60
80
100
120
140
160
180
PM-S (4-12)
PM-S (>12)
SKR-S
RT (<3)
RT (3-6)
RT (>6)
DC
LP
RCH
HTH
STB
BASS
MOQ
CP

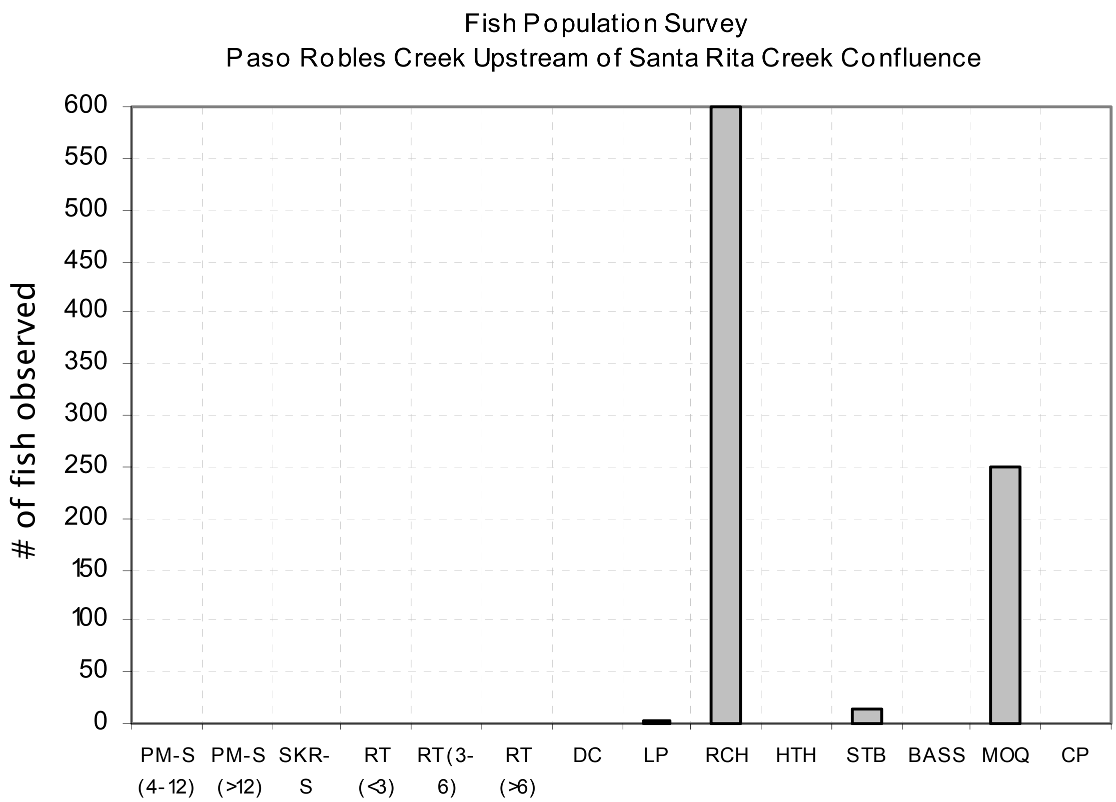

Fish Population Survey
Willow Creek (trib to Arroyo Seco River) nr Confluence
# of fish observed
180
160
140
120
100
80
60
40
20
0
PM-S (4-12)
PM-S (>12)
SKR-S
RT (<3)
RT (3-6)
RT (>6)
DC
LP
RCH
HTH
STB
BASS
MOQ
CP

Fish Population Survey
Nacimiento River nr Nacimiento Campground

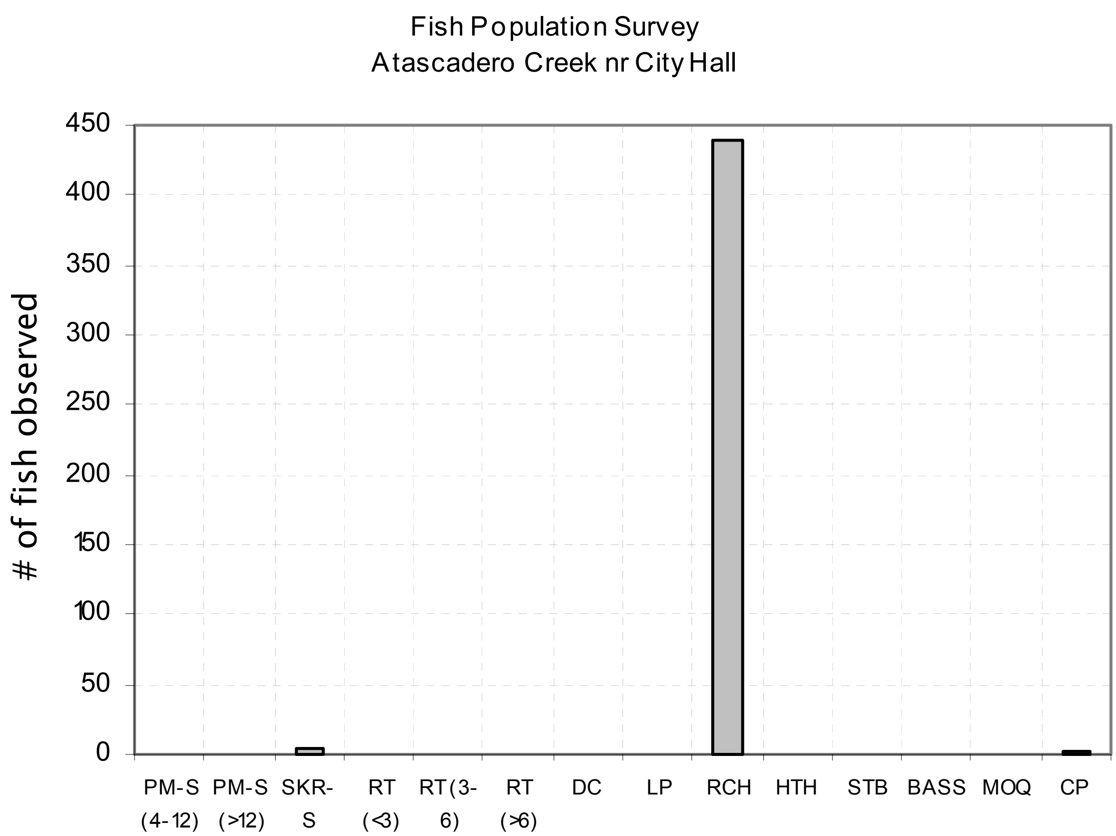


Fish Population Survey
Nacimiento River nr Summit Ranger Station

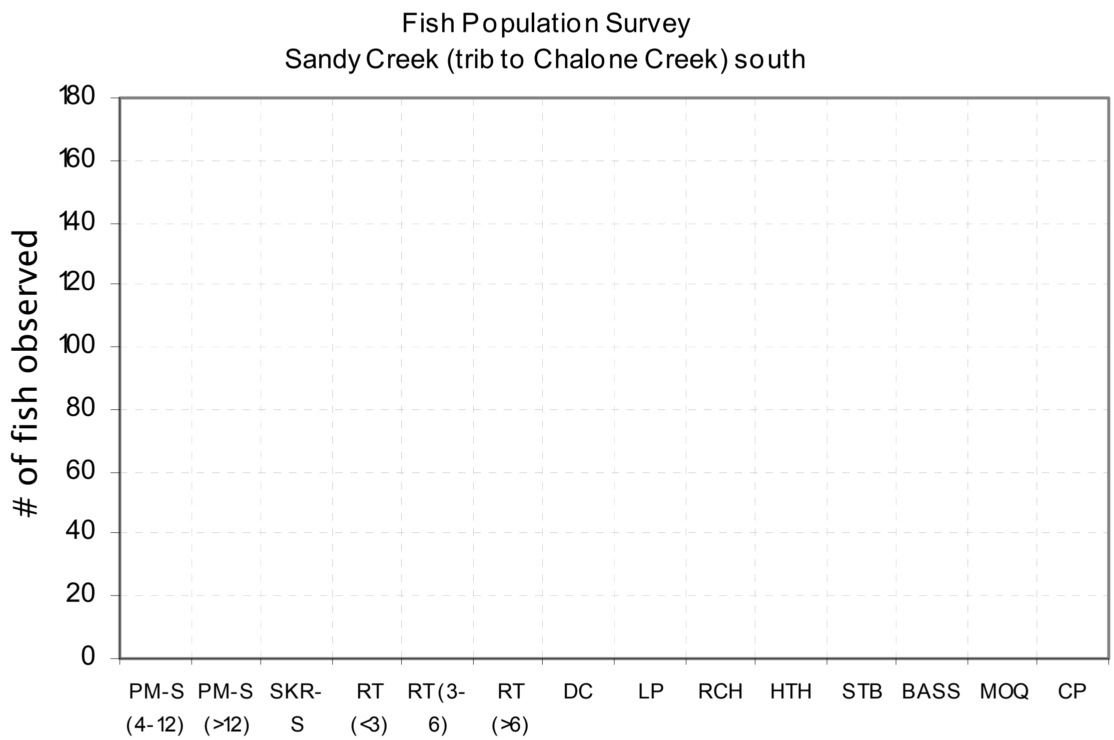


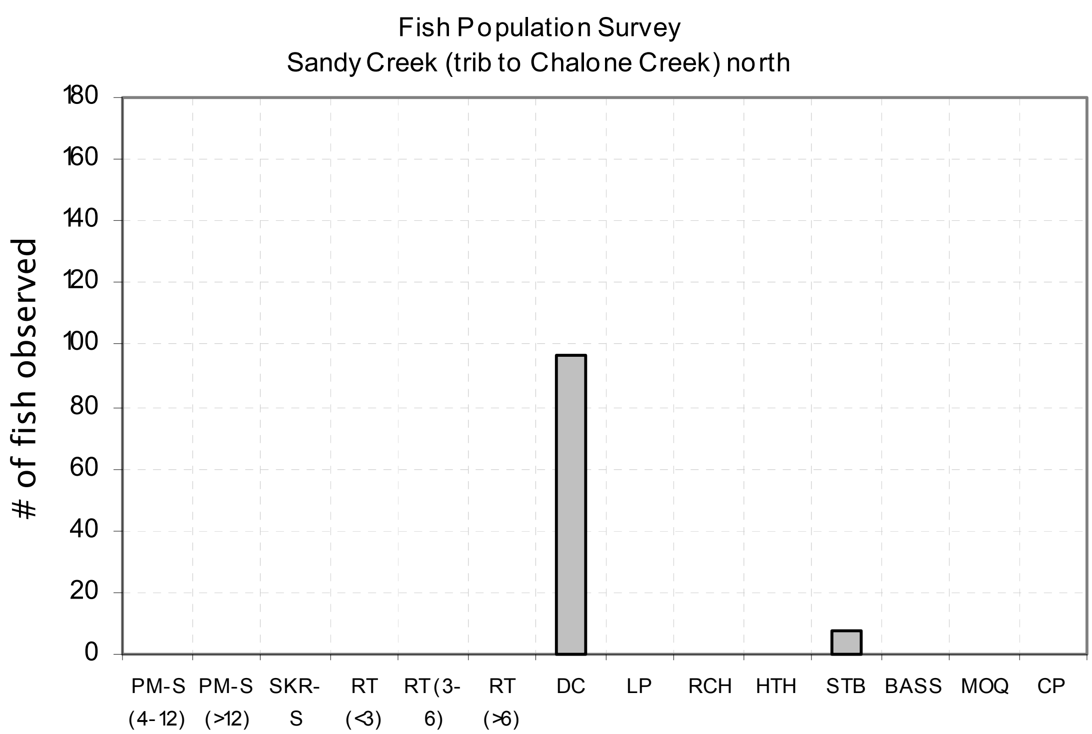


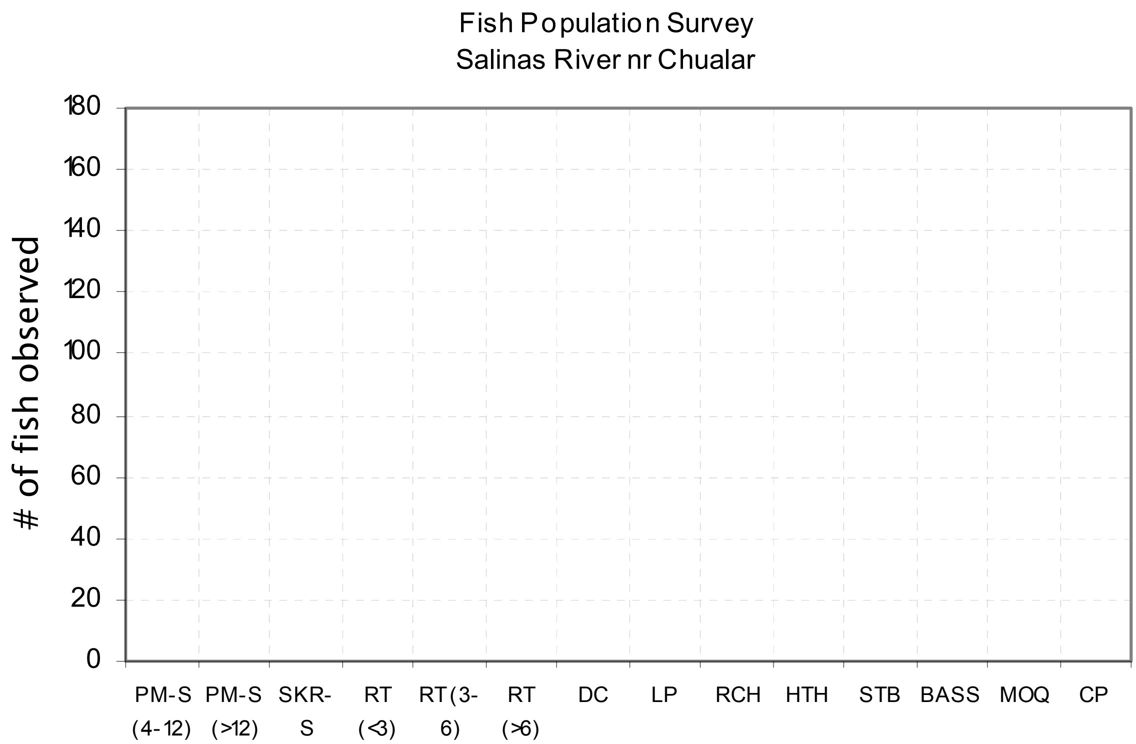
Fish Population Survey
Paso Robles Creek Upstream of Santa Rita Creek Confluence
# of fish observed
600
550
500
450
400
350
300
250
200
150
100
50
0
PM-S (4-12)
PM-S (>12)
SKR-S
RT (<3)
RT (3-6)
RT (>6)
DC
LP
RCH
HTH
STB
BASS
MOQ
CP

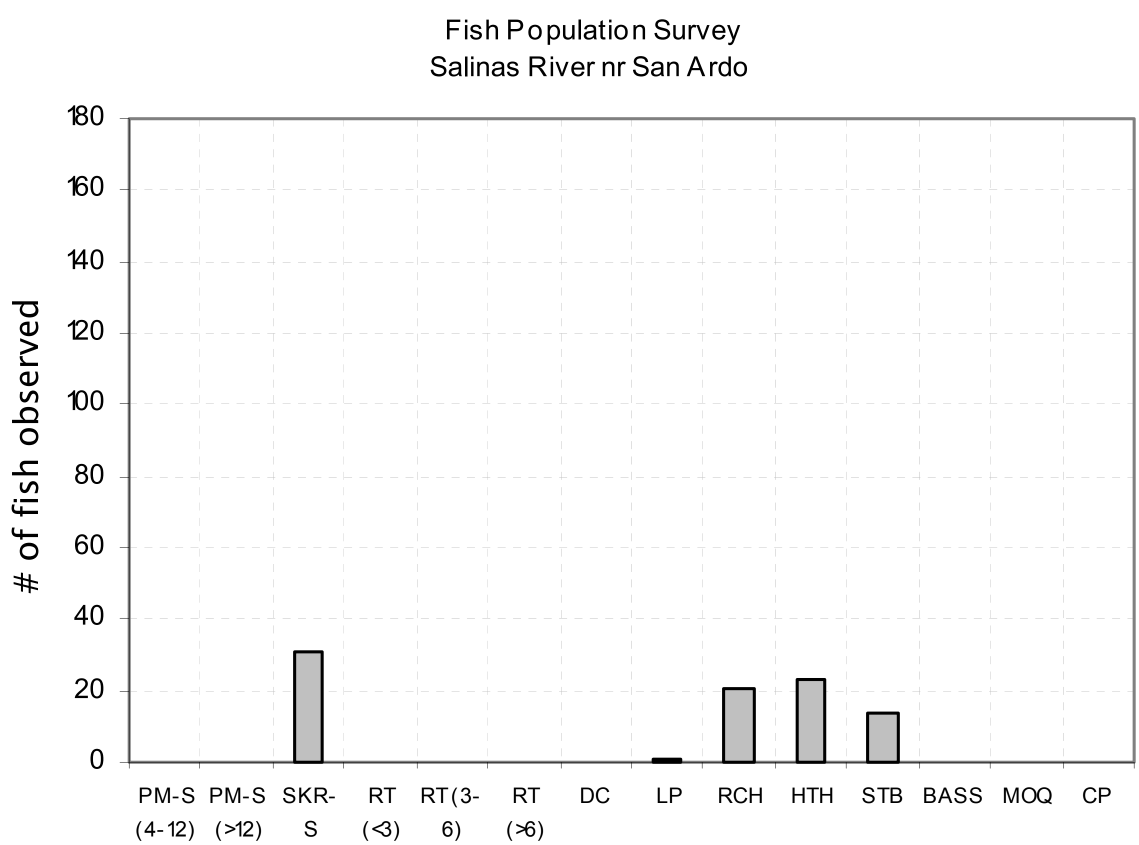


Fish Population Survey
Atascadero Creek nr City Hall
# of fish observed
450
400
350
300
250
200
150
100
50
0
PM-S (4-12)
PM-S (>12)
SKR-S
RT (<3)
RT (3-6)
RT (>6)
DC
LP
RCH
HTH
STB
BASS
MOQ
CP

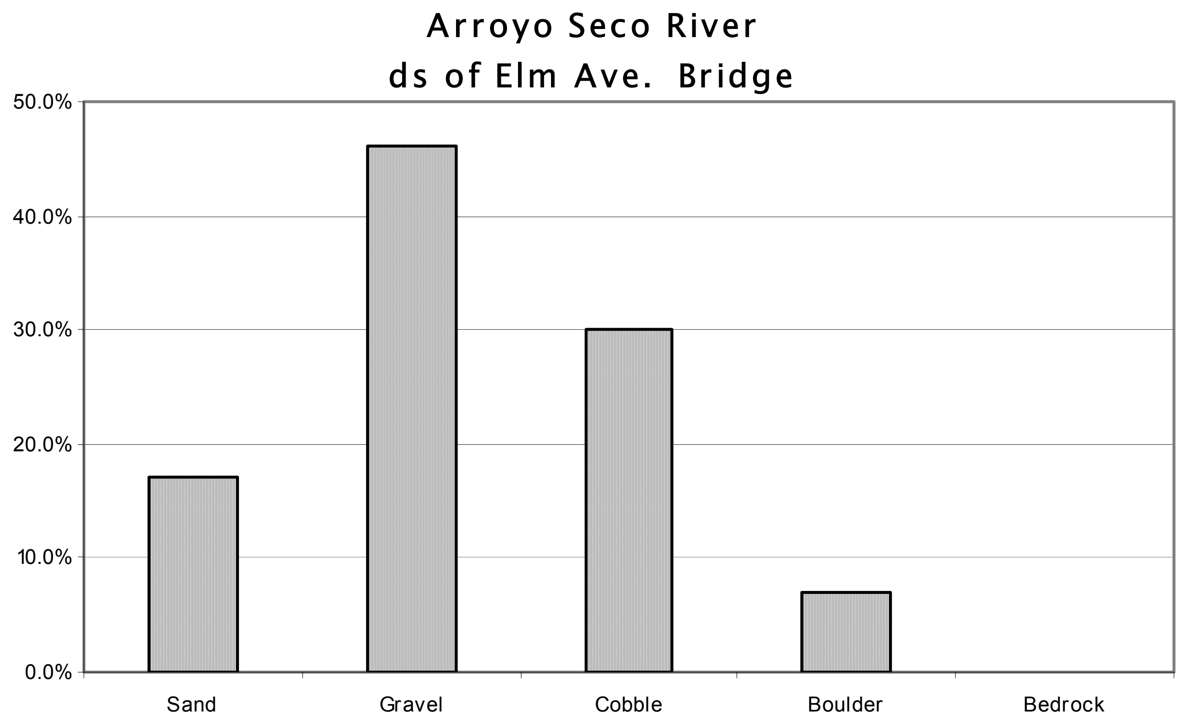

Fish Population Survey
Sandy Creek (trib to Chalone Creek) south
# of fish observed
0
20
40
60
80
100
120
140
160
180
PM-S (4-12)
PM-S (>12)
SKR-S
RT (<3)
RT (3-6)
RT (>6)
DC
LP
RCH
HTH
STB
BASS
MOQ
CP

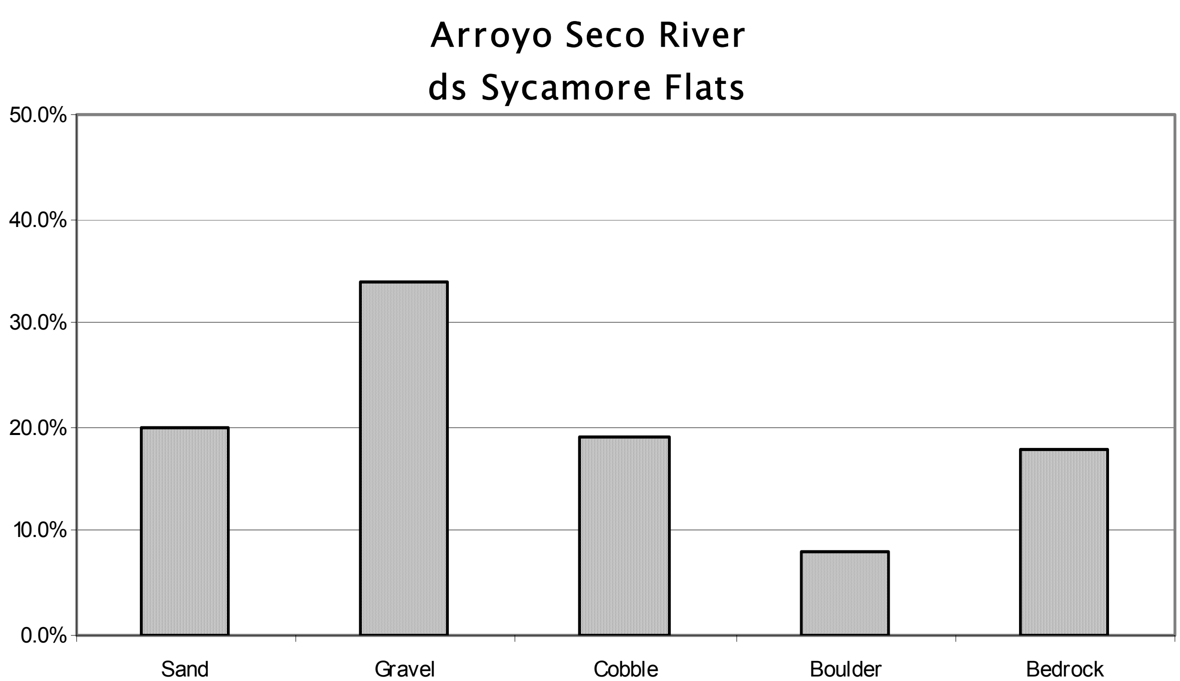

Fish Population Survey
Sandy Creek (trib to Chalone Creek) north
# of fish observed
0
20
40
60
80
100
120
140
160
180
PM-S (4-12)
PM-S (>12)
SKR-S
RT (<3)
RT (3-6)
RT (>6)
DC
LP
RCH
HTH
STB
BASS
MOQ
CP

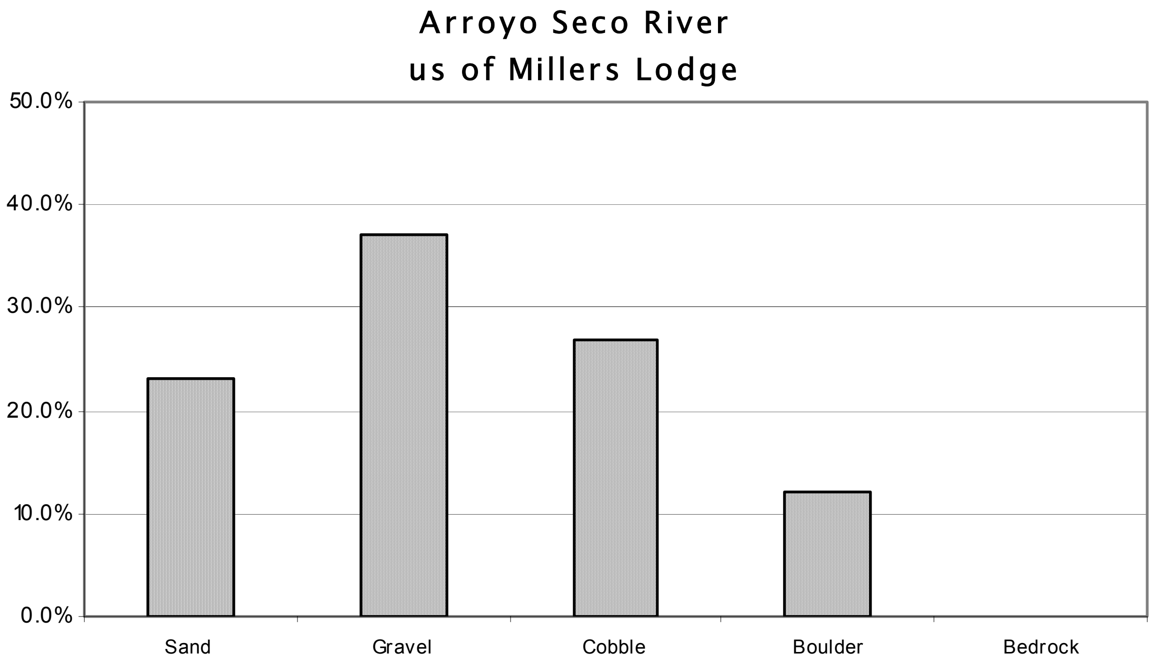

Fish Population Survey
Salinas River nr Chualar
# of fish observed
0
20
40
60
80
100
120
140
160
180
PM-S (4-12)
PM-S (>12)
SKR-S
RT (<3)
RT (3-6)
RT (>6)
DC
LP
RCH
HTH
STB
BASS
MOQ
CP

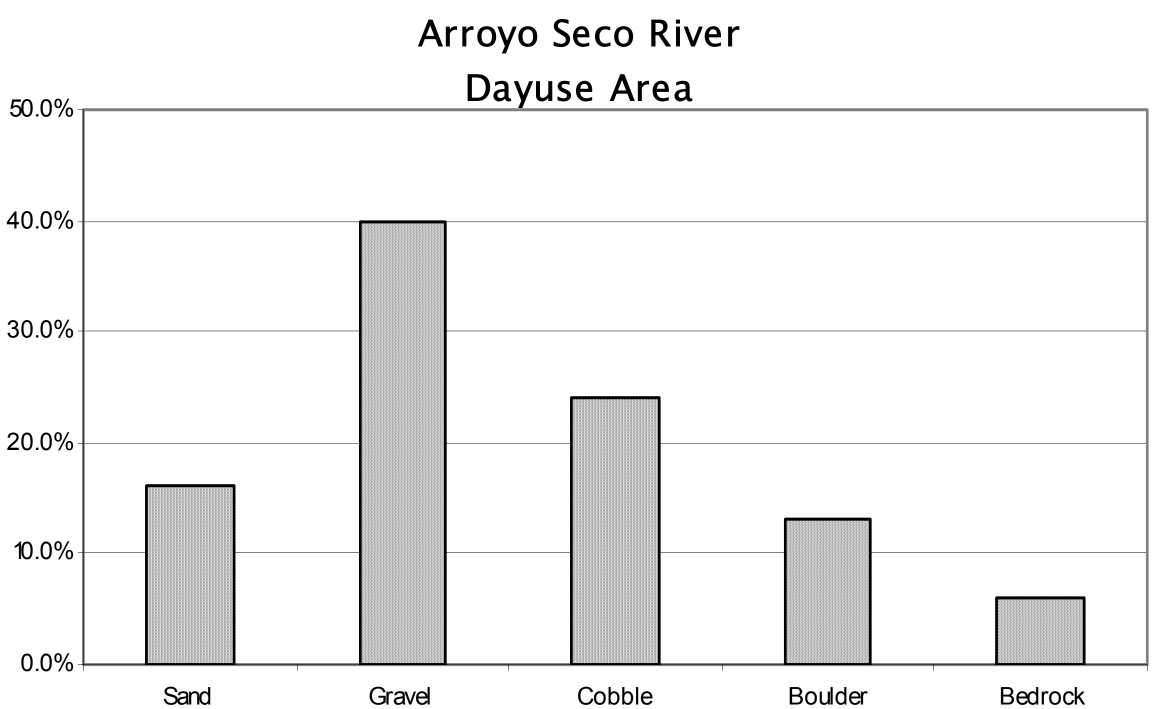

Fish Population Survey
Salinas River nr San Ardo
# of fish observed
0
20
40
60
80
100
120
140
160
180
PM-S (4-12)
PM-S (>12)
SKR-S
RT (<3)
RT (3-6)
RT (>6)
DC
LP
RCH
HTH
STB
BASS
MOQ
CP

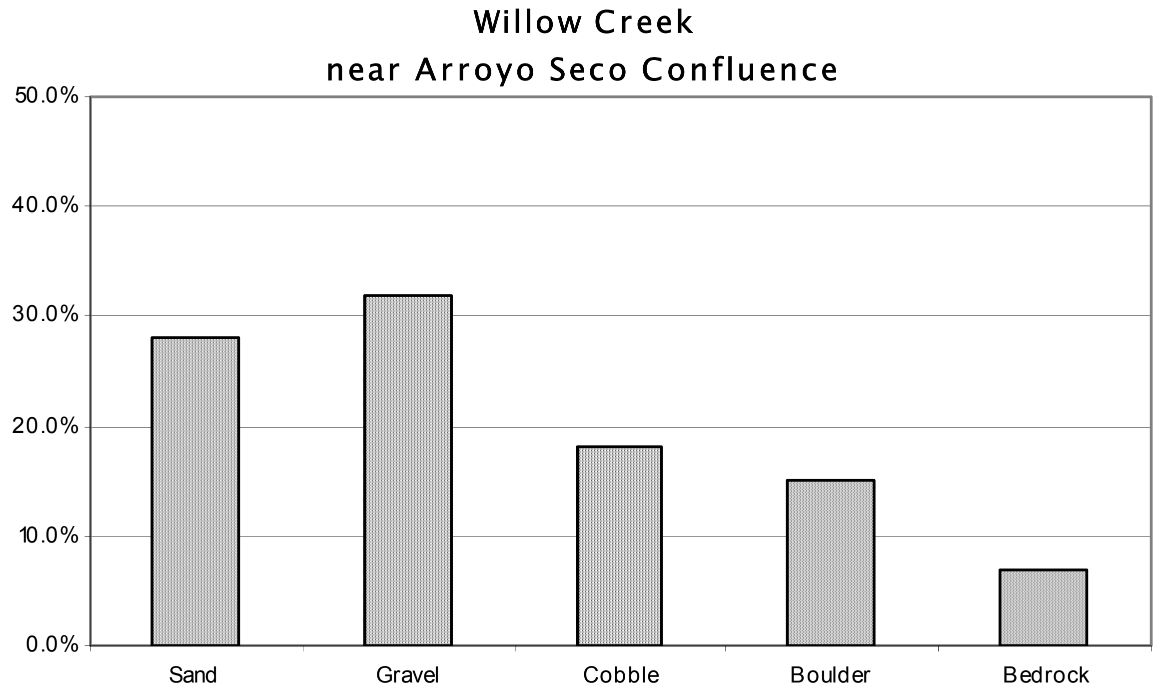
15.2 Appendix B: Reach Average Median Bottom Particle Size

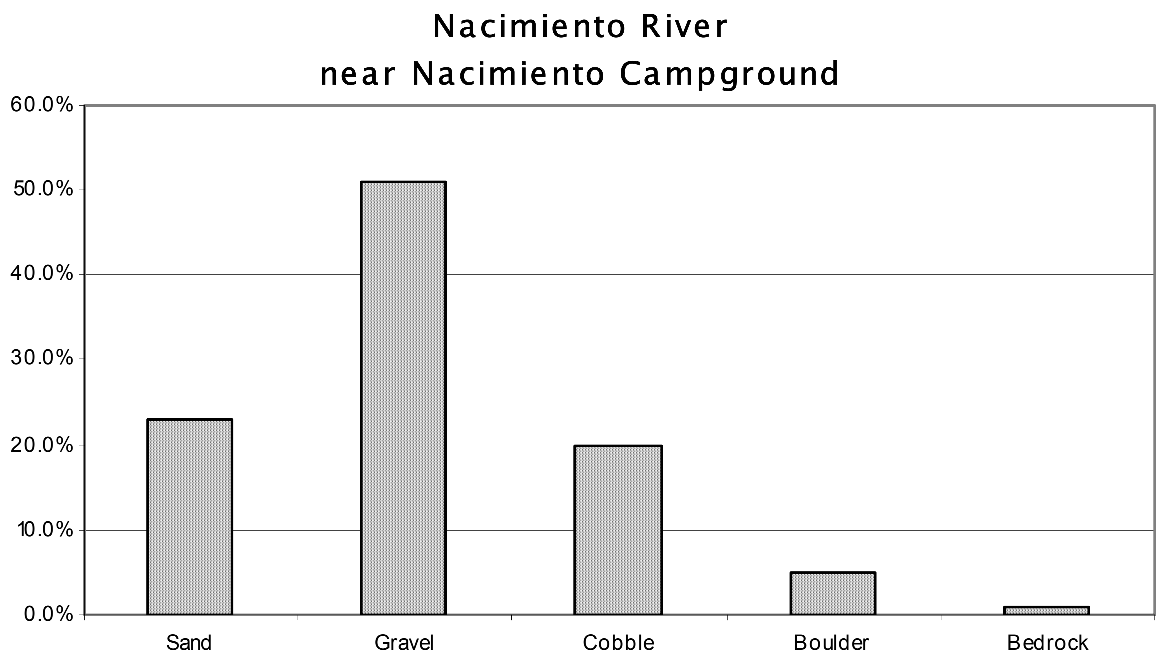


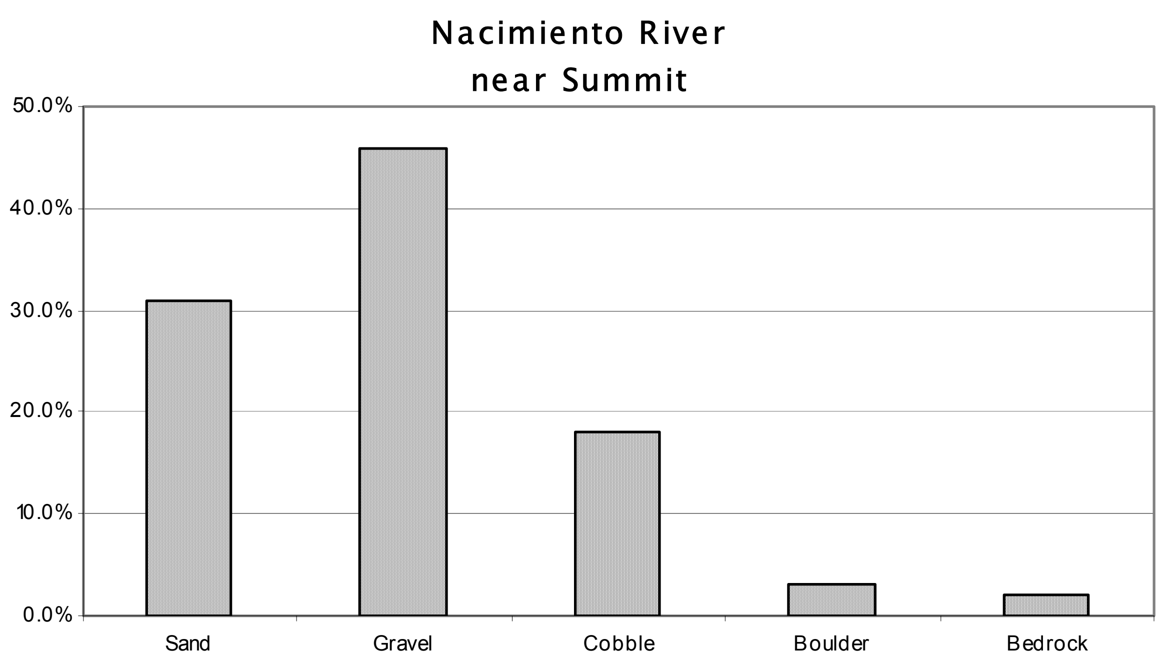



Arroyo Seco River
us of Millers Lodge
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Sand
Gravel
Cobble
Boulder
Bedrock

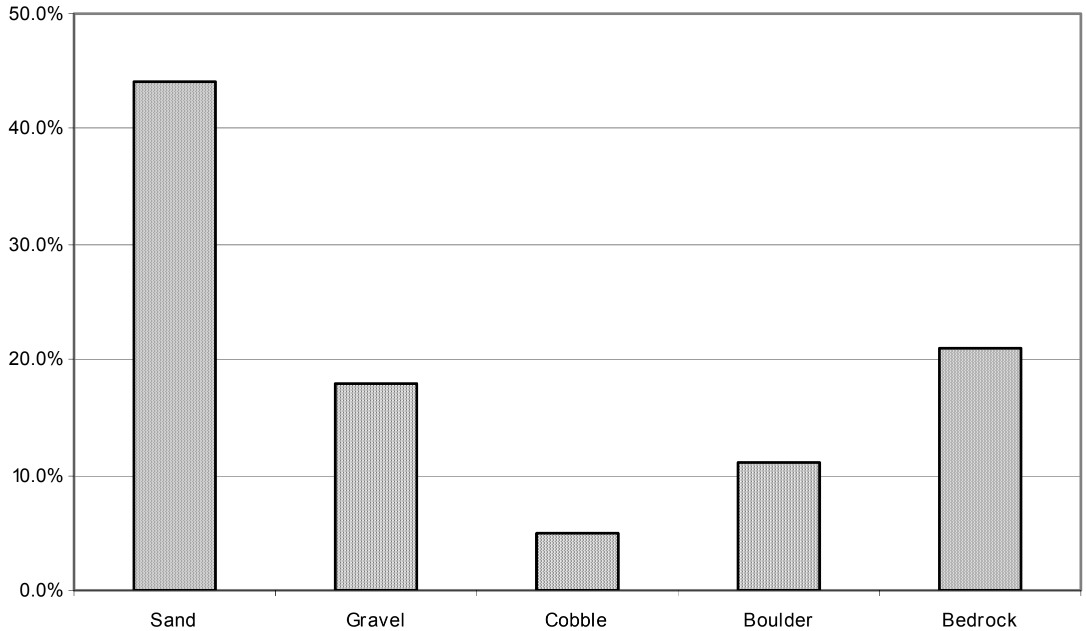

Arroyo Seco River
Dayuse Area
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Sand
Gravel
Cobble
Boulder
Bedrock


Willow Creek
near Arroyo Seco Confluence
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Sand
Gravel
Cobble
Boulder
Bedrock

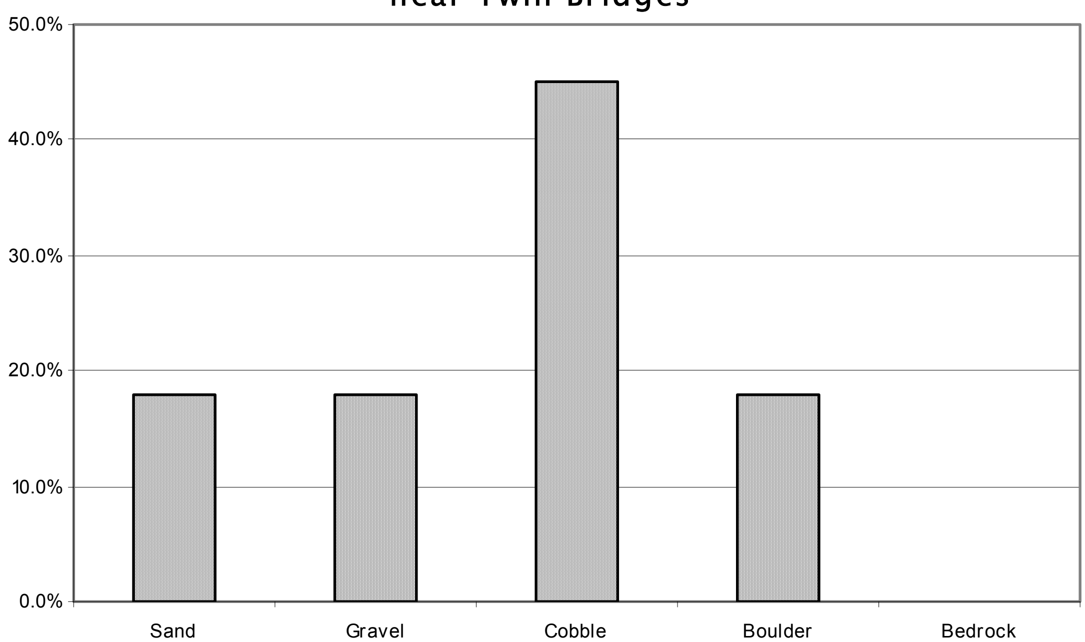

Nacimiento River
near Nacimiento Campground
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Sand
Gravel
Cobble
Boulder
Bedrock

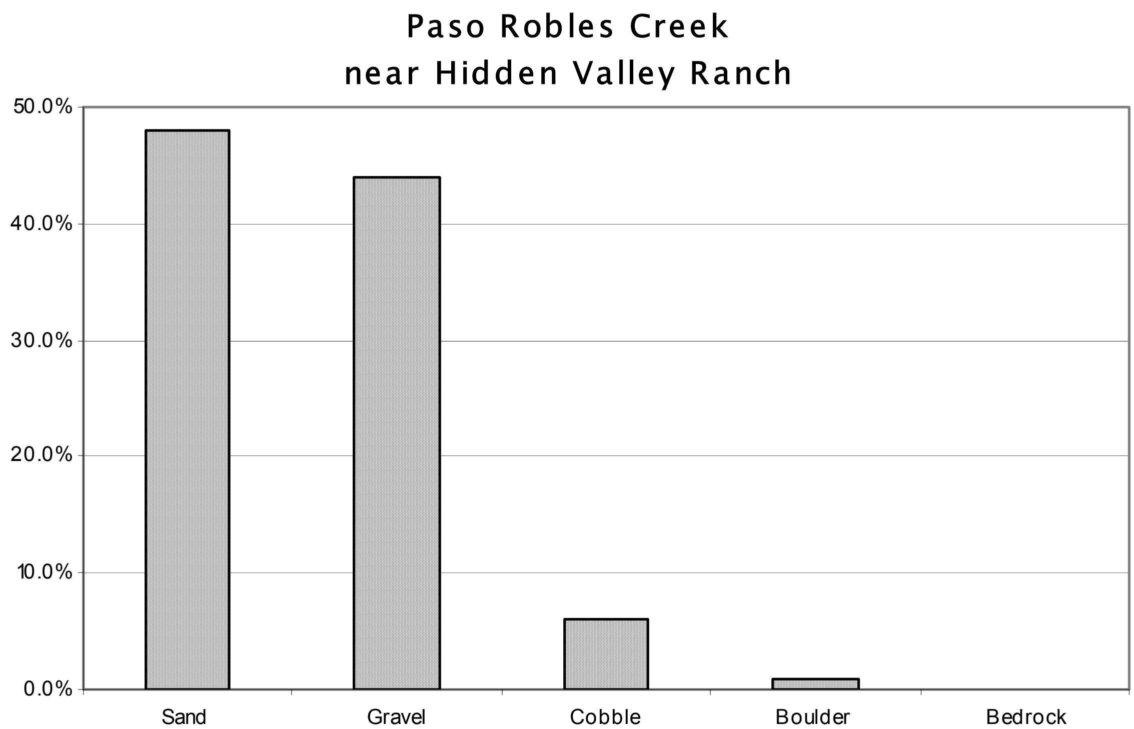

Nacimiento River
near Summit
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Sand
Gravel
Cobble
Boulder
Bedrock

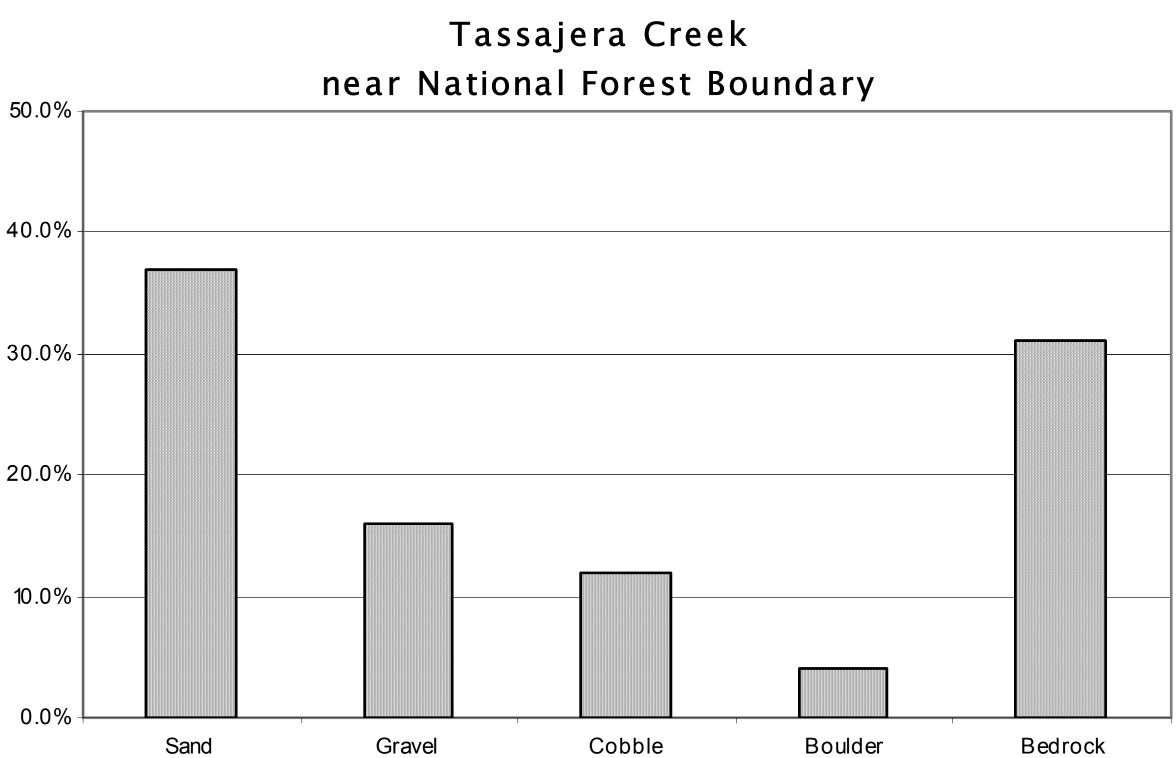
Atascadero Creek
near US HYW 101

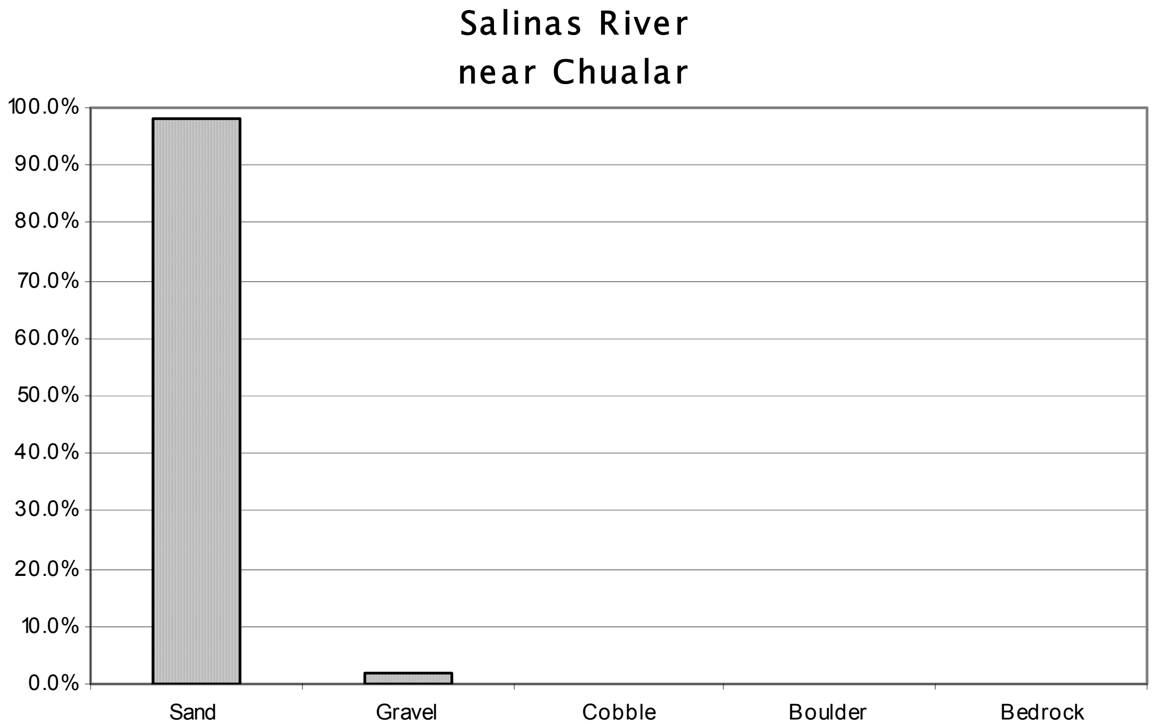


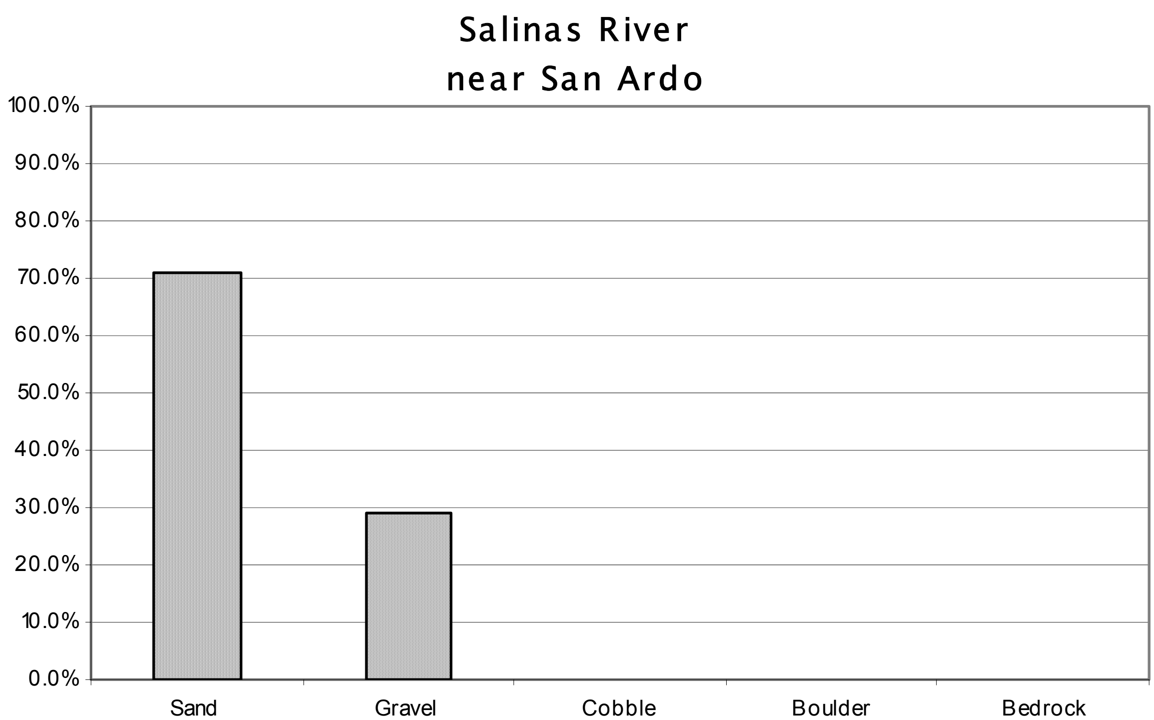
Atascadero Creek
near Twin Bridges

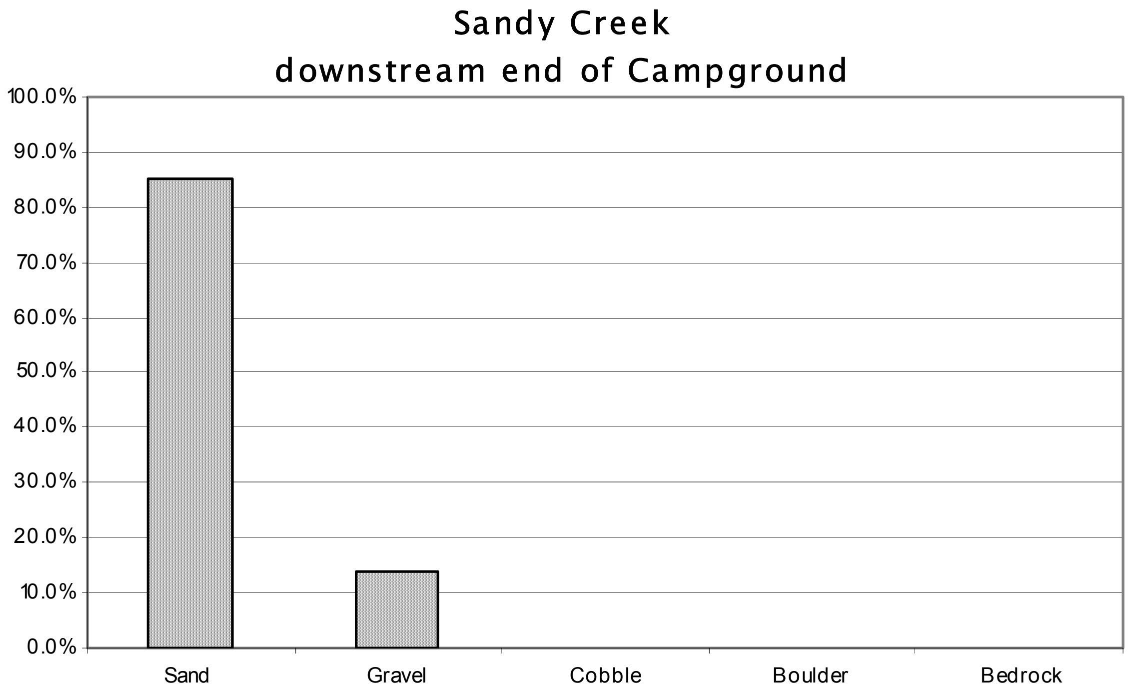


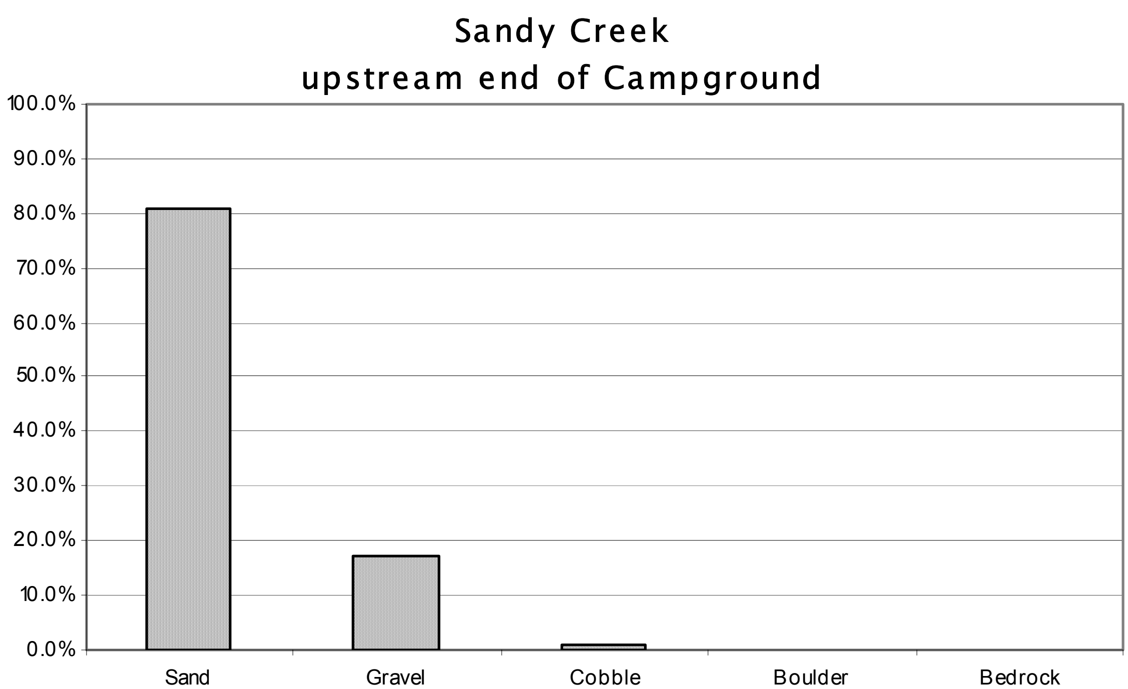

Paso Robles Creek
near Hidden Valley Ranch
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Sand
Gravel
Cobble
Boulder
Bedrock


Tassajera Creek
near National Forest Boundary
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Sand
Gravel
Cobble
Boulder
Bedrock


Salinas River
near Chualar
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Sand
Gravel
Cobble
Boulder
Bedrock


Salinas River
near San Ardo
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Sand
Gravel
Cobble
Boulder
Bedrock


Sandy Creek
downstream end of Campground
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Sand
Gravel
Cobble
Boulder
Bedrock


Sandy Creek
upstream end of Campground
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Sand
Gravel
Cobble
Boulder
Bedrock