ASSESSMENT OF STEELHEAD PRESENCE
AND HABITAT IN SAN LORENZO CREEK WATERSHED

A University Thesis Presented to the Faculty

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Master of Science in Riparian Wildlife Ecology

By

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Abstract

Steelhead (*Oncorhynchus mykiss*), a federally listed threatened species, were once common in San Lorenzo Creek, a highly modified urban stream in the east San Francisco Bay Area. Since the 1940's, increased urbanization of the watershed has degraded stream habitat, and construction of dams and flood control channels have eliminated most of the upstream habitat from steelhead access. Despite these extensive impacts, there have been occasional reports of steelhead in the creek during wet years, such as 1982-83.

Downstream migrant trapping in the spring of 1997, visual surveys for parr in the fall of 1997, and isolated electroshocking surveys in 1997-98 failed to find any young steelhead in the stream system.   During adult steelhead surveys in the winter and spring of 1997-98, persistent turbidity inhibited the ability to survey the stream, especially deeper pools, using either visual or electroshocking methods. Exotic fishes were found to be present in San Lorenzo Creek, but two native fishes; California roach and Sacramento sucker were found to be the dominant species throughout the stream system.

Evaluation of San Lorenzo Creek for steelhead habitat found limitations for the species at every life stage. Upstream migrant access was evaluated at a 4.6-mile concrete channel on San Lorenzo Creek and a 1670-foot concrete box

culvert on Crow Creek in the winter of 1997-98. When compared to established maximum cruising (swimming) speeds for steelhead, these flood control channels were found to be virtually impassable barriers. Only very shallow depths were found where flow velocities were suitable for steelhead passage within San Lorenzo Creek concrete channel (maximum depth of 1.2 feet in channel center (e.g. V-notch)). In a section where steel baffles were placed in the V-notch to reduce velocities, maximum depth suitable for passage increased to only 1.8 feet in the channel center, and 1.0 feet along inside bends. No suitable conditions for steelhead passage were found at the Crow Creek box culvert.

Steelhead spawning and rearing habitat were evaluated in spring 1998 in both San Lorenzo Creek and a reference stream, San Francisquito Creek, which still retains a steelhead run. Results revealed four limitations in steelhead spawning and rearing habitat in San Lorenzo Creek: 1) few pools; 2) lack of large woody debris; 3) sedimentation of riffle habitats; and 4) low abundances of benthic macroinvertebrates.

Most or all of the San Lorenzo Creek sites scored below, and sometimes well below, the San Francisquito watershed sites for pool volume ($P=0.037$), pool length x average depth ($P=0.018$), and % pool (based on length) ($P=0.037$). Large woody debris was noted to occur 3.3 times less frequently within San

Lorenzo Creek sample sites. Results from pebble counts from both watersheds showed a pattern of higher percent fines (< 4 mm), and greater embeddedness within potential spawning gravels in San Lorenzo Creek watershed. Samples of benthic macroinvertebrates taken from two locations within each watershed showed abundances to be from 2 to 27 times lower at San Lorenzo Creek sample sites, though the highest number of EPT taxa occurred at a San Lorenzo Creek site (Crow Creek).

A review of water quality data collected by Alameda County Clean Water Program, augmented with additional data collected in this study, found extremely high water temperatures in the San Lorenzo concrete channel during spring and summer that would likely impact out-migrating steelhead smolts and in-migrating spring-run adults. Higher stream water temperatures in the summer and fall immediately downstream of the reservoirs could also impact rearing steelhead parr.

Due to the adaptability of steelhead and the wandering tendency of the species, recolonization of San Lorenzo Creek is possible, yet appears highly unlikely given the current access, spawning, and rearing habitat limitations. Some management, restoration, and research measures are recommended for improving habitat for steelhead in San Lorenzo Creek.

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CHAPTER 1: INTRODUCTION AND BACKGROUND

Purpose of Study

Steelhead (*Oncorhynchus mykiss*) were once common in San Lorenzo Creek, a highly modified urban stream in the east San Francisco Bay Area. Steelhead have not been thoroughly surveyed for in San Lorenzo Creek since 1975 (CDFG, 1975), and there have been occasional reports of adult steelhead in the creek during wet years, such as in 1982-83. Given the recolonization ability of this species, more recent surveys were needed.

Since the 1940's, increased urbanization of the watershed has degraded stream habitat, and construction of dams and flood control channels has cut-off or eliminated most of the historic upstream habitat for this species. The particular factors responsible for the decline and limitation of this species within San Lorenzo Creek have not been identified. Better understanding of these factors will assist in developing and evaluating restoration plans for this species. The recent listing in 1997 of steelhead as a threatened species in the Central California Coast region by the National Marine Fisheries Service (NMFS) underscores the importance of understanding and protecting this species within the drainages of San Francisco Bay.

This study was undertaken to: 1) assess the historical and present conditions of San Lorenzo creek watershed; 2) survey for steelhead parr and adults in San Lorenzo Creek watershed in the spring, fall, and winter of 1997/98; 3) assess upstream accessibility for migrating steelhead through concrete flood control channels in San Lorenzo Creek and it's tributaries; and 4) assess habitat quality for steelhead spawning and parr rearing at randomly selected locations within San Lorenzo Creek watershed and compare these conditions to a reference watershed.

Background: Steelhead

Life History

The steelhead is the anadromous form of rainbow trout. This species is considered to have a greater diversity of life history patterns than any other Pacific Salmonid species (Shapovalav & Taft, 1954). This diversity can include varying degrees of anadromy, differences in reproductive biology, and plasticity of life history between generations.

Steelhead can be divided into two basic reproductive ecotypes. The stream-maturing type (summer steelhead) , which enter fresh water in a sexually immature condition and require several months to mature and spawn; and the ocean-maturing type (winter steelhead), which enter fresh water reproductively mature with developed gonads and spawn shortly thereafter. Most steelhead populations are of the ocean-maturing type, while stream-maturing types are limited to a few northern California coastal rivers (NMFS, 1996).

In this region, (based upon data from Waddell Creek--Shapovalav & Taft, 1954--and Sacramento River--Hallock, 1986*: in NMFS, 1996*), steelhead typically spend two years in freshwater, and either one or two years in the ocean before returning to their natal stream to spawn. Steelhead can smolt and out-migrate at various age classes, and actual age distribution and timing of out-migration in San Lorenzo Creek is unknown.

Steelhead are different from other anadromous salmonids in that they can make more than one spawning migration from the ocean to freshwater in a lifetime. Most steelhead returning to freshwater are first-time spawners (83%), but a small percentage return to spawn two times (15%), three times (2%), and as many as five times in very rare cases (Shapovalav & Taft, 1954).

Steelhead migrate into streams in the late fall, winter and early spring when flows are relatively high. Typically the fish prefer to move at night during either a rising or falling stage, avoiding peak streamflows. Although steelhead and other salmonids are known to return to spawn in their natal stream, they will sometimes wander -- that is come up and spawn in streams other than their natal stream. Some steelhead populations have been found to wander more than others--(i.e. Waddell Creek-- Shapovalav & Taft, 1954). Wandering is likely an important mechanism for recolonization of streams in Central and Southern California where stream flows can fluctuate year to year between perennial and intermittent conditions.

Table 1. Hypothetical sequence of steelhead life cycle for San Lorenzo Creek (based upon historical observations of San Lorenzo Creek steelhead and research from other local streams).

Month	**Run**	**Adults**	**Smolts D/S migrants**	**Age class (year 0)**	**Age class (year 1)**	**Age class (year 2)**
December	Winter	ascending/ spawning		eggs	parr	parr
January	Winter	ascending/ spawning		eggs	parr	parr
February	Winter & Spring	ascending/ spawning	descending	eggs/fry	smolt	smolt
March	Spring	ascending/ spawning	descending	eggs/fry	smolt	smolt
April	Spring	ascending/ spawning	descending	fry/parr	smolt	smolt
May-November		Stream resident		parr	parr	parr

Most steelhead in the San Francisco Bay Area tend to migrate into streams in the winter months of January, February, and March after the migration of king (chinook) salmon in the fall. They tend to migrate in groups, and once in freshwater they essentially stop feeding. Their response to fishing lures is thought to be an instinctive response, rather than a need to feed. They can spend anywhere from a few days to a few months in freshwater before spawning, depending upon stream conditions.

Spawning occurs in shallow water, typically at the upstream end of a riffle, and downstream of a pool. Steelhead require coarse, clean gravels relatively free of silt with ample water movement (velocities of 20-90 cm/second) through the gravels to provide oxygen and remove metabolic wastes. The developing embryos require oxygen levels at or near saturation, and cool water temperatures in the range of 4-15^{o} C (Reiser and Bjornn, 1979; Barnhart 1986; Merritt Smith, 1995). Eggs hatch after about 30 days, and the steelhead fry complete early development and emerge from the gravels about 2-3 weeks later (typically in spring) depending upon temperature.

Steelhead young will typically spend two years growing and maturing in freshwater before migrating back to the ocean in spring. Age 0+ steelhead (recently hatched) have been found to prefer riffles with large woody debris, while age 1+ steelhead (hatched the previous year) prefer plunge, trench, and lateral scour pools with woody debris and undercut banks (Bisson, et. al. 1981). In the San Francisco Bay Area, stream levels drop during the summer and fall dry period, and steelhead young are dependent upon remnant pools with low water temperatures for survival during this period.

Steelhead feed on a variety of aquatic and terrestrial invertebrate species depending upon availability. In Alameda Creek (the largest stream in the East San Francisco Bay Area), Keith (1995**)** found that rainbow trout fed predominately upon insects in the Diptera, Ephemeroptera, and Trichoptera orders; overall diet however was diverse and corresponded closely to the taxonomic composition of benthic macroinvertebrates in rearing pools.

The peak out-migration for steelhead smolts is during high flow conditions in spring (Merritt Smith Consulting, 1995; Shapovalav & Taft, 1954), with the actual time depending upon the stream flow of each particular creek. As is the case with the upstream migrants, the downstream migrating fish tend to move at night.

Steelhead Status

During the last 30 years, population numbers of steelhead have dropped precipitously along the entire west coast of the contiguous United States. The National Marine Fisheries Service (NMFS) conducted a status review of 178 populations of steelhead in the states of Washington, Idaho, Oregon, and California. Of these, the NMFS identified 15 reproductively isolated populations or “evolutionary significant units” (ESU’s) of steelhead within this range. Of these 15, the NMFS has listed five as endangered and five as threatened under the Endangered Species Act (Federal Register, August, 1997). Almost all ESUs have declined steeply since the mid-1980's. Among the factors that are believed to be responsible for this decline are: regional climate change, ocean and freshwater over-fishing, increased sedimentation and pollution, loss of riparian vegetation, loss of in-stream habitat complexity, and barriers to fish movement (NMFS, 1996).

The Central California Coast ESU, which comprises the coastal drainages from the Russian River to Soquel Creek in Santa Cruz County and the drainages of San Francisco and San Pablo Bays (excluding the Sacramento-San Joaquin River Basin), is one of five ESUs that has received threatened status. Most steelhead runs in streams tributary to San Francisco Bay and San Pablo Bay are thought to be extirpated (McEwan and Jackson 1996). Nehlsen (1991) cited sedimentation and channel degradation due to poor land management practices as the factors responsible for the extirpation. Another important factor that is likely to have influenced the extirpation is the installation of flood control structures that prevent steelhead from reaching upstream spawning areas.

Historic Steelhead Run

Although there are no records of population sizes of steelhead in San Lorenzo Creek, there is much anecdotal information from local fisherman. According to these accounts, San Lorenzo Creek had highly productive steelhead runs up until the early 1950's (D. Staley, M. Steveco, J. Walton, D. Pulverosa personal communication). The stream system reportedly supported both a winter (8-12 lb fish) and spring (2-3 lb fish) steelhead run (J. Walton, personal communication). One longtime fisherman (D. Staley) referred to it as "one of the best steelhead streams in this area".

The California Department of Fish and Game characterized steelhead spawning attributes in San Lorenzo Creek as "severely limited" as early as 1953 (State of California, 1953). Fisheries surveys were conducted in 1960 and in 1975. The most comprehensive survey was done in 1960 when all of the major tributaries of San Lorenzo Creek (Cull, Palomeras, Crow, and Eden creeks) were surveyed by CDFG biologists. Rainbow trout and/ or steelhead fry were found in Palomeras Creek only. This was the last published observation of steelhead and/or rainbow trout fry in the system. The biologists characterized most of the habitat as poor to marginal for steelhead, and they noted that landowners were pumping water from the creek and this was cited as a probable reason for the observed lack of pools. In addition, burial of spawning gravels with fine sediments was observed in many places. This was attributed to overgrazing in the upper watershed, and to local landowners dumping yard waste into the stream (CDFG, 1960).

The CDFG survey in 1975 covered San Lorenzo and Crow Creeks and found resident adult rainbow trout in Bolinas Creek (a tributary of Crow Creek), but no young fish (CDFG, 1975). They also recorded fecal contamination and fish kills in the creek from horse stables along Crow Creek. California Department of Fish and Game biologists in 1975 concluded that the stream system no longer supported a viable steelhead run due to upstream migration barriers (i.e. Don Castro Dam, completed in 1965), and to channel degradation of the remaining available habitat (CDFG, 1975). Since that time only a few spot surveys have been done. Surveys by Leidy in 1981 (Leidy, 1984), and East Bay Regional Parks Department in 1996 (P. Alexander, personal communication), did not locate any adult or young salmonids. Periodic drought conditions in the 1970's, in the late 1980's, and early 1990's has on occasion caused much of the upper watershed tributaries to go dry during the summer months. This may have potentially caused the extirpation of any native steelhead/rainbow trout still surviving in the system.

Although young steelhead/rainbow trout have not been recorded in surveys since 1960, and adult fish since 1975, there have been reports of a few adult steelhead and rainbow trout being caught by local fisherman or observed in San Lorenzo Creek during wet years in the 1980's (Walton, pers. comm. 1997). In the early 1980's (between 1981 and 1983), one local fisherman observed a few steelhead trapped within the concrete channel section of San Lorenzo Creek between Grove Way and East 14th Street (S. Volkers, personal communication).

During this same period, Jon Walton reported catching wild steelhead in the section between Don Castro Dam and Center Street. These reports appear to be authentic based upon the tenability of the sources, and the description of the fish (elongate bodies and complete “square” tails).

Also reported, John Rusmiser with the Mosquito Abatement District recalled seeing “a couple old guys” attempting to catch steelhead with pitchforks and gunny sacks in the concrete channel near Hampton Road in the 1970's and 80's (J. Rusmiser, personal communication). This “pitchfork” method was apparently used often in the Creek to catch steelhead in the days before fishing regulations were in place or enforced.

Rainbow trout have been observed in San Lorenzo Creek and Cull Creek downstream of the Don Castro dam, and in Palomeras Creek upstream of the dam. These fish appear to have been hatchery-raised fish that were planted in the system, rather than native trout. In January 1997, I observed two adult steelhead in Castro Valley Creek near the confluence with San Lorenzo Creek, and was able to capture and photograph one of the individuals. This steelhead had markings (i.e. tail-fin wear) that was consistent with hatchery-raised fish (J. Smith, P. Alexander, personal communication). The fish was likely planted in Lake Don Castro, and washed over the spillway and into San Lorenzo Creek during high flows. It may have migrated back to the stream after spending time in the ocean, or may have taken on the physical characteristics of a steelhead after spending a few months in Lake Don Castro. This phenomenon of changing to a more silvery appearance has been observed in planted trout that have not migrated to the ocean (P. Alexander, personal communication). The extreme pectoral and anal fin wear, however, and "opalescent" coloration suggest that this particular individual had made a sea run and returned to the creek through the concrete channel (J. Walton, personal communication).

Background: San Lorenzo Creek Watershed

Climate, Hydrology, Soils, and Vegetation

San Lorenzo Creek is a highly modified urban stream in the east San Francisco Bay Area (Figure 1). It drains one of the largest watersheds in the East Bay Hills (50.1 $mi.^2$). The upper watershed comprises largely undeveloped foothills (74%) that are used primarily for cattle grazing, parkland, and low-density residential housing. In contrast, the lowland areas comprise 23% of the basin and are characterized by intensive residential and commercial land-uses (Woodward-Clyde, 1991). Vegetation consists of mixed oak woodland, grassland, and chaparral in the hills; while most of the flatland areas are nearly completely urbanized.

Soils in the hills of the watershed are the Millsholm - Los Gatos - Los Osos association, which are brownish soils developed on moderately sloping to very steep hillsides of hard sedimentary rocks (USDA Soil Survey, 1966); and the Xerorthents -Maymen - Millsholm association, which are well drained and somewhat excessively drained soils that have various textures that occur on steep to very steep slopes.

On the flatlands, soils are composed of the Sycamore - Yolo association which are nearly level, well drained and poorly drained silt loams on flood plains and alluvial fans; and the Danville - Botella association which are nearly level to moderately sloping, well drained loams and silty clay loams on low terraces and alluvial fans (USDA Soil Survey, 1977).

Seven major tributaries--Crow Creek, Cull Creek, Eden Creek, Palomeras Creek, Hollis Creek, Castro Valley Creek, and Chabot Creek--flow into San Lorenzo Creek (Figure 1). In most years, all of these tributaries are perennial in their lower reaches and intermittent in their upper reaches. Each is fed by several smaller forks. The most consistent year-to-year flow appears to occur in Crow creek and Castro Valley Creek.

Average rainfall in the watershed is approximately 20 inches per year, with the hills of the upper watershed generally receiving 5-10 inches more annual rainfall than the valley. The past three years have been above average with average annual rainfall totals of 28 inches in 1995-96, 24 inches in 1996-97, and 45 inches in 1997-98 (Alameda County Water Resources rain gauge data).

Average daily flows for San Lorenzo Creek range from about 5 cfs (cubic feet per second) in the summer dry period to about 1000 cfs during storms in the winter months. Maximum flood peaks range from about 900 cfs in dry years to over 5300 cfs in extremely wet years (USGS streamflow data; San Lorenzo Creek at San Lorenzo station).

History of Watershed

The flatland areas of the watershed were partially built up by the towns of Hayward and San Lorenzo even as early as 1878 (Figure 2). Roads were already in existence at this time along San Lorenzo, Crow, Palomeras, and Cull Creeks. The mouth of San Lorenzo Creek opened to the bay at Mulford‘s Landing, approximately 1.5 miles northwest of it’s present location. Sometime between 1878 and 1947 a small twenty-foot-wide ditch had been cut that bypassed the old channel in a shorter, more direct route to the bay at Robert’s Landing. The present mouth is a much larger earthen channel, and was constructed sometime before 1958, just south of this ditch.

Most of the valley portion of the watershed was already urbanized in many areas by the 1940's. Then in the late 1940's and 50's, the post-World War II building boom established residential neighborhoods along most of the remaining portions of the creek. Today (1998) urbanization covers nearly 100% of the valley portions of the watershed.

The hills of the watershed remained undeveloped and were used for ranching, orchards, dry farming, and other rural land-uses until the 1970's. In the 70's, 80's, and 90's large-scale residential developments were constructed on the ridge lines bordering Cull Canyon, Crow Canyon, Eden Canyon, and Don Castro Reservoir. The majority of land in the hill areas is still being used for ranching and grazing, but much of it is privately owned, which does not preclude future development.

Since the 1960's vegetation in the hills of the upper watershed appears to be (in several places along the creeks), gradually converting from grassland to scrub and woodland vegetation types, perhaps in response to the reduction in grazing and dry farming. The lack of wildfires due to fire suppression is also likely to be influencing this observed successional change from grassland to woody vegetation.

Impacts to Habitat Accessibility

Flood Control Modifications

Urbanization causes an increase in impervious surfaces in a watershed, and this leads to "flashier" streams, which rise and fall quickly due to less infiltration and greater runoff. To offset the resultant increased risk of flooding, flood control agencies have constructed dams, drop structures, retention basins, culverts, and concrete channels to control streamflows. These structures in most cases inhibit or prevent the upstream movement of fishes. For anadromous fishes that must move into upstream areas as part of their reproductive cycle, these structures can eliminate their entire population.

In the 1950's, 60's, and 70's San Lorenzo Creek was modified by a series of flood control projects. The largest of these modifications, a 4.6 mile-long concrete channel from San Francisco Bay to Foothill Boulevard in Hayward, was constructed between 1953 and 1962 by the U.S. Army Corps of Engineers. At the time, local fisherman and biologists feared that the concrete channel would be a barrier to steelhead returning to the stream. In response to this concern, a V-notch for fish passage was incorporated into the channel design. Additionally, CDFG recommended that removable steel baffles be placed within the V-notch to reduce flow velocities during the migration period of the fish (State of California, 1953). The steel baffles were apparently used only for a short period and then removed due to maintenance problems caused by sedimentation (CDFG memo, 1963).

In the early 1960's dams were constructed on Cull Creek creating Cull Reservoir (completed in 1962), and on Palomeras Creek creating Lake Don Castro (completed in 1965). These dams cut off two of the three major tributaries in the watershed (and their respective forks) from steelhead access. Then in 1972, a 1670-foot section of Crow Creek was culverted under Crow Canyon Road, possibly also cutting off Crow Creek from steelhead access. Since no fish passage structures (i.e. fish ladders or baffles) were incorporated into the design of these flood control structures, the potential impact was to render nearly all of the upstream spawning and rearing habitat inaccessible to steelhead. Table 2 shows the length of tributary reaches that are impeded by dams or extensive concrete culverts. Only 2 miles (6%) of tributary reaches are unimpeded by flood control structures.

Concrete Channels as Potential Velocity Barriers

Concrete channels are efficient at transporting high streamflows, but due to their higher velocity and greater uniformity of flow, they may present barriers to migrating fish. Fish migrate by expending short bursts of energy to dart through fast-water sections, or to jump over obstructions (USACE, 1991). After expending this energy, they require areas of slower velocities to rest. The banks of natural streams often have refuge areas, such as behind tree roots, logs, or boulders, where velocities are reduced. Steelhead and other Salmonids will typically hold up in these areas.

Table 2. Approximate lengths (in miles) of tributary reaches impeded by dams or extensive concrete culverts in San Lorenzo Creek watershed. (Does not include the 4.6 mile concrete channel at the mouth of San Lorenzo Creek).

Tributary	**Natural unimpeded**	**Natural--upstream of Dams**	**Natural--upstream of Concrete Culverts**	**Concrete Channel**	**Lake**
Crow Creek (including Bolinas Creek)	0	0	7.4	0.5	0
Cull Creek and section D/S of Cull/ Crow confluence	1.0	6.0	0	0.1	0.5
Palomeras Eden & Hollis creeks	0	12.1	--	0.2*	0.6
Castro Valley and Chabot Creek	1.0	0	0.1	3.0	0
Totals	2.0	18.1	7.5	3.8	1.1
Percent of total tributary miles	**6%**	**56%**	**23%**	**12%**	**3%**

* In addition to the dam on Palomeras creek, there is also a 0.2 mile concrete culvert under the 580 Freeway upstream of Don Castro Reservoir.

In concrete channels, however, resting areas for fish are absent and channel velocities may be too high and too consistent from bank to bank for salmonids to migrate through before exhaustion sets in. Steelhead can swim at velocities up to 27 f/s, but can maintain velocities of only up to 4.6 f/s for extended periods, such as during migration. In the design of in-stream facilities, velocities must be kept well below their maximum swimming capability for general passage (USACE, 1991).

Two reaches of San Lorenzo Creek in particular are characterized by potential velocity barriers to adult steelhead migration: 1) the 4.6-mile-long concrete channel between San Francisco Bay and Foothill Boulevard in Hayward; and 2) the 1670-foot concrete culvert on Crow Creek under Crow Canyon Road. There are 2 additional culverted sections along Crow Creek, each approximately 500 feet in length, which may also be velocity barriers. Steelhead may be able to traverse these sections as high flows recede, but their opportunity for passage may be very limited because water depth quickly becomes very shallow.

Impacts to Spawning and Rearing Habitat

Ever since the post-World War II building boom, fisheries biologists have documented an acceleration in the decline of fisheries across the state. The problems from the construction of dams, pollution, and erosion have been “the three horseman of civilization", that have destroyed valuable stream fisheries across the state (Cordone, 1960**)**. While the quantity of habitat for steelhead has been severely limited by flood control structures, the quality of the remaining habitat has been degraded by increasing urbanization (CDFG, 1953; CDFG 1960; CDFG, 1975). For successful reproduction, stream habitat needs to be of a high enough quality to allow for both spawning and rearing. Impacts to habitat that could inhibit successful spawning and rearing in San Lorenzo Creek include sedimentation and turbidity, increased temperature, chemical pollution, and introduced species.

Sedimentation and Turbidity

The degree of silting is likely the principle factor in determining the survival rate for salmonids in the embryo stage (Shapovalav & Taft, 1954). Salmonids build their nests or "redds" in fairly coarse gravels, usually in the 2-10 cm diameter range, to insure a steady flow of oxygenated water over the eggs. Low levels of silt characterize natural, less-disturbed stream systems, and spawning salmonids will winnow fine sediment from streambed gravels during construction of the redd (Kondolf, 1993). High amounts of silt will fill the interstices in the gravel and inhibit water flow through the redd, resulting in suffocation of the developing embryos. Numbers of benthic insectivore and herbivore fish species have been shown to be reduced as the percentage of silt increases, and this is likely due to the reduction of available insect foods inhabiting the voids within the gravels (Berkman and Rabeni, 1987).

The County of Alameda Public Works Department and the National Resource Conservation District (NRCD) have identified high levels of turbidity in Cull, Crow, and Norris creeks. In 1998, the level of silt in Lake Don Castro has been the highest in many years, with large islands now visible above the water line in much of the eastern part of the lake. Park personnel and local fisherman believe the source of this siltation to be the Five Canyons housing development on the east side of the lake. In Cull Reservoir, a similar sedimentation problem of lesser magnitude has been occurring and desilting operations are planned for both reservoirs as soon as permitting is finalized (C. Schultheis, Alameda County Water Resources, personal communication).

Management of both riparian and upland areas is important for controlling sediment pollution to streams. Rabeni and Smale (1995) found that even in areas where intensive management was being done to reduce soil erosion from upland areas, there was still no detectable change in streambed sediment composition because high rates of erosion and sedimentation continued to occur within the channel itself.

Norris Creek, Palomeras Creek, Crow Creek, and Cull Creek all have roads bordering them, and there are several locations where the roads impinge on the natural sinuosity of these tributaries, causing erosion scars. The major sediment sources to Cull Reservoir are believed to be stream banks, road cuts, storm drain culverts, gullies, and landslides--whereas sheet and rill erosion (affected mostly by range management practices) probably only contributes about 4% of the total sediment load to the reservoir (Alameda County Flood Control District, 1980). Stream restoration measures such as realignment of culverts to direct flows away from eroding banks, and revegetation of eroded banks and roadcuts, are therefore likely to be a higher priority than upland erosion control in reducing sediment supply to San Lorenzo Creek and it's tributaries.

Temperature

Lakes, open concrete channels, water diversions, and reduction in canopy cover can all raise stream water temperatures. Steelhead and other salmonids prefer a temperature range of 4 - 15^{o} C, (39 - 59^{o} F). Steelhead mortality occurs at approximately 25 - 27^{o} C (William Kier Associates, 1991; Merritt Smith, 1995), though this varies depending on the local adaptability of the stock. Steelhead caught in Walnut Creek, (about 30 miles northeast of San Lorenzo Creek) have been found to survive in water temperatures of 29^{o}C(84^{o} F) (Terri Williamson, personal communication).

Sublethal temperatures can promote lethal infection by pathogens, cause loss of body weight and adverse gonadal development, and inhibit parr/ smolt transformation (Bouck, 1977). For Columbia River salmon, these effects became apparent at temperatures above 16.5^{o} C.

The temperature thresholds for sublethal and lethal effects on steelhead in Central California streams have been found to be higher than the temperature ranges established in the literature, which are based on higher latitude streams in Washington, Oregon, and Northern California. It is therefore best to assess temperature impacts to steelhead by comparing stream temperatures to steelhead temperature thresholds that have been established in the same region.

Chemical Pollution

Prior to the establishment of landfills, many people used the creeks as a dumping ground. This was practiced ever since the area was settled in the mid-19th century. As an urban creek with rural landowners in the upper watershed, high density residential and commercial land uses in the flatlands, and a large homeless community living along the creek, an assortment of contamination problems are still observed today in San Lorenzo Creek watershed. While surveying the creeks in 1996-98, I observed paint, car batteries, concrete sand, soap, and motor oil pollution in the stream system.

Contamination of the creek was likewise observed during past field surveys. In the early 1970's a chlorine spill (source unknown) resulted in a fish kill in Cull Creek downstream of Cull reservoir (J. Walton, M. Steveco, personal communication). In the 1975 CDFG fisheries survey, fecal contamination from horse stables and an associated fish kill was observed in Crow Creek, (CDFG, 1975). In 1985, a fish kill resulted from dumping of well-drilling sediments into Crow Creek (CDFG, 1985). Stormwater runoff from highway 580 flows into the lake Don Castro and there have been two major freeway accidents in the past 5 years that have caused one quarter to one half of the lake surface to be contaminated by diesel oil (D. Defrees, personal communication).

Pesticides can have significant impacts on aquatic fauna. Diamond (1967) found that following spraying of DDT, an organochlorine pesticide, total insects and short-generation taxa such as midges among bottom fauna had returned to normal numbers after one year, but that recovery of forms with longer generations, (e.g. caddisflies) required 2-3 years to recover. Likewise drift, which develops from aquatic insect population surpluses, did not occur until 3-4 years after spraying (Dimond, 1967).

Diazinon, an organophosphate insecticide used widely in California, is a potential source of toxicity in San Lorenzo Creek watershed. Diazinon is expected to break down much sooner than organochlorine pesticides such as

DDT, but due to a variety of physical and chemical factors it's environmental fate is still unknown. Alameda County scientists have confirmed persistence of Diazinon concentrations in Castro Valley Creek of over 300 ng/l for periods of 48 hours after storm flows have receded. These exposures were sufficient to kill some macroinvertebrate animals in laboratory settings. Diazinon is toxic to mayflies at 10-40 ug/l, and to midges at 9-30 ng/l. However, these toxicity levels (LC 50 values) have been established using 48-hour static tests at 20^{o} C, and have not been verified under actual stream conditions.

Sources of Diazinon are widespread throughout the Castro Valley Creek watershed (Alameda County, 1997). Event mean concentrations ranged from 180-820 ng/l as measured during several storm events in the 1995-96 water year. Applications of liquid diazinon to home perimeter areas by residents is believed to be the source.

The Alameda County Mosquito Abatement District uses insecticides to control Mosquito larvae in the watershed, but primarily focuses on the San Lorenzo Creek concrete channel. The natural sections are sprayed infrequently, in response to mosquito complaints, approximately 2-3 times per year. Treatment is usually done in the summer (June - September) and is focused on controlling mosquitos in slack-water areas. Three substances are used: Altosid (an insect growth regulator); BTI *(Bacillus thuringiensis israeliensis*), a bacterial insecticide; and a larvaecide oil. Altosid is toxic to most insects, but only when applied to late in-stars. Larvaecide oil impacts all emerging insects by preventing species from emerging through the water surface, and BTI is more specific to dipteran larvae, which feed on the bacterial spores (personal communication; Pat Turney, Alameda County Mosquito Abatement District).

The impact of the Mosquito Abatement District's insecticide applications on the native macroinvertebrates is not known, but since they are applied in the summer time (after the peak emergence period in spring), are infrequently applied in the upper watershed areas, and do not persist in flowing environments, they are not expected to be a major impact upon the macroinvertebrate fauna.

Toxicity levels in the creeks may not be consistent, but in theory this may not be necessary to impact macroinvertebrate populations. In steep canyons where there are topographic barriers that inhibit the ability of adult insects to recolonize a site, periodic pulses of toxicity at vulnerable times of year (spring or fall), every few years may be sufficient to keep aquatic insects from recolonizing and reaching normal population levels.

Introduced Species

The stream system is stocked with fish each year by East Bay Regional Parks (EBRPD) , CDFG, Mosquito Abatement District, and individuals that release their own aquarium fish.

Don Castro and Cull Reservoirs are stocked with hatchery-raised fishes several times per year for recreational fishing by EBRPD and CDFG. Between 1990 and 1997, an average of 3,200 lbs of channel catfish (*Ictalurus punctatus*), 10,600 lbs of rainbow trout, and 60 largemouth bass (*Micropterus salmoides*) fingerlings were planted annually into Don Castro (East Bay Regional Parks fish stocking records).

Rainbow trout planted by EBRPD are “Hildebrand strain” raised at Mt. Lasson Fish Hatchery. These fish range from 3/4 -17 lbs, and are genetically engineered (triploid gene structure) to be larger and heavier than the typical genetic strains. Recently a brown trout (*Salmo trutta*) and rainbow trout cross were planted. The rainbow trout planted by CDFG are primarily the Shasta and Coleman strains, and to a lesser extent the Eagle Lake and Whitney strains (personal communication P. Alexander). These fish are stocked at a smaller size, approximately one-half-pound each, and for at least the last 3 years have had their adipose fins clipped (T. Stagnero, personal communication).

An average of 1000 lbs of channel catfish and 40 fingerlings of large mouth bass have been planted into Cull Reservoir annually from 1990-1997. Records show that prior to 1990 other fishes such as bluegill (*Lepomis macrochirus*) and black bass were planted (P. Alexander, personal communication).

The Alameda County Mosquito Abatement District has stocked mosquitofish (*Gambusia affinis*) in the San Lorenzo Creek system for many years. The district has been in operation in this area since the 1930's. In the period 1986 - 1996, plants were done in Cull Creek, Crow Creek, Eden Canyon Creek, Upper Castro Valley Creek, Norris Canyon Creek, and San Lorenzo Creek. Crow and Cull creeks have received the largest number of plantings, with a couple hundred fish on average nearly every year. All other locations have received only a few plantings over the past 10 years. In addition to the mosquitofish plantings, “bucketfuls” of California roach (*Hesperoleucus symmetricus*) and other fishes are sometimes caught and moved from one area of the stream system to another to better control mosquito breeding (J. Rusmiser, personal communication).

Other sources of exotic fish include overflowing stockponds and aquaria. Various landowners in Crow, Cull, and Palomeras Canyons have cattle ponds that are often stocked with bass or other non-native fishes. During storms these can overflow into the creeks. Individuals have planted aquarium fishes into the creek such as goldfish (*Carassius auratus*), Koi (*Cyprinus sp.*), green sunfish (*Lepomis cyanellus*), bluegill, and probably many other species.

Two introduced crayfish species have been thriving in the stream system for years, and the Chinese mitton crab (*Eriocheir sinensis*) has recently become established in San Lorenzo Creek watershed. It is unknown what impact these species would have on steelhead, but since they do not prey or compete directly with steelhead, it is unlikely that they would have as much of an impact as the highly competitive and predatory centrarchid (i.e. bass, sunfish and bluegill) and Ictalurid (catfish) fishes.

The introduced eucalyptus (*Eucalyptus globulus*) tree has been planted along the banks of the creeks in several locations. The relatively shallow root system and the strong allelopathic oils in the leaves of these trees inhibit growth of native vegetation and lead to bare banks that have less resilience to erosion. The eucalyptus leaves break down very slowly in the stream compared to other native tree species such as big leaf maple (*Acer macrophylum*) and box elder (*Acer negundo*), and this may decrease the amount of vascular plant tissue being converted to food resources by certain benthic macroinvertebrates called "shredders". Shredders serve an important function in stream food webs by converting vascular plant tissue in the form of coarse particulate organic matter (CPOM) to fine particulate organic matter (FPOM). The FPOM is then fed upon by other organisms (Cummins, et al. 1989).

Unregulated Fishing

Fishing, both legal and illegal, is likely to be a frequent occurrence in the creek. Adult steelhead that get stranded in the concrete channel or in shallow pools make easy targets. There are occasional reports of fisherman taking steelhead from the creek. In addition, a large homeless community exists along the creek and the creek is often used as a travel corridor. I have often seen fishing poles and equipment left on the banks of the creek. The impact of illegal fishing is unknown, but is likely a serious threat given the low numbers of this species.

CHAPTER 2: ASSESSMENT OF STEELHEAD PRESENCE

Methods: Fish Surveys

Steelhead were surveyed for in San Lorenzo Creek and it's major tributaries in 1997 and 1998 using a variety of methods. In spring 1997, downstream migrant trapping for smolts was undertaken with a downstream migrant pipe-trap that was constructed and set up in San Lorenzo Creek. In the fall of 1997, walking visual surveys (and one electroshocking survey) for juveniles was done on extensive stretches of San Lorenzo Creek and most of it's major tributaries. And in the winter and spring of 1997-98, spot surveys for adult spawners (using angling, observation or electroshocking) was conducted.

Downstream Migrant Trapping

Downstream migrant trapping has been used effectively on several streams in California and Oregon to assess numbers of out-migrating salmonids (Manning, unpublished; GGNRA, unpublished). Unlike electroshocking and seining, which must be done in several locations in a stream to assess population size, downstream migrant trapping can be used in a single location to estimate the numbers of out-migrating fish. In stream systems such as San Lorenzo Creek where most of the adjacent land is in private ownership and access for surveying is limited, this method is a convenient alternative to other methods. Downstream migrant trapping requires consistent (at least once a day) monitoring while the trap is in operation, and should be removed when flows exceed 80 cfs (B. Eastwood, personal communication).

In May of 1997, a downstream migrant pipe-trap (Figure 3) was constructed and set up in San Lorenzo Creek. The trap was located near the 580 Freeway overpass, approximately 1500 feet upstream of the Center Street bridge (Figure 4). Both a CDFG scientific collection permit and an Alameda County Public Works encroachment permit were obtained to operate the trap in the creek. The upstream end of the trap was erected in a flat bottomed run section, just upstream of a riffle. One-eighth-inch mesh nylon fencing was erected in a V-shape and anchored into the stream bed with T-posts every 4 feet. At the head of the V, a 2 foot x 3 foot plywood board was secured to the fencing, and an eight inch diameter plastic pipe was fit tightly into a hole in the board. The pipe extended 20 feet downstream and opened up into a 2 foot' x 2 foot x 4 foot live car that was submerged in a 3 foot deep pool. Signs were placed on the fencing to notify people that the trap was a California State University Hayward research project.

The trap was operated only at night and was checked once a day in the morning for twenty days, from May 11 to May 30, 1997. The live car was removed from the trap during the day. All fish were removed from the trap with a dipnet, and then identified, counted, weighed, measured for fork length, and returned to the creek downstream of the trap. All other species (i.e. crayfish and aquatic insects) were counted and released. On May 30, 1997 the trap was damaged by vandals and was removed from the creek.

Fall Parr Surveys

Visual surveys were undertaken in September and October 1997 when stream levels were low and water clarity was high. Figure 5 shows all surveyed areas of the stream. Each stream section was approached by one observer from the downstream direction and fish were identified and numbers estimated. A small dip net was used to periodically catch fish to verify identification. Overhanging banks and submerged vegetation were inspected for fish with a 14 watt halogen underwater flashlight. For pools with good visibility, identifications and abundance estimates were made from the banks with short focal length binoculars.

Since much of the upper watershed sections of the creek are privately owned, access was limited. A mailer was sent out in September 1997 to over 100 landowners along Crow Creek asking for access permission. Approximately 15% of those surveyed granted permission. Surveys were done in these sections, as well as where public property bordered the creeks.

By visiting other streams populated with steelhead parr, certain morphological and behavioral characteristics that allow them to be distinguished from other fishes were noted. These characteristics are outlined in Table 3.

Table 3. Physical and behavioral differences between steelhead and other common fishes.

Steelhead/ Rainbow trout (*Oncorhynchus mykiss*)	**California Roach** (*Hesperoleucus symmetricus*)	**Sacramento Sucker** (*Catostomus occidentalis*)
relatively large eye	relatively small eye	relatively small eye
6-10 distinct black marks (parr marks) on side body	dark lateral body stripe	2-3 black splotches on dorsal side
blunt head/mouth profile	tapered head/mouth profile	tapered head profile inferior mouth position
less tightly schooled than roach, quicker movements than roach or suckers	typically found in large schools	found in large schools when young (less so as adults)

Winter Adult Surveys

Spot visual surveys for upstream migrating adults were conducted in the winter and early spring of 1997-1998. The surveys were done by one observer with either short focal-length binoculars or polarized sunglasses at pools that have had a history of steelhead presence or had good potential for steelhead use (Figure 4).

Results: Fish Surveys

Downstream Migrant Trapping

The downstream migrant trap data did not detect any young steelhead/ rainbow trout in San Lorenzo Creek in the spring of 1997. This was not conclusive in determining if steelhead were in the system however, because no significant rainfall occurred while the trap was in operation. The spring of 1997 was extremely dry, with the months of February, March, April, and May yielding a combined rainfall totaling just 2 inches.

Table 4 shows the results of the downstream migrant trapping. The most common species trapped were California roach, Sacramento sucker, and largemouth bass. Figure 6 shows the total numbers of each fish species trapped over the 19-day trap period (May 11 to May 30).

Fall Parr Surveys

Approximately 5.7 miles of the San Lorenzo Creek system were visually surveyed, including 116 pools (Figure 5). Portions of all streams with perennial flow were surveyed. No steelhead/rainbow trout parr were observed in the San Lorenzo Creek system. Table 5 shows the encounter rates, length of reaches surveyed, and the number of pools/runs surveyed in each reach.

Table 4. San Lorenzo Creek downstream migrant trap results including fish species and numbers, spring 1997.

Date	**Ca. Roach**	**Sac. sucker**	**mosquito-fish**	**Lm bass**	**blue-gill**	**black crappie**	**green sunfish**	**gold-fish**	**cray-fish**
5/11/97	44		1			1			
5/12/97	62			3	2	1			1
5/13/97	30			3	2	2			3
5/14/97	17				1				4
5/15/97	18			8					3
5/16/97	6			5	3	3			4
5/17/97	33			2					7
5/18/97	25	1		3		1			?
5/19/97	31			7	1				5
5/20/97	25			9			1	1	5
5/21/97	42	15		6	2				1
5/22/97	21	5		1	1				3
5/23/97	1					1			1
5/24/97		1		2					6
5/25/97	2	2		75	2		1		4
5/26/97	5	2		65	1	1			4
5/27/97	5	3		26		1			4

Date	Ca. Roach	Sac. sucker	mosquito-fish	Lm bass	blue-gill	black crappie	green sunfish	gold-fish	cray-fish
5/28/97	12	4		7					?
5/29/97	11	3	1	3					?
Totals	**390**	**36**	**2**	**225**	**15**	**11**	**2**	**1**	**55**

The dominant species encountered in the stream system were two native fishes--California roach and Sacramento sucker. California roach were found to be common in all streams in the system. Sacramento suckers were also found to be common, but were not detected in Chabot or Castro Valley creeks. Non-natives such as mosquitofish, large mouth bass and channel catfish were observed in more than one stream section.

Table 5. Encounter rates of fishes in the San Lorenzo Creek system, based on visual surveys. Encounter rate equals the number of pools and runs that each species was encountered per mile of stream.

Creek	Reach Length (mi.)	Species	Pools/ Runs Present	Encounter Rate
San Lorenzo (unchannelized section above Foothill Blvd.)	1.42	California roach	34	23.9
		Sacramento sucker	12	8.5
		largemouth bass	7	4.9
		green sunfish/ crappie/ bluegill	4	2.8
		channel catfish	1	0.7
		carp/ koi	1	0.7
San Lorenzo	0.39	California roach	3	7.7

D/S (concrete channel near mouth)		mosquitofish/ rainwater killifish	2	5.1
		carp/ koi	1	2.6
		channel catfish	1	2.6
Crow	1.91	California roach	25	13.1
		Sacramento sucker	4	2.1
Cull (Below dam)	0.13	largemouth bass	1	7.7
		green sunfish/ crappie/ bluegill	1	7.7
		Sacramento sucker	1	7.7
		mosquitofish	1	7.7
Crow/Cull	0.36	California roach	6	16.7
		Sacramento sucker	5	8.5
		mosquitofish	1	2.8
		largemouth bass	1	2.8
Palomeras	0.24	California roach	1	4.2
		Sacramento sucker	1	4.2
		three-spined stickleback	2	8.3
Castro Valley	0.31	California roach	18	58.1
		channel catfish	1	3.2
Chabot	0.91	California roach	22	24.2
		goldfish	5	5.5

The number of species encountered was higher in the larger streams such as San Lorenzo Creek, and Crow /Cull below the confluence of Crow and Cull creeks, while the smaller tributaries such as Crow Creek had fewer numbers of species (Figures 7 and 8). This disparity was primarily due to the presence of non-native fishes in the larger stream sections.

Two electroshocking surveys were done in the fall, one in San Lorenzo and Castro Valley creeks upstream of Foothill Boulevard in Hayward in 1997, and one in San Lorenzo Creek upstream of A Street in the fall of 1998. The locations for all electroshocking surveys are shown in Figure 9. Species detected agreed with the fall parr surveys, with the exception of finding two (hatchery) rainbow trout adults, and one prickly sculpin (*Cottus asper*).

Winter Adult Surveys

No adult steelhead were detected in San Lorenzo Creek, or it's tributaries in the 1997-98 adult surveys. Surveys were hampered by the consistent rainfall in 1997-98, in which over 200% average rainfall occurred. This made for turbid conditions in most creeks in the watershed throughout the winter and spring.

Table 6. Results of winter surveys for adult steelhead.

Location	**Survey Dates**	**Method**	**Results**	**Water Clarity**
Castro Valley Creek Pool @ Japanese Gardens	12/10/97	Observation	0	Clear
	12/19/98	Observation	0	Clear
	12/24/97	Observation	0	Clear
	1/9/98	Observation	0	Turbid No visibility

Location	**Survey Dates**	**Method**	**Results**	**Water Clarity**
	1/24/98	Observation	0	Clear
	3/4/98	Observation	0	Clear
	4/11/98	Observation	0	Clear
San Lorenzo Creek Pool @ Arlette Ave.	12/24/97	Observation)	0	Turbid <1' visibility
	1/9/98	Observation	0	Turbid No visibility
San Lorenzo Creek Glide @ concrete channel juncture of vertical & trapezoidal channels	12/13/97	Observation	0	Moderately Clear 2' visibility
	4/11/98	Observation)	0	Turbid <6" visibility
San Lorenzo Creek Pool below DC spillway	3/1/98	Angling (from spillway to Crow/Cull confluence	0	Turbid <1' visibility
	3/21/98	Electro-shocking (from spillway d/s 1000 feet)	0	Moderately Clear 1'+ visibility
	4/11/98	Observation	0	Turbid <6" visibility
Cull/Crow and San Lorenzo confluence pool @ Grove Way	12/6/98	Observation	0	Turbid
	12/24/97	Observation	0	Turbid (More turbidity from San Lorenzo/ Don Castro tributary)

Location	**Survey Dates**	**Method**	**Results**	**Water Clarity**
	3/22/98	Angling (from Crow/Cull confluence d/s 700 feet	0	Turbid <1' visibility
Cull/ Crow Pool @ East Castro Valley Blvd.	12/13/97	Observation	0	Moderately clear visibility 1'
	12/24/97	Observation	0	Moderately clear visibility 1-2'
San Lorenzo Creek near mouth @ Railroad Bridge	12/13/97	Observation	0	Moderately clear
	12/19/97	Observation	0	Turbid visibility <1'
	12/24/97	Observation	0	Moderately clear visibility 1-2'

Discussion: Fish Surveys

Steelhead

The primary intent of the steelhead surveys was to determine if the historical native steelhead/ rainbow trout were present in the San Lorenzo Creek system. A thorough survey of the system was conducted using a variety of methods. Streams above dams, (upper Cull and Palomeras), were not as thoroughly surveyed. These creeks have been isolated from steelhead access for over 30 years, and could not support an anadromous fish population. They also have less flow than other tributaries (such as Crow creek), and are therefore more likely to have gone completely dry during drought episodes.

It should be noted that the visual surveys were biased towards pelagic fishes. Species such as prickly sculpin which are known to occur in San Lorenzo Creek, may have not been detected solely because of their cryptic coloration and behavior of sitting nearly motionless on the stream bottom. Other fishes such as Sacramento sucker may be under-represented in the counts for the same reason. In addition, deeper pools (>3 feet) were difficult to survey due to low water clarity. Pools this size were infrequent in the tributaries, but were more common in the main stem of San Lorenzo Creek.

The results of the visual surveys are presented as species occurrence per habitat unit (encounter rates). This was done because it is difficult to make accurate abundance estimates in streams relying solely on visual inspection. A test was conducted to determine the accuracy of visual counts to single-pass electroshocking and revealed that visual surveys tended to miss fish that were hiding under rocks. Alternatively, electroshocking seemed to miss fish in deeper pools where fish could dart around the “shock zone”.

Downstream migrant trapping was done in the late spring (May) of 1997. The timing of trapping was based on the reported peak timing of the out-migration for the species in Waddell Creek (Shapovalav and Taft, 1954). Due to a lack of rainfall in the spring of 1997, however, the trapping was not conclusive in determining that steelhead parr were no longer in the system. As a result, the visual surveys were conducted in the fall of 1997. Again, no steelhead/rainbow trout parr were found. Steelhead parr are readily visible in clear-water conditions, preferring both riffle and pool habitats. For this reason, the negative result of the visual surveys appears to indicate that the species is no longer reproducing in the San Lorenzo Creek system.

Although no steelhead adults were observed during the winter adult surveys, it was not conclusive that steelhead were not migrating into the system because observations were inhibited by turbid water. From observations of San Lorenzo Creek, Crow, and Cull Creek (below Cull reservoir), it typically takes 2 weeks or more for these streams to clear up after a storm event. This extreme level of water turbidity is not found in Castro Valley or Chabot creeks which tend to clear up within a few days after a storm event.

In watersheds adjacent to San Lorenzo Creek, (i.e. San Leandro Creek, 5 miles north; Ward Creek, 5 miles south; and Alameda Creek, 7 miles south), steelhead were observed during March and April 1998. These streams do not have the extensive concrete channel that San Lorenzo Creek has, which may prevent adults from reaching the natural sections of San Lorenzo Creek. Anecdotal information from knowledgeable fisherman indicates that a few wild steelhead have navigated the concrete channel in prior El Nino years, and made it into upstream tributaries in the 1970's and 80's (personal communication Marty Steveco, Jon Walton).

Although rainbow trout/ steelhead did not turn up in the downstream migrant trapping, nor in the adult and parr visual surveys, there were occasions that adult rainbow trout were caught through electroshocking, and seen during informal surveys. These fish all had hatchery-raised characteristics (e.g. stout body form, worn caudal fin), and appeared to be planted fish that were wash-overs from Lake Don Castro.

Introduced Fishes

The visual surveys and the downstream migrant trapping revealed that native and exotic species are found in the lower sections of San Lorenzo Creek, while the tributaries upstream of the dams appear to be exclusively native fishes. Exotic species such as largemouth bass, black crappie, green sunfish, bluegill, mosquitofish, channel catfish, and others are common to rare in the main stem of San Lorenzo Creek, downstream of the reservoirs. These species do not appear to have colonized the upper reaches of Crow, Cull, and Palomeras creeks. The dams on Cull and Palomeras creeks and the 1670-foot-long culvert on Crow Creek under Crow Canyon Road, combined with the intermittent flow conditions has likely kept these species from establishing in these tributaries.

These results are consistent with research in other impacted streams in the San Francisco Bay area (Leidy, 1983). Leidy found that the number of species in stream sections altered by flood control levees was greater than in undisturbed stream sections. This was due to the presence of exotic fishes, and therefore species diversity is not a good indicator of stream health in disturbed streams.

The presence of exotic species, especially Centrarchids (sunfish family) and Ictalurids (catfish family) are potential limiting factors on steelhead trout survival. In streams where these species are present, trout and other salmonids are often compromised from increased competition and predation. Channel catfish have been shown to be important predators on out-migrating juvenile salmonids (Poe, et al 1991). Although exotic species are a likely factor in the decline of steelhead in San Lorenzo Creek, the degree to which these exotic species have impacted or are preventing re-establishment of steelhead is unknown.

CHAPTER 3: ASSESSMENT OF STEELHEAD ACCESS

Methods: Assessment of Steelhead Access

This chapter focuses on an evaluation of access for upstream-migrating adult steelhead in San Lorenzo Creek. In the San Lorenzo Creek system, dams prevent adult steelhead from accessing Palomeras and Cull creeks. Steelhead may also be prevented from accessing nearly all upstream habitat by the 4.6-mile concrete channel located in San Lorenzo Creek, and the three concrete box culverts on Crow Creek (one that is 1670 feet long at mile 0.4, and two approximately 500 feet long at miles 1.7 and 2.0).

Also influencing the velocities within the concrete culverts on Crow Creek, and creating another likely barrier for steelhead are high-gradient concrete ramps. The long (1670-foot) box culvert on Crow Creek has an upstream ramp that extends for 60 feet and has a gradient of 8%. The next concrete culvert upstream (550 feet long at mile 1.7) has an upstream ramp that is 28 feet long and has a slope of 3.6 %. These ramps alone are probable barriers due to their steep gradients and shallow water depths under nearly all flow conditions.

To assess the impact of the concrete channel and culverted sections on adult steelhead upstream movement, flow velocities were measured at 5 different stations in the stream system in January, 1998 (Figure 10). Data was collected sequentially from upstream to downstream during a three-day rainy period from January 12-15, 1998. Each station represented a different set of conditions (Table 7). Stations were visited 5-10 times during the storm period in order to catch rising, peak, and descending flow stages. A few additional data points were gathered in late January and in the spring to capture low flow stages.

Velocities were measured using floats, (grapefruits), which were timed through a straight 50-meter stretch. Results of this method were compared to flow velocities recorded during low-flow stages with a *Flo-mate* (model 2000) portable flow meter and found to be within .01 m/s. At each station, surface velocities were measured at three locations in the channel (right bank, middle, and left bank). Replicates were taken on occasion and these were averaged. Measurements were taken at various flow stages and were then converted into actual depths. Average surface velocities were then converted into mean column velocities by multiplying by a coefficient (0.90 for concrete channels and culverts, 0.85 for natural channels), based on USGS flow measurements in San Lorenzo Creek (personal communication Jim Gibbons, USGS). Within the concrete V-notch, which had a more pitted surface and higher friction due to the constriction of the V shape, a coefficient of 0.85 was used (based on flow meter measurements).

Table 7. Water velocity stations, San Lorenzo and Crow Creeks.

Station	**Description**

SLC-1	Concrete Rectangular Channel - San Lorenzo Creek at Washington Avenue, straight section, steel baffles in V-notch in center of channel, approximate gradient 0.3 %.
SLC-2	Concrete Rectangular Channel - San Lorenzo Creek at Wickman Ct., straight section, approximate gradient 0.4 %.
CC	Concrete Box Culvert - Crow Creek at Crow Canyon Rd. (1670 feet long), approximate gradient 0.8%
SLN	Natural channel - San Lorenzo Creek, straight section downstream of I-580 overpass, approximate gradient 0.7%
CN	Natural channel- Crow Creek, straight section adjacent to Crow Canyon Road, approximate gradient 0.7%.

Results: Assessment of Steelhead Access

Flow velocity results are presented in Figures 11 through 17. Because of the V-notch in the center of the concrete channel in San Lorenzo Creek, velocities for the center and banks are presented separately (Figures 11 through 14). The V-notch is approximately 1.1 feet deeper than the rest of the channel. Steelhead need a minimum of 0.6 ft. water depth for passage (Thompson, 1972). In each figure, measured velocities are shown with respect to the maximum cruising speed for steelhead (4.6 f/s). This speed is the expected maximum velocity that steelhead can maintain for hours, such as during migration. Table 8 shows the swimming speeds for steelhead (Bell, 1990).

Table 8. Steelhead swimming speeds. Velocity ranges determined for steelhead 2.0-2.7' in length (Bell, 1990).

Steelhead swimming speed category	Velocity (f/s)	Duration
Cruising (migration)	0 - 4.6	hours
Sustained (passage through difficult areas)	4.6 - 13.7	minutes
Darting (escape and feeding)	13.7 - 26.5	seconds

At station SLC-2, at the right and left banks (Figure 11), and at station CC (Figure 15), water velocities exceeded maximum cruising speeds for steelhead at all depths above 0.6 feet.

For station SLC-1, streamflow velocities were below maximum steelhead cruising speed when flows were below 1.0 feet deep at the right and left banks, (Figure 13), and when flows were below 1.8 feet deep at the channel center (Figure 14). At station SLC-2 , at the channel center (Figure 12), velocities were below maximum cruising speed for steelhead when depths were 1.2 feet or less.

Water velocities recorded at Stations CN (Crow Creek natural) and SLN (San Lorenzo Natural) are shown in Figures 16 and 17. Velocities were measured during the same flow conditions as those in the concrete channels, however, velocities are plotted against stages rather than depths, since depth varied on the stream bottom. Both stations in the natural channel sections had flow velocities that were under steelhead maximum cruising speed in at least one or more location within the channels (i.e. right bank, left bank, or center), even at high flow stages. Maximum cruising speeds weren’t exceeded in the channels until flow stages reached above about 8-9 feet.

Discussion: Assessment of Steelhead Access

Sources of Error

Velocities were measured with floats (grapefruits) and a stopwatch over 50-meter distances along streambanks. Recording error was approximately 0.5 seconds over the 50-meter distance. This corresponds to an error of ± 0.1 f/s at a velocity of 5 ft/s, and ± 1.2 f/s at a velocity of 20 ft/s.

Velocities were measured in straight sections of the concrete channel due to the variation of depth and velocities at channel bends. Variation in depth at channel bends ranged from 0-2 feet, due to superelevation of the channel bottom. At baseflow conditions this confines most of the flow to the center of the channel within the V-notch and along the lower inside wall, leaving the outside bend of the channel dry. At higher flows, inside bends have slower velocities (estimated 20-50% slower) than outside bends (personal observation, and communication with Jim Gibbons, USGS). Stations were established in straight channel sections to avoid this difference in water velocities at bend cross-sections. However, bends just downstream of SLC-1 and SLC-2 stations appeared to effect recorded channel velocities, especially at lower flows. At most flow stages above one foot in depth, flow velocities along right and left banks were comparable.

Mean column velocities are a good representation of velocities in the channel even near the banks and bed due to the low Manning roughness coefficient (0.01 - 0.015) of smooth concrete. The friction caused by the banks and bed is not thought to provide refuge for fish, since the boundary layer is likely to be less than one inch thick, as opposed to a natural channel where channel roughness can range from 0.025 - 0.05 and provide a boundary layer of up to one foot thick (personal communication, Woody Trihey). The location of bank velocity measurements was within 25% of the bank side portion of the channel width. Most measurements ranged from approximately 0.5 - 4 feet from the bank, yet exact location did not seem significant due to the swiftness and uniformity of flow in the concrete channel under most flow conditions.

Steelhead Access Implications

Based on established swimming speeds of steelhead and minimum depth requirements for passage, the concrete flood control channel on San Lorenzo Creek and the concrete culverts on Crow Creek present virtually impassable velocity barriers for migrating fish. The exception to this is the area where steel baffles were placed within the V-notch of the channel at Washington Avenue (station SLC-1). Even here, however, the range of depths where flow velocities are suitable for steelhead passage are extremely limited (0.6 - 1.0 feet along the left bank, and 1.1 - 1.8 feet within the V-notch--Figures 13 and 14). Unlike the concrete channels where velocities rose quickly with increasing stage height and depth, the velocities recorded in the natural channels varied considerably at all but the highest stages due to turbulence and eddies which caused the floats to follow complex paths.

Within the concrete channel, the suitable range of depths and velocities typically only exists for a few hours, due to the transport efficiency of the channels, though it depends on the intensity and duration of rainfall and the amount of saturated ground within the watershed. Steelhead could theoretically come up the V-notch during base flow conditions (0.6 - 1.1 feet). Velocities measured at in the V-notch at baseflow were 2.0 ft./s at SLC-1, and 2.8 ft/s at SLC-2). The question is whether steelhead would use the V-notch during baseflow conditions. Since these fish are cued by rising or falling flows (Shapovalav & Taft, 1954; Merritt Smith, 1995), it seems unlikely that they would. Even during baseflow, however, velocities are constant, and there are virtually no resting areas available for four miles once a steelhead has entered the V-notch.

Based on the average velocity within the V-notch during baseflow conditions (2.4 ft./s), a steelhead swimming at maximum cruising speed (4.6 ft/s) would take 2.6 hours to migrate through the concrete channel. However this rate of travel is dependent upon a steelhead making the entire four-mile journey without rest. Based upon the Alaska curve (Zeimer *in CDFG, 1994*) the recommended distance between resting pools for migrating salmon at a water velocity of 2.4 ft./s is approximately 260 feet.

The few steelhead that have been seen in upper San Lorenzo Creek since the completion of the concrete channel in 1963 must have been able to migrate through the channel by swimming at speeds above maximum cruising speed within the V-notch and then resting at times in slower, shallower water, perhaps along the inside of bends in lower-gradient sections. They likely would have had to complete the four-mile journey in a matter of hours to prevent either 1) being stranded outside the V-notch as flows receded, or 2) being washed back to the bay with even a small rise in stage. Any steelhead that do make it into the natural sections of San Lorenzo Creek, would have to spawn either in San Lorenzo Creek below Don Castro Dam, or in Cull/ Crow Creek below the confluence of Cull and Crow creeks.

CHAPTER 4: ASSESSMENT OF STEELHEAD SPAWNING AND REARING HABITAT

In contrast to the uniform shape of concrete channels and culverts, natural channel sections have uneven bedrock, boulders, and large woody debris that contribute to a complex channel shape. These obstructions cause turbulence and eddies to form which provide lower velocity areas where steelhead can successfully migrate through during even high flow conditions. Once competing this journey, steelhead must locate adequate habitat conditions for successful spawning and rearing of their young.

Salmonids such as steelhead require different types of habitat for spawning and rearing. For spawning and subsequent survival of developing eggs and alevins, riffles or shallow runs that have instream gravels of a suitable size class range with appropriate water velocities and adequate levels of dissolved oxygen are required. Rearing juvenile fish (parr), require pools or deep runs with adequate cover, cool water temperatures, and sufficient food resources throughout the warm and dry summer/fall period. Once development has reached the smolt stage (1-3 years later) the fish require suitable flows and temperatures to allow movement downstream and back to the ocean (in this case via San Francisco Bay).

Spawning and rearing habitat were evaluated by comparing habitat conditions in San Lorenzo Creek to a similar local stream that still supports a steelhead population (San Francisquito Creek in Palo Alto, California). Since steelhead adapt to different conditions in different regions (i.e. temperature regimes, diet preferences), it is more appropriate to compare streams within the same region when possible.

San Francisquito Creek (Reference Stream)

San Francisquito Creek in the West San Francisco Bay Area drains a 46 mi^2 watershed (Figure 18). The mouth of San Francisquito Creek empties into San Francisco Bay, 12.6 miles southwest from the mouth of San Lorenzo Creek. This stream is similar in size to San Lorenzo Creek, yet has higher-elevation tributaries that drain a more densely vegetated upper watershed (the east side of the Santa Cruz Mountains). Vegetation consists of redwood forest, oak woodland, chaparral, and grassland. Three major tributaries flow into San Francisquito Creek: Bear Creek, Los Trancos Creek, and Corte Madera Creek. Soils are similar to San Lorenzo Creek watershed in the flatlands, consisting of Botella clay loam and alluvial fans.

San Francisquito Creek still has a steelhead run. Although population numbers have not been estimated, upstream migrants are often seen in the winter, and oversummering parr are known to occur in high numbers in the upper sections of San Francisquito Creek, Bear Creek, and Los Trancos Creek (A. Launer, personal communication). Steelhead/ rainbow trout fry were encountered in Bear and San Francisquito creeks during the habitat assessments in spring 1998.

San Francisquito has a similar land-use pattern as San Lorenzo Creek, with urbanization in the lower watershed, and rural land-uses in the upper watershed. San Francisquito Creek watershed has an estimated impervious cover of 22% (EOA, 1998), compared to 23% for San Lorenzo Creek (Woodward Clyde, 1991). Impacts are also similar in both watersheds, but less severe in San Francisquito Creek. Roads, equestrian centers, and ranching occur adjacent to upper San Francisquito Creek (similar to upper San Lorenzo Creek).

Despite these similarities, differences between the two watersheds are significant. San Francisquito watershed does not have extensive concrete channelization on it's lower reaches like San Lorenzo Creek, nor does it have concrete box culverts on any of it's tributaries in the upper watershed. It is also less impacted from development in it's upper watershed, and has portions of it's wateshed protected within a biological peserve (Jasper Ridge Biological Preserve, Stanford University).

Hydrology of San Lorenzo and San Francisquito Creeks

Hydrographs for the two streams from three successive water years (1979-80, 1980-81, and 1981-82) are shown in Figures 19 through 24 (historical cfs data from USGS). These years represent low, medium, and high streamflow conditions. The San Lorenzo Creek data is from the gauging station at Center Street in Hayward, (drainage area = 37.5 mi^2). The San Francisquito Creek data is from the USGS gauging station at Sand Hill Road (drainage area = 37.4 mi^2).

In several instances, flood peaks during winter and spring are almost identical for both streams. In summer and fall however, the two streams differ. Base flow conditions in San Lorenzo Creek are higher through the summer drought period, which would be more beneficial to sustaining a steelhead population (Figures 20, 22, and 24).

Methods: Assessment of Spawning and Rearing Habitat

A total of eight 250-meter-long reaches were randomly selected from within San Lorenzo Creek (5) and San Francisquito Creek (3) watersheds. Sampling sites were selected from upstream tributaries and lower valley sections in each stream system.(Table 9). Sites within San Francisquito Creek were chosen in areas upstream of major urban land-use impacts, and in specific areas where steelhead parr are known to occur in high numbers (Stanford University

Center for Conservation Biology, 1997).

Table 9. Creek reaches evaluated for steelhead spawning and rearing habitat, spring 1998.

Treatment Group	**Creek**	**Date of Habitat Assess ment**	**Grad-ient (%)**	**Est. Flow (CFS)**	**Land-use**
Experimental	San Lorenzo U/S	6/22/98	0.7	--*	Residential
	San Lorenzo D/S	6/22/98	0.7	11	Residential
	Crow	5/15/98	1.0	5	Residential / Ranching
	Palomeras	6/23/98	1.8	2	Residential / Ranching
	Castro Valley	6/24/98	1.8	--*	Residential
Control	San Francisquito U/S	6/25/98	1.1	9	Open space preserve
	San Francisquito D/S	6/25/98	0.8	11	Agriculture Equestrian
	Bear	6/25/98	1.3	3	Open space preserve

* Flow measurements were not made at these sites or did not appear representative of actual flow conditions.

Gradient was measured for reaches using USGS 7.5 minute quadrangles. This method gives a “ball park” estimate and was used to establish comparable stream sections in both watersheds. Gradient was measured on Crow Creek using a hand level and rod and was consistent (within 1%) with measurements from USGS maps.

Spawning and rearing habitat were evaluated at the same time, during the early summer of 1998. All reaches were evaluated within a 3-day period, with the exception of Crow Creek. Although steelhead spawn during winter and early spring, it was assumed that spawning substrate would not change substantially and could be assessed at the same time as rearing habitat. All creeks evaluated exhibited abnormally high base flow conditions due to the high rainfall of 1997-98.

Spawning Habitat

When assessing spawning gravels, two life stages should be considered, the sedentary egg and alevin stage, and the emerging fry stage. Egg and alevin development have been shown to be impacted by fine silt (particle sizes of <0.85 mm), whereas emergence of the fry has been shown to be impacted by sand and small gravel (0.85-9.5 mm). Therefore two methods were used in this study to assess spawning gravels: bulk sampling to assess fine silt within the gravels, and pebble counts (Wolman, 1954) to assess framework size which is indicative of the ability of fry to emerge (as recommended by Kondolf, 1988). Pebble counts consisted of collecting 100 pebbles from a single location in the sample reach. Rocks that could not be moved were recorded as embedded. Bulk sampling consisted of taking two substrate samples using a small shovel from each reach.

Knowledge of historical steelhead spawning locations in San Lorenzo Creek was not available for this study. In order to choose potential spawning locations for habitat assessment, stream channel conditions established in the literature for spawning steelhead were used. The criteria included: pool/ riffle interfaces with gravels in the 2-10 cm range; velocities from 20-90 cm/s; and depths between 10-70 cm--Barnhart, 1986. Primary emphasis was placed upon gravel size, since flow conditions at the time of evaluation (spring) may not have been representative of flow condtions at the time of spawning (winter).

Rearing Habitat

The most important habitat type for salmonids as far as rearing habitat is concerned is pool habitat. Pool habitat and other physical habitat data was collected using methods based on the California Salmonid Stream Habitat Restoration Manual (CDFG, 1991). Data collected included habitat types, habitat dimensions (width, length, depth), shelter types, and shelter % cover. Table 10 shows the types of rearing habitat data collected and the method used for each.

Shelter cover was measured at pools only. For each pool, the number of shelter types and percent cover within and directly above the water was estimated. These were then multiplied together to give an index of shelter cover.

Benthic macroinvertebrates were evaluated using the California Stream Bioassessment Procedure (CDFG, 1998). These protocols are used by biologists and citizen monitors to assess the condition of fish habitat and water quality conditions statewide. Two methods were used, the point and the nonpoint source method. The same number of samples and size of sample area are used in both methods, except that three samples are taken from within one riffle in the point method, while for the non-point method one sample from three replicate riffles are used. The point method was used at San Francisquito Creek watershed sites, while the non-point method was used at San Lorenzo Creek watershed sites.

Macroinvertebrate samples were taken on May 18 for San Francisquito and Bear Creeks, April 30 for Crow Creek, and June 4, 1998 for San Lorenzo Creek. Sampling area was standardized between field sample sites. Samples were taken in the field with a D-shaped kick net for all sample sites except for Crow Creek where a Hess sampler was used. Three replicate 100-organism samples were analyzed from each San Francisquito Creek site whereas one-100 organism sample was analyzed for each San Lorenzo Creek site. All organisms were keyed out to family level using keys from the CDFG biomonitoring protocol and McCafferty (1983).

Table 10. Spawning and rearing habitat evaluation methods.

Spawning and Rearing Habitat Data	**Method**
Potential Spawning Gravel (emergence stage)	Pebble Count sampling in potential spawning habitat in one location within each 250 meter section
Potential Spawning Gravel (egg and alevin stage)	Bulk sampling in potential spawning habitat in two locations within each 250 meter section
Potential Rearing Habitat	Habitat types and dimensions (length, average width, and average depth for each habitat unit, and maximum depth for pools) (CDFG fisheries assessment protocol)
Shelter	Shelter rating and % cover (CDFG fisheries assessment protocol)
Macroinvertebrates	CDFG Rapid Bioassessment Protocol for Macroinvertebrates. Point and Nonpoint sampling method.
Turbidity	Lamotte® turbidity test kit (model #7519) and Alameda County Water Resources turbidity data
Water Temperature	Hand thermometer and Alameda County Water Resources data
CFS	Water velocity, width and depth measurements at 3-7 locations along a cross-section within a glide or similar homogenous habitat type
Gradient	USGS 7.5 minute quadrangle maps

Flow was measured in each stream section by timing a float (tennis ball or other object) over approximately a meter at several points along a cross-section at a homogenous channel location (glide). Depth was measured where each velocity measurement was taken and a flow velocity was calculated for each cross-section unit. Stream flow was determined by adding the calculated flows for each unit (USGS, 1982).

Methods: Assessment of Water Quality

Substantial water temperature, dissolved oxygen, and turbidity data has been collected on San Lorenzo Creek by Alameda County Public Works, Water Resources Division. This data was collected in different reaches of the watershed at different times of year. For this study, some additional temperature data was collected downstream of the reservoirs and within San Lorenzo Creek concrete channel to provide more data on where temperature may be a problem for steelhead within the watershed.

Results and Discussion: Spawning Habitat

Pebble Counts and Bulk Sampling

Table 11 shows the pebble counts recorded at all sample sites. Figure 26 shows the percentage (by count) of particles <4 mm and embedded in all sample reaches. With the exception of Castro Valley/Chabot Creek, all San Lorenzo Creek sites had a higher percentage of fines than San Francisquito Creek sites. Similar results were found for embeddedness, with the exception of both Castro Valley Creek and Palomeras Creek.

When testing the <4 mm size class counts, no significant differences were found between San Francisquito and San Lorenzo Creek watershed sites at the 5% level using the Mann-Whitney-Wilcoxon (MWW) statistical test (one-sided only). Although San Lorenzo Creek sites had higher counts for the <4 mm size class than most of the San Francisquito Creek sites, the one exception--Castro Valley Creek--had the lowest outcome of all, and no significance was found. A similar result was found when comparing the embedded size class for both watersheds. Although a general pattern of greater numbers for embeddedness counts were found at San Lorenzo Creek sites, no significance was found at the 5% level using the MWW test (one-sided only).

The results of the bulk substrate sampling are shown in Table 12. Surprisingly, percent fines were in many instances as high or higher at San Francisquito Creek sites than at San Lorenzo Creek sites. Statistical tests were not conducted on this data due to the lack of any discernable pattern.

The results of the bulk sampling, and to a lesser degree the pebble counts conflict with the substrate appearance in streams of both watersheds. San Lorenzo watershed streams appeared to be more dominated by a mud bottom substrate than San Francisquito watershed streams.

The lack of conclusiveness is thought to be the result of the small number of samples taken (16 total) and the heterogeneity of the stream substrate. Although sampling was standardized as well as possible, the variability of grain size both horizontally and vertically within the stream substrate may obscure actual patterns. In addition, the high rainfall of 1997-98 may have brought in more silt than normal to both systems, and obscured differences that would have been detected in a normal rain year.

Table 11. Pebble counts at sample reaches in San Lorenzo and San Francisquito Creek watersheds.

Size classes (mm)	SF U/S	SF D/S	Bear	SLor-U/S	SLor-D/S	Crow	Palomer.	CV/ Chabot
<2	6	7	7	14	15	40	19	5
2-4	5	5	3	6	4	5	9	4
4-8	15	4	7	7	12	6	6	15
8-16	33	27	19	14	28	11	20	31
16-32	18	35	23	28	10	4	25	22
32-64	6	13	9	8	6	1	12	9
64-128		5	8	3		1	3	1
128-256	3	1		8		6	1	5
256-512								
512-1024								
embed.	7		5	20	13	32	3	5
Total	93	97	81	108	88	106	98	97
%< 4mm	**12**	**12**	**12**	**19**	**22**	**42**	**29**	**9**
% embed	**8**	**0**	**6**	**19**	**15**	**12**	**3**	**5**

In San Francisquito Creek watershed, silt levels are identified as being a potential problem, especially within Corte Madera Creek, which flows into Searseville Lake. Searsevill Lake has filled up with silt over the years, and is believed to currently have only 20% it’s original depth (A. Launer, personal communication).

It is important to consider that salmonids remove significant silt from gravels when spawning. Amounts removed can vary depending upon size of fish, species, and streams. For trout, an average of 30% of fines were removed from redds during the act of spawning (calculated from several studies--Kondolf, 1988). Steelhead have been observed to spawn successfully in reaches of the Guadalupe River with 40% embeddedness (D. Salsbury, personal communication). Steelhead appear to be capable of spawning with some success in stream systems that have higher levels of silt, regardless whether this is the result of natural processes or stream degradation. It is likely that silt levels are naturally higher for streams in the San Francisco Bay Area and subsequently steelhead reproduction is limited to a greater degree than it is in streams of other regions (i.e. Pacific northwest). Because of this, it is likely even more critical to protect suitable spawning gravels within these streams from further influxes of silt.

Table 12. Bulk sampling results at sample reaches in San Lorenzo and San Francisquito Creek watersheds.

Sample Site	**% finer 4.75 mm**	**% finer 2.0 mm**	**% finer 0.85 mm**
*San Francisquito @221m	34	25	17
*San Francisquito @99m	34	17	9
*San Francisquito @85.5m	21	12	8

Sample Site	**% finer 4.75 mm**	**% finer 2.0 mm**	**% finer 0.85 mm**
*San Francisquito @260m	38	22	10
*Bear @194.5m	42	28	18
*Bear @9m	44	30	19
San Lorenzo @107.5m	21	14	8
San Lorenzo @213m	98	78	42
San Lorenzo @94m	51	28	13
San Lorenzo @14m	33	23	15
Crow @220m	37	24	18
Crow @300m	32	22	16
Palomeras @66m	18	14	10
Palomeras @154.5m	25	17	10
Castro Valley/ Chabot @82m	32	20	10
Castro Valley/ Chabot @197m	22	12	5

* Control sites

Results and Discussion: Rearing Habitat

Habitat Typing

The most meaningful measure variable from the habitat typing is the amount of pool habitat. Results are shown in Figures 27, 28, and 29. Figure 27 shows total pool volume between sample sites. All control sites had greater pool volume than experimental sites, with the exception of the San Lorenzo Creek D/S site, which showed higher pool volume than Bear Creek. Using the Mann-

Whitney-Wilcoxon (MWW) nonparametric statistical test (one-sided only), pool volume was significantly lower (P=0.037) at San Lorenzo Creek sites than at San Francisquito Creek sites. Table 13 shows the summary of statistical tests.

Figure 28 shows average pool depth multiplied by pool length. This measure excludes width. All control sites had greater values than experimental sites using this index. Using the MWW statistical test, pool depth x length was significantly lower at San Lorenzo Creek sites than at San Francisquito Creek sites for both one-sided (P=0.018) and two-sided tests (P=0.037). This measure was applied as a supplement to the pool volume measure because it appeared that when comparing higher-order streams with lower-order streams, stream width could skew results in favor of higher-order streams.

Table 13. Summary of P-values for statistical tests.

	Two-sample t test		Mann-Whitney-Wilcoxon test	
Measure	One sided	Two sided	One sided	Two sided
Pool Volume	0.071	0.141	0.037*	0.074
Pool Depth X Length	0.044*	0.088	0.018*	0.037*
Percent Pool	0.017*	0.034*	0.037*	0.074
Shelter Cover	0.097	0.195	0.067	0.134

* Indicates significance at the 5% level.

For example, although Bear Creek had 10 pools and totaled 92 meters of pool length over a 250-meter sample reach, San Lorenzo Creek D/S scored higher in pool volume, even though San Lorenzo Creek D/S had only two pools totaling 34 meters in length over the same 250-meter sampling length. Ideally only streams of similar order should be compared, but due to the small sample sizes used in this study, it would not have been possible to make statistical comparisons.

Figure 29 shows a comparison of the pool/run/riffle ratio (based on length) for each creek sampled. A high ratio of pools is indicative of good steelhead habitat. Upper San Francisquito and Bear Creek had the highest percentage of pools, with close to 40%. With the exception of Castro Valley Creek (27%), all San Lorenzo Creek sites were 20% or less. Upstream San Lorenzo Creek (U/S) had the worst pool percentage with <1%. Using the MWW statistical test, percentage of pool habitat was significantly lower at San Lorenzo Creek sites than at San Francisquito Creek sites for the one-sided test (P=0.037). A two-sample t-test showed significance for both the one-sided test (P=0.017), and the two sided test (P=0.034).

The nonparametric Mann-Whitney-Wilcoxon rank sum test is probably the appropriate statistical test for the pool data. It does not assume the data are normally distributed. Two-sample t-tests conducted on the data show significance only for the percent pools measure. However such tests assume the data are normally distributed. Neither theoretical considerations based on the type of data, nor evidence from the small amount of data available settles whether the data are near enough to normal for t-tests to be preferred over MWW tests.

The MWW test is based solely on the relative ranks of the observations. In each case, three stream segments are compared to five. With such small sample sizes, statistical significance is hard to achieve. Before data were collected, it was expected that any observed differences would be in the direction of higher quality for the San Francisquito sites, thus one-sided tests are warranted.

Of the San Lorenzo Creek watershed sites, Castro Valley Creek and San Lorenzo Creek (D/S) had the highest values for pool habitat. Castro Valley Creek had substantial pool development compared to other San Lorenzo Creek sites. San Lorenzo Creek (D/S) had fair pool development, while San Lorenzo Creek (U/S) had extremely poor pool development. This is partly the result of this sample site being located within a section dominated by runs, step-runs, and glides. However the fact that either most or all of the San Lorenzo Creek sites scored below and sometimes well below the San Francisquito watershed sites on every measure of pool habitat suggests a system-wide deficiency in pool habitat.

In urban streams, a decrease in pools, and an increase in run/glide habitats has been observed (CRWQCB, 1996). The causes for this are threefold; 1) increase of peak flow during storm events due to increased watershed imperviousness which in turn causes greater erosive flows; 2) removal of bank vegetation which intensifies bank erosion; and 3) removal of instream pool-creating objects such as large woody debris (i.e. log jams) by flood control maintenance operations. The increased flows in urban streams erodes stream banks, causing bank material to collapse and deposit in the stream channel, filling pools and creating wider, shallower channels.

These hydraulically simple reaches, dominated by runs and glides, contrast sharply with the complex hydraulic characteristics of healthy streams. Pearsons (1992) found that following floods, hydraulically complex stream reaches lost proportionately fewer fish and had generally higher fish diversities than simple reaches.

Studies by Harza Northwest on urban streams in the Puget Sound area within the cities of Dent, Renton, and King County, found that low gradient glides were biologically depauperate in terms of macroinvertebrates and juvenile coho salmon (Allee, 1996). The percentage of pool habitat had been reduced to 1-2% of available instream habitat, and the highest densities of coho juveniles were found in a concrete-lined detention pond, underscoring the importance of deep pool habitat for rearing salmonids.

Shelter

An average index of shelter cover was calculated for each reach sampled. Results are shown in Figure 30. Average shelter cover was found to be highest at the San Francisquito Creek (D/S) and Bear Creek sample reaches. San Lorenzo Creek U/S had the next highest shelter rating. Although there was an observable pattern of higher values for San Francisquito watershed sample sites when compared to San Lorenzo Creek sample sites (Figure 30), the sites were not found to be significantly different at the 5% level using either the MWW test or the two-sample t-test (Table 13).

Shelter cover was estimated using a qualitative measure (number of cover types multiplied by the estimated percent cover for each). Based on visible differences during field observations of the two watersheds, it seems likely that with larger sample sizes a statistically (and biologically) significant difference in shelter cover between experimental and control sites could be found. The fact the differences between the two watersheds are not as extreme for shelter cover as they are for amount of pool habitat, however, indicates that shelter cover may not be as limiting when compared to other habitat components.

What is perhaps most revealing is the difference in presence of large woody debris between the two watersheds. Large woody debris is considered the most important type of shelter cover for salmonids, and is also an important structural component in pool formation. Large woody debris is often missing from urban streams due to removal by maintenance crews for flood control purposes. Large woody debris was noted to occur 3.3 times more frequently within San Francisquito Creek sample sites (average of 2 times per reach) than in San Lorenzo Creek sample sites (average of 0.6 times per reach).

Benthic Macroinvertebrates

Taxonomic groups identified at each sampling site are shown in Table 14, Metrics calculated from the taxonomic groups identified and the number of organisms within each group are shown in Table 15.

Figure 31 shows benthic macroinvertebrate abundances for each creek sampled. Each sample represents a 6 $ft.^2$ sample area. Both San Francisquito watershed sites (San Francisquito Creek and Bear Creek) show benthic macroinvertebrate abundances in the thousands of individuals per sample area. In contrast, Crow and San Lorenzo creeks are in the hundreds of individuals per sample area.

Table 14. Benthic macroinvertebrate taxonomic groups recorded in San Lorenzo Creek, Crow Creek, San Francisquito Creek and Bear Creek during spring 1998.

Order	**Family**	**San Lorenzo**	**Crow**	**San Fran-cisquito**	**Bear**
Trichoptera	Hydropsychidae	X		X	

Order	**Family**	**San Lorenzo**	**Crow**	**San Fran-cisquito**	**Bear**
	Lepidostomatidae				
	Rhyacophilidae		X		
Plecoptera	Perlodidae				X
	Chloroperlidae		X		
Ephemeroptera	Baetidae	X	X	X	X
	Ephemerellidae		X	X	X
	Leptophlebiidae			X	X
	Heptageniidae		X	X	
	Caenidae			X	
Coleoptera	Elmidae				X
Diptera	Ceratopogonidae			X	X
	Simulidae	X	X	X	X
	Chironomidae	X	X	X	X
	Empididae				X
***Other**	Oligochaeta	X		X	X
	Suborder: Acari				X
	Daphnia			X	
	Ostracoda			X	
	Gastropoda			X	
Totals		**5**	**8**	**13**	**10**

San Francisquito Creek and Bear Creek benthic macroinvertebrate samples were collected and analyzed at the California Stream Bioassessment Workshop held at Jasper Ridge Biological Preserve, May 18-20, 1998. Data presented here with permission of Jim Harrington and the American Fisheries Society.
* Non-insect groups.

The most dramatic differences were found between Bear and Crow creeks, with Bear Creek (calculated abundance of 3537 organisms per sample area) having 27 times the abundance of Crow Creek (calculated abundance of 131 organisms per sample area).

Differences between the San Francisquito Creek sampling site and the San Lorenzo Creek sampling site also showed large differences. San Francisquito Creek had approximately two times the abundance of San Lorenzo Creek per sample area.

Table 15. Macroinvertebrate metrics for San Lorenzo Creek and San Francisquito Creek Sample Sites. Standard deviations are shown in parenthesis.

Metric	**San Lorenzo**	**Crow**	**San Francis-quito**[1]	**Bear**[1]
Taxa Richness[2]	**5**	**8**	**10** (0)	**9** (0.8)
EPT Taxa	**2**	**6**	**5** (0.5)	**3** (0.5)
EPT Index	17	62	9 (1.5)	23 (5.8)
% Dominance	55	36	61 (0.5)	51 (5.1)
Tolerant Taxa	5.81	4.09	5.8 (0.1)	5.5 (0.3)
Sample #	100	100	94 (5.5)	93 (2.4)
Abundance	**864**	**131**	**1633** (83)	**3537** (1404)

[1] San Francisquito Creek metrics are an average of 2 replicates, (one replicate thrown out due to suspected bias in recording), while Bear Creek metrics are an average of 3 replicates.
[2] Non-insect groups were excluded from taxa richness calculations.

Figure 32 shows the number of all taxa (taxa richness), and number of

EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera) recorded at each site. High numbers of EPT taxa are good indicators of stream health (Merritt and Cummings, 1996, Chapter 7). Both San Francisquito Creek sites had higher numbers of taxa richness than the San Lorenzo Creek sites, although Crow Creek had the highest number of EPT taxa (6).

Sampling time may have affected macroinvertebrate data at one sampling site (San Lorenzo Creek sampling site). Sampling was done in June at this site and may have missed the peak emergence time. Samples taken at the Crow Creek, San Francisquito Creek, and Bear Creek sample sites were taken during April and May and should have intercepted the peak emergence period for these locations (A. Feng, personal communication).

The high rainfall of 1997-98 could have reduced macroinvertebrate abundances by “blowing out” existing leaf packs, loose substrate, and woody debris from San Lorenzo Creek. This is not likely to be the cause for the disparity between watersheds however, because San Francisquito Creek experienced some of the worst flooding this century in 1998, yet still had much higher benthic macroinvertebrate abundances than San Lorenzo Creek the following spring.

Benthic macroinvertebrate abundance can be highly variable statistic due to natural variation in spatial distribution and timing of emergence (Merritt and Cummings, 1996, Chapter 6). However the large disparity between abundances in San Lorenzo Creek and San Francisquito Creek is suggestive of degraded conditions within San Lorenzo Creek watershed. Good representation of EPT taxa yet very poor abundances is similar to previous years findings on Crow Creek (A. Feng, personal communication).

A number of factors are potentially responsible for this observed reduction in abundance. Factors include: 1) a lack of nutrient-rich leaf packs that are the primary producers in the stream food web; 2) reduction in living space for benthic macroinvertebrates due to siltation of riffle habitat; 3) reduction in natural cobble and gravel substrate and increase in concrete rubble substrate; and 4) stormwater/pesticide pollution.

Leaf packs provide an important nutrient source to the stream food web. The lack of pool habitat suggests that there are less slow-water areas where leaf packs can develop. In addition, the types of leaves within leaf packs in the San Lorenzo Creek watershed are often composed of non-native blue-gum eucalyptus *(Eucalyptus globulus*) leaves. Genera of this family tend to exhibit low biological processing rates compared to other (especially deciduous) trees (Cummins et al., 1989).

The high incidence of fine sediments (<4 mm) found in riffles with the pebble count data suggests that there may be a deficiency of microhabitat living space for benthic macroinvertebrates within San Lorenzo Creek watershed. In addition, the prevalence of embedded concrete rubble in the substrate as opposed to cobble and/or gravel substrate further reduces available habitat for these animals.

Pesticides may also be responsible for impairing macroinvertebrate numbers. Diazinon, an organophosphate insecticide used widely in California, is a potential source of toxicity in San Lorenzo Creek watershed (see water quality discussion on pesticides).

Results and Discussion: Water Quality

Temperature

Stream water temperature is affected by factors such as depth, velocity, shade, substrate absorbence, and temperature of supplying waters. There is a natural rise in stream temperatures as water moves downstream through the watershed, moving from steeper, more shaded canyons to lower gradient meandering higher-order streams. This natural slow increase in temperature with distance has been magnified in San Lorenzo Creek due to the presence of reservoirs and open concrete flood control channels.

Water temperatures in the upstream natural sections of San Lorenzo

Creek watershed appear to be relatively healthy for steelhead. Weekly water temperature data collected by the County of Alameda in 1995 and 1996 showed San Lorenzo Creek to be between 9.5 - 23.7^{o}C. Data recorded every two hours with Hobo© remote temperature data loggers in August of 1996 showed a diurnal range of 2-3^{o}C, with a minimum temperature of 17^{o} C, and a maximum of 22^{o} C for the entire month (Alameda County Water Resources, station SLZ- 3). Slightly lower temperatures were recorded for Crow Creek. Weekly water temp-eratures for Crow Creek in 1995 and 1996 ranged from 8.1-20.4^{o} C, while remote temperature data taken in August 1996 ranged from 14-20^{o} C, with a diurnal fluctuation of 1.5-4^{o} C (Alameda County Water Resources, station SLZ-5).

In contrast, water within the concrete channel in lower San Lorenzo Creek has very high water temperatures during spring, summer, and fall. The concrete channel is not suitable for spawning or rearing, and so provides only a migration corridor for steelhead. Temperatures during the winter months, when adult steelhead are migrating upstream, tend to stay relatively cool (8-16^{o} C in February, with a diurnal fluctuation of 0.5-4^{o} C). During the spring (the period of steelhead smolt outmigration), however, temperatures rise. In March and April 1996, temperatures ranged from 10 - 24^{o} C , with a fluctuation of 2.5 -10^{o} C in a 12-hour period. In late spring and summer water temperatures range from 14 -31^{o}C, with a 12-hour fluctuation of 10 - 15^{o} C (Alameda County Water Resources, station SLZ-2). These severe temperature swings would likely cause sublethal effects (e.g. increased parasitism, adverse development) on smolts attempting to migrate through the channel during the spring. In the summer, water temperatures would likely be lethal to steelhead.

Water temperatures in the open concrete channel also increase in a downstream direction. I measured water temperatures in the San Lorenzo concrete channel on a warm summer day (August 23, 1996), using a thermometer. Taking measurements every one-quarter mile over a three-hour period, I found that water temperatures increased by about 2.2^{o} C per mile within the unshaded concrete channel. This corresponded to a 10^{o} C increase (from 19.5^{o} C to 29.5 ^{o} C) over the entire 4.6 mile concrete channel section from Foothill Boulevard in Hayward to the Southern Pacific RR crossing near the mouth of the Creek.

Sources of thermal pollution into the upper San Lorenzo Creek system include heated runoff from urban areas and heated water from reservoir spillways. Temperatures measured by hand thermometer upstream and downstream of the reservoirs in June 1998, showed an increase of 5^{o} C (from 16 to 21^{o} C) at Cull Reservoir, and an increase of 3^{o} C (from 17 to 20^{o} C) at Lake Don Castro.

The present water temperatures in the upper watershed tributaries (Crow, Palomeras, Cull) are probably close to the natural condition since tree canopy cover is good and there are no unusual thermal inputs into these streams. Water temperatures in the concrete channel during winter, the time of steelhead upstream migration, are also not likely to be a problem. However, within the concrete channel section of San Lorenzo Creek during the spring, and creek sections immediately below Don Castro and Cull Reservoirs, there are significant temperature increases. State and Federal Water Quality Standards for California require that elevated temperature waste (ETW's) shall not raise receiving water temperature greater than 5^{o} F beyond 1000 feet downstream of the point of discharge. This water quality standard is probably exceeded downstream of Don Castro reservoir and within the open concrete channel of San Lorenzo Creek during warm weather periods in the spring, summer, and fall. Heated waters discharging from Cull Reservoir are partially ameliorated by the larger and cooler flows of Crow Creek, only a few hundred feet from the Cull Reservoir spillway.

Theoretically the optimum temperature range for steelhead is $4\text{-}15^{o}$ C. Water temperatures above about 18^{o} C are unfavorable, and sustained temperatures from $22\text{-}27^{o}$ C are lethal to embryos and juveniles. As stated earlier, these temperature thresholds were established in cooler climates than the San Francisco Bay Area. During episodic heat waves in summer and fall, stream water temperatures in relatively natural sections of San Lorenzo Creek can rise to 22-23^{o} C. If there is substantial macroinvertebrate prey and good oxygen levels, native steelhead parr can sustain themselves through these periods (J. Hagar, personal communication). With low macroinvertebrate abundances, and additional thermal inputs to these streams, survival becomes less likely.

Dissolved Oxygen

Weekly dissolved oxygen (DO) measurements in the unchannelized sections of Crow and San Lorenzo creeks by Alameda County Water Resources during 1995 and 1996 show dissolved oxygen levels at or above 7 mg/ l during the summer and fall. During the winter DO was typically at 10 mg/l and near 100% saturation. These measurements were typically taken during the morning at stations in the concrete channel, and during the afternoon at stations in the upper watershed (L. Kilgour, personal communication).

Dissolved oxygen measurements in the concrete channel showed extreme levels of oxygen (supersaturation) during the spring and summer. This is likely the result of the exposed conditions, shallow water, and high algae blooms. At night and during algae die-off periods the channel likely has large DO drops from biological oxygen demand. Dissolved oxygen therefore is likely to be an additional problem for smolts (or spring-run adults) moving through the concrete channel during the spring.

Low DO levels are not uncommon within remnant pools during the summer and fall dry period, and the measured levels of water column DO appear to be sufficient to sustain steelhead parr in the upstream natural sections of the watershed. However intragravel DO (an important measure of DO available to eggs and developing alevin) may be limiting due to the high amounts of silt in the stream system.

Turbidity

Turbidity data collected during habitat assessments in mid-summer did not reveal a turbidity problem in any of the creeks sampled. (All measurements < 5 Jackson Turbidity Units (JTU). Turbidity, however, is more likely to be a problem during winter when higher flows are actively eroding stream banks. Turbidity data collected by Alameda County Water Resources once a week for several weeks during the winter of 1995, 1996, and 1997 documented a turbidity problem in all creeks except Castro Valley Creek. Table 16 shows turbidity data for San Lorenzo Creek, Crow Creek, Palomeras Creek, and Castro Valley Creek over a 7-week period in the winter of 1997. The county has identified extreme turbidity problems in Norris and Crow Creeks, where turbidity levels >12,000 JTU have been recorded.

Turbidity data collected by Alameda County in 1995, 1996, and 1997 is consistent with my visual observations during the winter of 1998. Castro Valley Creek was observed to take approximately 2 days to clear after a storm event, while all other streams in the watershed would take approximately 2 weeks or more.

Table 16. Turbidity levels in San Lorenzo Creek, winter 1997.

Date	**San Lorenzo (station SLZ-3)***	**Crow (Station SLZ-5)***	**Palomeras**	**Castro Valley**
1/3/97	560	480	--	50
1/10/97	25	50	50	5
1/16/97	50	70	80	0
1/24/97	220	180	200	5
1/30/97	200	320	320	0
2/6/97	80	400	160	0
2/13/97	40	160	120	0
2/20/97	30	60	120	5

*Alameda County Water Resources San Lorenzo Creek water quality station designations.

California water quality standards state that where natural turbidity is between 0-50 JTU, increases shall not exceed 20%. For 50-100 JTU, increases shall not exceed 10 JTU, and for over 100 JTU, increases shall not exceed 10%. It is difficult to say with confidence what the natural turbidity level is for San Lorenzo Creek watershed. Castro Valley Creek is mostly confined within concrete or bedrock and naturally has lower turbidity than the other tributaries of the watershed which flow through unconsolidated sediments consisting primarily of clay. However the persistence of turbid conditions for weeks after rainfall events is indicative of unnaturally high levels of fine silt and clay coming in to these streams.

SUMMARY AND CONCLUSIONS

Based on the negative results from fish surveys that included downstream migrant trapping, visual surveys for parr, and electroshocking surveys in 1997-98, it appears that steelhead are no longer reproducing in San Lorenzo Creek watershed. Reports of adult native steelhead migrating into the creek in wet years could not be confirmed from surveys conducted in 1997-98, however persistent turbidity in the creek inhibited the ability to survey the stream. Exotic fishes were found to present in San Lorenzo Creek, but two native fishes; California roach and Sacramento sucker, were found to be the dominant species throughout the stream system.

Evaluation of San Lorenzo Creek for steelhead habitat found limitations for the species at every life stage. Upstream migrant access was evaluated at a 4.6-mile concrete channel on San Lorenzo Creek and a 1670-foot concrete box culvert on Crow Creek in the winter of 1997-98. When compared to established maximum cruising (swimming) speeds for steelhead, these flood control channels were found to be virtually impassable barriers. Only very shallow depths were found where flow velocities were suitable for steelhead passage within San Lorenzo Creek concrete channel (maximum depth of 1.2 feet in channel center (e.g. V-notch)). In a section where steel baffles were placed in the V-notch to reduce velocities, maximum depth suitable for passage increased to only 1.8 feet in the channel center, and 1.0 feet along inside bends. No suitable conditions for steelhead passage were found at the Crow Creek box culvert.

By comparing spawning and rearing habitat conditons in San Lorenzo Creek to a reference stream (San Francisquito Creek), four limitations in steelhead spawning and rearing habitat were revealed: 1) lack of pool habitat; 2) lack of large woody debris; 3) excessive silt deposition in potential spawning areas; and 4) low abundances of benthic macroinvertebrates.

Most or all of the San Lorenzo Creek sites scored below, and sometimes well below, the San Francisquito watershed sites for pool volume (P=0.037), pool length x average depth (P=0.018), and % pool (based on length) (P=0.037). Large woody debris was noted to occur 3.3 times less frequently within San Lorenzo Creek sample sites. Results from pebble counts from both watersheds showed a pattern of higher percent fines (< 4 mm), and embeddedness within potential spawning gravels in San Lorenzo Creek watershed. Samples of benthic macroinvertebrates taken from two locations within each watershed showed abundances to be from 2 to 27 times lower at San Lorenzo Creek sample sites, though the highest number of EPT taxa occurred at a San Lorenzo Creek site (Crow Creek).

High water temperatures in the San Lorenzo concrete channel during spring and summer would likely impact out-migrating steelhead smolts and in-migrating spring-run adults. In addition, elevated stream water temperatures downstream of the reservoirs may impact rearing habitat in these stretches.

Due to the wandering ability of steelhead, recolonization of San Lorenzo Creek is possible, yet appears highly unlikely given the current access, spawning, and rearing habitat limitations.

It is important to recognize that steelhead do appear to persist in some urban streams such as San Francisquito Creek. The habitat components that are still intact in these systems can be instructional as to what is most important for preserving anadromous fish populations in urban streams.

The lower (valley) portion of San Francisquito Creek is highly urbanized, and is similar to upstream San Lorenzo Creek in it's level of degradation. Conversely, much of the upstream portions of San Francisquito Creek and it's tributaries are in good condition, partially the benefit of less development in the upper watershed, and having portions protected within a biological preserve (Jasper Ridge Biological Preserve). It is because of the existence of this high-quality protected habitat in the upstream section, combined with the lack of any significant access barriers in the downstream section, that this watershed still supports a steelhead population.

Alternatively San Lorenzo Creek watershed has little protected land, and several access barriers. Protected stream-side parkland areas are small, totaling approximately 500 meters in length (this includes all stream-side parks combined). All portions of the stream system are isolated by access barriers, and the least impacted tributaries (i.e. Cull, Crow, and Palomeras Creeks) are completely inaccessible to steelhead.

If the various stakeholders within San Lorenzo Creek watershed agree that restoring this stream system for steelhead is a worthwhile endeavor, then restoring access, spawning, and rearing habitat will need to be pursued. Meanwhile continued development in the watershed will further degrade the system, unless streamside areas are protected.

RECOMMENDATIONS

1) Improve Access

- Solicit designs for modifying the concrete channel in San Lorenzo Creek to allow fish passage by lowering velocities and providing pool refuge areas while still maintaining flood capacity.

- Investigate using baffles in upstream concrete culverts on Crow Creek (i.e. Washington baffles), to allow fish passage.

- Reduce temperatures within the San Lorenzo concrete channel by providing shade through tree planting or other methods.

2) Improve Spawning and Rearing Habitat

- Institute erosion control projects using biotechnical erosion control methods that can restore streambank integrity and increase habitat values.

- Conduct a focused sediment loads study to identify specific sediment source areas in both hillside areas and along stream banks in San Lorenzo Creek watershed.

- Install pool enhancement structures using large woody debris in upstream sections of the stream system.

3) Improve Protection and Understanding of Steelhead

- Provide better protection of steelhead from poachers, especially during the spawning season.

- Establish the carrying capacity of San Lorenzo Creek for steelhead and identify target population estimates for different restoration scenarios.

3) Improve Watershed and Stream Function

- Establish County-wide stream side buffer zones for all new development. A suggested corridor width is a minimum of 10 times the stream bank width (top of bank).

- Institute projects to reduce the amount of impervious surface area in the watershed and decrease peak flows to San Lorenzo Creek.

- Continue stormwater pollution and monitoring especially within the highly urbanized sections of the watershed (i.e. Castro Valley, Hayward, and San Lorenzo).

- Reduce stormwater runoff temperatures by continuing urban forestry programs in the watershed.

- Continue watershed education programs to foster greater understanding and involvement in the protection of stream ecosystems.

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APPENDIX A: VELOCITY MEASUREMENTS IN SAN LORENZO CREEK, JAN.-APRIL, 1998.

APPENDIX B: HABITAT ASSESSMENT DATA FROM SAN LORENZO CREEK AND SAN FRANCISQUITO CREEK WATERSHEDS, SPRING, 1998.

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