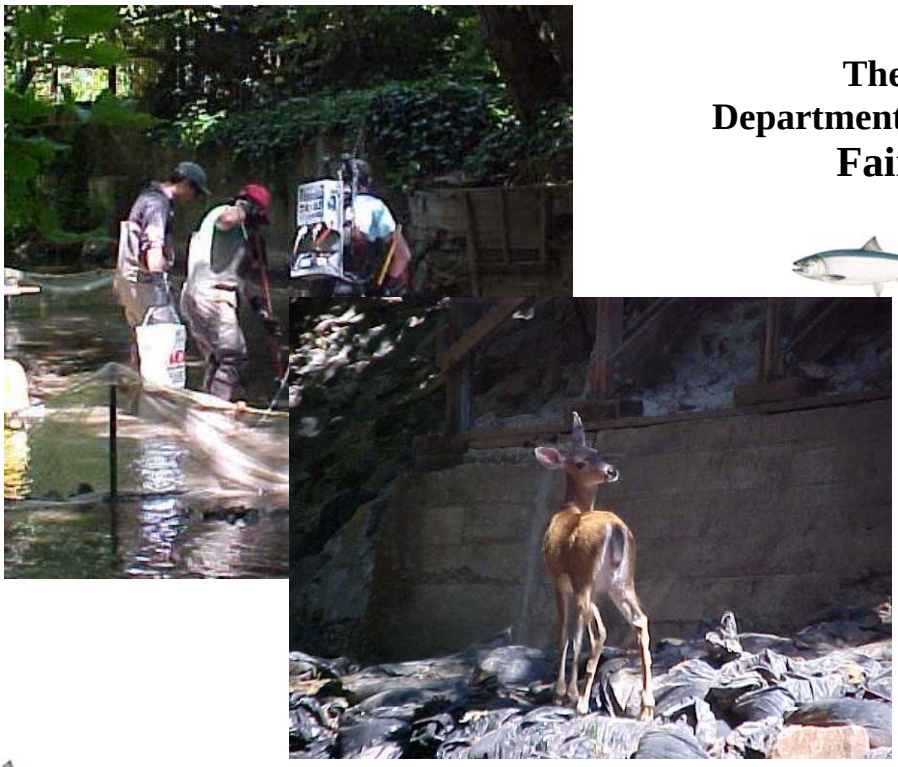
Fishery Resources Assessment For the Town of Fairfax Project Sites



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EXECUTIVE SUMMARY

Due to the damage caused by the December 31, 2005 flooding, the Town of Fairfax (Town) has the following six necessary repair projects.

(1) <u>San Anselmo Creek</u>

- Site 1: Pastori Avenue Storm Drain Outlet Repair
- Site 2: Creek Road Bridge Foundation and Reconstruction, and Bank Repair
- Site 3: Spring Creek (tributary to San Anselmo Creek) Culvert Replacement under Cascade Drive near 633 Cascade Drive

(1) <u>Fairfax Creek</u>

- Site 4: Peri Park Pedestrian/Bike Bridge Replacement and Bank Repair
- Site 5: Peri Park Tennis Courts Bank Repair
- Site 6: Sir Francis Drake at Glen Drive/Village West Storm Drain Outlet Repair

During the preparation and construction of the six projects, biological and other types of background information are necessary. To that end, A. A. Rich and Associates ***(AAR***) was contracted by the Town to provide assistance, with regard to fishery resources.

Next year when the design and permitting activities for the six projects occur, there will be an Addendum to this Report that will include the following Tasks:

- Impacts of the six projects on the sensitive fish species;
- Recommended mitigation measures to minimize impacts; and,
- A Fish Relocation Plan for the sites that require collection and moving of fish.

This Report addresses a portion of the Corte Madera Creek Watershed, including the two creeks within Fairfax (San Anselmo Creek and Fairfax Creek), and, two of the creek areas within the Cascade Canyon Open Space Reserve (San Anselmo Creek,and Cascade Creek). More specifically, the objectives of this study were to:

- Provide life stage and habitat information on the rainbow/steelhead trout;
- Provide a historical perspective, to the extent possible, on the fishery resources conditions;
- Assess fishery resources conditions in the vicinity of the Town's six flood-related Project Sites and the rest of the creek areas surveyed;
- Assess fishery resources population conditions; and,
- Identify limiting factors for the rainbow/steelhead trout.

To carry out the objectives, the following types of surveys were undertaken: (1) Water temperature monitoring; (2) "Spot check" water quality monitoring; (3) Fishery resources habitat surveys; and, (4) Fish population surveys.

Detailed discussions are provided for the Town's six flood-related Project Sites. It is assumed that the Town's projects will be undertaken at the end of summer (i.e., August-September), when flows are low. It is during the low-flow season that relocating fish is easiest and, in some case (e.g., Peri Park projects), it is the only time of year when it is possible, due to the large volume of water in the creek.

Sites #3 and #6 will not require fish relocation. Site 3 (Spring Creek, a tributary to San Anselmo Creek flowing into San Anselmo Creek near 633 Cascade Drive) will have no water in it. It dries up early in the summer. Site #6 (Sir Francis Drake Storm Drain Outlet Repair near Glen Drive/Village West) is above the "Millbrae Dam" on Fairfax Creek. The dam is a barrier to anadromous fish migration; there are no other listed fish species in that area of the creek.

San Anselmo Creek had the greatest variety of habitats of the creek areas surveyed, due to its length, the fact that it was flowing through both the Town of Fairfax, and its origin lies in the relatively unimpacted reaches within the Cascade Canyon Open Space Preserve. Throughout its length, it was characterized by alternating lateral scour pool/riffle sequences. In the lower urban reaches, the lateral scour pools were associated with retaining walls and rip rap, whereas in the upper, more natural areas in the Cascade Canyon Open Space Reserve, they were associated with bedrock (Appendix F, Table F-1). At the time of the habitat survey, the creek along Cascade Road, beginning just downstream of Canyon Road, was dry for more than a mile, extending up into Cascade Canyon Open Space. Substrate in this long stretch consisted almost entirely of gravel that was suitable for trout. Hence, during the winter months, it would be a good spawning area for steelhead. A number of man-made structures (denil fish ladders, old cement dams) exist in San Anselmo Creek.

Fairfax Creek flows down the slopes above and through the town of Fairfax to its confluence with San Anselmo Creek at the "Fairfax Culvert" that runs under downtown Fairfax. Fairfax Creek was characterized by numerous lateral scour pools, alternating with small riffle areas from Bolinas Road upstream to Olema Road. Upstream of Olema Road, there were more natural areas, with pools suitable for salmonids, although many of the bank areas had erosion problems. Substrate consisted of gravel (with some spawning areas), sand and silt, and there was abundant vegetative cover throughout most of the creek areas surveyed

Cascade Creek flows into San Anselmo Creek in the Cascade Canyon Open Space Reserve. Although short on water by the end of summer, Cascade Creek offered juvenile rearing habitat. It was characterized by bedrock pools and cascades, abundant canopy, and clean water. Although the many small pools provide rearing habitat, and the creek was relatively cool during the warming months of the year, there was not much spawning habitat. The uppermost boundary for fish migration is the Cascade Falls.

The greatest numbers of trout were collected in San Anselmo and Cascade creeks within the Cascade Canyon Open Space Preserve. Compared to the other fish species, trout were the most numerous in San Anselmo Creek; only trout were collected in the creek areas (i.e., San Anselmo and Cascade creeks) within the Cascade Canyon Open space Reserve. Sculpin were prevalent in both San Anselmo and Fairfax Creek; and, roach were the most prevalent species in Fairfax Creek.

Based on the size distribution, the rainbow/steelhead trout were probably from three to four different age classes. Most of the trout were young-of-the-year (i.e., hatched last spring) fish, but there were some older fish in both San Anselmo and Cascade creeks. The greatest variety of age classes came from these two creeks, as well, suggesting that there is a self-sustaining population of rainbow/steelhead in the watershed.

PREFACE AND ACKNOWLEDGEMENTS

I was raised in Mill Valley during the 1950's and 1960's in a house that my parents built on the slopes of Mount Tamalpais. I spent much of my childhood playing in the creeks and on Mt. Tam. In fact, there are few creeks in Marin County that I did not plunge into as a child, including all of the creeks in Fairfax. I have fond memories of what was, to me, a magical place to grow up. It is a continual joy to me to study the creeks in which, as a child, I spent many a day watching the trout and catching unwary crayfish, using string "baited" with raw bacon. Little did I know that my childhood pastimes would become an adult passion.

This is the second comprehensive survey that my firm, A. A. Rich and Associates, has conducted within the Corte Madera Creek Watershed. It is the sixth watershed in Marin County that I have had the privilege, as an adult, to study.

This Report had many contributors and, as such, there are a number of individuals that I thank wholeheartedly. First, without Debra Sue Johnson's (Public Works Director, Town of Fairfax) interest in protecting the Corte Madera Creek Watershed within Fairfax and contacting FEMA initially, there would not have been this comprehensive study.

In addition, I had the privilege of meeting many helpful homeowners along the creeks during our surveys this year. Among those homeowners that I spoke with, there were a number who allowed us direct access to the creek via their properties, including Laurie and Dave Hennessey at 21 Creek Road, Richard Petamante at 30 Baywood, and the Levinsons at 161 Cascade Drive. Carrying bulky and heavy nets, buckets, and other sampling equipment is strenuous and time-consuming. It is always a relief to find direct access to creeks. In addition, Maire Vidal at 217 Cascade Drive, who was born in a house along San Anselmo Creek, was a wealth of anecdotal "fish information". Gregory Crossman (on Scenic Road) provided me with both still photos and video footage of rainbow/steelhead in Fairfax Creek. Pat Phillips at 223 Cascade Drive, and Tina Browne, whom I met walking along Cascade Drive in June were helpful, as well. The information these homeowners shared with me, regarding present and past creek conditions and steelhead and salmon "sightings" provided valuable anecdotal information.

Finally, last, but certainly not least, thanks to Jason Phillips for the numerous hours spent battling with the GIS and Sigmaplot computer programs to create the figures in the Report.

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CHAPTER 1

INTRODUCTION AND SCOPE OF WORK

A. BACKGROUND

Due to the damage caused by the December 31, 2005 flooding, the Town of Fairfax (Town) has the following six necessary repair projects (Figure 1.:

(2) <u>San Anselmo Creek</u>

- Site 1: Pastori Avenue Storm Drain Outlet Repair;
- Site 2: Creek Road Bridge Foundation and Reconstruction, and Bank Repair;
- Site 3: Spring Creek (tributary to San Anselmo Creek) Culvert Replacement under Cascade Drive near 633 Cascade Drive

(3) <u>Fairfax Creek</u>

- Site 4: Peri Park Pedestrian/Bike Bridge Replacement and Bank Repair;
- Site 5: Peri Park Tennis Courts Bank Repair; and,
- Site 6: Sir Francis Drake at Glen Drive/Village West Storm Drain Outlet Repair

During the preparation and construction of the six projects, biological and other types of background information are necessary. To that end, A. A. Rich and Associates ***(AAR***) was contracted by the Town to provide assistance, with regard to fishery resources.

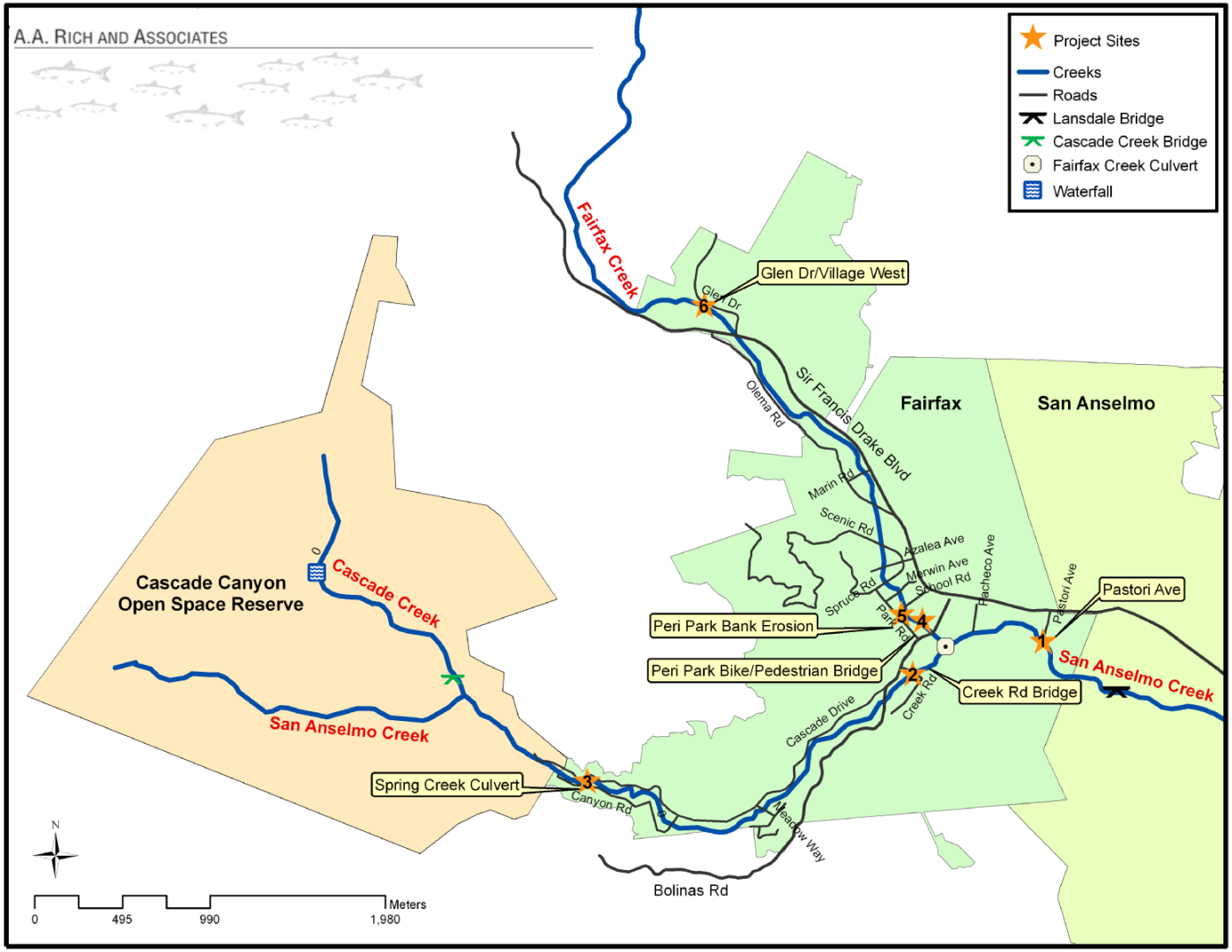

FIGURE 1. TOWN OF FAIRFAX FLOOD-RELATED PROJECTS

B. SCOPE OF WORK

With regard to the fishery resources, the Scope of Work to be undertaken by ***AAR*** includes the following Tasks:

- Communications/meetings/coordination with agencies and other working on the projects;
- Fish habitat and population surveys of the creeks;
- Preparation of this Fishery Resources Technical Report (Report);
- Collection and relocation of fishes for any of the projects sites that require such activities; and,
- Follow-up report submitted to the agencies, summarizing the results of the collection and relocation of fishes and the condition of the creeks after project implementation.

This Report addresses the status of the existing fishery resources conditions within the Town of Fairfax and the Cascade Canyon Open Space Reserve. More specifically, the objectives of this Report were to:

- Provide life stage and habitat information on the rainbow/steelhead trout;
- Provide a historical perspective, to the extent possible, on the fishery resources conditions;
- Assess fishery resources conditions in the vicinity of the Town's six flood-related Project Sites and in the other areas surveyed;
- Assess fishery resource population conditions in the creeks; and,
- Identify limiting factors for the rainbow/steelhead trout.

Next year when the design and permitting activities for the six projects occur, there will be an Addendum to this Report that will include the following Tasks:

- Impacts of the six projects on the sensitive fish species;
- Recommended mitigation measures to minimize impacts; and,
- A Fish Relocation Plan for the Project Sites that require collection and moving of fish.

C. CREEK AREAS COVERED IN THIS REPORT

This Report addresses a portion of the Corte Madera Creek Watershed, including the two creeks within Fairfax (San Anselmo Creek and Fairfax Creek), and, two of the creek areas within the Cascade Canyon Open Space Reserve (San Anselmo Creek and Cascade Creek).

To address existing fishery resources (particularly for the anadromous steelhead that migrate in and out of watersheds) conditions for the Town, it is necessary to provide background information for the creek areas upstream of the Town. Hence, Debra Sue Johnson, Fairfax Public Works Director, requested that, in addition to the Town's creek areas, ***AAR*** survey the upper watershed in the Cascade Canyon Open Space Reserve.

The Corte Madera Creek Watershed covers about 28 square miles. It is located in the southeastern quarter of Marin County and encompasses the towns of Fairfax, San Anselmo, Ross, Kentfield, Corte Madera, and Larkspur. The watershed extends from latitude 37° 55' 50" N to 38° 1' 30" N and from longitude 122° 30' 40" to 122° 36' 45" W. The watershed includes Cascade, Fairfax, Sleepy Hollow, Tamalpais, San Anselmo, Ross, and Corte Madera creeks, and Phoenix Lake. Larkspur and Tamalpais creeks drain directly into the estuary/tidal portion. The watershed drains into San Francisco Bay just south of the San Quentin Peninsula, approximately 10 miles north of the Golden Gate Bridge. The watershed ranges in elevation from sea level to 2,571 feet at the East Peak of Mount Tamalpais.

The Corte Madera Creek Watershed and its tributaries are among the few streams flowing to San Francisco Bay that retain a steelhead trout population. The watershed is situated within the Central California Coast Steelhead Evolutionary Significant Unit (ESU). The National Marine Fisheries Service (NMFS) listed the steelhead trout within this ESU as threatened, under the Endangered Species Act (Federal Register, 1997, 1998).

D. TOWN OF FAIRFAX SIX FLOOD-RELATED PROJECTS

As a result of the December 31, 2006 flood, the Town must repair damage to six project areas. Three of the projects are on San Anselmo Creek and three are on Fairfax Creek. A summary description of each is provided below (taken from Smeltzer and Orum, 2006)

1. San Anselmo Creek

a. S*ite 1: Pastori Avenue Storm Drain Outlet Repair*

Street runoff from the flood caused the suspended terminal section of a 24-inch CMP to fail and discharge Stormwater directly on the right[1] bank (facing upstream) beneath the failed culvert, immediately downstream from the Pastori Avenue Bridge (see Appendix A photos). To prevent another minor bank failure immediately downstream , the culvert outlet needs to be replaced and the bank stabilized To improve fish passage, the existing denil-type fish ladder under the Pastori Avenue bridge needs to be replaced (Ross Taylor and Associates, 2006). The design of the replacement of the fish ladder would require biotechnical bank stabilization in the vicinity of the bridge, including the storm drain outlet sit (Smeltzer and Orum, 2006).

[1] Fisheries biologists customarily walk upstream. Hence, “left” and “right” bank is in relation to facing upstream, rather than facing downstream (the orientation that hydrologists, geologists, and fluvial geomorphologists customarily use).

b. ***Site 2: Creek Road Bridge Foundation and Reconstruction, and Bank Repair***

The Creek Road Bridge is not a flood constriction but, by normal geomorphic processes, the December 31, 2005 flood eroded the outside bank (the right bank looking upstream) of San Anselmo Creek over a 122-foot reach – upstream, within, and downstream from Creek Road Bridge (see Appendix A photos). The bank failure exposed the right bank abutment of Creek Road Bridge. The Town plans to repair the 122-foot long site.

c. Site 3: Spring Creek (tributary to San Anselmo Creek) Culvert Replacement under Cascade Drive near 633 Cascade Drive

Spring Creek is a tributary to San Anselmo Creek, draining a portion of the south-facing slope of Pam's Blue Ridge. Spring Creek flows beneath Cascade Drive within an existing undersized and/or poorly designed culvert (see Appendix A photos). The December flood reportedly exceeded the existing culvert capacity and overflowed Cascade Drive. This required road closure that potentially restricted residential and emergency vehicle access. The Town plans to replace the existing culvert with a larger and/or more appropriately configured culvert beneath Cascade Drive.

2. Fairfax Creek

a. *Site 4: Peri Park Pedestrian Bridge Replacement and Bank Repair*

Significant bank erosion during the December 31, 2005 flood extended downstream from the Peri Park tennis courts and caused the complete failure of the left (facing upstream) bank abutment and a clear-span pedestrian footbridge (see Appendix A photos). The footbridge provided the only safe pedestrian crossing, connecting between the Town's recreational facilities on both sides of the creek. It is recommended that the pedestrian footbridge be replaced with a pre-manufactured clear-span bridge, set on vertical reinforced concrete abutments with an 18-ft minimum inside edge to inside edge opening width (Smeltzer and Orum, 2006).

b. Site 5: Peri Park Tennis Courts Bank Repair

The December 31, 2006 flood flows significantly eroded the 8 to 9 ft-high left bank (facing upstream) of Fairfax Creek along nearly the entire length of the Peri Park tennis courts, leaving a very steep exposed earth bank that is near-vertical in places (see Appendix A photos). The edge of the existing tennis courts fence line is now at the new top of bank, and extends over the new top of bank in places. To prevent against toe undermining, bank erosion by direct flow attached on the mid- and upper bank area, and rotational slump failure. It is recommended that the 113 ft-long reach be repaired (Smeltzer and Orum, 2006).

c. Site 6: Sir Francis Drake at Glen Drive/Village West Storm Drain Outlet Repair

The December 31, 2005 flood caused the downstream-most approximately 18 ft-long segment (s) of an 8 ft-diameter SSP culvert beneath Sir Francis Drake to detach and transport downstream, leaving a severly destabilized site in its place. It is recommended that the raw banks and headwall be stabilized from the new culvert outlets downstream 16-22 ft (Smeltzer and Orum, 2006).

CHAPTER 2

SALMONIDS AS INDICATOR SPECIES OF A WATERSHED'S ECOLOGICAL HEALTH

Although a variety of fish species have been collected and/or sighted within the areas surveyed for this Report (Table 1), the steelhead/rainbow trout is the fish species of primary interest in Corte Madera Creek Watershed. Both the anadromous (fish which spawn in freshwater, are reared for a period of time in fresh water, emigrate to sea for several years, and return to their natal streams to spawn), steelhead and resident rainbow trout, inhabit Corte Madera Creek and its tributaries. In addition, coho and chinook salmon have been sighted occasionally.

Biologists often use salmonids (salmon and trout) to assess the ecological well-being of creeks. The reason is that salmonids are what are referred to as ***indicator species*** (McCarthy and Shugart, 1990). Salmonids respond more quickly to environmental perturbations than other fishes. Thus, the condition of salmonids and their habitat provide a good indication of the relative health of a creek. Salmonids are to fisheries biologists what the canary was to miners: ***a warning sign***. The salmonid's response to its environment can provide an indication of the health of the watershed ecosystem, just as the condition of the canary was used to assess poor air quality conditions in mines. Thus, the salmonid health and salmonid habitat are ***environmental harbingers*** of events to come, if we do not remedy or remove the causative agent (s).

TABLE 1. FISH SPECIES THAT HAVE BEEN SIGHTED AND/OR COLLECTED IN THE CREEK AREAS SURVEYED FOR THIS REPORT

Common Name	Native Species	San Anselmo Creek	Fairfax Creek	Cascade Creek
Salmonidae (Trout and Salmon)				
Chinook Salmon *Oncorhynchus tshawytscha*	X	10	10	
Coho Salmon *Oncorhynchus kisutch*	X	8,10	10	10
Steelhead Trout *(adults)* *Oncorhynchus mykiss*	X	10	10	10
Rainbow/Steelhead Trout *Oncorhynchus mykiss*	X	1,3,5,6,8,9	7	1,7
Cyprinidae (Minnows)				
California Roach *Lavinia symmetricus*	X	1,3,5,8		4
Catostomidae (Suckers)				
Sacramento Sucker *Catostomus occidentalis*	X	1,5,8		
Gasterosteidae (Stickleback)				
Threespine Stickleback *Gasterosteus aculeatus*	X	1,3,5,8	2,4	
Cottidae (Sculpins)				
Sculpin spp. (probably riffle and prickly)	X	1,3		

Key

1	-	Rich, 2000 (collected from August-November, 1999)
2	-	Rich, 1994 (personal observation; adult spawners in USACE channel)
3	-	Leidy, 1993 (collected in July, 1993)
4	-	Cited in Leidy, 1984 (Leidy and Fiedler, collected September 18, 1981)
5	-	Michaels and Thompson, 1969 (collected in July, 1969)
6	-	NMFS, 1997 (collected in September, 1996)
7	-	NMFS, 1997 (collected in May, 1997)
8	-	Fry, 1936
9	-	Snyder, 1905
10	-	Anectodal (no written record found)
11	-	Gregory Crossman, personal observation, personal communication with A. A. Rich

CHAPTER 3

IMPORTANCE OF IDENTIFYING HABITAT REQUIREMENTS AND LIMITING FACTORS

Understanding the biological and physical factors that are necessary to sustain the salmonid populations in the Corte Madera Creek Watershed is critical to developing management strategies to protect populations when instream and creek bank work is required. Salmonid production is affected by environmental conditions during each life stage. Salmonids, similar to other fishes, have different habitat requirements for the successful completion of each of their life stages. Thus, it is essential to understand what the watershed has to offer salmonids, before one can protectively manage construction projects. This Chapter describes the general habitat requirements and limiting factors for salmonids. The results of the study are presented in Chapters 7-9.

Life history events for any organism, including salmonids, must be discussed in concert with key ***life stage requirements***. Life stage requirements are those features of an organism's environment that are essential to its continued survival and reproductive success. Critical life stage requirements for the rainbow/steelhead trout include:

- Appropriate water temperatures;
- Appropriate water quality;
- Abundant food;
- Accessibility to spawning and rearing areas; and,
- Appropriate physical habitat.

Each of the life stage requirements may vary, depending upon the season and the life stage and condition of the fish. If any life stage of any species is deprived of a life stage requirement, the population as a whole can be negatively affected. When life stage requirements are not met, or are limited in some way, the fish's survival and reproductive success can be jeopardized.

Factors that have the potential to restrict populations are called "limiting factors". The term limiting factor was originally used in a physiological context to describe environmental factors (e.g., food, dissolved oxygen, other respiratory gases) that limited the metabolic rate of fishes (Fry, 1971). However, during the past decade, agency biologists have expanded the limiting factor concept to apply to ecological systems. Thus, many of the terms that were originally used to describe physiological processes that affect fish production are now used in a much broader context to describe ecological functions (Reeves et al., 1989). Potential limiting factors from an ecological context include: water temperature; water quality; and, quantity and quality of habitat suitable for spawning and rearing. Some limiting factors, such as not enough woody debris (habitat which trout prefer and need), can be influenced by human intervention. Other limiting factors, such as the lack of water, often cannot be altered. Thus, in order to protect steelhead, one must identify the following:

- The requirements of the fishes; and,
- Any Limiting Factors that may exist.

As each life stage of the trout has specific life requirements, it is imperative to understand both the events of each life stage and the factors that affect those events.

The anadromous steelhead, and the resident rainbow, trout require special conditions for successful spawning, egg development and hatching, growth and survival of juveniles, and smoltification (during which the anadromous fish change from a freshwater to a seawater animal, and emigrate to sea). Although many general requirements (e.g., good water quality, abundant food, etc.) are the same for the steelhead and rainbow trout, specific factors may limit production (i.e., limit the number of fish in the stream). For example, barriers to adult fish immigration may limit the success of spawning for steelhead trout. Thus, to protect steelhead, with regard to the Town's projects, and any other project in the future, it is essential to understand the existing conditions of the creeks.

CHAPTER 4

LIFE HISTORY STAGES AND REQUIREMENTS OF STEELHEAD AND RAINBOW TROUT

A. LIFE HISTORY STAGES

1. *Steelhead*

The steelhead is a polymorphic subspecies of the resident rainbow trout. Similar to other anadromous salmonids, the steelhead trout begins life in a freshwater stream or river, rears for a period of time in freshwater, emigrates to sea for several years, and returns to its natal streams to spawn. Except for their ocean-going habits and larger spawning size, the steelhead trout is visually indistinguishable from its non-migratory counterpart, the rainbow trout. Whether or not a particular stream supports an anadromous or resident trout population appears to be the result of local adaptation and geographic location. Populations may be migratory, resident, or mixed, where the two forms presumably interbreed. Both the anadromous and resident forms may exist in the stream, and, in some instances, may be physically discrete from one another, due to an impassable barrier to upstream migration, such as a waterfall. In these situations, the steelhead trout does not exist above the barrier (Utter et al., 1980; Behnke, 1992; Needham and Gard, 1959).

Steelhead migrate to sea at various ages, spend varying amounts of time in the ocean (one to four years), and return to their natal stream to spawn. The life history information for steelhead can be divided into five life stage events, which include (Figure 2 and Table 2):

- Adult immigration;
- Spawning;
- Egg and alevin incubation;
- Fry and juvenile rearing; and,
- Smoltification and emigration.

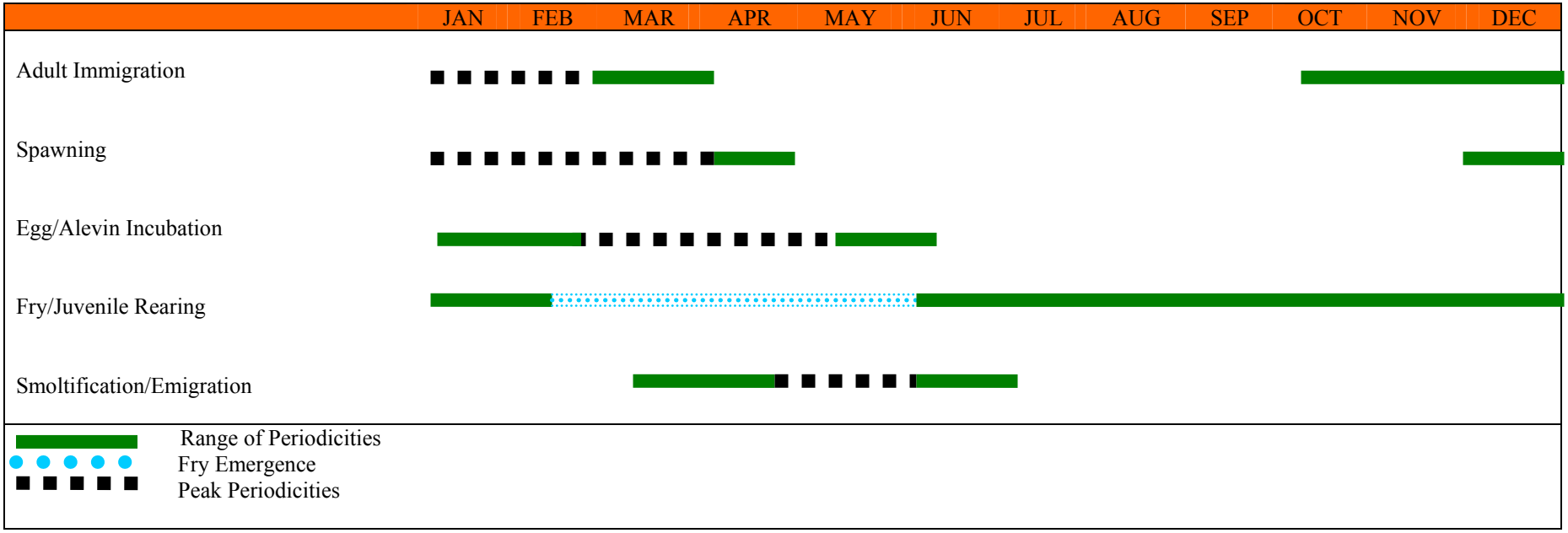

FIGURE 2. LIFE STAGE PERIODICITIES OF STEELHEAD

Sources: Shapovolov and Taft, 1954; Giddings, 1948-1977; Briggs, 1953; Bovee, 1979; Clarke and Shelborne, 1980.

TABLE 2. OPTIMUM CONDITIONS FOR STEELHEAD

Lifestage	Water Temperature Preference (°F)	Dissolved Oxygen (mg/l)	pH	Water Depth (ft)	Water Velocity (ft/s)	Substrate Size (inches)
Immigration and Passage	46.0-52.0	≥ 7 at ≤ 59 °F ≥ 9 at > 59 °F	7-8	> 0.6	< 2.4	N/A
Spawning	46.0-52.0	≥ 7 at ≤ 59 °F ≥ 9 at > 59 °F	7-8	> 0.8	1.3-3.0	0.5-4.0
Incubation	46.0-52.0	≥ 7 at ≤ 59 °F ≥ 9 at > 59 °F	7-8	> 0.1	< 6.0	0.5-4.0
Fry Emergence	48.0-52.0	≥ 7 at ≤ 59 °F ≥ 9 at > 59 °F	7-8	> 0.1	< 6.0	0.5-4.0
Rearing	35.0-60.1	≥ 7 at ≤ 59 °F ≥ 9 at > 59 °F	7-8	0.6-2.2	0.2-0.8	2.5-9.8
Smoltification and Emigration	14.4-52.3	≥ 7 at ≤ 59 °F ≥ 9 at > 59 °F	7-8	0.6-2.2	0.2-0.8	2.5-9.8

Sources: Rich, 1987; Dickson and Kramer, 1971; Doudoroff and Shumway, 1970; Orcutt et al., 1968;Thompson, 1972; Adams et al., 1973, 1975 Smith, 1973; Phillips and Campbell, 1961;Davis, et al., 1963.; Wagner, 1974; Zaugg and Wagner, 1973; Zaugg et al., 1972

A description of the timing and general biology of each of these stages is provided below. Life stage requirements are discussed in the subsequent section.

The steelhead that migrates into the Corte Madera Creek watershed (beginning in December usually) to spawn is referred to as the "winter run". These are steelhead that enter and spawn during rising stream levels during the winter and early spring months (Withler, 1966). Most steelhead begin to immigrate into San Francisco Bay in November, although the timing is dependent upon streamflow levels in the riverine systems (Figure 2). Storm events result in streamflow changes, which cue anadromous fish immigration into Corte Madera Creek, and from there, into the tributaries. Immigration of steelhead occurs in "waves" or pulses, coinciding with storm events, resulting in temporary high water flows (freshet conditions). Studies suggest that these freshet conditions are required to initiate both movement into a lagoon or bay, and upstream into the creeks (Shapovolov and Taft, 1954; Briggs, 1953).

The entry of steelhead into streams is not determined entirely by either sexual maturity or age. Although, California steelhead typically return to freshwater after one to two years at sea, they have a highly variable life history; some return after three or four years at sea (Shapovolov and Taft, 1954; Briggs, 1953). Steelhead which have spent only one year at sea, but have returned to spawn, are termed "grisle"; such males are commonly called "jacks".

After the adult steelhead move into a stream, they will seek out a pool or glide habitat located near the spawning area; many will "hold" in these areas for two to four weeks while their reproductive products (eggs and milt) ripen. In the Corte Madera Creek Watershed, most steelhead spawn in January and February.

Most adult steelhead die after spawning, but some return to the ocean and then to the stream to spawn again; these fish are called "repeat spawners". The incidence of repeated spawning by steelhead is more common among females than males. Repeated spawning by females allows each female to return in subsequent years to release eggs and, hence, increase the number of fish produced. Males usually serve more than one female during spawning. Thus, in terms of perpetuation of the species, it is not as important for males to return to spawn year after year. Research on coastal streams has shown that the percentage of repeat spawners varies from three to over 50 percent of a run. Although, most steelhead return to

spawn only once, as many as five returns have been recorded, although not in recent years (Fulton, 1970; Bjornn, 1969; Withler, 1966; Shapovolov and Taft, 1954; Briggs, 1953).

Steelhead eggs incubate for a variable period of time (usually 30-60 days), depending upon water temperature (Leitritz and Lewis, 1980; Shapovolov and Taft, 1954). In the Corte Madera Creek Watershed, most incubation probably occurs from January through March, although the incubation period may extend further in wet years.

Once the yolk sac is absorbed, steelhead fry begin to emerge from the gravel. In the Corte Madera Creek Watershed, most fry emergence begins in March. The distinction between fry and juvenile is, admittedly, an arbitrary one. "Fry" status is assigned to the fish emerging from the gravel; "juvenile" status is assigned to the fish when it has reached a given length; the length differs from study to study. After emerging from the gravel, the young fish feed and tend to congregate in schools close to shore. As the fish grow, they spread out, eat larger foods, and are thought to inhabit moderately swift portions of creeks. Most steelhead trout spend from one to two years in the streams, before returning to sea (smoltification), where they spend from one to three years, before returning to freshwater to spawn. A very small percentage of fish emigrate out of California creeks during their first year (Moyle, 2002; Withler, 1966; Shapovolov and Taft, 1954; Briggs, 1953).

Smoltification, or the ***parr-smolt transformation***, consists of behavioral, morphological, and biochemical changes which transform a darkly pigmented, bottom dwelling freshwater salmonid (the parr) into a pelagic silvery fish (the smolt) (Folmar and Dickhoff, 1980). During this process, salmonids emigrate from their natal streams into the sea. In the Corte Madera Creek Watershed, smoltification and emigration probably extend from March into June. The fish then emigrate out to San Francisco Bay and from there to the Pacific Ocean.

If steelhead undergoing smoltification are unable to reach the Pacific Ocean, due to environmental problems (e.g., low streamflow, thermal blocks), they revert to an immature parr-like condition (Folmar and Dickhoff, 1980). Depending upon conditions, the trout may de-smoltify and re-smolt the following year, or it may die, particularly if it is a small fish.

2. *Rainbow Trout*

Although not sea-dwelling, the rest of the life history of the resident rainbow trout is similar to that of the steelhead trout. Most rainbow trout are spring spawners (February to June) (Figure 3; Table 3). Most resident trout mature in their second or third year, although the time of first maturity can vary from the first to the fifth year of life (size at maturity can be 13 centimeters or larger) (Moyle, 2002).

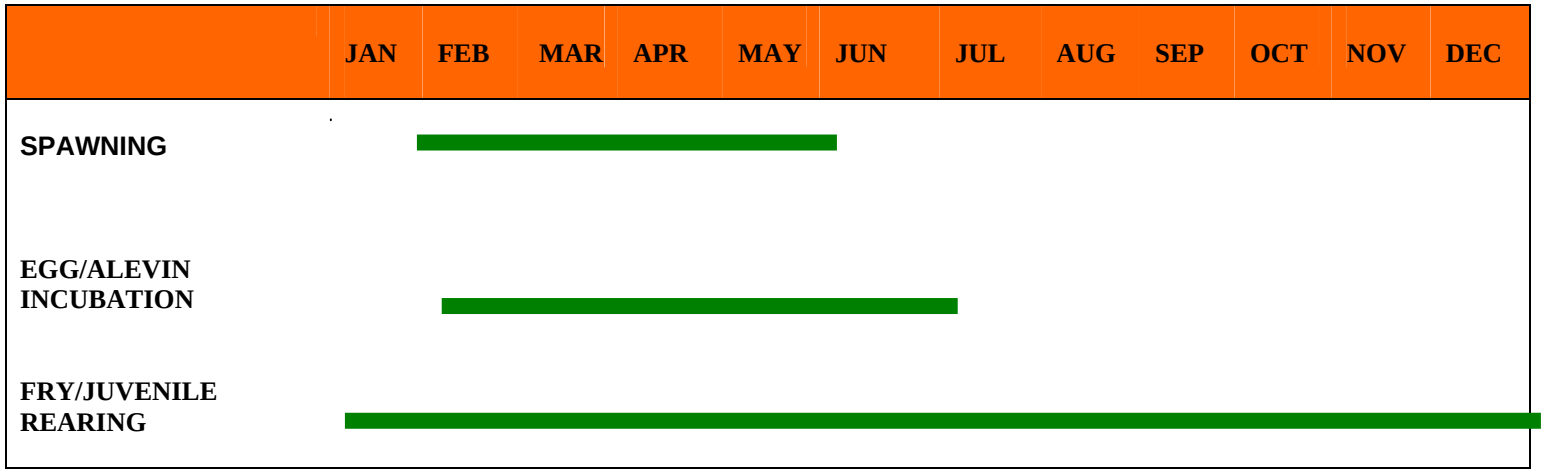

FIGURE 3. LIFE STAGE PERIODICITIES OF RAINBOW TROUT

TABLE 3. OPTIMUM CONDITIONS FOR RAINBOW TROUT

Lifestage	Water Temperature Preference (°F)	Dissolved Oxygen (mgl)	pH	Water Depth (ft)	Water Velocity (ft/s)	Substrate Size (inches)
Spawning	53.6-64.4	≥ 7 at ≤ 59 °F ≥ 9 at > 59 °F	7-8	0.6-6.5	1.0-2.3	0.6-2.4 for spawners < 20 in long 0.6-2.4 for spawners ≥ 20 in long
Rearing	59.0-68.0	≥ 7 at ≤ 59 °F ≥ 9 at > 59 °F	7-8			

Sources: Reiser and White, 1981; Dickson and Kramer, 1971; Doudoroff and Shumway, 1970; Orcutt et al., 1968.

B. IMPORTANT ENVIRONMENTAL FACTORS

For any given species, each life stage has specific environmental requirements, or ***life requirements***. When life requirements are not met, or are limited (i.e., limiting factors) in some way, the fish's survival and reproductive success can be jeopardized. Each of the requirements vary, depending upon the season of the year and life stage of the fish. If any life stage of any species is deprived of a life requirement, the population as a whole can be negatively affected (Figure 4).

By integrating the knowledge of salmonid habitat requirements with that of historical and current conditions, one can determine how habitat conditions for salmonids have been affected by past and ongoing watershed activities. From this information, it is possible to determine what types of activities are needed in order to protect steelhead habitat. Due to the fact that the Town's six projects will be undertaken using methods that are protective of the riparian corridor and the sensitive trout, the projects may actually improve steelhead trout habitat.

The best method for identifying salmonid requirements and determining whether or not these requirements are being satisfied is to use site-specific data. However, as site-specific information is incomplete for all of the life stages of both the steelhead and rainbow trout in the areas surveyed for this Report, relevant data from other systems has been used. As more information becomes available, the requirements for each life stage of the trout should be re-evaluated on an ongoing basis. Then, if necessary, one or more of these requirements can be modified, if there is a scientific basis for such a change.

In the absence of studies conducted in a specific geographical area, it is common to analyze information from other areas or laboratories and to identify a "threshold" value" or "threshold" effect. Threshold values and threshold effects are two commonly used terms that are usually only defined in peer-reviewed scientific publications. Biologically speaking, a "threshold" is a level or value that must be reached before an event occurs; a "threshold effect" is the harmful effect of a small change in the environment that exceeds the limit of tolerance of an organism or population (Lawrence, 1995). There are several problems with using thresholds based on data from laboratories or areas other than the site of interest. First, in the laboratory environment, one is forced to control or eliminate many of the factors (e.g., effect of ration size on thermal requirements, effect of energy expenditure as a result of

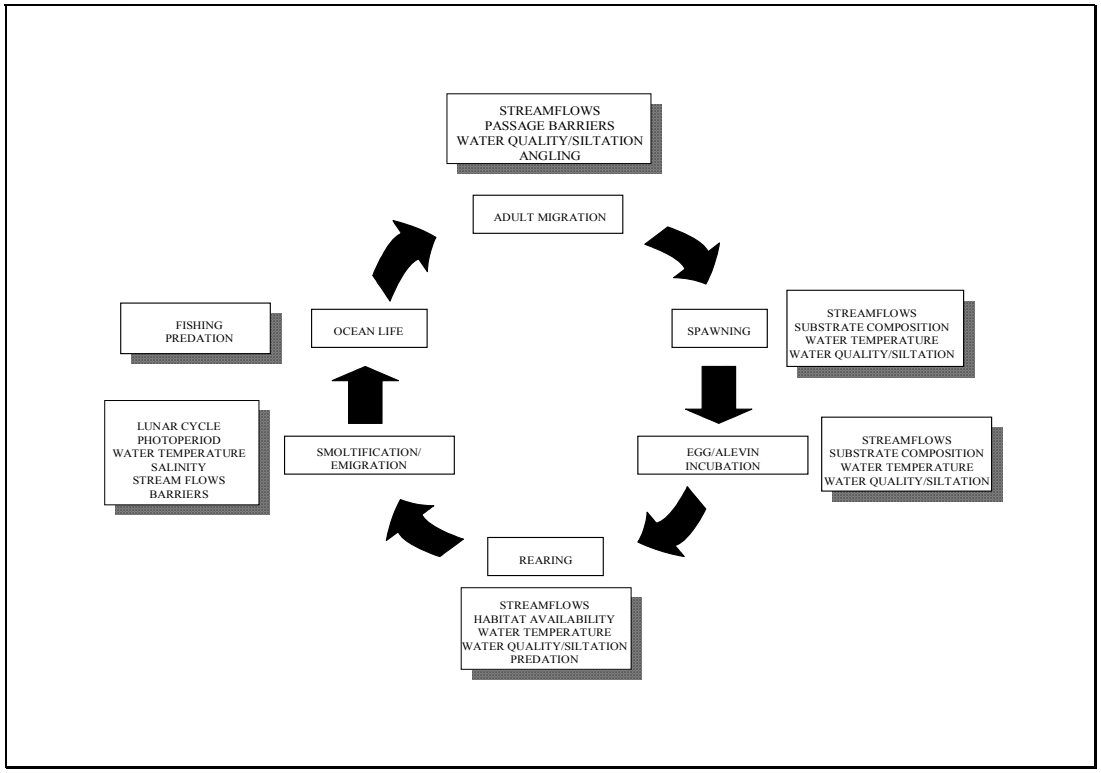

FIGURE 4. FACTORS THAT AFFECT SALMONIDS

escaping predators or seeking prey, effect of previous stressors) that affect fish in the wild. Thus, laboratory data are not analogous to those collected in a stream. Data from other geographical areas can also misrepresent the requirements for the area in question; thermal and physical requirements vary from creek to creek, depending upon existing conditions.

Similar to other studies that ***AAR*** has undertaken in Marin County, I am going to err on the side of being conservative, with regard to the various life stage requirements for these fish. For example, the results of various studies demonstrate a range of thermal optimal values for juvenile steelhead. However, until we know whether or not any or all of the creeks provide the necessary food to sustain higher optimal temperatures, it is best to assume that food is a limiting factor (i.e. there is not enough food). Thus, given a choice of several "optimal" water temperatures, based on laboratory studies, the lowest temperature will be chosen, initially, as being optimal. Then, in the future, if studies are conducted within the watershed that demonstrate that optimal water temperature are higher than those selected here, the requirements can be modified, based on the results of those site-specific studies.

1. *Appropriate Water Temperatures*

Of all of the life stage requisites, water temperature is the most important, yet, perhaps, least understood. A major problem hindering precise understanding of temperature effects is that many environmental factors (e.g., food availability, previous exposure to stress, genetic adaptation, age and size) simultaneously influence a fish's response to temperature. Water temperature can really be considered in two ways: (1) as a factor affecting the rate of development, metabolism and growth; or, (2) as a stressful or lethal factor. The two, of course, are inseparable.

By contrast to us, as mammals, fishes are poikilotherms, which means that their internal body temperature varies, according to the external environment. This means that a fish has little physiological control (i.e., thermoregulation) over its body temperature; if the water is hot, the fish is hot and if the water is cold, the fish is cold, etc. Thus, the poikilothermic fish, unlike the homeothermic mammal (which can thermoregulate), has no physiological way to acclimate quickly to changes in water temperature. And, a fish's metabolism, which controls all aspects of

its body, is directly proportional to water temperature, within certain limits. Thus, as water temperatures increase, so does the metabolic rate and the need for food. If there is enough food available and dissolved oxygen and other conditions are satisfactory, then the fish will grow, within certain thermal ranges. However, if the amount of food is limited and/or other stressors exist (e.g., low dissolved oxygen, pollution), the fish will not grow. In addition, beyond certain physiological limits, even an increase in food availability will not assist the fish; beyond this point, water temperature can be stressful and even lethal.

Despite a fish's inability to change quickly, physiologically, they often use behavior to thermoregulate. This is of great importance when their habitat provides more than one thermal option. For example, in studies on the Navarro River Watershed (Rich, 1991), juvenile coho salmon were collected in water temperatures that would be considered stressful according to the results reported from laboratory studies in the scientific literature. Yet, the fish had good growth rates and appeared to be healthy. It was surmised that both the abundant food resources and cool "thermal refugia" accounted for this apparent anomaly (Rich, 1991). Thus, within the thermocline in the pool, the cooler areas provided a refuge for the salmonids during the hot part of the day. The fish could then digest their food at physiologically acceptable water temperatures, even though a large percentage of the pools were characterized by high water temperatures.

Chronic sublethal stressful water temperatures are usually of more importance to long-term fish population health than acute lethal temperatures. Stressful water temperatures are more common and the results less easily studied and understood than a "fish kill", resulting from lethal water temperatures. However, sublethal water temperatures can effectively block migration, reduce growth rate, create disease problems, and inhibit smoltification. Hence, it is of paramount importance that the impacts of sublethal stressful water temperatures be understood and, when possible, mitigation measures be implemented, to reduce the long-term impacts: reduced productivity within the watershed.

Water temperature standards used for selected fish species by fisheries biologists are often subject to debate. One of the primary reasons for this problem stems from the fact that it is common to base water temperature standards on selected laboratory data, rather than site-

specific field data for a given species. For example, water temperature requirements for salmonids, are often developed without any understanding of the physiological and/or behavioral response of the fish to changes in water temperature in the wild. Therefore, water temperature standards often do not agree with field data for a given fish species.

Thus, to identify appropriate water temperature requirements for fishes, it is of paramount importance to use site specific data, preferably temperature-physiology studies. The status of knowledge, regarding the impacts of water temperature on steelhead trout is provided in Appendix B. Based on available information, physiological optimal water temperature ranges are summarized in Tables 2 and 3 for the steelhead and rainbow trout, respectively.

2. *Acceptable Water Quality Conditions*

Sensitivities of fishes differ, with regard to dissolved oxygen (DO) concentrations, siltation/ sediment, and pollutants. Salmonids are particularly sensitive to low DO, high sediment loads, and various pollutants.

Dissolved Oxygen

Although sensitivity of fish to low DO concentrations differs between species (e.g., salmonids are more sensitive than suckers), the requirements (e.g., feeding, growth, reproducing, etc.) for each life stage controls the amount of oxygen needed at any given time. If these requirements are not met, the fish undergoes a stress reaction. The stress reaction can influence the fish's life processes and, sometimes, whether or not the fish lives or dies. Chronic sublethal DO levels can result in the following impacts on salmonids: (1) Cessation of immigration; (2) Negative impact on swimming performance; (3) Reduced growth rate; (4) Reduced food consumption rate; and, (5) Avoidance reactions. Any of these responses can affect the fish's ability to complete its life cycle and perpetuate the species. For salmonids, DO concentrations should generally be above 7 mg/l, although at low water temperatures, 5 mg/l is probably also suitable (Brett and Blackburn, 1981; Jones, 1971; Whitmore et al., 1960).

Sedimentation and Turbidity

Salmonids require and seek out clean (silt-free) gravel. Although, they will spawn and rear in embedded substrate if nothing else is available, there may be a subsequent reduction in survival to emergence (Folmar and Dickhoff, 1982). It is well-known that fine sediments can influence the survival of salmonids, particularly at the egg and alevin life stages. Fine sediments (defined in most studies as particles with a diameter of less than 3 mm or less than 0.85 mm) may reduce intergravel flow and the delivery of dissolved oxygen to incubating eggs and developing alevins in the redd, impede or obstruct the emergence of alevins, reduce the carrying capacity of rearing habitats for juvenile salmonids, and smother food organisms. In addition, chronic turbidity that is caused by fine sediment suspended in the water column may interfere with feeding by juvenile salmonids and, thereby, reduce growth. Other potential effects of suspended sediment on salmonids include irritation of gill tissues, avoidance behavior, and mortality (McNeil and Ahnell, 1964; Cooper, 1965; Koski, 1966; Cloern, 1976; Phillips et al., 1975; Noggle, 1978).

Although, it is generally accepted that increased input of fine sediments can be harmful to salmonids, determining the exact threshold amount that may limit production of salmonid populations in a watershed is more problematic. Many stream systems in California, including those in the Corte Madera Watershed (Stetson Engineers, 2000) have high sediment loads during the winter and early spring,, including an abundance of fine materials less than 1 mm diameter. Yet, historically these streams supported healthy populations of salmonids.

Pollutants

Compared to many of the other urban creeks I have surveyed throughout the western states, the creeks in the Corte Madera Creek Watershed are relatively clean. However, many of the human activities in the Corte Madera Watershed result in degradation of the creeks inhabited by steelhead and other fishes. Water from storm drains flows into many of the creeks and into San Francisco Bay. Oil from cars, detergents from washing cars, lawn and garden sprays containing herbicides, are all toxic to fishes, particularly the sensitive salmonids, and can result in chronic stress or even be lethal, depending upon the circumstances In addition, sediment problems, originating from headwater areas, primarily, and, to a lesser extent, creek banks in the towns,

result in increased siltation in the creeks (Stetson Engineers, 2000). Finally, high coliform bacteria counts have been detected during the winter months in various segments of the creeks, although this is probably more of a problem to humans than to fishes (Marshall et al., 1994 a,b).

3. *Abundant Food Resources*

Salmonids are opportunistic predators that eat a wide variety of aquatic invertebrates, as well as terrestrial invertebrates that fall into the stream (Mundie, 1969; Tippets and Moyle, 1978). Abundant food is particularly important to salmonids during warm summer months, when water temperatures and metabolisms are high. Young salmonids require a large and constantly replenished supply of food, in order to survive and grow.

4. *Accessibility to Spawning and Rearing Areas*

Sometimes barriers (e.g., dams, shallow riffles, waterfalls, debris jams) will delay, or even curtail immigration beyond the barrier. Migration barriers may limit the success of spawning for steelhead trout. Some barriers are insurmountable, but, given suitable conditions (e.g., deep pools at the base of an obstruction), steelhead trout may be able to get past many obstacles that appear to be barriers. Ross Taylor and Associates (2006) analyzed potential barriers to salmonid migration in the Corte Madera Creek Watershed, using formulas provided by the Department of Fish and Game and other relevant information. Such models are useful as a "first step" for determining potential barriers to steelhead migration. Ultimately, to determine the extent to which these potential barriers affect the salmonids' ability to migrate upstream, site-specific spawning surveys need to be undertaken.

5. *Appropriate Physical Habitat*

The amount of streamflow, substrate quality and quantity, appropriate water depths, and adequate shelter or cover affect all life stages of salmonids.

The amount of streamflow affects all life stages of trout. Of the factors known to influence anadromous salmonid's ascent of creeks, streamflow connected with storm events is one of the most important. Once the fish immigrate into Corte Madera Creek, there has to be enough water for them to "pass over" barriers in order for the fish to reach their spawning areas. Streamflow regulates the amount of spawning area available; as flows increase (up to a point), more gravel is covered and becomes suitable for spawning. During egg incubation and fry emergence, adequate streamflows are necessary to cover the eggs and wash away excretory products. During rearing, streamflow is related to the amount of food and physical habitat available. Streamflow is also an important factor during the parr-smolt transformation and emigration of anadromous fishes.

Trout require and seek out clean (silt free) gravel. Although they will spawn and rear in embedded substrate, if nothing else is available, there is usually a reduction in survival. Successful spawning, incubation, and fry emergence depends upon the following: (1) Size class composition of the substrate; (2) Existing degree of embeddedness; (3) Porosity of the substrate down to below the point of egg deposition in the fish's redd; and, (4) Percolation rate of water through the substrate. General substrate requirements for salmonids are provided in Tables 2-3.

Water depth is important to salmonids, particularly during the immigration and spawning season. Steelhead trout in California streams rarely choose redds that will later be exposed by receding stream levels. During egg development, there must be an abundance of well-oxygenated water flowing over the redds. Preferred depths have been determined by measuring the water depth over active redds (Smith, 1973; Hooper, 1973; Hunter, 1973; Thompson, 1972; Shapovolov and Taft, 1954).

Cover is an important factor in a fish's life. Cover provides protection from predators (e.g., birds, mammals, other fishes), as well as, sometimes, reduced water temperatures during hot days. Cover can be provided by overhanging vegetation, undercut banks, submerged rocks and vegetation, submerged objects such as logs, floating debris, and even turbulence and depth, sometimes. Young salmonids prefer habitats that are characterized by abundant cover. The

nearness of cover to a spawning area may be a factor in the actual selection of spawning sites; some salmonids select areas adjacent to undercut banks and overhanging vegetation (Reiser and Bjornn, 1979; Moyle, 2002).

One of the important characteristics of urban areas, such as in the creeks surveyed, is the need to reduce the impacts of flooding. Unfortunately, for salmonids, reduction of in-channel structure, including large woody debris, as a result of flood control measures, may lead to the loss of habitat features important to both juvenile and adult salmonids. Reductions in structure may cause decreased frequency, depth, and complexity of pool habitat used by rearing juvenile and holding adult salmonids. In particular, the carrying capacity of streams for older age classes of juvenile salmonids may be reduced because these life stages typically prefer deeper pool habitats (Bisson et al., 1988). Stream channels tend to become simpler and less stable after removing woody debris and/or channelizing the streams. As a result, the structural complexity that provides substrate diversity, low-velocity refugia during high flows, and cover from predation is lost (McMahon and Reeves, 1989). Other potential impacts of reduced in-channel structure include: reduced retention and sorting of spawning gravels and fine sediment; reduced retention of fine and coarse organic materials important for maintaining macro invertebrate communities (used as food by juvenile salmonids); and, reduced retention of salmonid carcasses that contribute important nutrients to the stream and food for juvenile salmonids.

CHAPTER 5

LIFE HISTORY STAGES AND REQUIREMENTS OF OTHER FISHES

The main non-salmonid fish species the areas surveyed for this Report include the California roach, probably two species of sculpin, the threespine stickleback, and, although we did not collect any this year, the Sacramento sucker (Table 1). All of these species are hardier than salmonids and are able to adapt, establish, and re-establish themselves more easily than salmonids.

A CALIFORNIA ROACH

California roach are habitat generalists, being found in cold "trout" streams, as well as warm intermitted streams and main channels of rivers (e.g., Russian and Tuolumne rivers). They are tolerant of relatively high temperatures (86-95 °F) and low oxygen concentrations (1-2 parts per million) (Moyle, 2002).

Reproduction occurs from March to June, but may be extended through late July. During the spawning season, schools of fish move into shallow areas with moderate flow and gravel/riffle substrate. Females deposit adhesive eggs in the substrate within 2-3 days and the fry remain in the substrate interstices until they are free-swimming. Roach are bottom feeders, and feed on filamentous algae, as well as crustaceans and insects. Growth is seasonal. With rapid growth occurring during the summer months.

B SCULPIN SPECIES

Not only is the variety of sculpin species enormous, but identification of the various species is a royal headache, even for an experienced ichthyologist. Hence, as the focus of this project is on trout, sculpin collected were not keyed to species. However, based on results of previous surveys (Leidy, 1997), they were probably either prickly or riffle sculpin. Sculpin are bottom fish with a large flattened heads, fan-like pectoral fins and smooth, scaleless, but occasionally

prickly, bodies. These features and the absence of the balancing organ, the swim bladder, enable sculpin to remain on the bottom, even in fast-flowing streams. Generally, this is a hardy family of fishes, which will adapt to a wide variety of coastal conditions (Bond, 1963; Kresja, 1965; Millikan, 1968).

C. THREESPINE STICKLEBACK

There are two types of three-spine stickleback: (1) estuarine anadromous; and, (2) freshwater resident. The stickleback that inhabits the creeks areas surveyed for this Report is the freshwater resident form. The resident form spawns in the spring and summer. The breeding cycle lasts two or three months, during which an elaborate courtship ritual takes place (Tinbergen, 1953). Once the eggs hatch (six-eight days at 64-68 °F), the fry remain in the nest for a couple of days. Once the fry begin to swim about, the male continues to guard them, grabbing wanderers in its mouth and spitting them back into the main school. Eventually, the fry become more active, the male has more difficulty guarding them, and begins the spawning cycle again with another female, or joins a school of fish that have finished reproducing. The young fish join schools of similar-sized fish.

Stickleback live in weedy pools and backwaters, or among emergent plants at streams edges, over bottoms of sand and mud (Moyle, 2002). They require cool water for long-term survival; it is unusual to find them in water warmer than 73-75 °F. It is also unusual to find them in turbid water, since they are visual feeders, as the large eyes suggest. They feed primarily on bottom organisms or organisms living on aquatic plants (Hagen, 1967; Hynes, 1950; Snyder and Dingle, 1989).

Most stickleback appear to complete their life cycle in one year. Usually a majority of the stickleback in one area will be uniform size. Freshwater stickleback seldom exceed 60 millimeters total length in California; anadromous stickleback commonly reach 80 millimeters. Females are usually larger than males.

D. SACRAMENTO SUCKER

Sacramento suckers inhabit a wide variety of waters, from cold, rapidly flowing streams to warm, nearly stagnant pools. Adults tend to be most numerous in large bodies of water and juveniles tend to inhabit tributary streams where adults have spawned. They are usually associated with native minnows, such as the California roach. The food of the Sacramento sucker consists of algae, detritus, and invertebrates associated with the bottom.

Spawning usually occurs in the fourth or fifth year of life, between February and early June, although it may take place in July and August, as well. Suckers spawn over gravel riffles in streams. A sudden cooling spell may halt migration until the water warms up again. At the onset of spawning, females are accompanied by two to five males, the eggs are broadcast over the gravel to which they adhere after sinking into the interstices. Eggs hatch in three to four weeks and the young are soon washed into warm shallows, where they sometimes occur in large schools. Typically, they spend two to three years in the spawning stream before they finally move down to a larger river during fall high water (Moyle 2002; Brauer, 1971).

CHAPTER 6 METHODOLOGY

A. GENERAL APPROACH

To understand what the creeks have to offer, with regard to habitat and other conditions, the following types of information was collected:

(1) Water Temperature (continuous monitoring);
(2) Water Quality Data ("spot check");
(3) Fishery Resources Habitat Data; and,
(4) Fishery Resources Population Data.

Water temperature was monitored from June through October; water quality "spot checks" were recorded monthly at each of the water temperature monitoring sites. Most of the habitat surveys were conducted in June and July. The fish sampling surveys were conducted in June and July.

After we had begun this project for the Town, I was notified by Debra Sue Johnson, the Town's Public Works Director, that the project might be cancelled, due to the fact that FEMA might not pay for the work we were undertaking. At that time, per the request of Ms. Johnson, I re-arranged the field schedule to focus on the Town's six project areas, specifically, and put the rest of the survey areas "on hold". Later, after being told that ***AAR*** could complete the entire project, ***AAR*** resumed the rest of the habitat typing later in the summer.

It should be noted, however, that despite the fact that there was a delay in some of the habitat survey work, all fish sampling sites were chosen and undertaken in June and July, based on representative habitat types selected during the June and July habitat typing surveys.

B. WATER TEMPERATURE MONITORING

To monitoring water temperature conditions in various pools in the creeks, initially a total of 18 thermographs ("Tidbits" and "Hobos", Onset Computer, Massachusetts) were installed in San Anselmo, Fairfax, and Cascade creeks. The sites chosen were those with deeper pools, based on the hope that the sites would not dry up during the summer months. For a variety of reasons, including vandalism, by the end of the summer, there were 14 thermograph sites (Figure 5). Prior to installation, each thermograph was calibrated to record water temperature every 30 minutes, 24 hours a day.

The thermographs were attached to perforated bricks using nylon zip-ties. A plastic coated cable was then used to secure the brick to shore (tree trunk/root/wall) and was secured using cable-clamps. The brick was then set on the creek bottom so that the thermograph sat just above the substrate in the water column in the deepest part of the pool. The thermographs were installed in June and removed in October.

We have had problems in the past with keeping our thermographs and, frankly, keeping them in the water. In urban areas, thermographs often disappear or someone may take the instrument out of the water. Hence, the thermographs were replaced and the data downloaded each month. It was my belief that it was better to lose a month's worth of data, due to theft or displacement, than many months worth of data.

C WATER QUALITY CONDITIONS

"Spot check" water quality conditions were recorded on a monthly basis at the thermograph sites, when the thermographs were replaced at each of the thermographs sites, using a YSI 55 (DO) and YSI 63 (pH, water temperature).

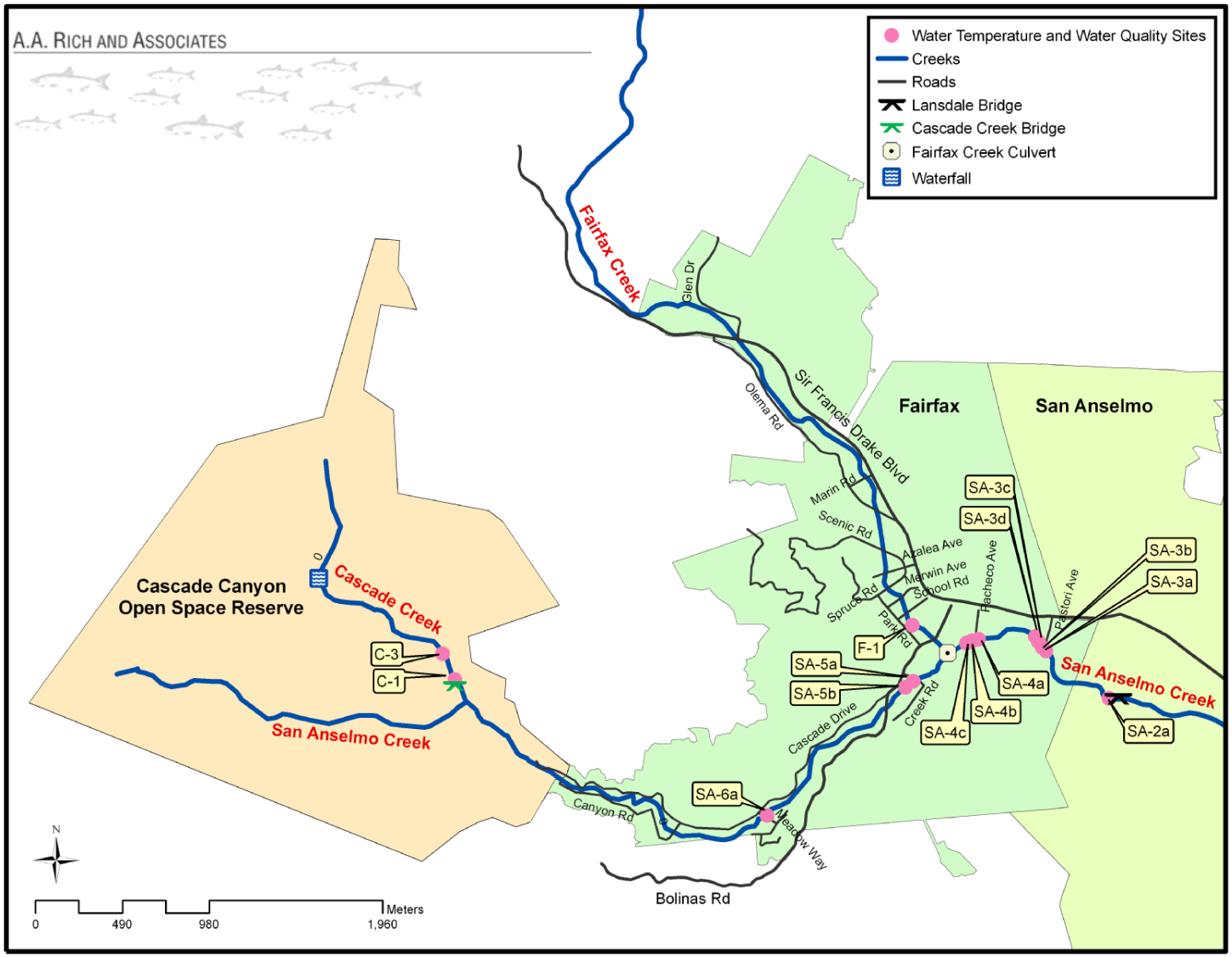

FIGURE 5. WATER TEMPERATURE MONITORING AND WATER QUALITY "SPOT CHECK" SITES

D. EXISTING FISH HABITAT CONDITIONS

To accurately describe the existing fishery resources conditions in creeks, identification of the components of fish habitat is essential. To describe the stream habitat conditions, **Habitat Typing** (Bisson et al., 1982) and general descriptive measurements were used (Appendix C). Habitat Typing consists of measuring the individual habitat units, or types, within a selected stream. This information is then compared with the habitat needs of the fishes collected from the stream. The habitat typing methodology was modified to include artificial habitats created in urban areas (Rich, 2000a). For example, stream banks composed of rip rap, gabions, concrete, or wood walls would not be considered natural habitats, whereas a stream bank composed of an undercut bank would be considered a natural habitat according to Bisson et al (1982). However, both natural and artificial pool habitats are often inhabited by fishes. Thus, if one were to encounter a lateral scour pool associated with an undercut bank, one would call it "a lateral scour pool associated with an undercut bank", according to Bisson et al. (1982). By the same reasoning, if one or both banks were composed of rip rap and this rip rap was the physical attribute creating the lateral scour pool, this habitat would be called "a lateral scour pool associated with rip rap." Habitat measurements were made where water existed; some of the creek areas were dry even in late June.

In San Anselmo Creek, the habitat survey began at the Lansdale Station Bridge in San Anselmo and proceeded upstream through Fairfax and to the confluence with Cascade Creek in the Cascade Canyon Open Space Reserve. In Fairfax, the habitat survey began at the upstream end of the "Fairfax Culvert" (taking photos of the downstream end of the culvert where it the water flows into San Anselmo Creek), and proceeded upstream to the "Millbrae Dam" (impassable to anadromous trout migration). Hence, no habitat survey, per se, was needed for the Town's Project Site #6 on Fairfax Creek, although photos were taken at the site. Steelhead could not access this portion of the creek. The habitat survey for Cascade Creek began at the confluence with San Anselmo Creek within the Cascade Canyon Open Space Reserve and extended upstream to the impassable Cascade Falls (Figure 1).

E FISH POPULATION ESTIMATES

To assess fish population conditions within the creek areas surveyed, electrofishing surveys were conducted in June and July. Electrofishing is commonly used by fisheries biologists for collecting fish. However, in order to minimize the capture stress on the fishes, this method must be used with caution and only by trained personnel. When used efficiently, and knowledgeably, this method is less stressful than that of beach seining and/or other collection techniques.

To obtain an accurate estimate of the fishes in the creeks, it was necessary to electrofish **representative samples** of each habitat type observed in the creek. From previous experience, I have concluded that, to provide a statistically-sound study, one needs, first, to identify the number of **habitat types,** and then sample (randomly) about 20-30% of each habitat type (Figure 6).

The electrofishing proceeded as follows. To prevent the fish from escaping during the sampling procedure, block nets were placed at the lower and upper ends of the sampling site. To sample the site, an electrofisher (Smith-Root Type 12 backpack) was used. The fish sampling crew consisted of one "electrofisher", who operated the electrofishing unit, and one or two netters, depending upon the size of the habitat. Starting at the downstream block net, the electrofisher waded upstream through the sampling station, operating the electrofisher. Stunned fish were netted and placed in water-filled buckets. In order to estimate fish population sizes by the maximum-likelihood method (Van Deventer and Platts, 1983, 1986), three or more passes were completed at each station (see Appendix C for sample electrofishing survey sheet).

After each pass, fish were identified to species and enumerated. For each fish, the following items were recorded: species name; fork length; and, weight.[1] After the electrofishing was completed, the fishes were returned, carefully, to the sampling station from which they were collected. After the electrofishing was completed at each station, the physical dimensions of the habitat were recorded. The dimensions were used to calculate the number of fish (by species) per square meter of stream. The fish were weighed, using an Ohaus scale accurate to 0.1 gram. The scale was calibrated before each field day, using standard weights certifiable to the National Institute of Standards and Testing.

[1] We did not record information on the stickleback. These fish were so small that they passed through the nets. Hence, an accurate population estimate could not be obtained.

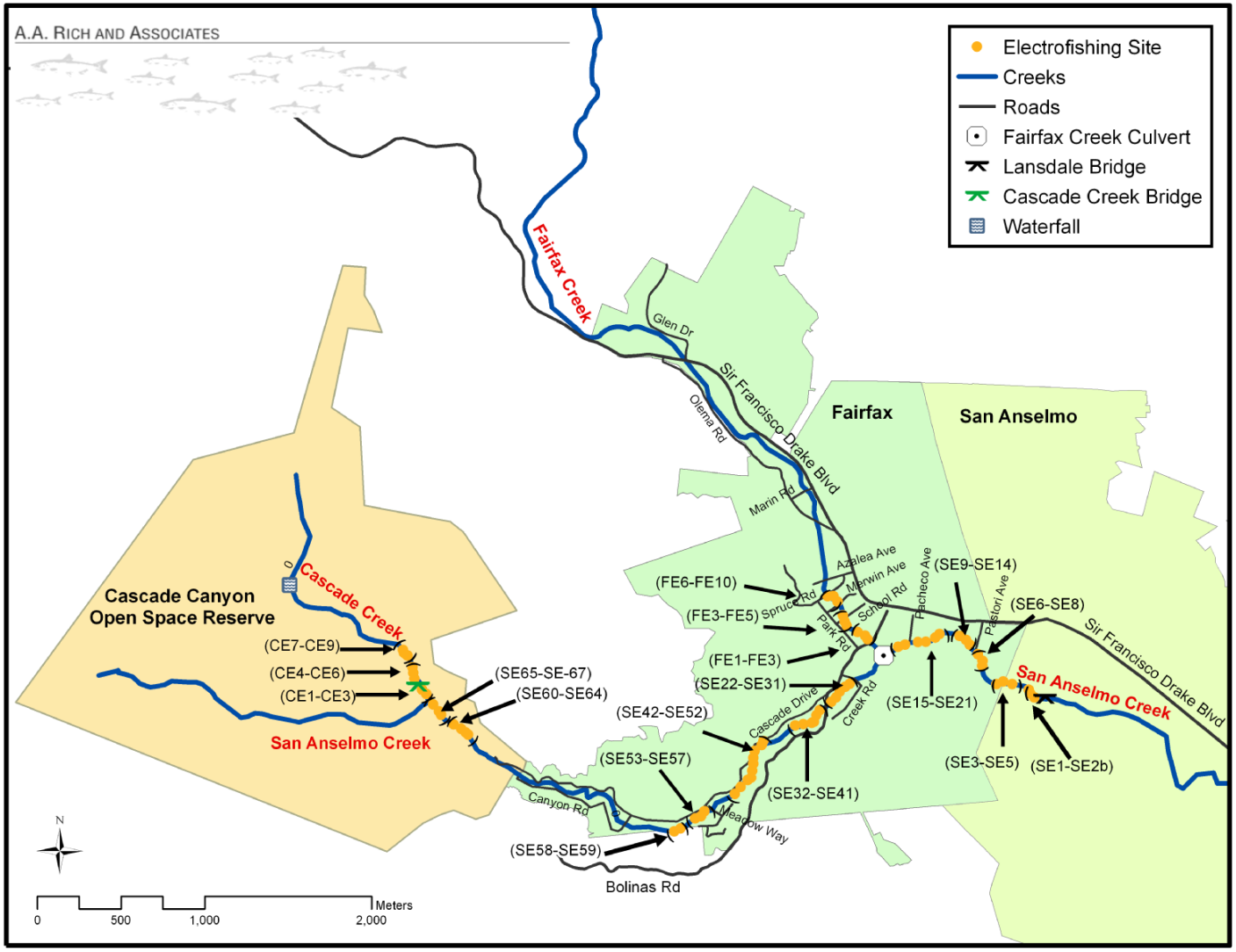

FIGURE 6. FISH SAMPLING LOCATIONS

To reduce the stress of capture on the fishes, particularly the sensitive trout, the fish were placed in a buffered (sodium bicarbonate to pH 7.0, 75 parts per million) anaesthetic (methane trisulphonate, 50 parts per million); previous studies (Rich, 1979, 1983) demonstrated that salmonids exhibited little stress response when such a mixture was used. In addition, battery-operated pumps aerated the water in the buckets in which the fish were residing, prior to release back into the creek.

We also used a special measuring board that I designed over 20 years ago, that minimizes stress on fish by allowing the fish to remain in the water during length measurements. Finally, rocks were placed in buckets that had fish residing in them; this reduces the stress on fish, as well (Rich, 1979).

F. DATA ENTRY AND ANALYSIS

The data were entered into Excel. Population (maximum-likelihood method) size, lengths, weights and total biomass (i.e., total weight of the fish) estimates, together with standard deviations, were calculated on the computer, using Microfish (Van Deventer and Platts, 1983).

CHAPTER 7:

WATER TEMPERATURE AND WATER QUALITY CONDITIONS

A. WATER TEMPERATURE CONDITIONS

The results of the water temperature monitoring discussed below identify potential thermal stress, not actual thermal stress. Due to the fact that water temperature is such an important factor for cold-blooded animals, such as salmonids, it is best to err on the side of caution and assume that, if water temperatures exceed the thermal optima (based on results from the scientific literature) for a given life stage, there is thermal stress. Without site-specific food-fish growth studies, we have no way of knowing whether or not the higher water temperatures that occurred in portions of the creeks actually affected steelhead productivity. As water temperatures increase, the trout requires more food to sustain itself. If there is more than enough food available to sustain a trout, and if the fish isn't eaten by a predator, it has a good chance of growing and emigrating out of the system. If future studies demonstrate that the salmonids are more tolerant of water temperature conditions than reported in the scientific literature, the thermal optima for the steeelhead and rainbow trout can be modified as warranted.

The 2006 study was not very rigorous, compared to the water temperature monitoring that ***AAR*** conducted in 1999 (i.e., in 2006 there were far fewer sites and thermographs were installed only from mid-June through mid-October). However, there were a number of general similarities for the two years, including (Appendix D):

(1) For the anadromous steelhead, July and August were stressful in all of the monitoring pools (note: Cascade Canyon was not monitored during any of the smolt months);

(2) For resident rainbow trout that have a higher thermal threshold than steelhead, rearing water temperatures were generally satisfactory; and,

(3) The creeks in the Cascade Canyon Open Space Reserve were much cooler through the summer months than either San Anselmo Creek or Fairfax Creek within the Town limits.

B. WATER QUALITY "SPOT CHECK" MEASUREMENTS

Of the water quality "spot check" measurements, DO was the most important because it appeared to be the most stressful for salmonids. The DO measurements recorded followed a pattern of quite low DO at the substrate (bottom) level and either adequate or "borderline" DO concentrations at the surface. From a number of habitat surveys for other Fairfax projects that ***AAR*** conducted this past summer, this pattern was typical. Obviously, to adequately determine the impacts on steelhead, a more rigorous study would be necessary. However, the summer months appear to be stressful to salmonids, due to both high water temperatures and low flows in these creeks.

CHAPTER 8:

FISHERY RESOURCES HABITAT CONDITIONS

In order for trout to thrive, there must be appropriate habitat conditions, including the following: accessibility to spawning sites; adequate streamflows; acceptable water temperatures and water quality; appropriate substrate composition; and, abundant food. This Chapter is divided into the following three sections:

(1) A summary of the general habitat conditions in the creeks surveyed;

(2) Detailed discussion of habitat conditions in each of the areas surveyed; and

(3) Detailed discussion in the vicinity of the Town's Six Project Sites.

Data from habitat typing surveys are provided in Appendix F. Photographs of each Stream Reach Unit (SRU) in each of the creek areas surveyed are provided in Appendix H (San Anselmo Creek), I (Fairfax Creek), and J (Cascade Creek).

A. SUMMARY OF HABITAT CONDITIONS

1. *San Anselmo Creek*

San Anselmo Creek had the greatest variety of habitats of the creek areas surveyed, due to both its length, the fact that it was flowing through both the Town of Fairfax, and its origin lies in the relatively unimpacted reaches within the Cascade Canyon Open Space Preserve (Figure 1). Throughout its length, it was characterized by alternating lateral scour pool/riffle sequences. In the lower more urban reaches, the lateral scour pools were associated with retaining walls and rip rap, whereas in the upper, more natural areas in the Cascade Canyon Open Space Reserve, they were associated with bedrock (Appendix F, Table F-1). At the time of the habitat survey, the creek along Cascade Road, beginning just downstream of Canyon Road, was dry for more than a mile, extending up into Cascade Canyon Open Space, but substrate consisted almost entirely of gravel suitable for trout. Hence, during the winter months, it would be a good spawning area for steelhead. A number of man-made

structures (denil fish ladders, old cement dams) exist in San Anselmo Creek (Figure 7). Ross Taylor and Associates (2006) recently evaluated these structures, with regard to the ability of salmonids to migrate past them.

2. *Fairfax Creek*

Fairfax Creek flows down the slopes above and through the town of Fairfax to its confluence with San Anselmo Creek at the "Fairfax Culvert" that runs under downtown Fairfax, beginning at Bolinas Road (Figures 1 and 7). Fairfax Creek was characterized by numerous lateral scour pools, alternating with small riffle areas from Bolinas Road upstream to Olema Road. Upstream of Olema Road, there were more natural areas, with pools suitable for salmonids, although some of the stream bank areas had erosion problems. Substrate consisted of gravel (with some spawning areas), sand and silt, and there was abundant vegetative cover throughout most of the creek areas surveyed (Appendix F, Table F-2).

3. *Cascade Creek*

Cascade Creek flows into San Anselmo Creek in the Cascade Canyon Open Space Preserve. Although short on water by the end of summer, Cascade Creek offered rearing habitat for trout habitat. Cascade Creek was characterized by bedrock pool and cascades, abundant canopy, and clean water. Although the many small pools provide rearing habitat, and the creek was relatively cool during the warming months of the year, there was not much spawning habitat. The uppermost boundary for fish migration is the Cascade Falls (Figures 1 and 7, Appendix F, Table F-3).

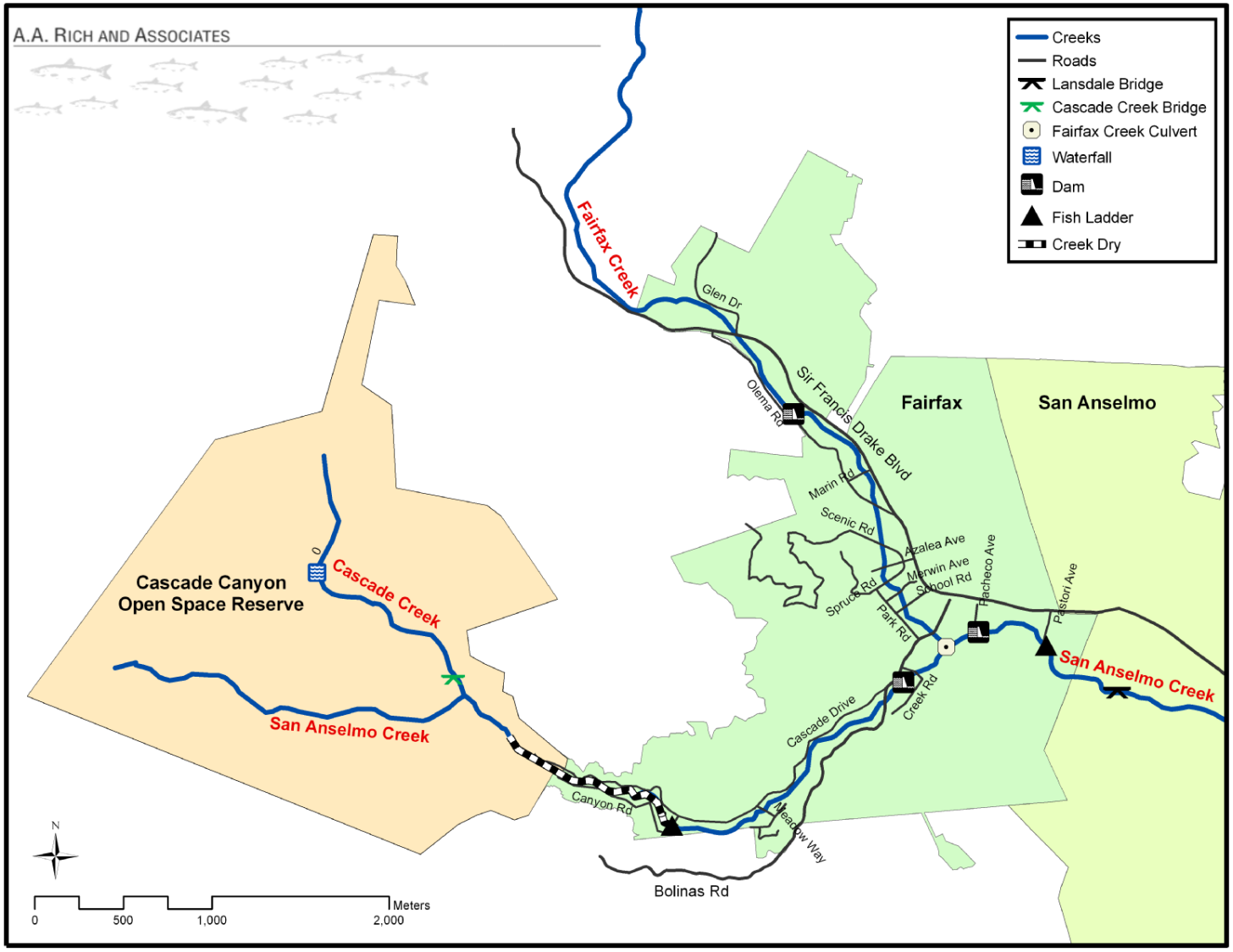

FIGURE 7. POTENTIAL FISH MIGRATION BARRIERS

B. EXISTING FISHERY RESOURCES HABITAT CONDITIONS

In the following paragraphs, stream reaches are summarized; a detailed listing of habitat types and characteristics for the areas surveyed for San Anselmo, Fairfax, and Cascade creeks is provided in Appendix F (Tables F-1 to F-3). The abbreviations in parentheses, such as SA-33, depict the Stream Reach Unit (SRU) numbers reported in Tables F-1 through F-3 in Appendix F. For example, for San Anselmo Creek, "SA-33" would represent the SRU number SA-33 (in Appendix F, Table F-1).

1. San Anselmo Creek

San Anselmo Creek extends from the confluence with Ross Creek in Ross, upstream through Ross, San Anselmo, and Fairfax, and well into the Cascade Canyon Open Space Reserve (Figure 1). The survey area extended from the Lansdale Avenue Bridge upstream into Cascade Canyon Open Space Preserve to the confluence with Cascade Creek. The San Anselmo Creek habitat descriptions in this Report have been divided into the following sections:

(1) Lansdale Station Bridge upstream to Pastori Avenue Bridge;

(2) Pastori Avenue Bridge upstream to Pacheco Avenue;

(3) Pacheco Avenue upstream to Creek Road Bridge;

(4) Creek Road Bridge upstream to Bolinas Road;

(5) Bolinas Road Bridge upstream to Meadow Way Bridge;

(6) Meadow Way Bridge upstream to Canyon Road Bridge;

(7) Canyon Road Bridge upstream to the downstream boundary of the Cascade Canyon Open Space Preserve; and,

(8) Downstream boundary of the Cascade Canyon Open Space Preserve to the confluence with Cascade Creek.

a. Lansdale Station Upstream to Fish Ladder at Pastori Avenue (SA-0 to SA-33)

This portion of the creek, upstream of Lansdale Station, had some fairly deep (more than 0.5 meters deep) lateral scour pools, particularly at the downstream end. These pools (1 m to 90 m in length, average width ranged from 2.2 m to 6.8 m, average depth ranged from 0.04 m to over 0.5 m) were associated with large concrete walls, rootwads, and cut banks. In addition, beginning about SA-11 (near 30 Baywood Road, Petamante residence) and extending upstream to about SA-18, the gradient increased and there were a series of bedrock-based pools in a cascade sequence in June that became high gradient riffles with mid-channel bedrock pools by October. Substrate consisted primarily of gravel and sand in the pools and gravel in the riffles (3-30 m length; average width ranged from 0.9 m to 7 m; average depth ranged from 0.05 m to 0.9 m). Abundant canopy and overhanging cover were present. The bedrock pools that were present in June in the upstream reaches of this section provided excellent habitat for both adults and juveniles. Later in the year (i.e., October), this upper section still had pools that were suitable for juvenile rearing salmonids. In both June and October, the large cement-based pool (SA-32) below the Pastori Avenue fish ladder (SA-33) was over a meter in depth throughout much of the area.

b. Pastori Avenue Upstream to Pacheco Road (P-1 to P-25)

Beginning at the downstream end of this stretch, with the exception of one large rootwad pool (P-4) just downstream of the Fair-San Anselm parking lot complex, most of the habitat in this reach was of very poor quality. However, the rootwad pool had numerous salmonids in it that were visible to the naked eye. The pool was too deep, however to effectively sample. Hence, no trout were collected.

Much of this stretch of creek ran under the parking lot and building connected with the Fair-Anselm Plaza (P-5 upstream to P-9). It was characterized by lateral scour pools created by concrete pilings. Upstream of that was the collapsed wooden wall (P-10) behind the Fair-Anselm Plaza near the Fairfax Post Office. By October, the pools were stagnant and only roach and stickleback were seen swimming about.

Beginning from the Fairfax Post Office (P-10) and proceeding upstream to a concrete dam at Pacheco Road, the habitat was characterized by the continuation of the lateral scour pool/riffle sequences. The lateral scour pools were associated primarily with rip rap and concrete walls, with some eroded banks (MacIntosh property at Town and Country) along the lateral scour pools. There were a few lateral scour pools associated with root wads (e.g., at 40 Inyo, P-18, there was a large root wad pool, too deep to sample, but large trout were seen) in this stream section. These pool habitats provided good depth and structural cover for rearing salmonids. The lateral scour and dam pool types (8-47 m length; average width ranged from 1.7 m to 12 m; average depth ranged from 0.12 m to 0.38 m). Substrate consisted primarily of sand and gravel in the pools and gravel in the riffles (8-22 m length; average width ranged from 1.8 m to 4 m; average depth ranged from 0.08 m to 0.15 m) and abundant canopy/overhanging cover was present. At the upstream end of the reach, at Pacheco Road, there was a large concrete dam, with a cut in the middle at its base that allowed the creek to flow down through it.

c. Pacheco Avenue Upstream to Creek Road (P-25 to P-50; CR-21-1 to CR-21-4)

From the Pacheco Road Bridge (P-25) upstream to Creek Road Bridge (CR-21-4), the habitat was characterized by the continuation of the pool/riffle sequences, with lateral scour pools being the predominant pool type. Most of the lateral scour pools were associated with cement walls and cut banks; there were a few rootwad and bedrock pools. In this stretch of San Anselmo Creek, the lateral scour pools ranged from 9 m to 32 m length, 1.8 m to 8 m average width, and 0.05 m to over 0.5 m average depth. The riffles ranged from 7-30 m in length, 1.7 m to 7 m average width, and 0.03 m to 0.13 m average depth. Predominant substrate was sand in the pools, gravel and sand in the riffles. There were few spawning areas.

A more natural habitat (i.e., riffles, bedrock, rootwad) was characteristic of this stretch from P-26 to P-37. Beginning at P-38, there were a series of lateral scour pools associated with large vertical cement walls. In addition, the confluence of San Anselmo Creek with Fairfax Creek occurred at P-40. At that junction, Fairfax Creek flowed out of the large Fairfax Creek Culvert that is underneath much of downtown Fairfax, and plunged into the P-40 pool

in San Anselmo Creek. Upstream of the confluence with Fairfax Creek, in the vicinity of P-46, there was a collapsed wall with large pieces of cement and cement pilings strewn about the creek.

d. Creek Road Bridge Upstream to Bolinas Road (CR-21-4 to CR-21-26)

From the Creek Road Bridge (CR-21-4), upstream to the Bolinas Road Bridge (CR-21-26), habitat was characterized, primarily, by alternating lateral scour pools associated with cement walls and low gradient riffles. The severely eroded right bank (CR-21-20) at 323/325 Bolinas Road (duplex owned by the Wassermans) was repaired in October.

With few exceptions, this section of San Anselmo Creek was channelized by numerous concrete retaining walls and large undercut concrete-covered lateral scour pool areas. In addition, there was a cement dam (CR-21-12) that was too deep to sample but contained many good-sized rainbow/steelhead. There was also a good-sized rootwad pool (CR-21-17) that contained large rainbow/ steelhead, but was too deep to sample. In this stretch of San Anselmo Creek, the lateral scour pools ranged from 7-23 m length, 2.2 m to 5.3 m average width, and 0.13 m to 0.34 m average depth. The riffles ranged from 5-38.8 m in length, 2 m to 5 m average width, and 0.05 m to 0.07 m average depth. The substrate was composed of sand, silt, and gravel, with very few areas suitable for spawning.

e. Bolinas Road Upstream to Meadow Way (CR-21-26 to CR-21-95)

From the Bolinas Road Bridge (CR-21-26), upstream to the Meadow Way Bridge (CR-21-95), the habitat was characterized, primarily, by alternating lateral scour pools and low gradient riffles. The types of lateral scour pools were those associated with rip rap (5), cut bank (20), cement and wooden walls (8), bedrock (7), and rootwads (4). In addition, there was one pool created by a cement dam (not a fish passage barrier) in the vicinity of 217 and 223 Cascade Drive, three backwater pools, and two side channel habitat areas at the time of the survey (June). The substrate in the pools was composed of gravel, sand, and silt, depending where the habitat was located; generally, the lowermost sections contained better

substrate; the upper sections had less water and in many areas, the pools were stagnant and filled with algae. Suitable-sized spawning gravel was present in various areas of this section. There was abundant shade throughout most of this section; the creek areas that were exposed to direct sunlight had abundant algae growth in them.

In this stretch of San Anselmo Creek, the pools ranged from 6.3 m to 51 m length, 1.8 m to 9 m average width, and 0.03 m to over 0. 5 m depth. The riffles ranged from 3 m to 34 m length, 0.9 m to 5 m width, and 0.04 m to 0.16 m depth.

In 1999, there was a huge root wad pool (CR-21-37) that contained many very large (fork length: 30 cm or 12 inches) rainbow/steelhead. At the time of the 1999 survey, the creek was effectively dry upstream of that rootwad pool. This year, probably from the floods, this habitat had changed substantially. There was still a rootwad pool, but it had diminished in size. It was still too large and the substrate too silty to sample effectively, but there were no rainbow/steelhead observed this year. In 1999, there was no surface flow upstream of this large rootwad pool; this year, there was water in the creek until just downstream of Canyon Road.

There was some debris of human origin strewn about, such as pipes, cement, metal racks, asphalt, and bricks.

The severely eroded right bank (CR-21-30 and CR-21-31) at 39 Cascade Drive (owned by Steve Katz) was repaired in October.

f. Meadow Way Bridge Upstream to Canyon Road CR-21-95 to CR-21-122)

Beginning at the Meadow Way Bridge, and proceeding upstream to the fish ladder at Canyon Road Bridge, San Anselmo Creek began to dry up. Throughout this section there were stranded pools, many filled with young-of-the-year rainbow/steelhead. Many of the pools were filled with algae. Most of the dry reaches contained spawning-size gravel. The stranded pools ranged from 7 m to 42 m length, 1 m to 3.5 m average width, and 0.06 m to over 0.5 m depth.

g. Canyon Road Upstream to the Cascade Canyon Open Space Preserve

This entire section was dry at the time of the habitat survey.

h. Cascade Canyon Open Space Preserve (SA-O-1 to SA-O-16)

The first 1829 meters of this section were dry. Although short on water, similar to what we found in 1999, the pools were full of young-of-the-year rainbow/steelhead. At the time of the survey June and July) this section was characterized by alternating lateral scour pools associated with bedrock, followed by cascades. Pools ranged from 4 m to 20 m length, averaged from 0.9 m to 3.3 m width, and averaged 0.9 m to 0.36 m depth. Although there really was no spawning gravel within the area of the creek that was flowing, in the dry areas downstream of the flowing surface area, there was abundant spawning-size gravel. There was abundant cover in the form of canopy, overhanging vegetation, and bedrock areas. Later in the year (October), much of the area dried up further and there were fewer pools and many fewer trout than in June and July.

2. Fairfax Creek

a. Bolinas Road Upstream to Merwin Avenue (FC-1 to FC-21)

Proceeding upstream, the first SRU is the Fairfax Creek Culvert. Beginning upstream of Bolinas Road, within this section of creek are two of the Town's Project sites: Project Sites # 4 and #5, both within Peri Park. The section of Fairfax Creek from Bolinas Road upstream to Merwin Avenue contained some fairly deep (more than 0.5 meters deep) lateral scour pools, particularly within Peri Park. The lateral scour pools pools (7 m to 33.20 m length; average width ranged from 2 m to 4.6 m, average depth ranged from 0.1 m to 0.24 m) were associated with large concrete and gabion walls, wood, cut banks, and roots. Most of the habitat was pool habitat, although there were a few very shallow low gradient riffles (1 m to 17.4 m length; 0.5 m to 3.5 m width; 0.03 m to 0.06 m depth). Substrate consisted primarily of sand and silt in the pools and gravel in the riffles. Some structural cover was present in the rootwad-based pools and abundant canopy cover was present.

On June 26, when I was selecting representative sites for fish sampling, we came upon some pollution in the creek. The creek was murky white beginning downstream of Merwin Bridge and extending down the creek to below the Peri Park Tennis Court. We reported it to the Town's Public Works Department and they took care of the problem. An apartment building at the corner of Park and Merwin was being painted and some of the workers had let paint flow into Fairfax Creek.

b. Merwin Avenue Upstream to Azalea Avenue (FC-21 to FC-29)

Beginning upstream of Merwin Avenue, this section was channelized from cement and rock walls. There were only two deep (more than 0.5 m deep) pools. The first (FC-22) was immediately upstream of the Merwin Avenue Bridge, the second (FC-27) was downstream of Spruce Road. The lateral scour pools (11 m to 27 m length; average width ranged from 1.9 m to 3.8 m, average depth ranged from 0.09 m to 0.29 m) were associated with large concrete and gabion walls, wood, cut banks, and roots. There were a few very shallow low gradient riffles (3.5 m to 10 m length; 2.5 m average width; 0.1 m to 0.03 m average depth) Substrate consisted primarily of sand, with some gravel (embedded). Cover was provided by canopy shade, riparian vegetation, and depth cover in the two large pools.

c. Azalea Avenue Upstream to Olema Road (FC-29 to FC-46)

Beginning upstream of Azalea Avenue, this section continued to be highly channelized from cement and rock walls. However, even late in the season when we finished this survey, there were a number (FC-32, FC-34, FC-36, FC- 37, FC-44) of deep (more than 0.5 m deep) pools in this section. The lateral scour pools (8.8 m to 45.1 m length; average widths ranged from 1.2 m to 4.2 m, average depths ranged from 0.02 m to 0.9 m) were associated with large concrete and rip rap walls, root wads, and cut banks. Most of the habitat was pool habitat, although there were a few very shallow low gradient riffles (3.3 m to 17.7 m length; average widths ranged from 0.6 m to 2 m; average depths ranged from 0.01 m to 0.29 m). Substrate consisted primarily of sand and gravel. Cover was provided by canopy shade, riparian vegetation, and depth cover in the large pools.

A life-time resident at 21 Olema Road along the Fairfax Creek told us that when he was a child (in the 1960's) and in his father's day (back in the 1940's and 1950's), they used to see and catch adult steelhead and salmon in the large pools near their house. He said that there were still large trout in those pools.

d. Olema Road Upstream to Marin Road (FC-46 to FC-57)

Beginning at the Olema Road Bridge and proceeding up to Marin Road, this section was characterized primarily by lateral scour pools, although there were a few riffles between the pools. Similar to the downstream areas, there were a lot of cement and rock walls. Although most of the section was fairly shallow, there were two large and deep (greater than 0.5 m depth) pools (FC-47, FC-49) that provided good habitat for salmonids in this section. The lateral scour pools in this section (9.1 m to 39.9 m length; average widths ranged from 2.1 m to 3.3 m, average depths ranged from 0.14 m to 0.39 m) were associated with large concrete and wood walls, root wads, and cut banks. Most of the habitat was pool habitat, although there were a few very shallow low gradient riffles (10.4 m to 28 m length; average widths ranged from 1.8 m to 2 m; average depths ranged from 0.05 m to 0.09 m). Substrate consisted primarily of sand and gravel. Cover was provided by canopy shade, undercut banks, roots, and depth cover in the large pools.

e. Marin Road Upstream to "Millbrae Dam" (FC-57 to FC-84)

Beginning at the Marin Road Bridge and proceeding up to "Millbrae Dam", this section was characterized, primarily, by lateral scour pools, although there were a few riffles between the pools. Similar to the downstream areas, there were a lot of cement and rock walls. There were a number of large and deep (greater than 0.5 m depth) pools (FC-60, FC-62, FC-64, FC-74, FC-76, FC-80) that provided good habitat for salmonids. The lateral scour pools (6.1 m to 39.9 m length; average widths ranged from 1.7 m to 3.5 m, average depths ranged from 0.08 m to 0.38 m) were associated with large concrete and wood walls, rootwads, and cut banks. Most of the habitat was pool habitat, although there were a few very shallow low gradient riffles (9.4 m to 34.7 m length; average widths ranged from 1.3 m to 2.8 m; average depths ranged from 0.05 m to 0.1 m). There were also a couple of stretches of high gradient riffles (6.4 to 20.7 m length; 2 m average width; and, 0.1 m average depth). Substrate was variable (gravel, sand, boulders, cobble). Cover was provided by canopy shade, undercut banks, roots, and depth cover in the large pools. The upstream end of this reach was the large "Millbrae Dam" (approximately 100 feet to Millbrae Drive).

Due to the fact that this dam is a complete barrier to steelhead migration, we did not proceed any further upstream with our survey. However, there is about a mile of potential salmonid habitat upstream of this dam (Ross Taylor and Associates, 2006).

3. Cascade Creek

Although higher in gradient, Cascade Creek offered some of the same good quality rearing habitat that was present in San Anselmo Creek within the Cascade Canyon Open Space Reserve. This section was characterized by alternating cascades with bedrock pools, followed by high gradient riffles and, in the lower portion, a few lateral scour pools. The bedrock pools ranged from 7 m to 22 m in length, with pools averaging 0.8 m to 2.9 m width, and 0.04 m to 0.3 m depth. Although there really was very little spawning-size gravel within Cascade Creek, the pools provided rearing and small adult habitat and downstream of this area there was spawning gravel spread out for over a mile distance. There was abundant cover in the form of canopy, overhanging vegetation, and bedrock areas, similar to the uppermost section of San Anselmo Creek (Appendix F, Table F-3).

C. TOWN'S FLOOD-RELATED PROJECT SITES

Following are summary descriptions of the creek sections within, downstream, and upstream of each of the Town's flood-related projects. This section will be amended a bit next year, if creek conditions are different, compared to those surveyed during 2006. Even if there is some change in creek conditions at the time of the 2007 construction phase for these project, it is highly likely that the following four projects will require fish to be relocated prior to any construction work:

(1) Site 1-Pastori Avenue Project;

(2) Site 2-Creek Road Bridge Project;

(3) Site 4-Peri Park Pedestrian Bridge Project; and,

(4) Site 5: Peri Park Tennis Courts Bank Repair Project.

It is assumed that all projects would be undertaken at the end of summer (i.e., August-September), when flows are low. It is during the low-flow season that relocating fish is easiest and, in some case (e.g., Peri Park projects), would not be possible until the late summer, due to the large volume of water in the creek.

Sites #3 and $6 will not require fish relocation. Site # 3 (Spring Creek, a tributary to San Anselmo Creek flowing into San Anselmo Creek near 633 Cascade Drive) will have no water in it. It dries up early in the summer. Site #6 (Sir Francis Drake Storm Drain Outlet Repair near Glen Drive/Village West) is above the "Millbrae Dam" on Fairfax Creek. The dam is a barrier to anadromous fish migration; there are no other listed fish species in that area of the creek.

Following is a summary of the habitat conditions in the vicinity of each of the project areas. With the exception of Site 6, specific details of creek conditions and fish sampled are provided in Appendices F and G, respectively. Other than photographing Project Site #6 during several site visits, ***AAR*** did not conduct any surveys at that Project Site. The reason for this is that no federal- or state-listed fishes (i.e., steelhead) were present, due to the migration barrier ("Millbrae Dam") downstream of Project Site #6.

1. Site 1: Pastori Avenue Storm Drain Outlet Repair

Beginning about 110 m downstream of the Pastori Avenue fish ladder, and proceeding upstream to the fish ladder (SA-28 to SA-33), the habitat consisted of lateral scour pools (associated with bank cut and rotwad), a high gradient riffle and pocket water area about 50 m downstream of the cement pool at the downstream end of the denil fish ladder. The pools ranged in size from a length of 20 m to 50 m, average widths ranged from 4.7 m to 5.1 m, and average depths ranged from 0.22 m to 0.25 m. The pocket water area and the high gradient riffle area were 20 and 12 m long, respectively, with little depth (0.10-0.15 m deep). Substrate consisted of gravel, cobble, and boulder, with some sand in the lowest pool area (lateral scour pool associated with bank cut). Cover was provided by canopy, overhanging vegetation, rocks, and in some of the pool areas, depth (greater than 0.5 m deep). Although most of the good salmonid pool habitat was more than 50 meters downstream of the project area, there were some rootwad pool areas immediately downstream of the denil fish ladder in which I saw some juvenile rainbow/steelhead. In addition, the large cement pool immediately below the denil fish ladder remains fairly deep (much of it more than 1 meter deep in some areas) throughout the summer and even into the fall months prior to the rainy season.

Proceeding upstream of the denil fish ladder, there was a very long lateral scour pool associated with a cement wall and then a lateral scour pool associated with a cut bank (P-2 and P-3), followed by a good-sized rootwad pool that had many rainbow/steelhead in it.

Two of the thermographs were installed in two pools (SA-3a, SA-3b) immediately downstream of the denil fish ladder and another two in pools (SA-3c, SA-3d) immediately upstream of the ladder. Water quality measurements were recorded monthly, as well, at these four sites. From June through August, water temperatures in the two pools below the fish ladder were too hot for steelhead rearing; from June through September, water temperatures in the two pools above the fish ladder were too hot for steelhead rearing (Appendix D, Figures D-2 through D-5). Except for a high peak for a week during the latter part of July, the water temperatures in the four pools (Appendix D, Figures D-17 through D-20) were generally acceptable for resident rainbow trout; juvenile resident rainbow trout are more tolerant of higher water temperatures than juvenile steelhead.

From the "spot check" monthly water quality records, except for thermograph site number Site SA-3d (upstream of the fish ladder), the DO concentrations at the bottom of the other three pools were often too low (less than 5 mg/l); pH was within an acceptable range throughout the pools (Appendix E, Table E-1).

2. Site 2: Creek Road Bridge Foundation and Reconstruction and Repair

Beginning about 70 m downstream of the Creek Road Bridge, and proceeding upstream to the Creek Road Bridge (Cr-21-1 to CR-21-3b), the habitat consisted of alternating low gradient riffles, a lateral scour pool (associated with bank cut) and a mid-channel pool under the bridge. The pools ranged in size from a length of 13 m to 32 m, average widths ranged from 4.8 m to 5 m, and average depths ranged from 0.22 m to 0.315 m. The length of the low gradient riffles ranged from 6 m to 9.5 m, the average widths ranged from 4.2 m to 4.5 m, and the depths ranged from 0.08 m to 0.25 m. Substrate consisted of sand and silt in the pools and gravel, cobble, and boulder in the riffle areas. Cover was provided by canopy, rocks, overhanging vegetation (blackberries), turbulence in the riffles, and depth (more than 0.5 m deep) in some of the pool areas.

Proceeding upstream from the bridge for about 45 m (CR-21-5 through CR-21-8), there was a series of pools followed by short low gradient riffles. The pools ranged in size from a length of 14 m to 18.4 m, average widths ranged from 2.3 m to 4.5 m, and average depths ranged from 0.132 m to 0.34 m, with much of the first pool underneath a large slab of concrete attached to the concrete wall. The length of the low gradient riffles ranged from 5 m to 6 m, the average widths ranged from 2.5 m to 5 m, and the depths ranged from 0.05 m to 0.07 m. Substrate consisted of sand and silt in the pools and gravel, cobble, rip rap and boulders in the riffle areas. Cover was provided by canopy, rocks,, turbulence in the riffles, and depth (greater than 0.5 m deep) from the pools.

One of the thermographs was installed in a pool (SA-5a) about 30 m upstream of the Creek Road Bridge. Water quality measurements were recorded monthly, as well. From July through part of September, water temperatures in this pool were too hot for steelhead rearing (Appendix D, Figure D-9). Except for a high peak that lasted about a week during the latter part of July, the water temperatures in the pool (Appendix D, Figure D-24) were generally acceptable for resident rainbow trout.

From the "spot check" monthly water quality records, the DO concentrations at the bottom of the pools were too low (less than 5 mg/l) during the August through September readings; pH was within an acceptable range throughout the pools (Appendix E, Table E-1).

This Project Site is very important, from the standpoint of the existence of various ages (some were large fish) of rainbow/steelhead. The large pool (most of which is under a cement slab), immediately upstream of the bridge, contained dozens of rainbow/steelhead of different sizes, the largest ones over 30 cm (12 inches) in length. Due to the depth, it was difficult to sample, but we collected many trout. Downstream of the Project Site were some pools that contained juvenile rainbow/steelhead.

3. Site 3: Spring Creek (tributary to San Anselmo Creek) Culvert Replacement under Cascade Drive near 633 Cascade Drive

Spring Creek flows into San Anselmo Creek near 633 Cascade Drive. Spring Creek, upstream of Cascade Drive does not provide suitable rearing or spawning habitat. In fact, the creek becomes dry beginning in late Spring. Downstream of Cascade Drive, in the vicinity of the culvert that needs to be replaced, the creek is dry beginning in June usually. Due to the lack of water in Spring Creek at the time when construction would occur, this Project Site is not anticipated to require any biological surveys or fish relocation.

4. Sites 4 and 5: Peri Park Pedestrian Bridge Replacement and Tennis Court Bank Repair

Beginning about 32 m downstream of Project Sites #4 and #5, and proceeding upstream (FC-14b, and FC-15), the habitat consisted of two lateral scour pool, the lower one a bank cut, the upper one a combination of rootwad and bank cut. The pools ranged in size from a length of 20.7 to 31.7 m, average widths ranged from 3.8 m to 4.6 m, and average depths ranged from 0.11 m to 0.145 m. Substrate consisted of gravel and sand. Cover was provided by canopy, and depth (greater than 0.5 m deep).

Proceeding upstream along the tennis courts, there was a very long mid-channel pool (June) /glide (October), followed by a deep lateral scour pool associated with a large rootwad (FC-16 and FC-17) upstream end of the tennis courts.

One of the thermographs was installed in a large pool (FC-10) about 25 m downstream of the lateral scour pools associated with Project Site #4 (pedestrian bridge repair). Water quality measurements were recorded monthly, as well, at this site. From June through part of August, water temperatures in this pool were too hot for steelhead rearing (Appendix D, Figure D-27). Except for a high peak that lasted for about a week during the latter part of July, the water temperatures in the pool (Appendix D, Figure D-28) were generally acceptable for resident rainbow trout.

From the "spot check" monthly water quality records,,except for the September 11th record, the DO concentrations were accpetable; pH was within an acceptable range throughout the pool (Appendix E, Table E-2).

5. Site 6: Sir Francis Drake at Glen Drive/Village West Storm Drain Outlet Repair

Project Site #6 is located upstream of the impassable "Millbrae Dam". There are no federal- or state-listed species in the vicinity of this Project Site. Hence, this Project Site is not anticipated to require any biological surveys or fish relocation.

CHAPTER 9 FISHERY RESOURCES CONDITIONS

A. HISTORICAL CONDITIONS

There are few written records of "how things used to be" before the Europeans arrived, with regard to the fishery resources. However, there is no question that trout were ample enough for the Coastal Miwok Indians to rely upon for food. Malcolm Margolin (1978) quoted the nineteenth century ethnologist, Stephen Powers, when describing the California Indians as "almost amphibious. They were always splashing in water." California had so much water in those early days; freshwater swamps; San Francisco Bay rimmed with vast saltwater marshes, rivers throughout the year, springs out of the hillsides, natural lakes and enumerable creeks. The clear creeks provided the native Indians with abundant fish and freshwater.

Comparison of historical and anecdotal information with more recent information strongly suggests that, as the years have passed, there have been fewer and fewer salmonids in the Corte Madera Creek Watershed. Given the urbanized nature of the watershed, it is likely that, of the salmonid species (i.e., steelhead, Chinook salmon, coho salmon) that have inhabited this watershed the rainbow/steelhead trout is the only salmonid species persisting to the present time in terms of year-round use and abundance. Stressors include high water temperatures, hydrograph changes, water quality degradation, streambed changes, loss of riparian habitat, land use and human impacts. However, in spite of these problems, the Corte Madera Creek Watershed has been identified as one of the watersheds that should be targeted for protection.

Stream surveys within the Corte Madera Creek Watershed demonstrated a wide assortment of fish species, reflecting both the estuary and freshwater environments (Table 1) (Allen, 1960a, b; Michaels and Thomson, 1968; Scoppettone 1976; Eimoto and Walkup 1980; Leidy, 1997, 1993, 1984; Jones, 1969). However, in the creeks surveyed for this Report, the dominant fish species collected and observed were rainbow/steelhead, sculpin species, California roach, and three-spine stickleback.

B. CURRENT FISHERY RESOURCES CONDITIONS

1. Population Estimates

Fish species collected in the creeks for this Report included rainbow/steelhead trout, threespine stickleback, California roach, and sculpin species (Appendix G). Limiting factors for trout production were lack of stream flows, probably high water temperatures in the Town's creeks, potential migration barriers (fish ladders, dams), and the more than a mile long dry stretch in San Anselmo Creek that extends up into Cascade Canyon Open Space Reserve.

The mean estimates for trout, within the Corte Madera Creek Watershed were as follows (Figures 8-10, Appendix G, Tables G-1 through G-3):

(1) San Anselmo Creek (entire survey area)
(66 sampling sites):

0.36 trout/square meter [1] (range: 0.02-5.54 trout/square meter)

(2) San Anselmo Creek, downstream of Cascade Canyon Open Space Reserve
(59 sampling sites):

0.19 trout/square meter (range: 0.02-2.07 trout/square meter)

(3) San Anselmo Creek, within Cascade Canyon Open Space Reserve
(7 sampling sites):

1.78 trout/square meter (range: 0.26-5.54 trout/square meter)

[1] square meter = surface area = length (meters) X width (meters) of fish habitat

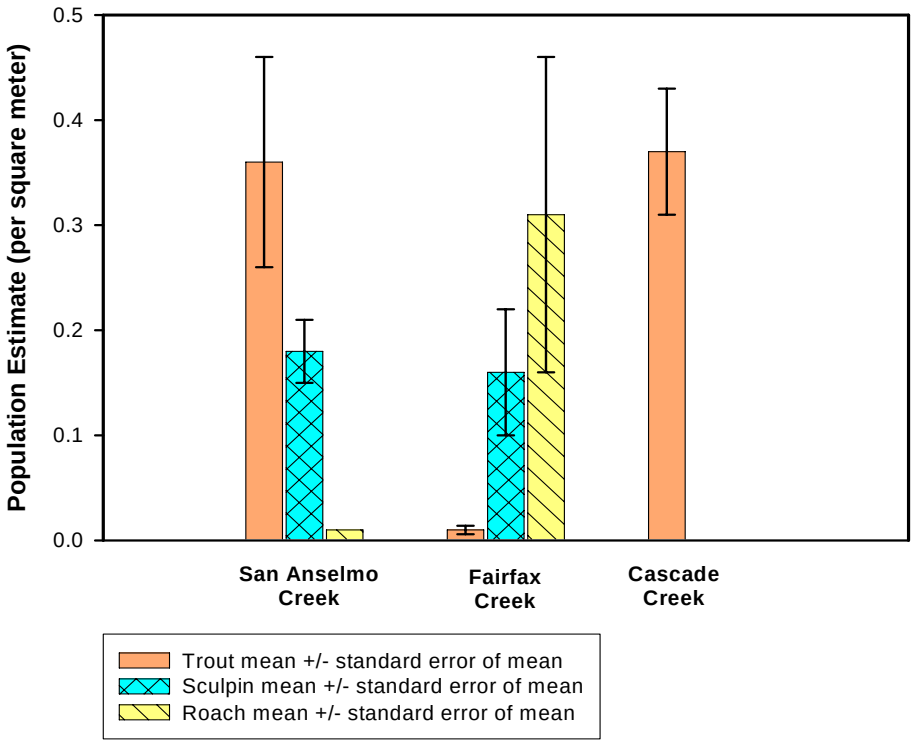

FIGURE 8. POPULATION ESTIMATES OF EACH FISH SPECIES WITHIN THE CREEKS SAMPLED

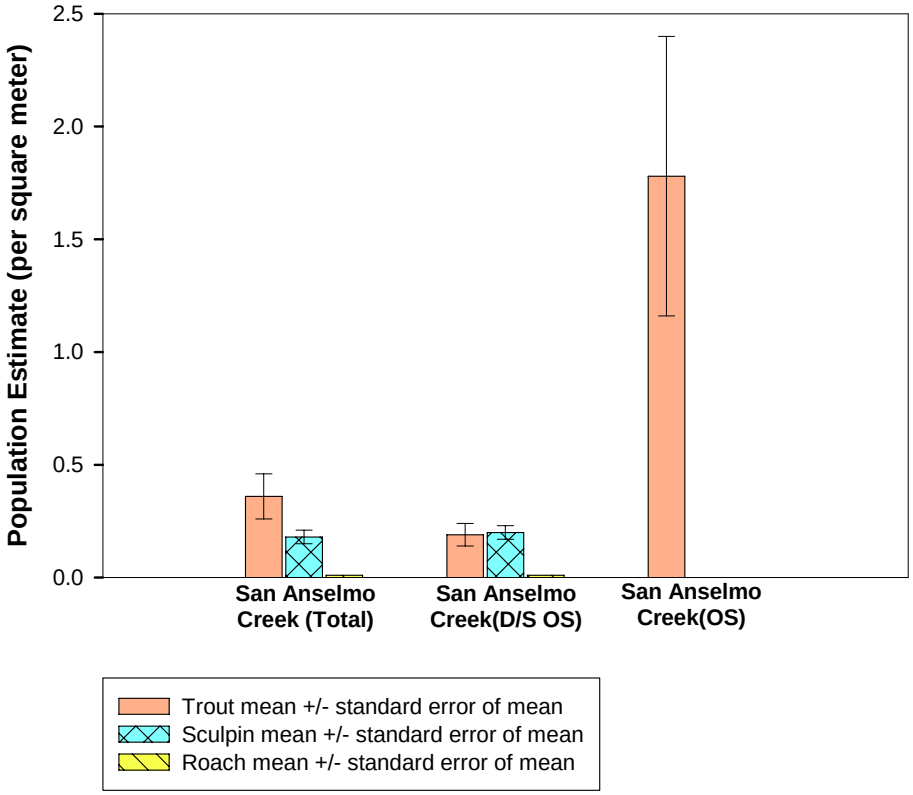

FIGURE 9. POPULATION ESTIMATES OF EACH FISH SPECIES FOR DIFFERENT SECTIONS OF SAN ANSELMO CREEK

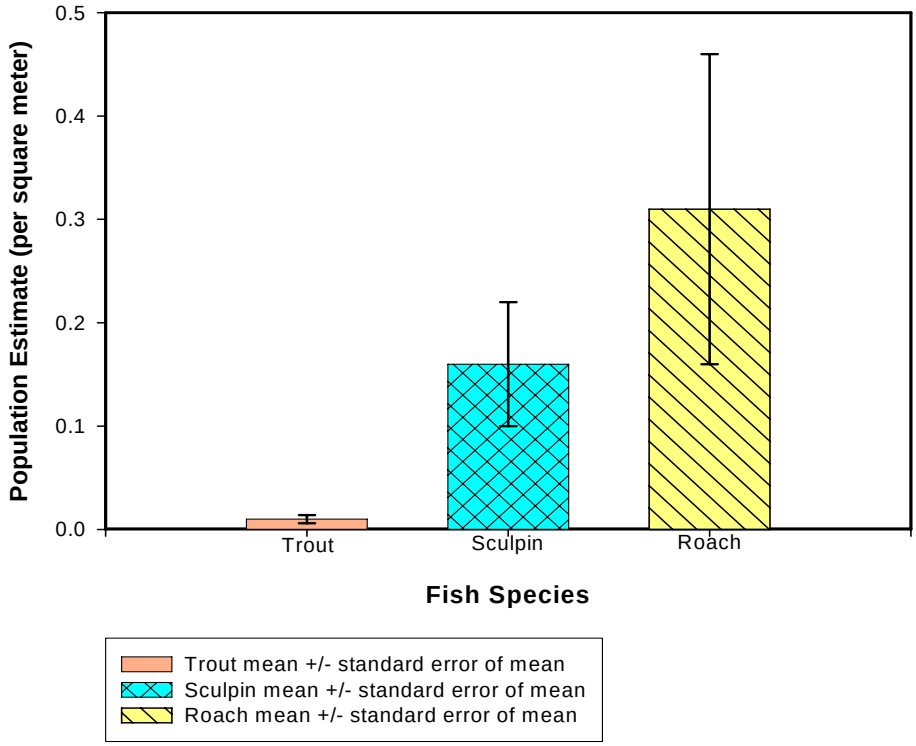

FIGURE 10. POPULATION ESTIMATES OF EACH FISH SPECIES ITHIN FAIRFAX CREEK

(4) Cascade Creek (10 sampling sites):

0.37 trout/square meter (range 0.05 trout/square meter)

(5) Fairfax Creek (9 sampling sites):

0.01 trout/square meter (0.09-1.46 trout/square meter)

The greatest numbers of trout were collected in San Anselmo and Cascade creeks within the Cascade Canyon Open Space Preserve. Compared to the other fish species, trout were the most numerous in San Anselmo Creek; only trout were collected within the Cascade Canyon Open Space Reserve. Sculpin were prevalent in both San Anselmo and Fairfax creeks. Roach were the most prevalent species in Fairfax Creek (Figures 8-10).

Compared to ***AAR's*** 1999 fish sampling surveys, the rainbow/steelhead collected in the Cascade Canyon Open Space Reserve in 2006 were smaller and more numerous. The cause for this was probably the timing of the fish sampling. In 1999, sampling was conducted during October; in 2006 sampling was undertaken during June and July. It is customary to sample salmonids during the low-flow season, or end of summer. At that time of year, the conditions are the worst; many of the fish that are present during the earlier summer months such as in June and July are most likely to either be eaten or die from the pools drying up throughout the summer. The pools in the Reserve were "teaming" with young-of-the-year rainbow/steelhead when we sampled the area during June and July this year.

2. Age of the Rainbow/Steelhead

Based on the size distribution (Figures 11-14 and Appendix G, Tables G-4 to G-6) and the age analysis of the trout undertaken in 1999, the rainbow/steelhead trout were probably from three to four different age classes. Most of the trout were young-of-the-year (i.e., hatched last spring) fish, but there were some older fish in both San Anselmo and Cascade creeks. The greatest variety of age classes came from these two creeks, as well, suggesting that there is a self-sustaining population of rainbow/steelhead in the watershed. This was similar to our results in 1999.

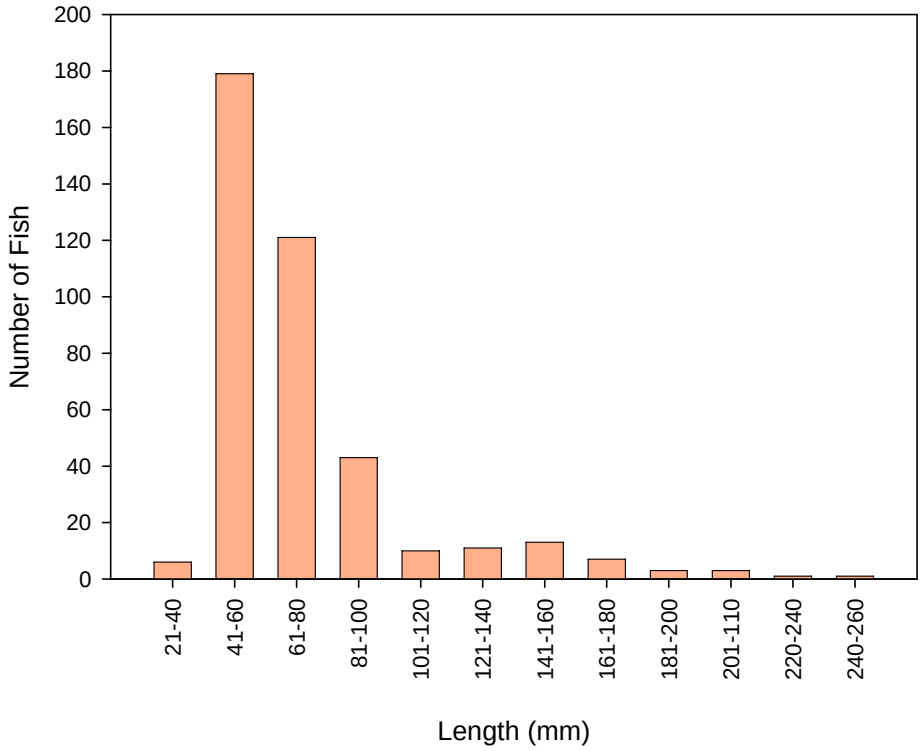

FIGURE 11. RAINBOW/STEELHEAD TROUT LENGTH-FREQUENCY DISTRIBUTION IN SAN ANSELMO CREEK

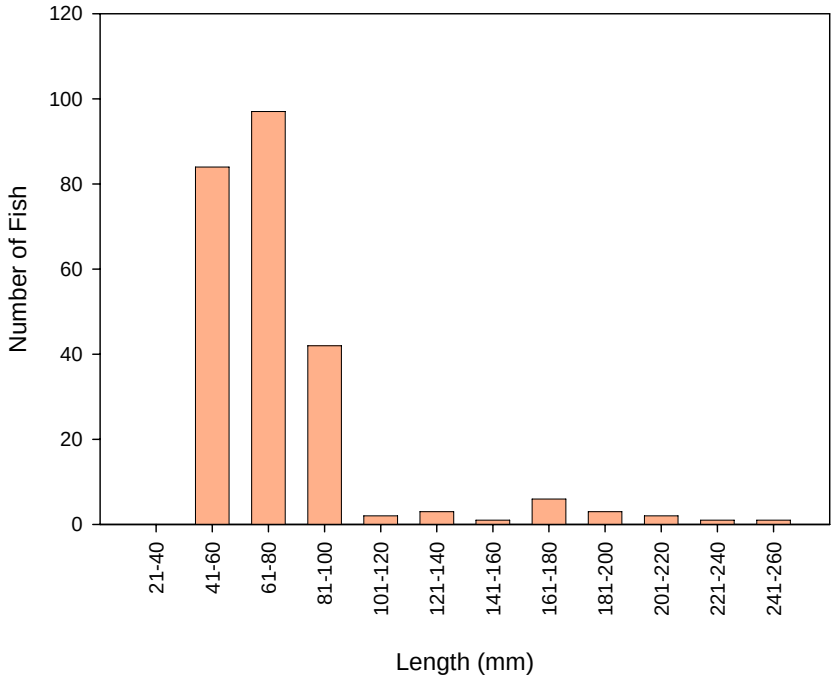

FIGURE 12. RAINBOW/STEELHEAD TROUT LENGTH-FREQUENCY DISTRIBUTION IN SAN ANSELMO CREEK DOWNSTREAM OF CASCADE CANYON OPEN SPACE.

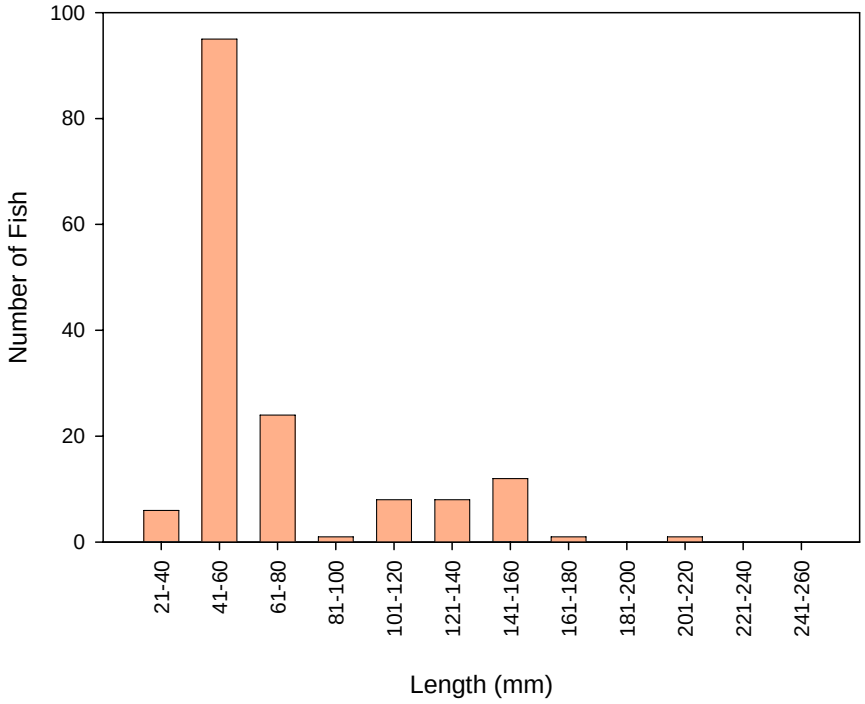

FIGURE 13. RAINBOW/STEELHEAD TROUT LENGTH-FREQUENCY DISTRIBUTION IN SAN ANSELMO CREEK CASCADE CANYON OPEN SPACE.

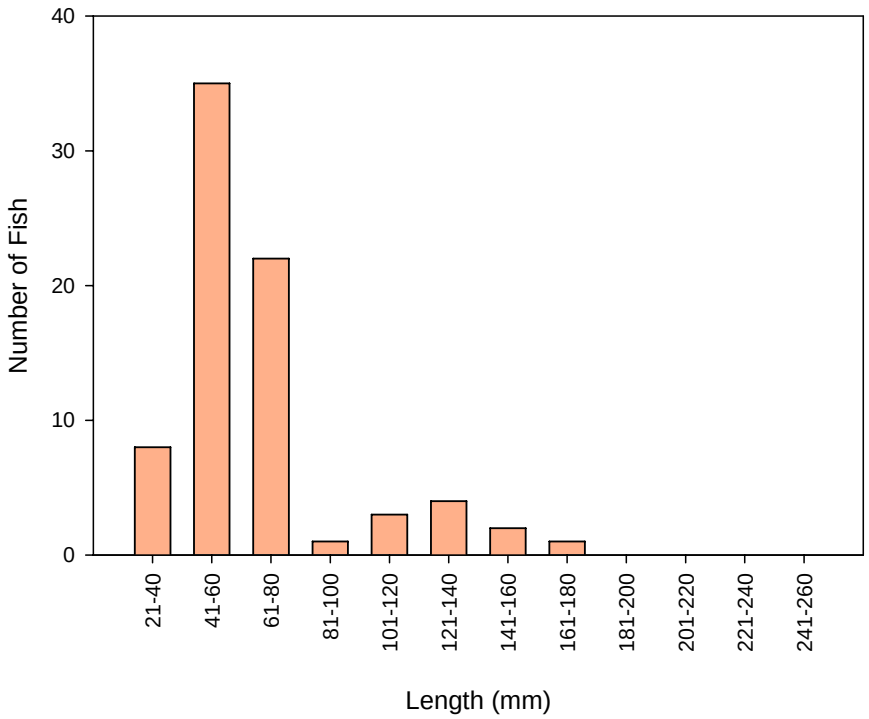

FIGURE 15. RAINBOW/STEELHEAD TROUT LENGTH-FREQUENCY DISTRIBUTION IN CASCADE CREEK.

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