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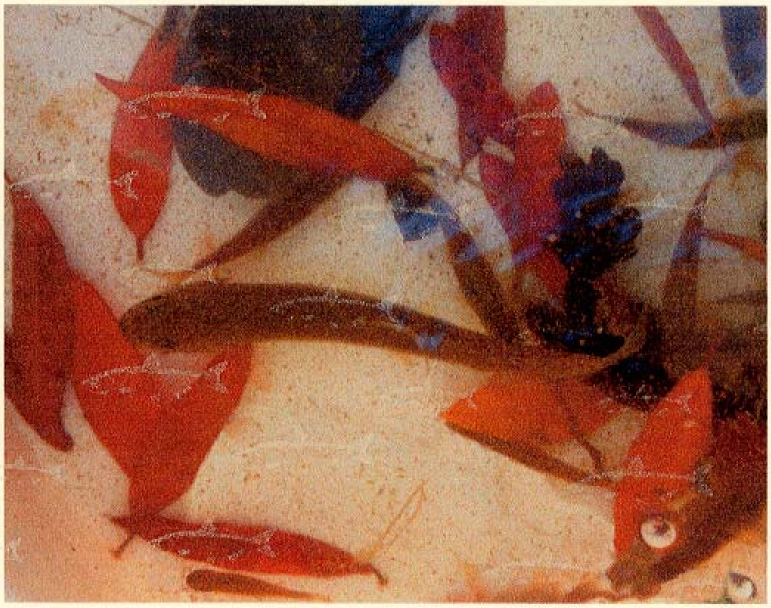
FISHERY RESOURCES CONDITIONS OF THE CORTE MADERA CREEK WATERSHED, MARIN COUNTY, CALIFORNIA



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Prepared for:

Friends of Corte Madera Creek Watershed
P.O. Box 415
Larkspur, California 94977

November 10, 2000

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EXECUTIVE SUMMARY

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 Friends of Corte Madera Creek Watershed (Friends) are interested in restoring the watershed. As part of the watershed project, Friends contracted with ***A. A. Rich and Associates (AAR)***, a fisheries and ecological consulting firm, to undertake a fishery resources investigation and prepare this Fishery Resources Technical Report. The results of this study, including the proposed restoration and monitoring suggestions are part of a comprehensive watershed plan to improve water quality, fishery resources, and native vegetation and wildlife in the Corte Madera Creek Watershed. This fishery resources report identifies how the declining trend in the steelhead population can be reversed. The report identifies some of the factors limiting the steelhead trout population, formulates corrective actions, describes how to monitor the success of those actions, and presents an action plan for the restoration of the Corte Madera Creek Watershed as long-term steelhead trout habitat.

This report addresses the status of the existing fishery resources conditions within the Corte Madera Creek Watershed. More specifically, the objectives of this study are 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 water temperature conditions from April to October;
- Assess physical habitat conditions during the low-flow season;
- Assess fishery resources population conditions during the low flow season;
- Identify some limiting factors for the rainbow/steelhead trout; and,
- Design a Steelhead Restoration Plan which will improve rainbow/steelhead populations.

To carry out the objectives, the following types of surveys were undertaken: (1) Water temperature monitoring, beginning in the spring and extending through the summer; (2) Habitat surveys during the dry months; and, (3) Fish population surveys during the dry months.

The results from the water temperature monitoring demonstrated that, despite potentially thermally stressful conditions in many areas of the watershed, there appeared to be "thermal refuge" (thermal refugia) areas where the trout could reside during the hotter summer months. The areas where water temperatures were suitable appeared to be the areas where the greatest number of salmonids were collected. With regard to smoltification, water temperatures began to become thermally stressful, beginning in May. If the fish emigrate out of the system before May, as they may, this would not be a problem.

Corte Madera Creek is highly channelized, as a result of various activities (e.g., USACE concrete flood control channel and landowners' retaining walls) undertaken to control flooding during the winter months. The U.S. Army Corps of Engineers (USACE) flood control channel serves only as a migration route for the anadromous steelhead trout. The upstream areas of Corte Madera Creek consist of long lateral scour pools alternating with riffle areas, habitat used by a variety of fish species, although none in great abundance.

San Anselmo Creek had the greatest variety of habitats of any of the creeks within the Corte Madera Creek Watershed, probably due to the fact that it flows through towns, but 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 more urban reaches, the lateral scour pools were associated with retaining walls and rip rap, whereas in the upper more natural areas, they were associated with bedrock. The creek along Cascade Road in Fairfax was dry for more than a mile, but substrate consisted almost entirely of gravel suitable for trout spawning.

Although short on water by the end of summer, Cascade Creek offered the best trout habitat of the entire creek system. It was characterized by bedrock pools and cascades, abundant canopy, and clean clear water. Although there was no spawning gravel, the pools provided rearing habitat for trout. The uppermost boundary for fish migration was the Cascade Falls.

Sleepy Hollow Creek was characterized by low flows, and a heavily urbanized (e.g., retaining walls, bridge pillars, concrete in the creek) channel. In the lowermost reaches, the habitat during the late summer months was suitable for stickleback and roach; higher up in the drainage, there were some appropriate pools for trout. Although dry throughout much of the upper sections, the substrate was gravel suitable for trout spawning.

At the time of the habitat surveys, most of Ross Creek was dry. The only area where there was flowing water and a number of pools suitable for trout was within the Natalie Coffin Greene Park area.

From the results of our "spot check" observations, it appeared that Fairfax Creek had little water in it by the end of the dry season. There were lateral scour pools and shallow riffles throughout the Creek, substrate consisted of gravel, sand and silt, and there was abundant vegetative cover.

Fish species collected in the Corte Madera Creek Watershed included rainbow/steelhead trout, threespine stickleback, California roach, sculpin species, and Sacramento sucker. Limiting factors for trout production were lack of stream flows and high water temperatures, depending upon both the creek and location of the reach within a creek.

Of the five fish species collected, trout were the most abundant in San Anselmo, Cascade, and Ross creeks; only trout were collected in Cascade and Ross creeks. Roach, stickleback and sucker were the predominant species in Corte Madera Creek; trout and roach were the most prevalent species in San Anselmo Creek; and, stickleback and roach were the most prevalent species in Sleepy Hollow Creek.

The mean trout populations, as a function of habitat type, within the Corte Madera Creek Watershed were as follows: (1) Corte Madera Creek - 0.03-0.14 fish/square meter of fish habitat; (2) San Anselmo Creek - 0.01-12.76 fish/square meter; (3) Cascade Creek - 0.59-0.84 fish/square meter; (4) Sleepy Hollow Creek - 0.02-0.41 fish/square meter; and, Ross Creek - 0.25 fish/square meter. The greatest numbers of trout were collected in San Anselmo and Cascade creeks within the Cascade Canyon Open Space Preserve. However, there was no statistical difference in population sizes between any of the various creeks, due to the wide variability in the number of rainbow/steelhead trout in the various habitat types.

Based on the size distribution, the juvenile rainbow/steelhead trout were probably from three to four different age classes. Most of the trout were young-of-the-year (i.e., hatched during spring of 1999) fish, but there were some older fish in both San Anselmo and Sleepy Hollow 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 trout in the watershed, albeit small. Of particular interest was the variety of age classes in the first bedrock pools sampled in the Cascade Canyon Open Space Preserve, upstream of the dry creek bed which extended for over a mile in length.

Based on the length data, the stickleback collected were young-of-the-year fish, the roach and suckers, from one to four years old, and the sculpin from one to five years old.

The report provides a Steelhead Restoration Plan for the Corte Madera Creek Watershed which incorporates both science and public involvement to achieve watershed improvement. The three phases to the plan are: (1) Phase I- Undertake preliminary baseline surveys; (2) Design Steelhead Restoration Plan; (3) Phase III - Implementation of restoration actions, research and surveys; (4) Phase IV - Monitoring Results of Restoration Actions; and, (5) Adaptive Management.

PREFACE

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 the Corte Madera Watershed. 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 catching unwary crayfish, using string, "baited" with raw bacon, and observing the myriad of organisms, not the least of which were trout. The Corte Madera Creek Watershed is the fifth watershed in Marin County that I have had the privilege, as an adult, to study.

ACKNOWLEDGMENTS

A number of people helped immeasurably with this project. First, I thank Sandy Guldman, both for making this project happen when I had profound doubts several years ago, and for acting as my “buffer”. Secondly, I really appreciate what I affectionately referred to as the “three therms”, Jack (with assistance from his sons Jonathon and Benjamin) Judkins, Charlie Kennard, and Richard Wheeler, who painstakingly checked 32 thermographs throughout the spring and summer, a tedious and boring, albeit a very essential, task. I am also indebted to my field biologists, all of whom suffered the excruciating itches of poison oak (whereas, of course, I, their boss, never got it!). To Kat Berry, my “left finned” super fisheries biologist, I owe you more than wages for the work you have done at all hours of the day and night and without whom I would never have finished writing this report. Finally, a profound thank you to Dr. Kathleen Aswell, an editor extra ordinaire.

On the financial side, I also thank Cheryl Lovato Niles, the grant manager at the National Fish and Wildlife Foundation for her efficiency and good humor. Thanks to CALFED and the Bureau of Reclamation for partially funding the study. I am grateful to the Marin Community Foundation who enabled us to distribute this report to the Watershed Planning Advisory Committee and other interested parties.

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1. INTRODUCTION AND SCOPE OF WORK

1.1. PROJECT AREA

The Corte Madera Creek Watershed, covering about 28 square miles, is located in the southeastern quarter of Marin County and encompasses the towns of Larkspur, Corte Madera, Kentfield, Ross, San Anselmo, and Fairfax. 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 Corte Madera, Ross, San Anselmo, Tamalpais, Sleepy Hollow, Fairfax, and Cascade creeks and Phoenix Lake. Larkspur and Tamalpais creeks drain directly into the estuary/tidal portion and they were not included in this study. 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 (Figure 1).

1.2. BACKGROUND

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 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).

In 1995, I wrote a Watershed Plan for the Corte Madera Creek Watershed, for Friends of Corte Madera Creek (Friends) entitled, *Preliminary Outline for a Corte Madera Creek Watershed Management Plan* (Rich, 1995). Several years later, Sandra Guldman, Co-Chairperson of Friends asked if I would be willing to join Friends in submitting a proposal to the Category III CALFED Bay-Delta Program for a steelhead trout restoration planning effort. I agreed and, fortunately, we received funding.

As a result of receiving the funding, Friends contracted with my firm, ***A. A. Rich and Associates (AAR)*,** to undertake a fishery resources investigation and prepare this Fishery Resources Technical Report.

The results of this study, including the proposed restoration and monitoring suggestions are part of a comprehensive watershed plan to improve water quality, fishery resources, and native vegetation and wildlife in the Corte Madera Creek Watershed. This fishery resources report identifies how the declining trend in the steelhead population can be reversed. The report identifies the factors limiting the steelhead trout population, formulates corrective actions, describes historic and current fishery resource conditions, describes how to monitor the success of those actions, and presents an action plan for the restoration of the Corte Madera Creek Watershed as long-term steelhead trout habitat. To that end, an Advisory Committee, comprised of representatives from local government, federal and state agencies, community groups, and other stakeholders, will review documents and guide formulation of the restoration plan. The proposed fishery resources effort will occur concurrently with an erosion/sedimentation planning project being conducted by Stetson Engineers (2000).

Although this study targets steelhead trout, habitat improvements in the riparian corridors will also benefit riverine aquatic habitat and the neotropical migratory bird guild that uses the riparian corridor. Similarly, improvements in water quality and water flows likely will benefit saline emergent wetland habitats in the lower reaches And, San Francisco Bay will also benefit from improvements in water quality, flow, and temperature.

1.3. SCOPE OF WORK

This report addresses the status of the existing fishery resources conditions within the Corte Madera Creek Watershed. 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;
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- Assess physical habitat conditions during the low-flow season;
- Assess fishery resource population conditions during the low flow season;
- Identify limiting factors for the rainbow/steelhead trout; and,
- Design a Steelhead Restoration Plan which will improve rainbow/steelhead populations.

With the exception of the U.S. Army Corps of Engineers (USACE) flood control channel, which is under tidal influence, this study is limited to the freshwater portions of the watershed.

FIGURE 1. PROJECT LOCALE

(Source: Friends of Corte Madera Creek Watershed)

FIGURE 1. PROJECT LOCALE (Source: Friends of Corte Madera Creek Watershed)

2. SALMONIDS AS INDICATOR SPECIES OF A WATERSHED'S ECOLOGICAL HEALTH

Although a variety of fish species inhabit the Corte Madera Creek (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 WHICH HAVE BEEN SIGHTED AND/OR COLLECTED IN THE CORTE MADERA CREEK WATERSHED

Common Name	Native Species	Corte Madera Creek	Ross Creek	San Anselmo Creek	Sleepy Hollow Creek	Fairfax Creek	Cascade Creek
Salmonidae (Trout and Salmon)							
Chinook Salmon *Oncorhynchus tshawytscha*	X	9	9	9	9	9	
Coho Salmon *Oncorhynchus kisutch*	X	4c,4d	9	7,9	9	9	9
Steelhead Trout *(adults)* *Oncorhynchus mykiss*	X	9	9	9	9	9	9
Rainbow/Steelhead Trout *Oncorhynchus mykiss*	X	1a,2,3,4a,4b	1a,2,5,6b	1a,3,5,6a,7,8	1a,4d,5,6b	6b	1a,6b
Brown Trout *Salmo trutta*		9					
Cyprinidae (Minnows)							
Sacramento Pikeminnow *Ptychocheilus grandis*	X	4a					
California Roach *Lavinia symmetricus*	X	1a,2,3,4a,4b,5		1a,3,5,7	1a,5	2	4d
Common Carp *Cyprinus carpio*		1b,9					
Catostomidae (Suckers)							
Sacramento Sucker *Catostomus occidentalis*	X	1a,3,4a,4b		1a,5,7			

TABLE 1 (CONT.). FISH SPECIES WHICH HAVE BEEN SIGHTED AND/OR COLLECTED IN THE CORTE MADERA CREEK WATERSHED

Common Name	Native Species	Corte Madera Creek	Ross Creek	San Anselmo Creek	Sleepy Hollow Creek	Fairfax Creek	Cascade Creek
Cyprinodontidae (Killifish)							
Rainwater killifish *Lucania parva*	X	4a,4b					
Poeciliidae (Mosquitofish)							
Mosquitofish *Gambusia affinis*	X	4a					
Atherinidae (Silversides)							
Topsmelt *Atherinops affinis*	X	4b					
Gasterosteidae (Stickleback)							
Threespine Stickleback *Gasterosteus aculeatus*	X	1a,2,3,4a,4b,5		1a,3,5,7	1a,4d,5	2,4d	
Centrarchidae (Sunfish)							
Sacramento Perch Archoplites interruptus	X	9					
Black Crappie *Pomoxis nigromaculatus*		9					

TABLE 1 (CONT.). FISH SPECIES WHICH HAVE BEEN SIGHTED AND/OR COLLECTED IN THE CORTE MADERA CREEK WATERSHED

Common Name	Native Species	Corte Madera Creek	Ross Creek	San Anselmo Creek	Sleepy Hollow Creek	Fairfax Creek	Cascade Creek
Embiotocidae (Surfperch)							
Tule Perch *Hysterocarpus traski*	X	4a					
Shiner Perch Cymatogaster aggregata	X	9					
Gobiidae (Gobies)							
Tidewater Goby *Eucyclogobius newberryi*	X	4b					
Longjaw Mudsucker *Gillichthys mirabilis*	X	4b					
Cottidae (Sculpins)							
Pacific Staghorn Sculpin *Leptocottus armatus*	X	4b					
Prickly Sculpin *Cottus asper*	X	1a,4a,4b					
Riffle Sculpin *Cottus gulosus*	X	1a,4a,4b					
Sculpin spp. (probably riffle and prickly)	X	1a,2,3		1a,3		2	

TABLE 1 (CONT.). FISH SPECIES WHICH HAVE BEEN SIGHTED AND/OR COLLECTED IN THE CORTE MADERA CREEK WATERSHED

Common Name	Native Species	Corte Madera Creek	Ross Creek	San Anselmo Creek	Sleepy Hollow Creek	Fairfax Creek	Cascade Creek
Pleuronectidae (Righteye Flounders)							
Starry Flounder *Platichthys stellatus*	X	9					

Key

1a - Rich, 2000 (collected from August-November, 1999)
1b - Rich, 1994 (personal observation; adult spawners in USACE channel)
2 - Leidy, 1997 (collected in July, 1997)
3 - Leidy, 1993 (collected in July, 1993)
4a - Leidy, 1984 (collected in his study)
4b - Cited in Leidy, 1984 (from collections at the California Academy of Sciences in San Francisco State University: 1950's to mid 1970's)
4c - Cited in Leidy, 1984 (personal communication with Dr. John Hopkirk)
4d - Cited in Leidy, 1984 (Leidy and Fiedler, collected September 18, 1981)
5 - Michaels and Thompson, 1969 (collected in July, 1969)
6a - NMFS, 1997 (collected in September, 1996)
6b - NMFS, 1997 (collected in May, 1997)
7 - Fry, 1936
8 - Snyder, 1905
9 - Anectodal (no written record found)
10 - Marin Independent Journal, July 14, 1986

3. IMPORTANCE OF IDENTIFYING HABITAT REQUIREMENTS AND LIMITING FACTORS

Understanding the biological and physical factors which are necessary to sustain the salmonid populations in the Corte Madera Creek Watershed is critical to developing management strategies to improve the habitat and enhance populations. 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 fishes, before one can determine what restoration measures would be most effective in improving salmonid populations. This Chapter describes the general habitat requirements and limiting factors for salmonids. The results of the study are presented in Chapters 7 and 8.

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 requirements, 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. One extremely important concept in enhancing fish populations is the following:

> ***If there is no change in the limiting factors (s) for the population (s), no increase in the target population (s) will occur.***

Factors which 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 which 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, before one can determine what measures are needed to help restore Corte Madera Creek and its tributaries, one must identify the following:

- The requirements of the fishes; and,
- Any Limiting Factors which 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 which 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, it is essential to understand what Corte Madera Creek and its tributaries have to offer these fish, before one can determine what measures are needed to help restore the Corte Madera Creek Watershed.

4. LIFE HISTORY STAGES AND REQUIREMENTS OF STEELHEAD AND RAINBOW TROUT

4.1. LIFE HISTORY STAGES

4.1.1. Steelhead Trout

The steelhead trout 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 trout 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 trout 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.

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

FIGURE 2. STEELHEAD TROUT LIFE STAGE PERIODICITIES IN THE CORTE MADERA CREEK WATERSHED

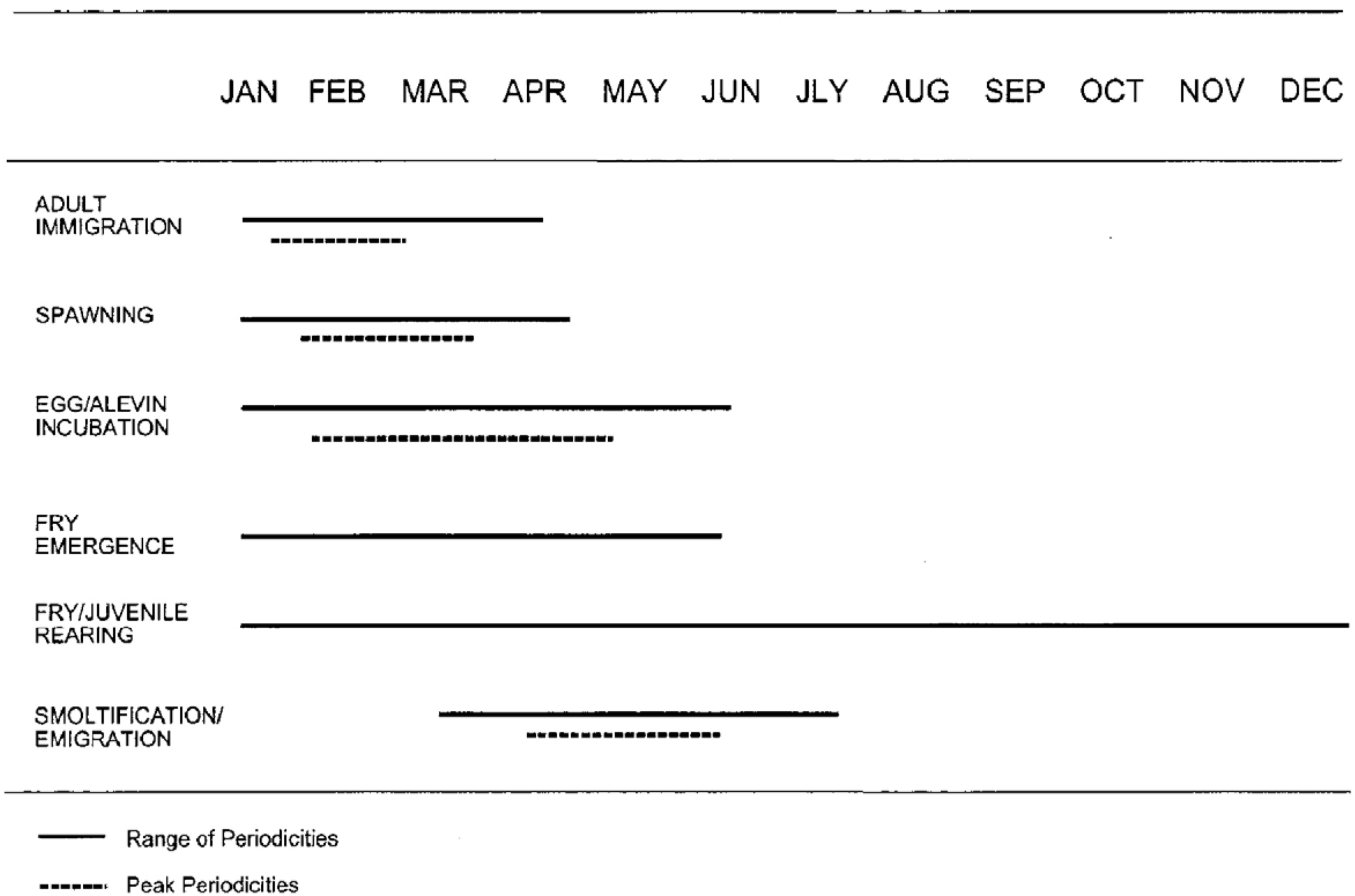


TABLE 2. HABITAT REQUIREMENTS FOR STEELHEAD TROUT

LIFE STAGE	OPTIMAL WATER TEMPERATURE	DISSOLVED OXYGEN (mg/l)	Ph	WATER DEPTH	WATER VELOCITY	TURBIDITY (mg/l)	SUBSTRATE SIZE
IMMIGRATION/ PASSAGE	7.8-11.2 °C 46.0-52.0 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	≥ 18 cm ≥ 0.6 ft	≥ 25 cfs	≤ 25	N/A
SPAWNING	7.8-11.2 °C 46.0-52.0 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	≥ 18 cm ≥ 0.6 ft	≥ 15 cfs	≤ 25	0.6-13 cm 0.2-5.0 in
INCUBATION	7.8-11.2 °C 46.0-52.0 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	≥ 18 cm ≥ 0.6 ft	≥ 7 cfs	≤ 25	0.6-13 cm 0.2-5.0 in
FRY EMERGENCE	8.9-11.2 °C 48.0-52.0 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	fry: 8-36 cm 3-14 in juvenile: 25-50 cm 10-20 in	≥ 7 cfs	≤ 25	0.6-13 cm 0.2-5.0 in
REARING	12.8-15.6 °C 55.0-60.1 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	18.3-67.0 cm 0.6-2.2 ft	≥ 2 cfs	≤ 25	6.4-24.9 cm 2.5-9.8 in
SMOLTIFICATION/ EMIGRATION	6.98-11.3 °C 44.4-52.3 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	18.3-67.0 cm 0.6-2.2 ft	≥ 7 cfs	≤ 25	6.4-24.9 cm 2.5-9.8 in

TABLE 2 (CONT.). HABITAT REQUIREMENTS FOR STEELHEAD TROUT

LIFE STAGE	REDD (mean area of redd per spawning pair)	COVER	FOOD	POOL/RIFFLE RATIO
IMMIGRATION AND PASSAGE				
SPAWNING	4.4-5.4 square meters 47-58 square feet			
INCUBATION				
FRY EMERGENCE				
REARING		Need abundant cover to protect them from predators, reduce summer water temperatures adn provide food resources Often use turbulence cover as they feed on drifting insects	Primarily insects, captured as drifting organisms	1:1 pool-to-riffle ratio, with areas of slow, deep water
SMOLTIFICATION AND EMIGRATION		Need abundant cover to protect them from predators, reduce summer water temperatures adn provide food resources Often use turbulence cover as they feed on drifting insects	Primarily insects, captured as drifting organisms	1:1 pool-to-riffle ratio, with areas of slow, deep water

Sources:
cm = centimeters
cm/s = centimeters per second
ft = feet
ft/s = feet per second
C = centigrade
> = greater than
F = fahrenheit
< = less than
in = inches
≥ = greater than or equal to
≤ = less than or equal to

Sources: Rich, 1987; Brett & Blackburn, 1981; Baracco, 1977; Hooper, 1973; Zaugg et al., 1972; Smith, 1973; Hunter, 1973; Zaugg and Wagner, 1973; Thompson, 1972; Dickson and Kramer, 1971; Doudoroff and Shumway, 1970; Orcutt et al., 1968; Hartman and Gill, 1968; Wagner, 1974; Philips and Campbell, 1961; Whitmore et al., 1960; Cloern, 1976; Bovee, 1978; Phillips et al., 1975; Adams et al., 1975; Hall and Lentz, 1969; Koski, 1966

The steelhead trout which migrate into Corte Madera Creek (beginning in December usually) to spawn is referred to as the "winter run". These are steelhead trout which enter and spawn during rising stream levels during the winter and early spring months (Withler, 1966). Most steelhead trout 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 trout 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 trout into streams is not determined entirely by either sexual maturity or age. Although, California steelhead trout 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 trout 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 trout 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 trout spawn in January and February.

Most adult steelhead trout 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 trout 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 trout 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 trout 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, 1976; 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 trout 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.

4.1.2. 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, 1976).

4.2. 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 help improve steelhead habitat. Restoration activities, together with monitoring of the success of those activities, could improve steelhead trout habitat and populations in the Corte Madera Creek Watershed.

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 Corte Madera Creek Watershed, relevant data from other systems has been used. As more

FIGURE 3. RAINBOW TROUT LIFE STAGE PERIODICITIES IN THE CORTE MADERA CREEK WATERSHED

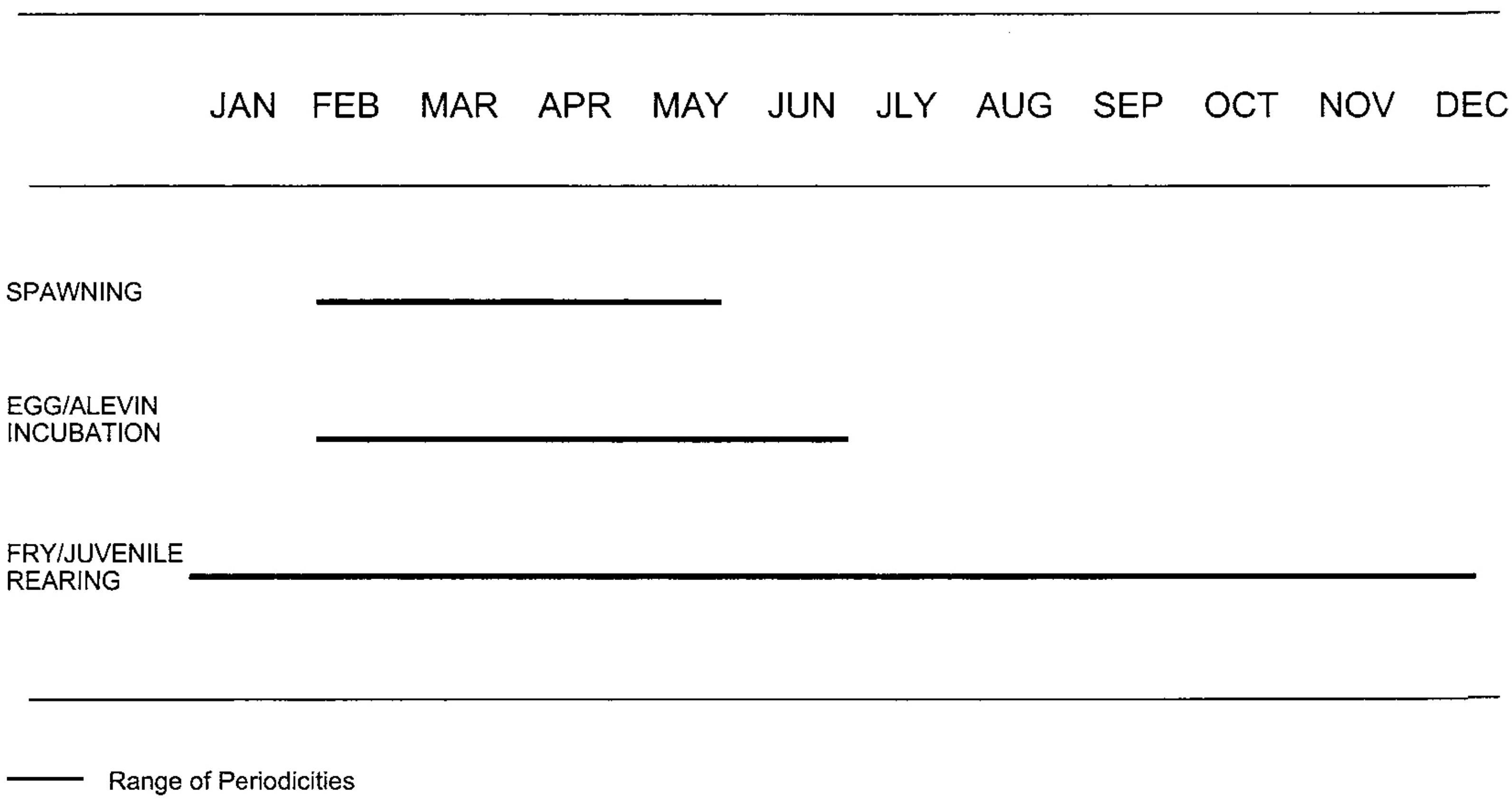


TABLE 3. HABITAT REQUIREMENTS FOR RAINBOW TROUT

LIFE STAGE	WATER TEMPERATURE	DISSOLVED OXYGEN (mg/l)	pH	WATER DEPTH	WATER VELOCITY	TURBIDITY (mg/l)	SUBSTRATE SIZE
SPAWNING	12-18 °C 54-64 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	6.5-8	> 18 cm > 7 in	≤ 122 cm/s ≤ 4 ft/s	≤ 25	fish < 50 cm long: 1.5-6.0 cm 0.6-2.4 in fish ≥ 50 cm long: 1.5-10.0 cm 0.6-4.0 in
INCUBATION	12-18 °C 54-64 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	6.5-8	> 18 cm > 7 in	≤ 48-91 cm/s ≤ 1.6-3 ft/s	≤ 25	0.3-10 cm 0.1- 4 in
FRY EMERGENCE	12-18 °C 54-64 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	6.5-8	> 18 cm > 7 in	≤ 8-30 cm/s ≤ .26-1 ft/s	≤ 25	0.3-10 cm 0.1- 4 in
REARING	15-18 °C 59-64 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	6.5-8	> 18 cm > 7 in	fry: ≤ 8-30 cm/s ≤ .26-1 ft/s juvenile: 10-22 cm/s .3-.72 ft/s	≤ 25	1.5-10 cm 0.6- 4 in
20 **ADULT**	15-18 °C 59-64 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	6.5-8	> 18 cm > 7 in	12-73 cm/s 0.4-2.4 ft/s	≤ 25	1.5-10 cm 0.6- 4 in

TABLE 3 (CONT.). HABITAT REQUIREMENTS FOR RAINBOW TROUT

LIFE STAGE	REDD SIZE (mean area of redd per spawning pair)	COVER	FOOD	POOL/RIFFLE RATIO
SPAWNING	0.2 square meters 2.2 square feet			
INCUBATION				
FRY EMERGENCE				
21 REARING		Need abundant cover to protect them from predators, reduce summer water temperatures and provide food resources Often use turbulence cover as they feed on drifting insects	Primarily insects, captured as drifting organisms	1:1 pool-to-riffle ratio, with areas of slow, deep water
ADULT		" "	Fishes, invertebrates	" "

cm = centimeters cm/s = centimeters per second
ft = feet ft/s = feet per second
C = centigrade > = greater than
F = fahrenheit < = less than
in = inches ≥ = greater than or equal to
≤ = less than or equal to

Sources: Rich, 1987; Hooper, 1973; Doudoroff and Shumway, 1970; Orcutt et al., 1968; Delisle and Eliason, 1961; Thompson, 1972; Smith, 1973; Horner and Bjornn, 1976; Hunter, 1973 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 which 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 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.

To protect the steelhead and rainbow trout in the Corte Madera Creek, I am going to err on the side of conservatism, 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 in the Corte Madera

Creek Watershed 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, I will, initially, choose the lowest temperature as being optimal. Then, in the future, if studies are conducted within the watershed which 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.

In the following paragraphs, critical life stage requirement variables for salmonids are discussed. These requirements are based both on the results of peer-reviewed studies published in a variety of scientific and various agency reports and documents.

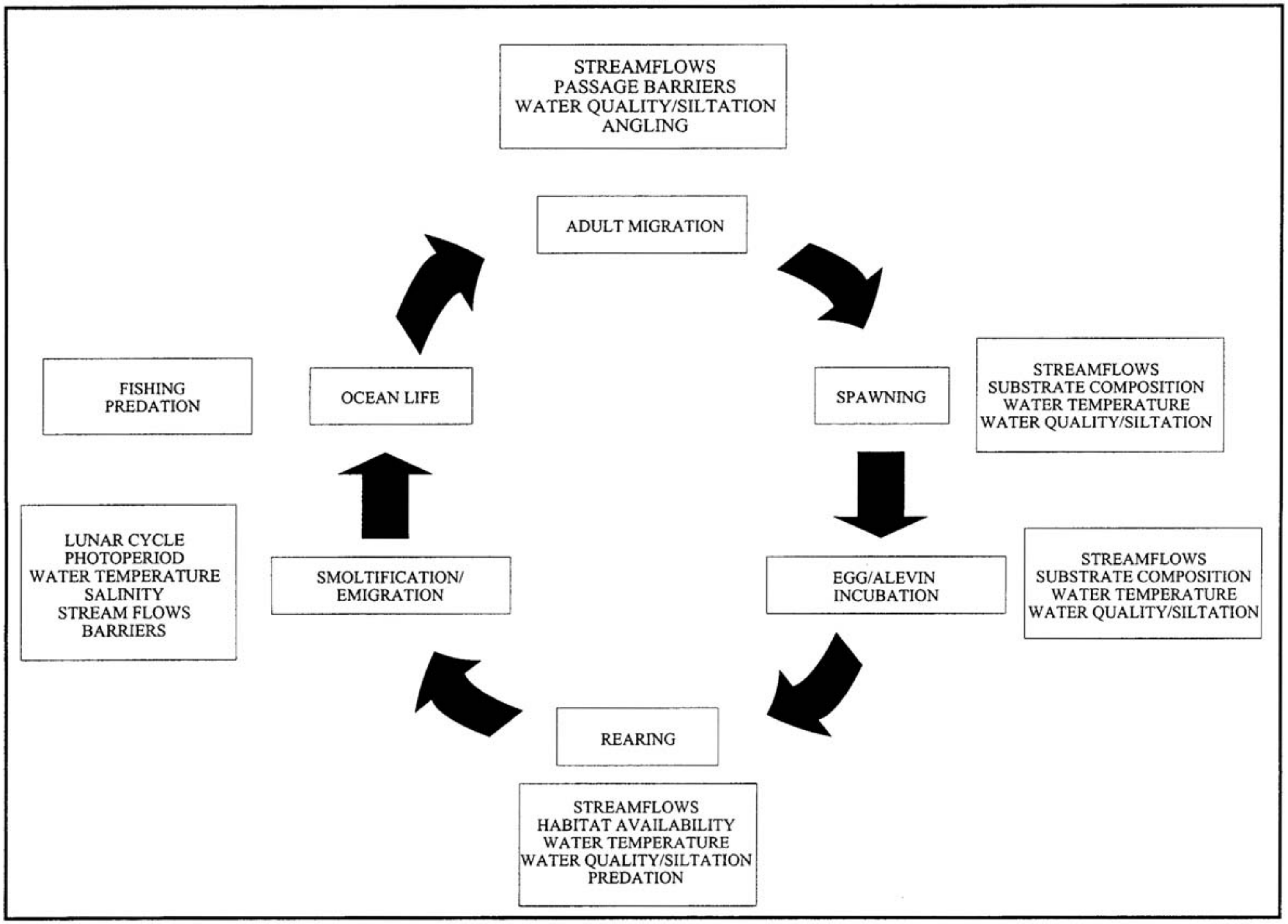
4.2.1. Appropriate Water Temperatures

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 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.

FIGURE 4. FACTORS WHICH AFFECT SALMONIDS



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. 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 G. Based on available information, physiological optimal water temperature ranges are summarized in Tables 2 and 3 for the steelhead and rainbow trout, respectively.

4.2.2. 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.

4.2.2.1. 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).

4.2.2.2. 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 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 (McNeil and Ahnell, 1964; Cooper, 1965; Koski, 1966; Cloern, 1976; Phillips et al., 1975).

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 (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, including an abundance of fine materials less than 1 mm diameter. Yet, historically these streams supported healthy populations of salmonids.

4.2.2.3. Pollutants

Compared to many of the other urban creeks I have surveyed, 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. Storm drains flow into many of the creeks and 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), which can be harmful to salmonids. Finally, high coliform bacteria counts have been detected during the winter months in various segments of the creek, although this is probably more a problem to humans than to fishes (Marshall et al., 1994).

4.2.3. 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.

4.2.4. 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 and coho salmon. Some barriers are insurmountable, but, given suitable conditions (e.g., deep pools at the base of a waterfall or cascade, etc.), steelhead trout may be able to get past many obstacles that appear to be barriers. The best method for determining whether or not a barrier to migration exists is to obtain site-specific information.

4.2.5. 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.

A number of dam barriers which have existed in the creeks of the Corte Madera Creek Watershed for many decades may have impeded the passage of steelhead to upstream spawning areas. While some now have fish ladders which allow passage of anadromous salmonids, some of the fish ladders are very old and need to be updated with new, more efficient structures.

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 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 which 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 which 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, 1976).

One of the important characteristics of urban areas such as the Corte Madera Creek Watershed 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 juvenile 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 as 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.

4.2.6. Competition from Non-Native Fish Species

Non-native fish species such as carp and sunfish compete with native trout for space and food. In addition, these non-native species are tolerant of high water temperatures and habitat conditions which are unsuitable for trout. Hence, enhancement of conditions suitable for trout will minimize habitation by non-native fish species, provided that non-native fishes are not released into the streams.

5. LIFE HISTORY STAGES AND REQUIREMENTS OF OTHER FISHES

The main non-salmonid fish species in the Corte Madera Creek Watershed include the threespine stickleback, California roach, several species of sculpin, and Sacramento sucker (Table 4). All of these species are hardier than salmonids and are able to adapt, establish, and re-establish themselves more easily than salmonids.

5.1. THREESPINE STICKLEBACK

There are two types of three-spine stickleback: (1) estuarine anadromous; and, (2) freshwater resident. In all probability, the stickleback collected in the Corte Madera Creek Watershed are of both types, with the estuarine type in the lowest most reaches Corte Madera Creek which is influenced by the tides, and the freshwater resident type throughout the rest of the watershed.

Anadromous populations ascend creeks to spawn in the spring and summer months; the resident form spawns in the spring and summer, as well (Table 4). The breeding cycle lasts two or three months, during which an elaborate courtship ritual takes place. At the beginning, the females remain in schools and the males build the nests. After the male builds a nest (out of vegetation and sand, glued together with mucus secretion from the kidney) on the substrate within his territory, the gravid female, performs a zig-zag courtship dance (Tinbergen, 1953). If a female is ready, she will respond to the dance by following the male to the nest and laying the eggs; the male will fertilize the eggs, chase the female away, repair, incubate and guard the nest. 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, 1976). 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). Anadromous populations feed more on free-swimming crustaceans, although they may also feed on bottom organisms.

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.

TABLE 4. HABITAT REQUIREMENTS OF THREESPINE STICKLEBACK

	ESTUARINE HABITAT		FRESHWATER HABITAT	
	Overwintering	Breeding	Overwintering	Breeding
Period of Occupation	September - April	May-August	September - February	March - August
Substrate	Sand	Sand, Mud	Fine gravel	Mud
Vegetation	Variable	Abundant	Sparse	Sparse
Water Depth	More than 1 meter	Less than 1 meter	Less than 1.5 meters	Less than 0.5 meters
Water Current	Strong	Moderate	Moderate	Weak
Water Temperature	10 - 15 ^{o}C	18 - 22 ^{o}C	12 - 17 ^{o}C	18 - 22 ^{o}C
Salinity	Approximately 20 parts per thousand	0 - 1 parts per thousand	0 parts per thousand	0 parts per thousand

Sources: Moyle, 1976; Snyder and Dingle, 1989; Hagen, 1967; Hynes, 1950.

Two adaptive features of the stickleback have enabled it to survive, despite its small size. First, the dorsal fin has three spines which the fish can maneuver into an upright position, thus diminishing its delectability to predators. Second, it is extremely euryhaline (i.e., it can withstand wide variations in salinity concentrations).

5.2. CALIFORNIA ROACH

California roach are habitat generalists, being found in cold “trout” streams, as well as warm intermitted streams and main channels of river (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, 1976).

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.

5.3. 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. In addition, these species have a darkly mottled coloration, which blends in with the rocky areas they prefer, concealing themselves from both predators and prey. Generally, this is a hardy family of fishes, which will adapt to a wide variety of coastal conditions (Moyle, 1976).

The prickly sculpin is tolerant of changing salinities and high water temperatures (78-, 82.4%F), prefers substrates of sand, silt and course gravel, and is often found in pools. Sculpin are voracious eaters, feeding mainly on benthic invertebrates, eggs and even small fishes; the food eaten varies with the size of the fish. Prickly sculpins become mature in their second through fourth year, depending upon the population. Spawning can occur from late February through June, although most spawning takes place in March and April; water temperatures usually need to be between 46-55 %G. Prior to spawning, they move into areas, in either a freshwater or intertidal zone, that contain large flat rocks and moderate currents. The male selects the nest site, prepares the nest by digging a small hollow under a large flat rock, and when the female is ready, she moves in, is courted by the male, and attaches the eggs to the ceiling of the hollow. The male then chases the female away and guards the eggs until they hatch. Movements by the male facilitate water circulation over the eggs, assuring normal development. The hatched fry are soon ready to swim, and as a result, are swept downstream, where they are planktonic for about a month. After that, they settle on the bottom and start a general upstream movement into their natal stream. Similar to other sculpin, growth is subject to much individual variation. Prickly sculpin feed mostly upon large benthic invertebrates, small fishes, and fish eggs (Patten, 1971; Moyle, 1976; Kresja, 1965; Kottcamp, 1973).

Riffle sculpin are well-named, as they are most common headwater streams where riffles predominate. In coastal streams, they are found in a variety of habitats, but seem to prefer cool water and gravel bottoms, avoiding the swifter riffle areas. They are opportunistic bottom feeders, with crustaceans the most important food. Age and growth characteristics are similar to those of other sculpins, with most growth during the spring and summer. Maturity occurs at the end of the second year of life and spawning occurs from late February through April. Riffle sculpins either spawn on the underside of rocks in riffles or inside cavities of submerged lots. Males stay in the nest guarding the eggs and fry and eggs hatch in11-24 days, depending upon water temperatures. After absorbing the yolk sac, the fry assume a benthic existence (Bond, 1963; Millikan, 1968; Moyle, 1976).

5.4. 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, 1976; Brauer, 1971).

6. METHODOLOGY

6.1. GENERAL APPROACH

To understand what the Corte Madera Creek Watershed has to offer steelhead trout, one must first collect information on habitat requirements and historical and existing conditions. Most of the habitat in Corte Madera Creek and its tributaries was surveyed and representative habitats were sampled for fishes during the low flow season; water temperature was monitored in the creeks from April through September.

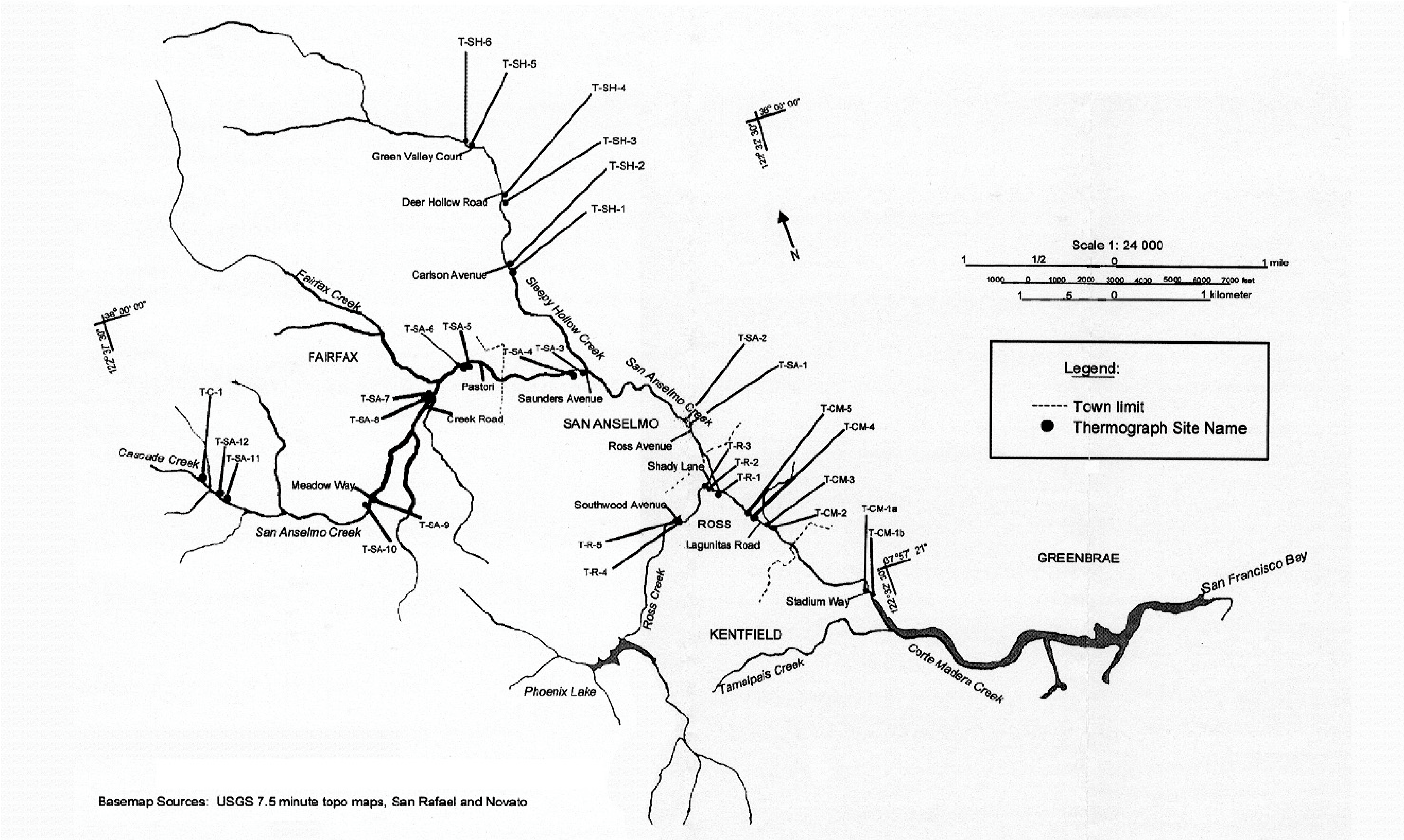
A Quality Assurance Project Plan was required by the EPA, one of the CALFED agencies. It was submitted in December, 1999 (Rich, 1999). The measures used for quality assurance are included in that plan which is in Appendix A, along with the Sample Survey Sheets.

6.2. WATER TEMPERATURE MONITORING

A total of 32 thermographs ("Tidbits" and "Hobos", Onset Computer, Massachusetts) were installed in representative areas of each stream reach in Corte Madera, San Anselmo, Cascade, Sleepy Hollow, and Ross creeks, beginning in April and extending to the end of September for the sites where water was still flowing; at some of the sites, thermographs were removed earlier because the site dried up (Figure 5; Appendix C, Tables 1-6). Each thermograph was cabled to a concrete landscaping block; each block was cabled to a tree. ***AAR's*** fisheries biologists and volunteers trained by Dr. Alice Rich (Appendix B) maintained the thermographs during their installation. At the time of their initial installation, the location of each thermograph was photographed and the latitude and longitude recorded, using a Garmin GPS 48 Personal Navigator. Prior to installation, each thermograph was calibrated to record water temperature every 10 minutes, 24 hours a day. The number of thermographs installed in each of the creeks were as follows: (1) Corte Madera Creek - 8; (2) San Anselmo Creek - 12; (3) Cascade Creek - 1; (4) Sleepy Hollow Creek - 6; and, (5) Ross Creek - 5 (Figure 5).

To monitor the water and habitat conditions of each site during the time when the thermographs were installed, photographs were taken (one facing upstream and one facing downstream) at each site on a weekly basis. Each thermograph was checked weekly to determine whether or not the thermograph was working (from the blinking light on each thermograph); (1) immersed in water; and, (2) residing in the original habitat in which it was placed. When any of the conditions did not apply, Dr. Rich was contacted and she assessed whether or not to either move or replace the thermograph. Some of the thermographs were removed early, as many of the stream reaches dried up (Tables C-1 through C-6, Appendix C). To preclude the possibility of losing data sheets, two sets of data sheets and two sets of photographs were stored at all times in the following locations: (1) One set in ***AAR's*** office; and, (2) One set at each volunteer's and/or ***AAR's*** biologist's house.

FIGURE 5. THERMOGRAPH MONITORING SITES



As the creeks have a lot of summer traffic, primarily school children, there was a good chance that some of the thermographs would be removed. Therefore, to minimize the chance of losing data (i.e., someone removing a thermograph), all thermographs were: (1) monitored weekly; and, (2) removed and replaced with new thermographs and the data downloaded on a monthly basis.

6.3. EXISTING FISH HABITAT CONDITIONS

To accurately describe the existing fishery resources conditions in the 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 A). 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. Dr. Rich modified the habitat typing methodology to include artificial habitats created in urban and some coastal areas, but not specifically identified in the methodology developed by Bisson et al. (1982). 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." Or, if a lateral scour pool had been created by a concrete wall, the habitat would be called a "lateral scour pool associated with concrete wall."

The habitat within the Corte Madera Creek Watershed was surveyed in August-November,. beginning at the mouth and proceeding upstream to the headwaters of the watershed (Figure 6). Habitat measurements were made where water existed; much of the channel and some of the creeks were dry at the time of the surveys. The following creeks were surveyed, using habitat typing: Corte Madera, San Anselmo, Cascade, and Sleepy Hollow. Due to the lack of financial resources, Ross and Fairfax creeks were surveyed in a more cursory manner; Larkspur and Tamalpais Creek were not surveyed at all. We walked and photographed all of Ross Creek, taking notes on creek conditions at each area where photographs were taken; Fairfax Creek was photographed and notes of the habitat recorded at each bridge crossing in November of 1999.

6.4. FISH POPULATION ESTIMATES

To assess fish population conditions within the Corte Madera Creek Watershed, electrofishing surveys were conducted from August through October, 1999. 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 quickly, efficiently, and knowledgeably, this method is less stressful than that of beach seining and/or other collection techniques.

To accurately sample the number and species of fishes in the creeks, it was necessary to electrofish **representative samples** of each habitat type observed in the creek. Ideally, to provide a statistically-sound study, one needs, first, to identify the number of **habitat types,** and then sample (randomly) about 30% of each habitat type. As there were budgetary constraints on this project, such a methodology was not practical. However, at least one representative of each habitat type was chosen for fish sampling for each creek and, except for Ross Creek, from 10-100% of each habitat type was sampled.. Based on the results of the habitat surveys, the total number of sampling sites was as follows: (1) Corte Madera Creek - 11 sites out of 26 habitats recorded (42%); (2) San Anselmo Creek - 41 sites out of 183 habitats recorded (22%), (3) Cascade Creek - 3 sites out of 32 habitats recorded (9%); (4) Sleepy Hollow Creek - 25 sites out of 216 habitats (12%); and, (5) Ross Creek - 2 sites (Ross Creek was not habitat typed) (Figure 6).

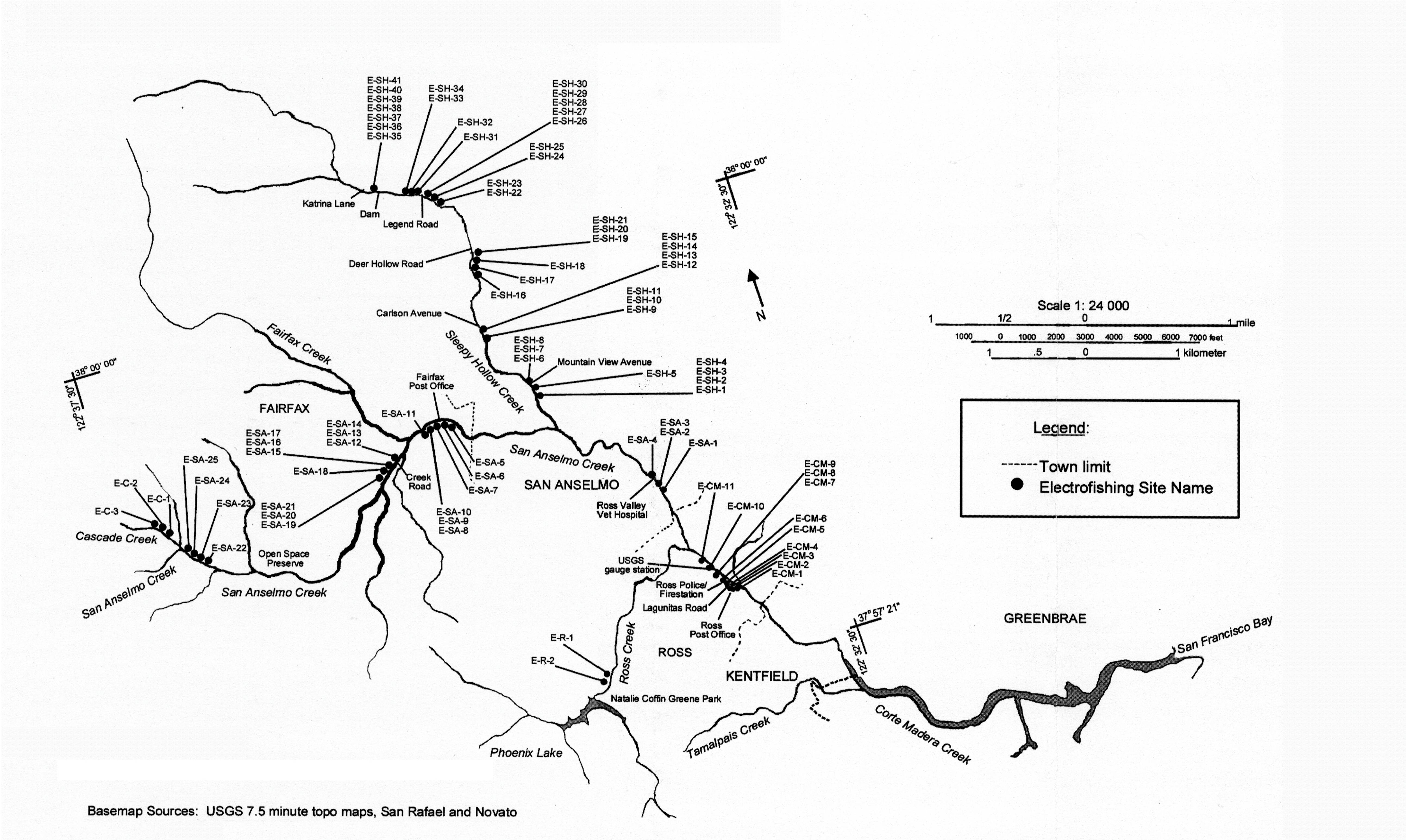
The electrofishing proceeded as follows. To prevent the fish from escaping during the sampling procedure, block nets were placed at the lower and upper ends of the sampling site. To sample the site, an electrofisher (Smith-Root Type 12 backpack) was used. The fish sampling crew consisted of one "electrofisher", 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 A 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. After the electrofishing was completed, the fishes were returned to the sampling station from which they were collected. After the electrofishing was completed at each station, the physical dimensions of the habitat (e.g., length, depth, width) 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 session, using standard weights certifiable to the National Institute of Standards and Testing.

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, a battery-operated pump aerated the water in the bucket in which the fish were residing, prior to release back into the creek.

We also used a special measuring board, designed by Dr. Rich over 10 years ago, which minimizes stress on fish by allowing the fish to remain in the water during length measurements. Finally, rocks were placed in buckets which had fish residing in them; this reduces the stress on fish, as well (Rich, 1979).

FIGURE 6. ELECTROFISHING SITES



6.5. DATA ENTRY AND ANALYSIS

The data were entered into DBASE (Windows 98) , a computer data management program. 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). Statistical analyses (analysis of variance) were conducted, using the computer statistical program, SPSS.

7. FISHERY RESOURCES HABITAT CONDITIONS

7.1. 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.

Although previous quantitative population studies are not available, 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 the rainbow/steelhead trout is the only salmonid species persisting to the present time. 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 by EPA (Leidy 1984) as one of the watersheds that should be targeted for protection.

Stream surveys on Corte Madera, San Anselmo, Cascade, Sleepy Hollow, Fairfax, and Tamalpais creeks 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, 1971). However, the five dominant species present in Corte Madera Creek and its tributaries included only sucker, roach, stickleback, sculpin, and rainbow/steelhead trout. In recent years, the most frequently observed species was limited to California roach, Sacramento sucker, threespine stickleback, sculpin, and rainbow steelhead.

7.2. SUMMARY OF 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 that there is thermal stress. Without site-specific food-fish growth studies, we have no way of knowing whether or not the higher water temperatures which occurred in portions of the creeks actually resulted in enough thermal stress that steelhead and rainbow trout productivity in the watershed was affected. 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, as this watershed project proceeds, 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. Tables 5 and 6 summarize the potential impacts on steelhead and rainbow trout, respectively, in the Corte Madera Creek Watershed.

Generally speaking the salmonids appeared in good condition, with the exception of the larger (12-14 inches in length) ones collected in pools in Sleepy Hollow Creek. These larger fish appeared emaciated, suggesting that they were not able to obtain enough food. As the fish were collected in stranded pools, there was no flowing water to provide either drifting insects or larger prey, such as other fishes. And, as the pools appeared to have been isolated from the rest of the creek, these larger fish were probably just waiting for the winter rains to move on to better "fish pastures".

One of the really exciting (albeit, probably only to a fish physiologist!) outcomes of installing so many thermographs in a relatively small system is that it provided the opportunity to observe the varying thermal conditions, depending upon the habitat type and area. For example, the USACE concrete channel provides no refuge areas and no cover; it is generally a stressful environment for salmonids, beginning about April and extending throughout the summer. However, as one proceeds up through the drainage, despite the lack of water in many of the reaches during the summer months, the results demonstrated varying thermal regimes, depending upon the habitat type and area. For example, in San Anselmo Creek, there was a range of times when water temperatures were potentially thermally stressful. Hence, as the timing of immigration, egg incubation, fry emergence, and smolt emigration vary from year to year, the trout may have the opportunity to adapt to some degree. In other words, the areas where water temperatures are suitable appeared to be the areas where the greatest number of salmonids were collected. In summary, despite potentially thermally stressful conditions in many areas of the watershed, there appeared to be "thermal refuge" (thermal refugia) areas where, if accessible, the trout could reside during the hotter summer months. With regard to smoltification, water temperatures begin to become thermally stressful, beginning in May. This would not be a problem, if most of the emigrating steelhead exit the watershed prior to May. Smolt trapping studies would allow us to determine when the smolt emigration was occurring.

TABLE 5. POTENTIAL IMPACTS OF WATER TEMPERATURE CONDITIONS ON THE STEELHEAD TROUT IN THE CORTE MADERA CREEK WATERSHED

Creek	Adult Immigration (Jan through March)	Spawning (Jan through first week in April)	Egg/Alevin Incubation (Jan through May)	Fry Emergence (mid-Jan through mid-May)	Juvenile Rearing (All year)	Smoltification/ Emigration (March through June)
Corte Madera	Stressful beginning in April	Stressful beginning in April	Stressful beginning in May	Stressful beginning in May	Stressful: [1] May through Sept	Stressful beginning in May
San Anselmo	*	*	Stressful beginning in May	Stressful beginning in May	Stressful: [2] May thru June June thru Aug June thru Sept Aug thru Sept Sept	Stressful beginning in May [3]
Cascade	*	*	*	*	Stressful: July through August	*

TABLE-5 (CONT.). POTENTIAL IMPACTS OF WATER TEMPERATURE CONDITIONS ON THE STEELHEAD TROUT IN THE CORTE MADERA CREEK WATERSHED

Creek	Adult Immigration (Jan through March)	Spawning (Jan thtrough first week in April)	Egg/Alevin Incubation (Jan through May)	Fry Emergence (mid-Jan through mid-May)	Juvenile Rearing (All year)	Smoltification/ Emigration (March through June)
Sleepy Hollow	*	*	Stressful beginning in May	Stressful beginning in May	Stressful: Satisfactory from Carlson upstream with a few peaks in July	Stressful beginning in May or June, depending upon habitat type
Ross	*	*	Stressful beginning in May	Stressful beginning in May	habitats where thermographs were installed dried up in June	Stressful: May thru June habitats where thermographs were installed dried up in late June

[1] Potential thermally stressful areas dependant upon habitat type and location (see Appendix G, Table G-1)

[2] Lower reaches generally warmer than upper reaches and Cascade Canyon area was not potentially stressful until August and September. In addition, potentially thermally stressful areas dependant upon habitat types.

[3] Except for Cascade Canyon Area where it is not known, as the thermographs were not installed until after June

* Unknown, as we did not begin to monitor water temperatures prior to mid-April

TABLE 6. POTENTIAL IMPACTS OF WATER TEMPERATURE CONDITIONS ON THE RAINBOW TROUT IN THE CORTE MADERA CREEK WATERSHED

Creek	Spawning (Feb through May)	Egg/Alevin Incubation (Feb through June)	Fry Emergence (Feb through June)	Juvenile Rearing (All year)	Adult (All year)
Corte Madera	Except for the USACE Channel (beginning in May, stressful temperatures), water temperatures were Satisfactory	Except for the USACE Channel (beginning in May, stressful temperatures), water temperatures were Satisfactory	Except for the USACE Channel (beginning in May, stressful temperatures), water temperatures were Satisfactory	Stressful: [1] June through Sept	Stressful: [1] June through Sept
San Anselmo	Satisfactory	Satisfactory	Satisfactory	Stressful: [1] July through Sept	Stressful: [1] July through Sept
Cascade	*	*	*	Stressful: July through Aug	*

TABLE-6 (CONT.). POTENTIAL IMPACTS OF WATER TEMPERATURE CONDITIONS ON THE RAINBOW TROUT IN THE CORTE MADERA CREEK WATERSHED

Creek	Spawning (Feb thru May)	Egg/Alevin Incubation (Feb through June)	Fry Emergence (Feb through June)	Juvenile Rearing (All year)	Adult (All year)
Sleepy Hollow	Satisfactory	Satisfactory	Satisfactory	Generally [2] Satisfactory	Generally [2] Satisfactory
Ross	Satisfactory	Satisfactory	Satisfactory	dried up in June	dried up in June

[1] Potential thermally stressful areas dependent upon habitat type and location (See Appendix G, Table G-2)

[2] Several thermal peaks in mid-June and mid-July in Sleepy Hollow Creek along Butterfield Road. Also, no thermographs were placed downstream of Carlson Avenue, as much of the creek dried up

* Unknown, as we did not begin to monitor water temperatures prior to mid-April

7.2.1. Corte Madera Creek

In the USACE channel, beginning in late May and extending through September[1], water temperatures were high (65-75 %F). These water temperatures were probably stressful to any steelhead in the area during spring and summer months and may have been lethal during the smoltification/emigration and rearing life stages of steelhead. Based on the 1999 data, if any adults were migrating through the channel after mid-April, stressful thermal conditions may have impacted steelhead. Similarly if the parr smolt transformation was not complete by the end of April, there may have been thermal stress, beginning in May. For rearing steelhead, summer water temperatures were potentially stressful, beginning in June and extending through September (Appendix C, Tables C-1, C-5, C-6 Figures C-1 through C-5).

Upstream of the USACE channel, the months for steelhead immigration through fry emergence were probably thermally stressful by mid-April. Water temperatures during fry and juvenile rearing were probably non-stressful until June. Water temperatures were stressful by mid-April for any steelhead remaining in the creek during the the parr-smolt tranformation. For rainbow trout in Corte Madera Creek upstream of the channel, water temperatures were probably not stressful most of the time. However, there were a some days during the hot summer months (July and August) when the maximum daily temperatures could have been stressful in some of the stream reaches, if the fish could not find thermally cool refuge areas (Appendix C, Tables C-1, Figures C-6 through C-33).

7.2.2. San Anselmo Creek

For steelhead trout, thermal conditions in San Anselmo Creek: (1) were stressful to incubation and fry emergence, beginning in May; (2) depending upon the habitat type and location, there was a number of times when juvenile rearing conditions were stressful; and, (3) with regard to smolt emigration, thermally stressful conditions began in May. For rainbow trout, thermal conditions were generally acceptable, provided the fish could find thermal refuge areas during the hot summer months (Appendix C, Table C-2, Figures C-34 through C-87).

7.2.3. Cascade Creek

Although, thermal conditions in Cascade Creek were potentially stressful during the hottest part of the summer (July and August), this was the area where we collected the greatest number of age classes of trout. This suggests that there is a self-sustaining resident trout population inhabiting the area. Portions of this area are heavily vegetated and relatively non-impacted by humans; there appear to be food resources to sustain the trout at higher temperatures (Appendix C, Table C-4, Figures C-88 through C-89).

7.2.4. Sleepy Hollow Creek

Thermal conditions in Sleepy Hollow Creek were generally satisfactory for all life stages of both steelhead and rainbow trout, with the exception of the lowest reaches near Sir Francis Drake High School. There were many areas which had dried up throughout this drainage. Yet,

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[1] And probably into October, as well, although thermographs were removed from Corte Madera Creek on October 1, 1999

we collected the largest trout in this creek And, in areas where there was sufficient pool habitat, trout were collected, albeit in small numbers (Appendix C, Table C-3, Figures C-90 through C-118).

7.2.5. Ross Creek

Although most of Ross Creek downstream of Phoenix Lake dried up by June, water temperatures were satisfactory for spawning, egg/alevin incubation, and fry emergence. As we did not have thermographs in the upper reaches of the creeks, assuming that it too would become dry, summer water temperatures are not known. However, although we only sampled two sites in Ross Creek, due to the fact that most of the creek was dry by late spring, it appeared that what little pool habitat there was in the uppermost reaches was used extensively by the trout. It would be of value to monitor water temperatures in the upper sections of Ross Creek. (Appendix C, Table C-4, Figures C-119 through C-143).

7.3. SUMMARY OF 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. A summary of the general habitat conditions in the Corte Madera Creek Watershed are discussed next, followed by a more detailed discussion of habitat conditions in the subsequent pages. Data from habitat typing surveys are provided in Appendix D. Photographs of representative areas throughout each of the creeks are provided in Appendix F.

The Corte Madera Creek Watershed can be divided into the following three very broad sections: (1) The lowest reach consists of wetland habitat, which supports estuarine fish species, waterfowl and shorebirds; (2) The middle reach consists mostly of urban creek habitat with homes and roadways lining the creek channels; and, (3) The upper reaches of the watershed encompass large open space areas and light housing development.

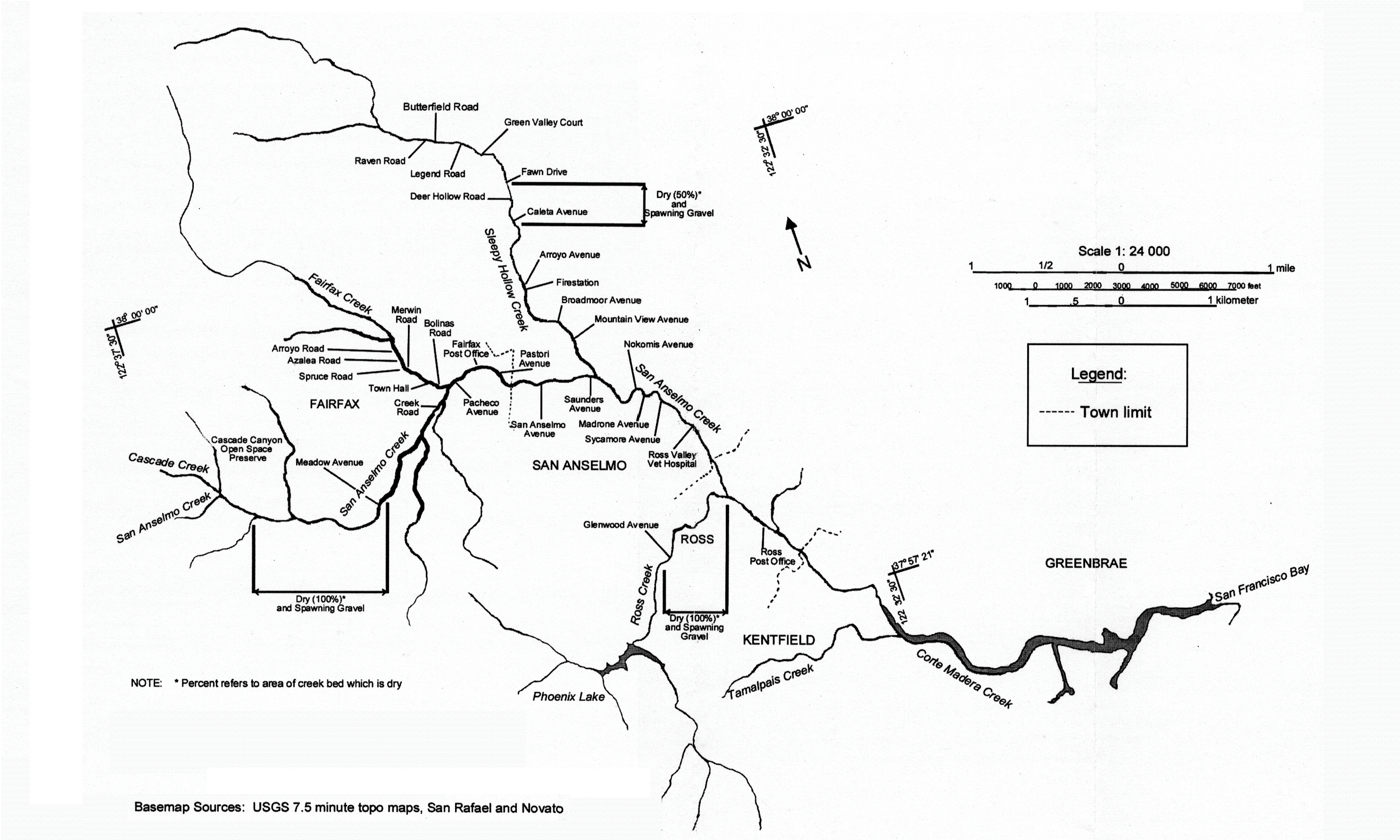
7.3.1. Corte Madera Creek

Corte Madera Creek is highly channelized, as a result of various activities (i.e., USACE concrete flood control channel and landowners' retaining walls) undertaken to control flooding during the winter months. The USACE flood control channel serves only as a migration route for the anadromous steelhead trout and even as a migration route, it is of low quality. The upstream areas of Corte Madera Creek consist of long lateral scour pools alternating with riffle areas, habitat used by a variety of fish species, although none in great abundance (Figure 7).

7.3.2. San Anselmo Creek

San Anselmo Creek had the greatest variety of habitats of any of the creeks within the Corte Madera Creek Watershed, probably because it flows through towns, but its origin lies in the relatively unimpacted reaches within the Cascade Canyon Open Space Preserve (Figure 7). Throughout its length, it was characterized by alternating lateral scour pool/riffle sequences. In

FIGURE 7. RESULTS OF HABITAT SURVEYS CONDUCTED FROM AUGUST THROUGH OCTOBER, 1999



the lower more urban reaches, the lateral scour pools are associated with retaining walls and rip rap, whereas in the upper more natural areas, they are associated with bedrock. The creek along Cascade Road in Fairfax was dry for more than a mile, but substrate consisted almost entirely of gravel suitable for trout. Hence, during the winter months, it would be a good spawning area for steelhead.

7.3.3. 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 the best trout habitat of the entire creek system. It was characterized by bedrock pool and cascades, abundant canopy, and clean water. Although there was no spawning gravel, the pools provided rearing habitat for trout. The uppermost boundary for fish migration is the Cascade Falls.

7.3.4. Sleepy Hollow Creek

Sleepy Hollow Creek flows from its headwaters above Sleepy Hollow in San Anselmo down along Butterfield Road and into Corte Madera Creek downstream of Sir Francis Drake High School (Figure 7). It was characterized by low flows, and a heavily urbanized (i.e., retaining walls, bridge pillars, concrete in the creek) channel. In the lowermost reaches, the habitat during the late summer months was suitable for stickleback and roach; higher up in the drainage, there were some appropriate pools for trout and, although dry throughout much of the upper sections, the substrate was gravel suitable for trout spawning.

7.3.5. Ross Creek

Ross Creek flows out of Phoenix Lake and into Corte Madera Creek in Ross (Figure 7). At the time of the habitat surveys, most of the creek was dry. The only area where there was flowing water and a number of pools suitable for trout was within the Natalie Coffin Greene Park area.

7.3.6. Fairfax Creek

Fairfax Creek flows down the slopes above and through the town of Fairfax its confluence with San Anselmo Creek (Figure 7). From my cursory observations (photos taken at bridge crossings), the physical appearance of Fairfax Creek suggested that this creek was similar to that of Sleepy Hollow in the dry months of a wet or normal year. From the results of our "spot check" observations, it appeared that Fairfax Creek had little water in it by the end of the dry season, there were lateral scour pools and shallow riffles throughout the Creek, substrate consisted of gravel, sand and silt, and there was abundant vegetative cover. A survey conducted by Leidy (1997) characterized the stream as follows: (1) channel incising; (2) bank vegetation trampled with bank erosion; (3) some good spawning gravel, but extensive sand and fines; and, (4) no salmonids sighted.

7.4. EXISTING FISHERY RESOURCES HABITAT CONDITIONS

In the following paragraphs, stream reaches are summarized; a detailed listing of habitat types and characteristics for Corte Madera, San Anselmo, Cascade, and Sleepy Hollow creeks is provided in Appendix D (Tables D-1 to D-4). The abbreviations in parentheses, such as SA-16, depict the habitat type number reported in Appendix D; in this example, "SA-16" would represent the sixteenth habitat as we proceeded upstream, from the beginning of San Anselmo Creek.

7.4.1. Corte Madera Creek

Corte Madera Creek is formed by the confluence of Ross Creek and San Anselmo Creek. Beginning at the downstream end, Corte Madera Creek extends from the USACE concrete channel in Kentfield upstream to the confluence with Ross Creek in Ross (Figure 7). Proceeding upstream, summer habitat conditions can be divided into the following four general stream reaches: (1) Lowermost USACE concrete flood control channel; (2) Fish ladder; (3) Long, shallow, alternating pool/riffle sequences from the fish ladder upstream to just beyond the Lagunitas Road bridge; and, (4) Longer and deeper pool/riffle sequences with more structure (e.g., large woody debris, rootwad) than the downstream areas (Appendix D, Table D-1).

The USACE concrete flood control channel is under tidal influence and serves as a migration corridor (both upstream and downstream) for steelhead trout and, at times, depending upon the tides and season, contains other fish species, as well. Due to the absence of any structure or cover for protection, and the poor quality of the old fish ladder, the channel also provides an excellent opportunity for birds to prey upon juvenile emigrating steelhead. In summary, the USACE flood control channel was created for flood control, not for fishes, particularly not for salmonids.

From the fish ladder joining the USACE flood control channel upstream to about 25 m upstream of the Lagunitas Road, the habitat was characterized by long (25-30 m), shallow (0.04 - 0.4 m average depth) alternating lateral scour pool/riffle sequences; riffles were very narrow (1-2 m wide) and shallow. Although there was abundant shade, the low streamflows, rip rap and wooden retaining walls resulted in fairly stagnant pool areas. Riffle areas were extremely shallow. Substrate in the pool areas consisted of sand, silt and organic detritus; in the riffles, small gravel was the predominant substrate.

From just beyond Lagunitas Road and extending upstream to the confluence with Ross Creek, the pool habitat was characterized by longer (10-140 m) and had deeper (0.25 - 0.50 m average depth) lateral scour pool/riffle sequences, with more structure (e.g., large woody debris, rootwad) than in the downstream areas. Abundant shade, some structure, wider riffle areas (5-7 m average width), with much of the substrate composed of small gravel offered better salmonid habitat than in the downstream reaches of Corte Madera Creek. However, the reach was deeply incised throughout with concrete retaining walls along much of the area. Substrate in pool areas was primarily sand and silt. Just downstream of the confluence with Ross Creek, there was a large woody debris jam (about 30 m length) which was difficult to walk through; pool depth in that area was over a meter in many areas and the water was stagnant; the woody debris needs to be modified, although not removed, so that the stream can flow through it.

7.4.2. San Anselmo Creek

San Anselmo Creek extends from the confluence with Ross Creek upstream through Ross, San Anselmo, and Fairfax, and well into the Cascade Canyon Open Space Preserve (Figure

7). San Anselmo Creek had the greatest variety of habitat types of any of the creeks within the Corte Madera Creek Watershed, probably due to the fact that it flows through the towns, but its origin lies in the relatively unimpacted reaches within the Open Space Preserve**.** Proceeding upstream, summer habitat conditions are described by general stream sections, as follows (Appendix D, Table D-2).

7.4.2.1. Confluence with Ross Creek Upstream to Sir Francis Drake Boulevard Bridge at San Anselmo Town Limit (just downstream of Bolinas Road) (SA-1 to SA-7)

The lowermost reach of San Anselmo Creek was characterized by long alternating lateral scour pool/riffle sequences, again with a lot of man-made retaining walls and concrete in the creek. Except for the large pool underneath Sir Francis Drake bridge near the town limit of San Anselmo, pools were generally shallow (0.1 - 0.2 m average depth) and ranged from 20-70 m long; riffles ranged from 4-6 m in width, with substrate composed of gravel; several potential spawning areas were seen in this area. Although there was abundant shade, sand and silt substrate and low streamflows limited summer trout habitat. A hose, which appeared to be a diversion hose (although not pumping water at the time of the survey) was located on the left (facing upstream) side of the creek under the Sir Francis Drake bridge.

7.4.2.2. Sir Francis Drake Bridge at San Anselmo Town Limit (near Bolinas Road) Upstream to Sir Francis Drake Boulevard Bridge at Ross Valley Veterinary Hospital (near Bank Street) (SA-8 to SA-17)

This reach of San Anselmo Creek was characterized by long alternating lateral scour pool/riffle sequences, again with a lot of man-made structures, including a rock dam at SA-12, concrete retaining walls, what appeared to be an old asphalt/concrete boat ramp (right bank as one faced upstream), and concrete in the creek. Pools (lateral scour associated with concrete walls, primarily) were generally shallow (0.2 - 0.5 m average depth) and ranged from 15-90 m long, with gravel substrate, but covered with organic detritus; riffles ranged from 3-6 m average width, with substrate composed of gravel and cobble; one potential spawning area was seen. Again, hoses in the creek were spotted (SA-12 and SA-16), one with a pump at the Sunnyside Nursery. Although there was abundant shade and clean gravel, low streamflows limited summer trout habitat.

7.4.2.3. Sir Francis Drake Bridge Upstream through Downtown San Anselmo to Sycamore Avenue Bridge (SA-18 to SA-22)

Except for a similar reach through downtown Fairfax, the reach of San Anselmo Creek flowing through downtown San Anselmo consists of very poor trout habitat, but is very suitable for roach (we collected more roach in one of the pools in this section than anywhere else in the entire watershed). This reach was characterized by long, deep (some more than 1 m deep) stagnant lateral scour pools created by concrete retaining walls and huge pieces of concrete strewn throughout the creek bottom. Even in the section adjacent to Creek Park, the faster moving riffle area was full of concrete pieces. The fish species observed throughout the area was the hardy California roach, which thrive in this type of urban environment. Cover was provided by bridges and buildings.

7.4.2.4. Sycamore Avenue Bridge Upstream to Madrone Avenue Bridge (SA-23 to SA-36)

Compared to the previous section, creek habitat improved a bit in this reach, with lateral scour pools associated with logs and root wads interspersed with those associated with rip rap and concrete walls. Pools ranged from 8-37 m in length, 1-6 m average width, and 0.1-0.4 m average depth. Abundant canopy/overhanging was present, substrate consisted of gravel, primarily, with several potential trout spawning areas in riffle areas. Some concrete blocks were strewn about, although few by comparison to those in the creek in downtown San Anselmo. A log (about 30 cm diameter) in SA-26, although not an anadromous fish passage barrier, created a stagnant pool behind it. A large (about 2/3 m long and 30 cm diameter) iron pipe lay in the substrate at SA-28. A hose, with pump attached, was sighted in SA-30. Just downstream (SA-37) of the Madrone Avenue Bridge, there was an eroding bank on the left side (facing upstream) of the creek, which appeared to be contributing silt to the creek.

7.4.2.5. Madrone Avenue Bridge Upstream to Nokomis Avenue Bridge (SA-37 to SA-48)

Proceeding upstream from Madrone Avenue to Nokomis Avenue, the pool/riffle sequence continued, with pools (20-35 m length; 3-5 m average width; 0.1-0.4 average depth) mostly associated with rip rap walls. Substrate consisted primarily of sand in the pools and gravel in the riffles (4-12 m length; 1-5 m average width; 0.05-0.1 average depth) and abundant canopy/ overhanging cover was present. California roaches were seen throughout this reach. At SA-64, there was a tributary (dry) on the right (facing upstream). This tributary, Sorich Creek, runs underneath Sir Francis Drake Blvd from under the Red Hill Shopping Area.

7.4.2.6. Nokomis Avenue Bridge Upstream to Saunders Avenue Bridge (SA-49 to SA-76)

From Nokomis Avenue upstream to Saunders Avenue, the habitat was characterized by the continuation of the pool/riffle sequences. There were a combination of pool types (10-95 m length; 2.5-8.5 m average width; 0.2-0.6 m average depth), but most associated with concrete walls, rip rap, with a few root wads and cut banks. At the most upstream end there was a cascade consisting of three bedrock pools (15 m long), some concrete in the channel, and a denil fish ladder underneath the Saunders Avenue bridge. Substrate consisted primarily of gravel in both the pools and riffles (6-20 m length; 1-7 m average width; 0.03-0.08 m average depth) and abundant canopy/overhanging cover was present. A good portion of this habitat had long concrete or wood retaining walls for flood control, thereby channelizing the creek and creating good roach habitat and poor trout habitat.

7.4.2.7. Saunders Avenue Bridge Upstream to San Anselmo Avenue Lansdale Station) (SA-77 to SA-102a)

Upstream of the denil fish ladder, the creek flows adjacent to Sir Francis Drake High School. The habitat continued with pool/riffle sequences. The pools (10-50 m length; 2-8 m average width; 0.1-0.5 m average depth) were associated primarily with concrete walls and rip rap, although there were also a few pools associated with bank cuts. Substrate consisted primarily of gravel and sand in the pools and gravel in the riffles (3-18 m length; 0.5-5.3 m average width; 0.03-0.07 m average depth). There were several long (e.g., 105 m) concrete and wood retaining walls (at both the downstream and upstream ends of the reach) for flood control, thereby channelizing the creek and creating good roach habitat and poor trout habitat in those areas. There was also abundance of huge concrete slabs and a radiator discarded in the creek bed near Lansdale Station. A very long curved concrete culvert ran underneath the road at Lansdale Station.

7.4.2.8. San Anselmo Avenue (Lansdale Station) Upstream to Dam at Pastori Avenue, Fairfax (SA-102b to SA-122)

This portion of the creek, upstream of Lansdale Station was fairly shallow (lateral scour pools mostly from 0.1-0.3 m depth), but the gradient increased and there were a series of cascades near the upstream end of the reach (before the old denil fish ladder under Pastori Avenue). This provided some added current down through the reach. The habitat continued with pool/riffle sequences. The pools (14-80 m length; 3.5-8 m average width) were associated primarily with concrete walls, root wads, and cut banks. Substrate consisted primarily of gravel and sand in the pools and gravel in the riffles (4-13 m length; 1.8-5.3 m average width; 0.04-0.05 m average depth) and abundant canopy/ overhanging cover was present. There were fewer retaining walls than in the previous reach which gave the creek the feel a more natural feel. There were some large concrete blocks in the creek and a collapsed left bank at SA 110, where an old wood retaining wall was falling into the creek.

7.4.2.9. Pastori Avenue Upstream to Behind Fairfax Post Office (SA-123 to SA-128)

The habitat in this reach was of very poor quality, similar to that in downtown San Anselmo. Much of this reach ran under an overhang of the Fair-Anselm Plaza. It was characterized by lateral scour pools created by concrete pilings and a collapsing wooden wall behind the Fair Anselm Plaza. The pools were stagnant and only stickleback were seen swimming about.

7.4.2.10. Behind Fairfax Post Office Upstream to Dam at Pacheco Road (SA-129 to SA-144)

From the Fairfax Post Office upstream to a concrete dam at Pacheco Road, the habitat was characterized by the continuation of the lateral scour pool/riffle sequences. There was a combination (rootwad, cut bank, backwater, rip rap, concrete wall) of lateral scour and dam pool types (8-47 m length; 1.4-8.8 m average width; 0.7-0.4 m average depth). Substrate consisted primarily of sand and gravel in the pools and gravel in the riffles (8-22 m length; 1-5 m average width; 0.02-0.05 m average depth) and abundant canopy/overhanging cover was present. Behind 40 Inyo Avenue the left bank (as one faced upstream) in a curve in the creek was bare and appeared to be eroding into the creek. At the upstream end of the reach, at Pacheco Road, there was a large (about 3 m high, 9 m wide, and over 0.5 m deep) concrete dam, with a cut in the middle at its base, which allowed the creek to flow down through it.

7.4.2.11. Pacheco Road Upstream to Creek Road (SA-145 to SA-169)

From Pacheco Road bridge upstream to Creek Road, the habitat was characterized by the continuation of the lateral scour pool/riffle sequences. There was a combination (bedrock, rootwad, cut bank and a few concrete walla) of lateral scour pool types (6-39 m length; 2.2-13 m average width; 0.1-0.5 m average depth). A more natural habitat (i.e., bedrock, rootwad) was characteristic of the lower half of this reach; the upper reach was characterized by a number of lateral scour pools associated with large concrete and wood retaining walls. Substrate consisted primarily of gravel in both the pools and riffles (3-41 m length; 1- 4.5 m average width; 0.02-0.05 m average depth) and abundant canopy/overhanging cover was present.

7.4.2.12. Creek Road Upstream to Upstream of Bolinas Road Bridge (SA-170 to SA-196)

From the Creek Road bridge upstream to SA-196 (upstream of the Bolinas Road bridge), the habitat was characterized mostly by lateral scour pools, with a few riffles in the downstream portion of the reach. In addition, this was the first reach in San Anselmo Creek where significant (i.e., over 100 m length) dry areas (i.e., creating stranded pools) appeared during the course of the surveys. The downstream half of the reach was heavily channelized, by numerous wooden and concrete retaining walls constructed for flood control purposes. In addition, there were a number of man-made concrete dams (slabs of concreate as substrate) which created pools over 0.5 m deep. There were a few good-sized root wad and lateral scour pools associated with cut banks throughout the reach. Lateral scour pools ranged from 3 to 43 m length, 1-6 m average width, and 0.04-0.5 m average depth. Substrate consisted primarily of sand and silt in the pools and gravel in the riffles (1.5-16 m length; 1-1.5 m average width; 0.04-0.05 m average depth) and abundant canopy/ overhanging cover was present. The upstream end of the reach ended in a bedrock pool. Just downstream of the bedrock pool was a large (9 m length, 6 m average width, more than 1 m deep) lateral scour pool with rootwads and woody debris; it formed at the confluence with an unnamed tributary.

7.4.2.13. Dry Reach for about 1700 Meters (about 1 mile), Upstream into Cascade Canyon Open Space Preserve (SA-197 to SA-199)

San Anselmo Creek was dry for over a mile of creek bed, beginning at SA-197 and extending to SA-199. The downstream end of this reach began at a bedrock pool just upstream of the junction of an unnamed tributary. Upstream of this point, there was no water until well into the Cascade Canyon Open Space Preserve. Although the creek bed was dry, the substrate for almost the entire reach was composed of spawning gravel. About 150 m upstream of the beginning of the reach there was a 1.1 m high and 5.8 m wide concrete dam. With low flows, it might be a passage barrier for anadromous salmonids during the winter months. However, with typical high winter flows, the height of the dam would not be sufficient to prevent steelhead trout from passing during the spawning season.

7.4.2.14. Cascade Canyon Open Space Preserve Upstream to Cascade Creek (SA-200 to SA-214)

Although short on water by the end of summer, there is no question that San Anselmo Creek within the Cascade Canyon Open Space offered the best trout habitat of the entire creek. The reach was characterized by alternating lateral scour pools associated with bedrock, followed by riffles and, in some, cases, cascades and pocket water areas. Pools ranged from 3-14 m length, averaged from 1.5-4.5 m width, and averaged 0.1-.75 m depth. Although there really was no spawning gravel within the area of the creek which was flowing, downstream of this area there was spawning gravel. There was abundant cover in the form of canopy, overhanging vegetation, and bedrock areas.

7.4.3. Cascade Creek

Although higher in gradient, Cascade Creek offered some of the same good quality habitat as San Anselmo Creek within the Cascade Canyon Open Space Preserve. The reach was characterized by alternating cascades with bedrock pools, followed by high gradient riffles and, in the lower portion a few lateral scour pools and pocket water areas. The cascades ranged from 3-26 m length, with pools averaging 1-3.5 m width, and 0.1-0.2 m. Although there really was no spawning gravel within Cascade Creek, the pools provided rearing habitat and downstream of this area there was spawning gravel for over 1700 m (approximately a mile) distance. There was abundant cover in the form of canopy, overhanging vegetation, and bedrock areas, similar to the uppermost reach of San Anselmo Creek (Appendix D, Table D-3).

7.4.4. Sleepy Hollow Creek

Sleepy Hollow Creek extends from the confluence with San Anselmo Creek in San Anselmo, several hundred meters downstream of the denil fish ladder at the Saunders Avenue bridge, and extends upstream through residential areas, mostly along Butterfield Road and into the hills of Sleepy Hollow (Figure 7). Proceeding upstream, summer habitat conditions are described by general stream sections, as follows (Appendix D, Table D-4).

7.4.4.1. Confluence with San Anselmo Creek to the Upstream Side of Sir Francis Drake Boulevard (SH 1 to SH-2)

From the confluence with San Anselmo Creek to the upstream side of the Sir Francis Drake Boulevard culvert, the creek was partially channelized by concrete and wood retaining walls. In addition, there were numerous areas where rip rap had fallen into the creek Although there was water, much of it was not flowing, and the areas where it was deeper, forming lateral scour pools associated with walls, the substrate was composed primarily of sand and silt. Generally, this was habitat suitable for stickleback and roach, not salmonids.

7.4.4.2. Sir Francis Drake Boulevard Upstream to the Arroyo Avenue Bridge(SH-3 to SH-50)

This portion of the creek flowed under Mountain View Avenue and Broadmoor Avenue and upstream along Butterfield Road. It was characterized by the lack of stream flow, with some areas only a trickle; the creek was mostly dry behind Roble Court. The habitat consisted primarily of lateral scour pools and trickles, with a few shallow pocket water areas. The lateral scour pools were associated with rip rap and concrete retaining walls, primarily. The pools were ranged from 6-84 m in length, 1.2-4.7 m average width and 0.03-0.35 m in average depth. Substrate consisted primarily of sand, silt and concrete. Cover consisted of canopy and some cut bank areas, but mostly it was in the form of concrete or rip rap blocks. The habitat appeared suitable for roach and stickleback, but not trout. In addition to numerous pieces of concrete and rip rap, there was a water heater (SA-17), a hose (SA-25) in the creek, and two recently dead (whether from natural causes or poisoning was not known) racoons (just upstream of Sir Francis Drake Boulevard).

7.4.4.3. Arroyo Avenue Bridge Upstream to Caleta Avenue Bridge (SH-51 to SH-97)

From Arroyo Avenue upstream to Caleta Avenue, San Anselmo Creek was characterized mostly by lateral scour pools associated with retaining walls (concrete, wood, rip rap) and concrete pilings from bridges; there were a few rootwad pools, as well. Although pools were larger and deeper than downstream of Arroyo Avenue, there generally was not enough flowing water to create pool/riffle sequences at the time of the survey. Many of the pools were not connected and, hence, stranded any fish which had been residing in them. The lateral scour pools ranged from 5 to 42 m in length, 1-5 m average width, and 0.03-0.4 m average depth;. Substrate consisted primarily of small gravel and sand, asphalt, and concrete blocks, and abundant canopy/overhanging cover was present. A hose was seen in one pool (SH-60) and an various pieces garbage (cans, plastic, water heaters) had been strewn into the creek throughout this section. Although the upstream end of the reach ended with a good-sized (14 m length by 5 m width) rootwad lateral scour pool, such types of habitat were not common.

7.4.4.4. Caleta Avenue Upstream to Deer Hollow Road (SH-98 to SH-114)

From Caleta Avenue upstream to Deer Hollow Road, the habitat was characterized, primarily, by lateral scour pools associated with rootwad and cut banks, with a few concrete retaining walls. Although, there was an increase in structure within the pool habitats, compared to downstream areas, almost 50% of this section had dried up. Hence, as before, many of the pools were stranded. The lateral scour pools ranged from 5 to 21 m in length, 1-5 m average width, and 0.07-0.3 m average depth and there was abundant canopy cover. Substrate consisted primarily of gravel, particularly in the dry areas which, presumably are riffles during the wet season. A hose and old metal pipes were seen at SH-107. At the upstream end of the section just below Deer Hollow Road bridge, there was a series of bedrock/concrete pools. During the winter, the upper pool is deep (over 2 m) and water cascades down through the pools. In summary, although much of the section was dry at the time of the survey, this section was characterized by a great deal of spawning gravel and some good rearing pools with structure in them.

7.4.4.5. Deer Hollow Road Upstream to Fawn Drive (SH-115 to SH-125)

Over 50% of the creek was dry from Deer Hollow Road upstream to Fawn Drive. Lateral scour pools and dam in this reach were associated with bedrock (7-13 m in length; 1-3 m average width; and, 0.04 - 0.14 m depth). As with the preceding sections, dry areas in this section were comprised of substrate suitable for spawning trout. A hose was seen at SH-121 and at the upstream end of the section, just below the bridge, the pool was stagnant and had a rotten smell to it.

7.4.4.6. Fawn Drive Upstream to Culvert Underneath Butterfield Road, Just Downstream of Legend Road (SH-126 to SH-163)

This section was characterized by alternating pools, and a few bedrock cascades, with dry sections in the creek. The pools in the lower portions were associated with bedrock; the pools in the upper areas were associated with cut banks, rootwads, and concrete pilings (from foot and driveway bridges). Pools ranged from 4-28 m in length,0.8-4 m average width, and, 0.05 - 0.36 m depth. As with the downstream areas, the substrate in the dry areas was suitable for trout spawning. Just upstream of Butterfield Lane, extending upstream for about 100 m, the pools were stagnant, completely covered with duckweed.

7.4.4.7. Culvert Underneath Butterfield Road, Just Downstream of Legend Road Upstream to Dam (SH-164 to SH-179) Across From 33 Raven Lane

This section was characterized by very limited amounts of water, most of which was found at the beginning and the end of the section. The pool just upstream of Butterfield Road was 25 m long, and averaged 2.8 m wide and 0.12 m depth. At the end of the section there was a bedrock pool and a man-made concrete dam, approximately 2.5 m high (impassable to steelhead immigration); the pool was 13 m long and about 6 m wide, with a depth of over 0.5 m in the deepest part. The rest of the section was alternately dry or almost dry, with a few shallow (0.1-0.2 m depth) lateral scour pools associated with bedrock, cut bank and root wads. As the gradient increased as one proceeded up the creekbed, this section is probably really "ripping" during the winter season. During the summer, though, there is limited habitat, due to the lack of water.

7.4.4.8. Upstream of Dam Across From 33 Raven Lane (SA-180 to SA-183)

Upstream of the dam to Katrina Lane, there were a few stranded shallow pools. The area directly below Katrina Lane was very dense with overgrown vegetation. The section above Katrina Lane continued with alternating stranded pools and dry reaches. Substrate consisted of small gravel throughout most of the area, smaller than in the downstream areas.

7.4.5. Ross Creek

At the time of the survey, Ross Creek was dry from its confluence with Corte Madera/San Anselmo creeks upstream to Glenwood Avenue. In the lower reaches of the dry area there was gravel substrate suitable for spawning trout. Within Natalie Coffin Greene Park, extending upstream to just below the spillway at Phoenix Lake, the habitat was characterized by lateral scour pools associated with bank cut, rootwads and large woody debris. There was a lot of structure in the creek in the upstream areas and the water in the creek was concentrated in a few pools. These areas provided rearing habitat for trout, albeit to a rather limited extent.

7.4.6. Fairfax Creek

Fairfax Creek flows down the slopes above and through the town of Fairfax to its confluence with San Anselmo Creek. From my cursory observations (photos taken of Fairfax Creek at the bridge crossings), it appeared that the habitat in Fairfax Creek was similar to that of Sleepy Hollow in the dry months of a wet or normal year. From the results of our "spot check" observations,

it appeared that Fairfax Creek had little water in it by the end of the dry season, there were lateral scour pools and shallow riffles throughout the creek, substrate consisted of gravel, sand and silt, and there was abundant vegetative cover.

Allen (1960a) stated that Fairfax Creek usually went dry, beginning in April or May. He also stated that the lack of summer flows, heavy pumping by private landowners, and trashing of the creek by humans had destroyed the creek for salmonids for all practical purposes.

8. EXISTING FISH POPULATION CONDITIONS

8.1. POPULATION SIZES

Fish species collected in the Corte Madera Creek Watershed included rainbow/steelhead trout, threespine stickleback, California roach, sculpin species, and Sacramento sucker (Appendix E). Limiting factors for trout production were lack of stream flows and probably high water temperatures, depending upon both the creek and location of the reach within a creek.

Compared to the other four fish species, trout were the most numerous in San Anselmo Creek; only trout were collected in Cascade and Ross creeks. Roach, stickleback and sucker were the predominant species in Corte Madera Creek; trout and roach were the most prevalent species in San Anselmo Creek; and stickleback and roach were the most prevalent species in Sleepy Hollow Creek. Only trout were collected in Cascade and Ross creeks (Figures 8-15[2]).

The mean trout populations, within the Corte Madera Creek Watershed were as follows: (1) Corte Madera Creek - 0.03-0.14 fish/square meter [3]; (2) San Anselmo Creek - 0.01-12.76 fish/square meter; (3) Cascade Creek - 0.59-0.84 fish/square meter; (4) Sleepy Hollow Creek - 0.02-0.41 fish/square meter; and, Ross Creek - 0.25 fish/square meter. The greatest numbers of trout were collected in San Anselmo and Cascade creeks within the Cascade Canyon Open Space Preserve. However, there was no statistical difference in population sizes between any of the various creeks, due to the wide variability in the number of rainbow/steelhead trout in the various habitat types (Figure 8).

8.2. AGE OF THE FISH SPECIES COLLECTED

8.2.1. Rainbow/Steelhead Trout

Based on the size distribution (Figures 16-20 and Appendix E, Tables E-10 to E-14), the juvenile 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 Sleepy Hollow 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 trout in the watershed, albeit small. Of particular interest was the variety of age classes in the first bedrock pools sampled in the Cascade Canyon Open Space Preserve, upstream of the dry creek bed (i.e., approximately 1700 m of dry creek). In other urban systems that I have sampled, such an area would usually produce most, if not all, young-of-the-year fish, not a variety of age classes. Hence, it is important that the area be protected from man-made stressors.

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2 These figures show mean populations and include a bar showing the standard error of the mean.

3 square meter = surface area = length (meters) X width (meters) of fish habitat

8.2.2. Other Fishes

Based on the length data (Figures 17-21 and Appendix E, Tables E-10 to E-14), the stickleback collected were young-of-the-year fish, the roach and suckers, from one to four years old, and the sculpin from one to five years old.

FIGURE 8. RELATIVE NUMBERS OF EACH FISH SPECIES WITHIN CORTE MADERA CREEK

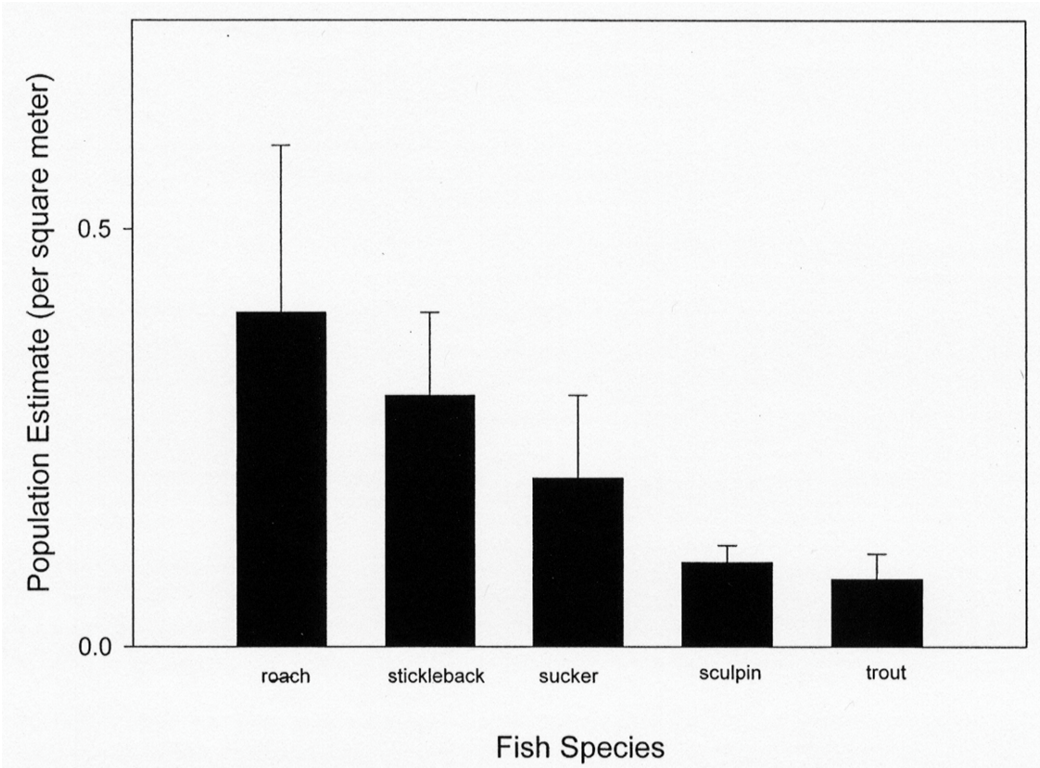


FIGURE 9. RELATIVE NUMBERS OF EACH FISH SPECIES WITHIN SAN ANSELMO CREEK

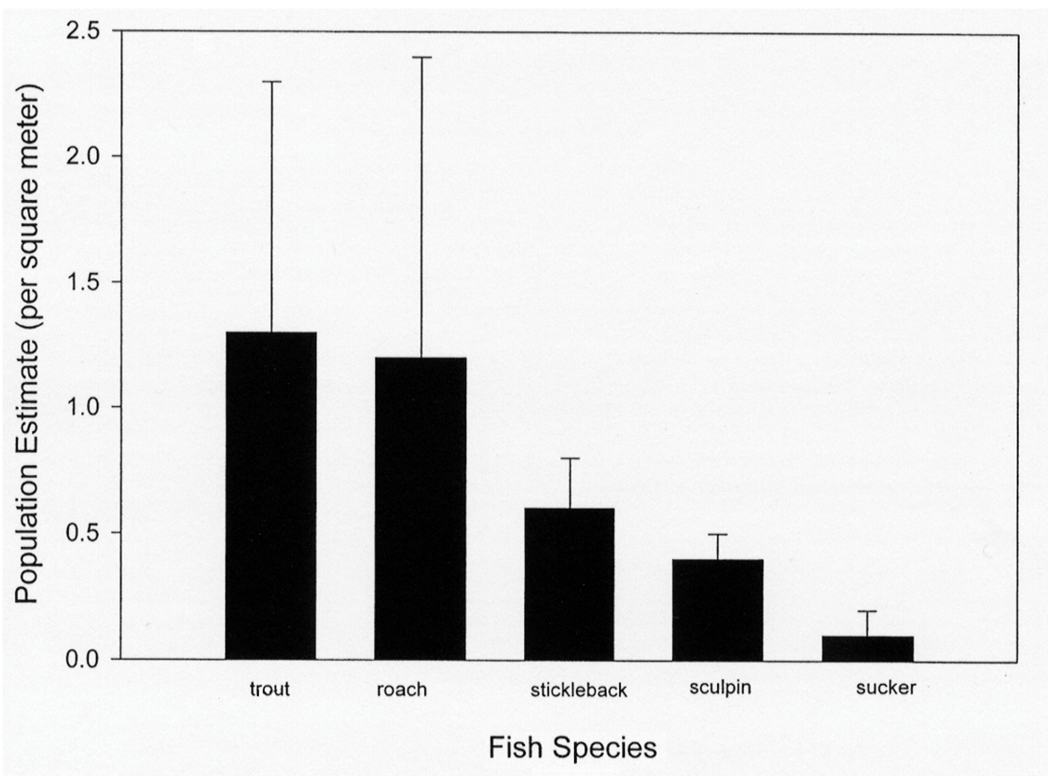


FIGURE 10. RELATIVE NUMBERS OF EACH FISH SPECIES WITHIN SLEEPY HOLLOW CREEK

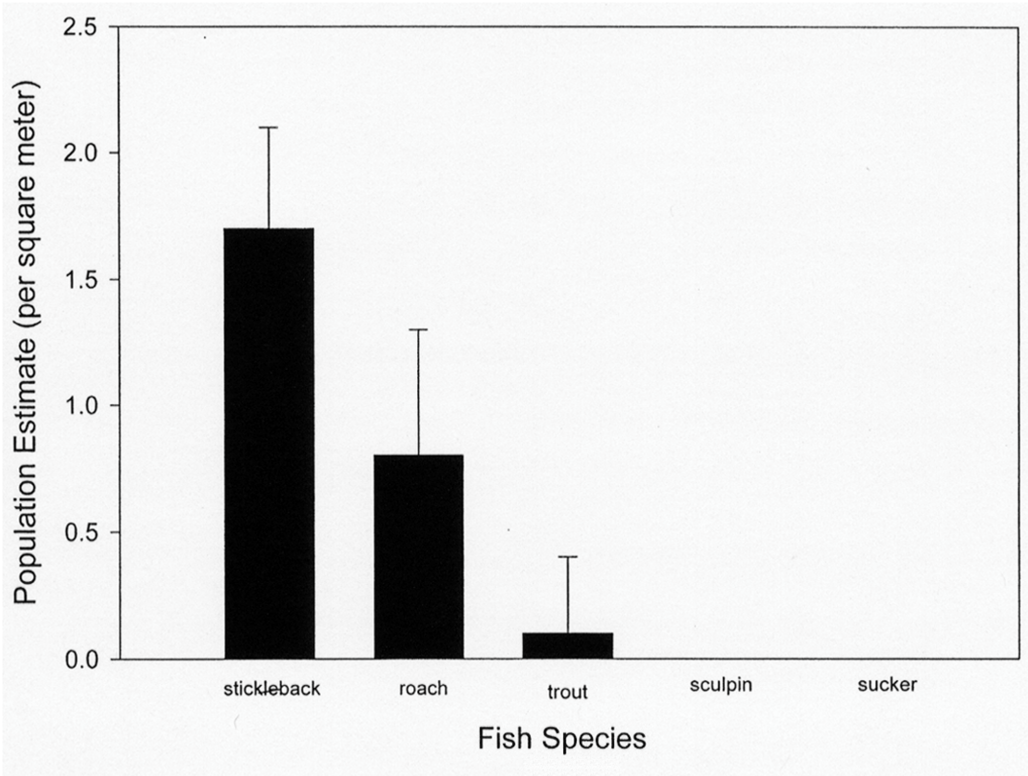


FIGURE 11. RAINBOW/STEELHEAD TROUT POPULATIONS IN THE CORTE MADERA CREEK WATERSHED

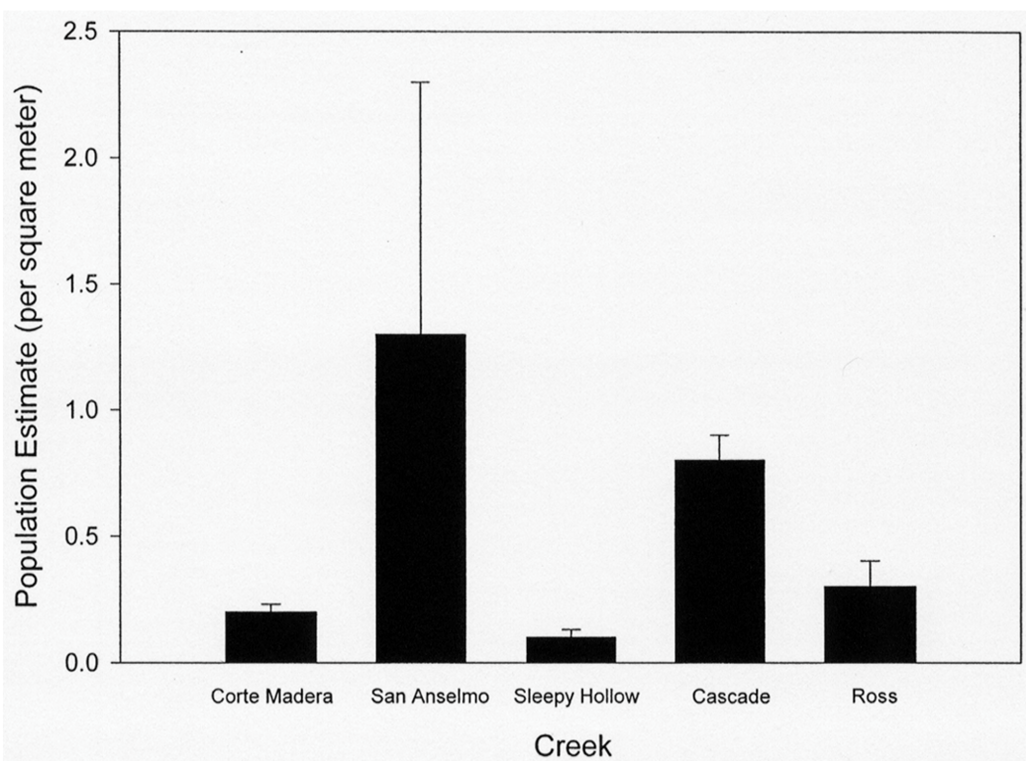


FIGURE 12. CALIFORNIA ROACH POPULATIONS IN THE CORTE MADERA CREEK WATERSHED

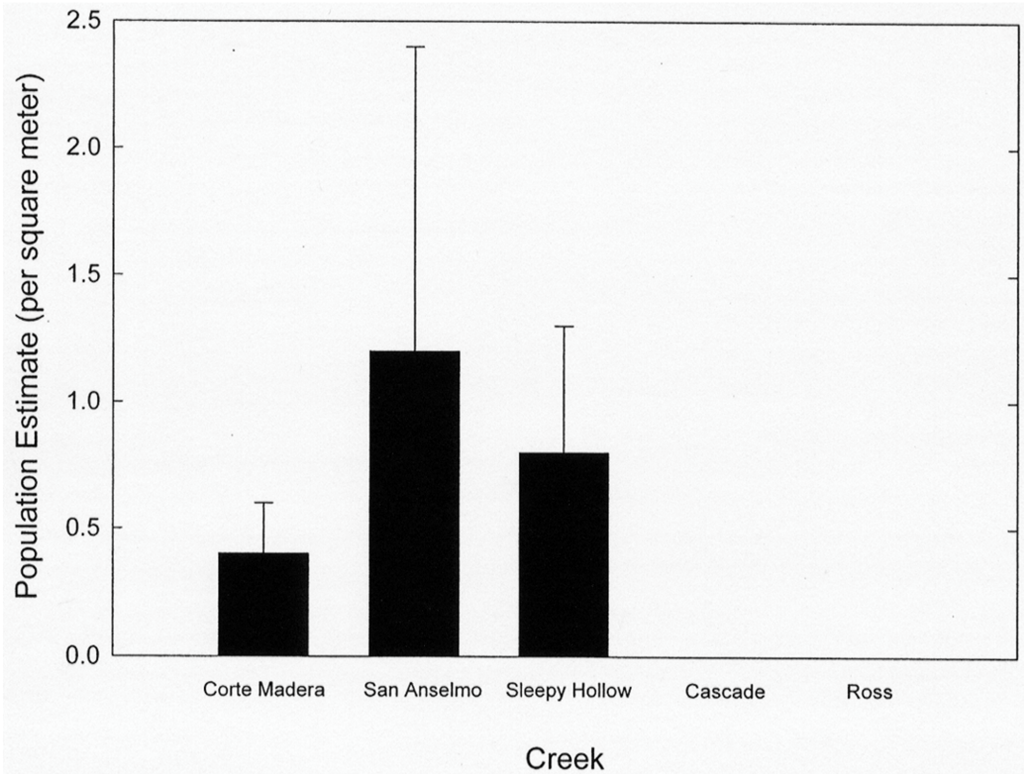


FIGURE 13. THREESPINE STICKLEBACK POPULATIONS IN THE CORTE MADERA CREEK WATERSHED

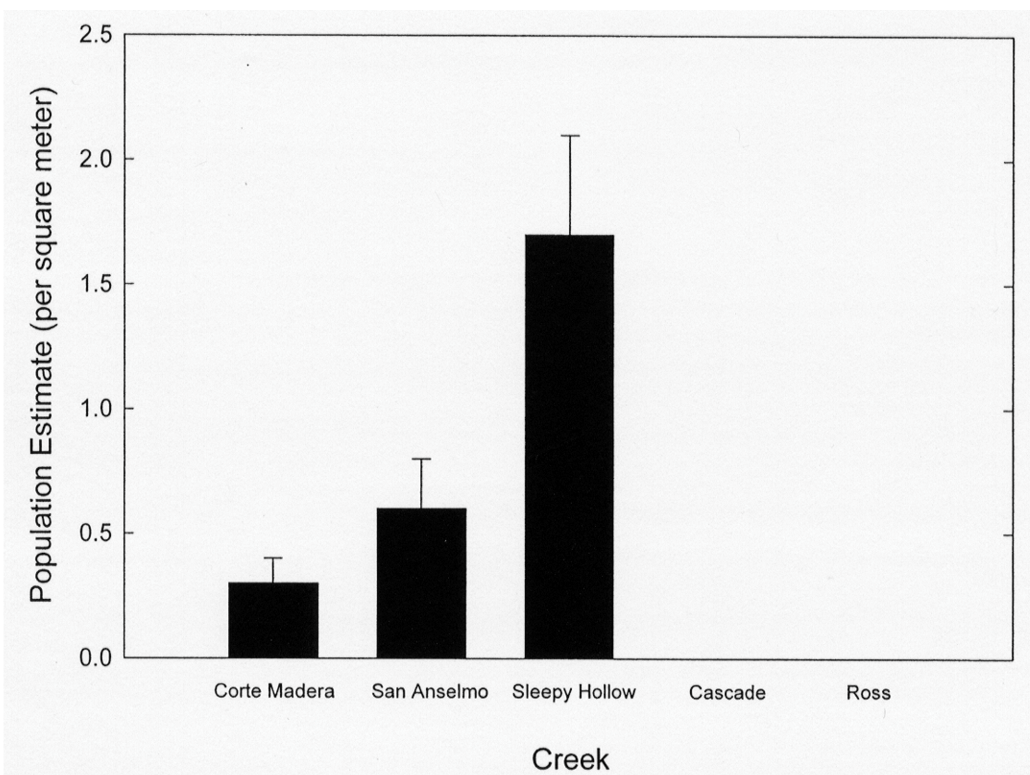


FIGURE 14. SCULPIN POPULATIONS IN THE CORTE MADERA CREEK WATERSHED

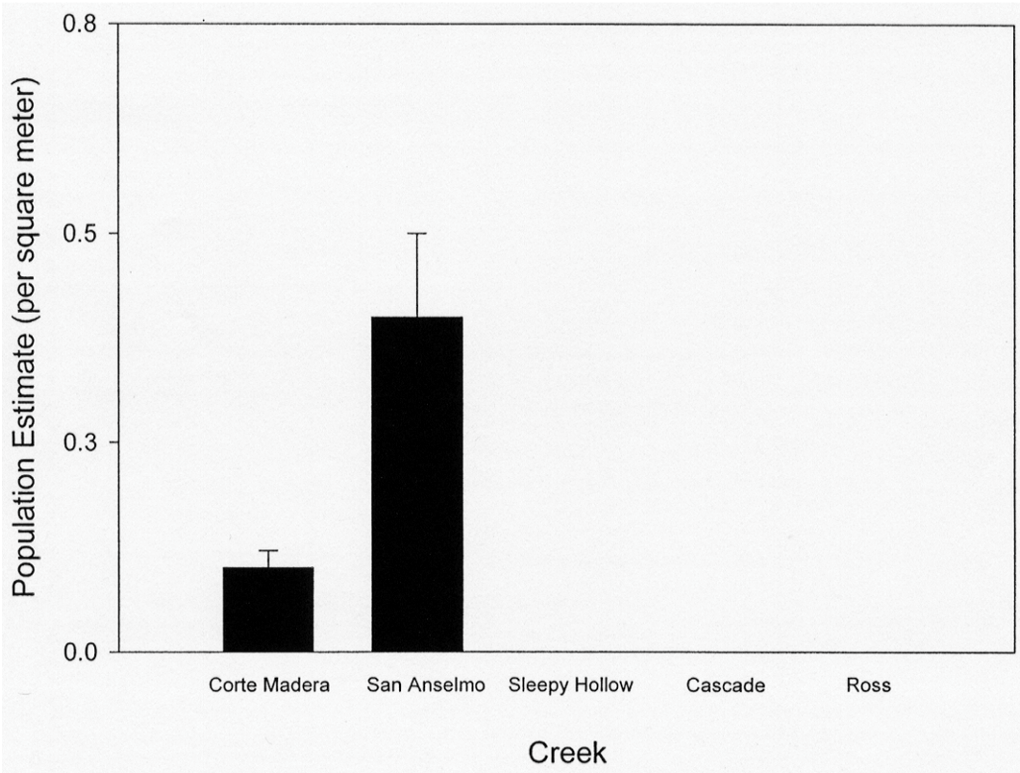


FIGURE 15. SACRAMENTO SUCKER POPULATIONS IN THE CORTE MADERA CREEK WATERSHED

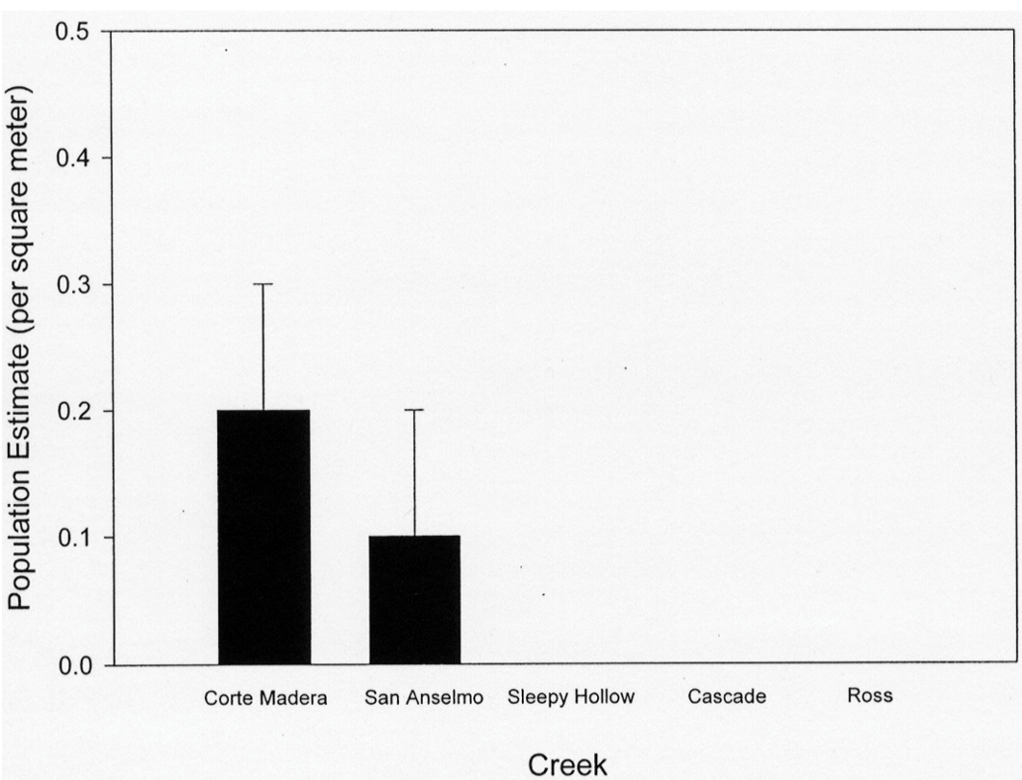


FIGURE 16. RAINBOW/STEELHEAD TROUT LENGTH-FREQUENCY DISTRIBUTION IN CORTE MADERA CREEK

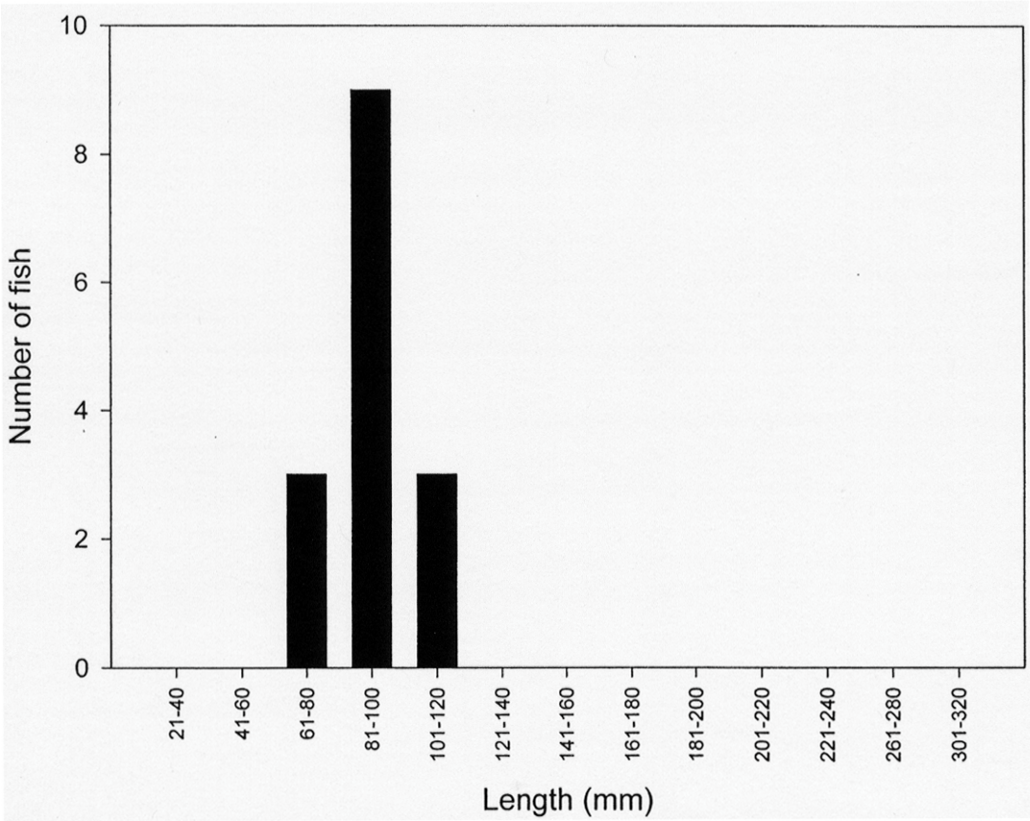


FIGURE 17. RAINBOW/STEELHEAD TROUT LENGTH-FREQUENCY DISTRIBUTION IN SAN ANSELMO CREEK

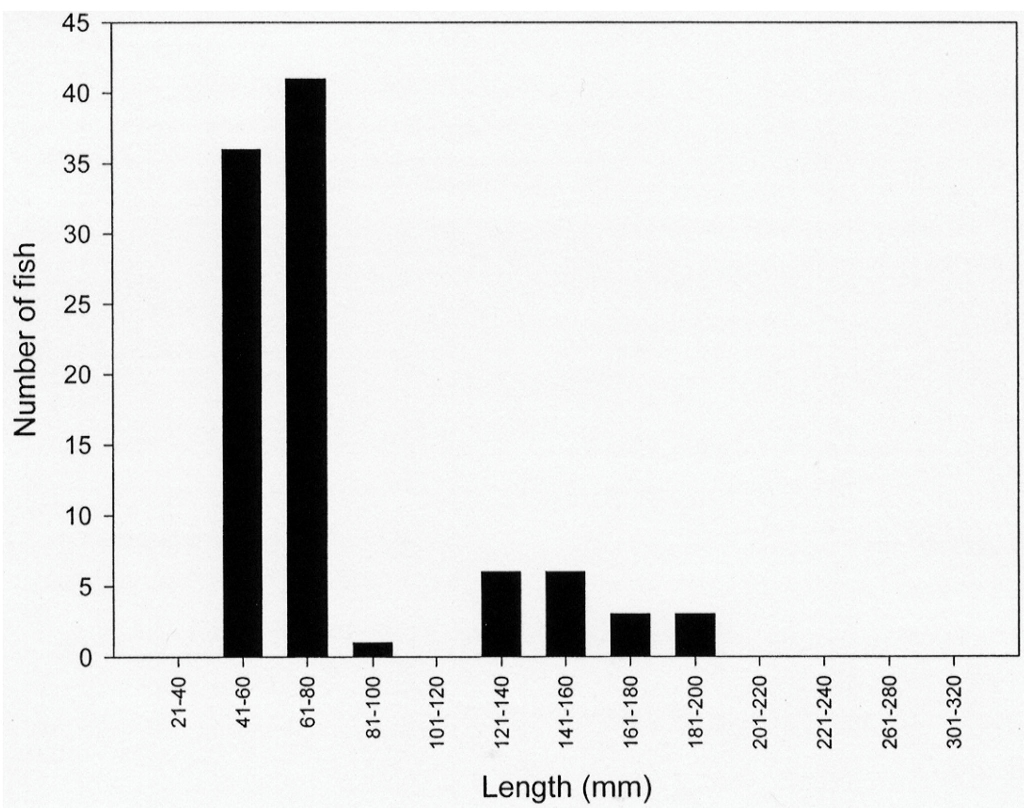


FIGURE 18. RAINBOW/STEELHEAD TROUT LENGTH-FREQUENCY DISTRIBUTION IN CASCADE CREEK

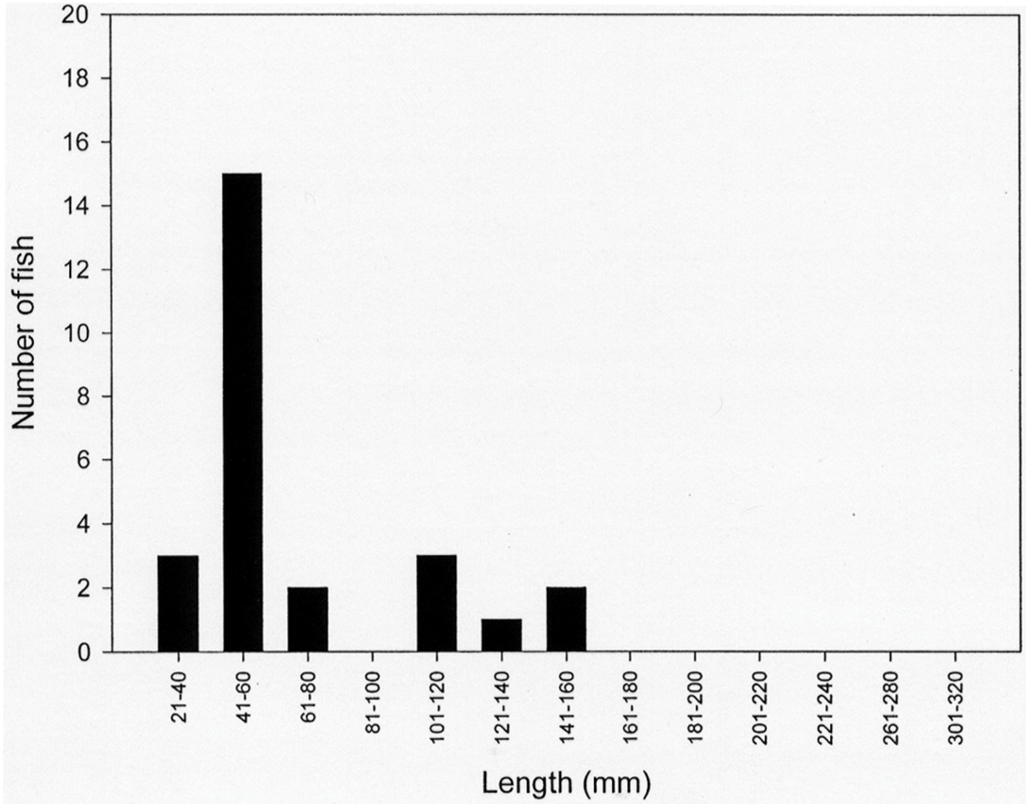


FIGURE 19. RAINBOW/STEELHEAD TROUT LENGTH-FREQUENCY DISTRIBUTION IN SLEEPY HOLLOW CREEK

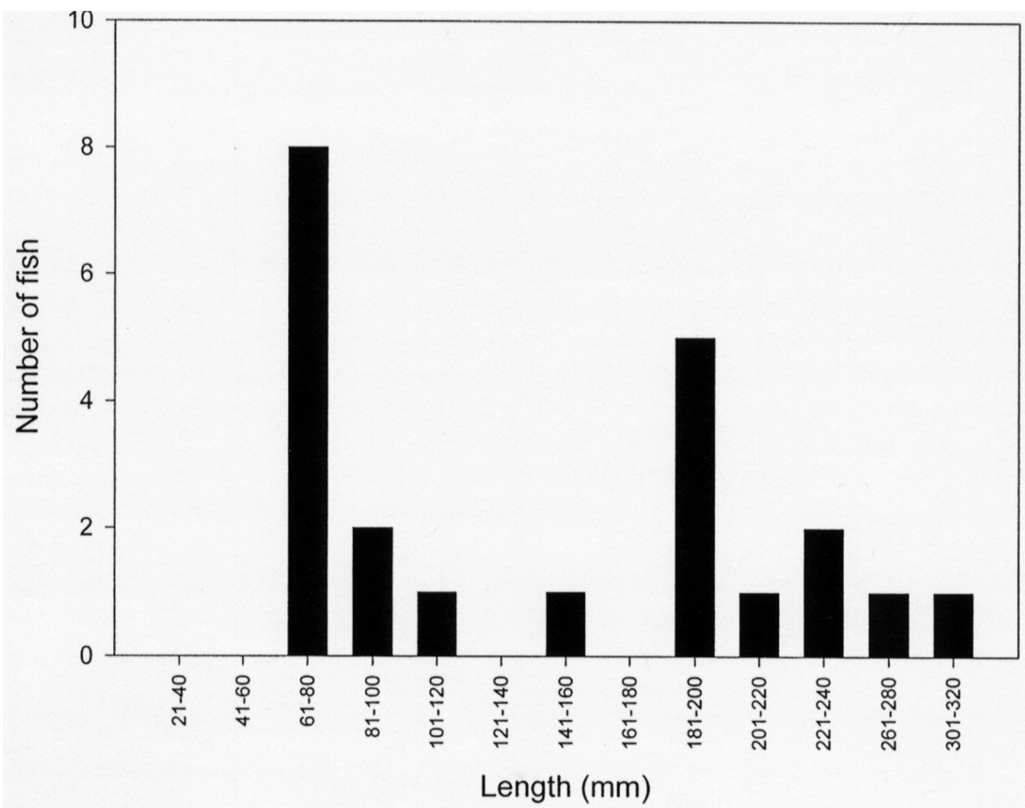
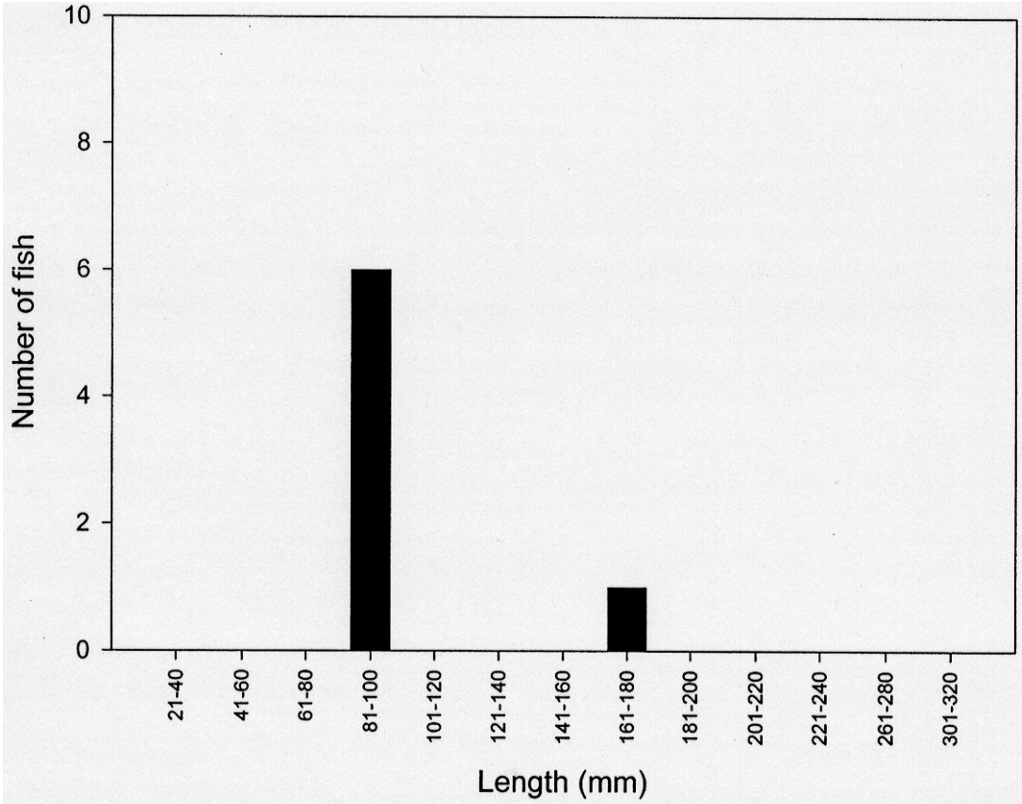


FIGURE 20. RAINBOW/STEELHEAD TROUT LENGTH-FREQUENCY DISTRIBUTION IN ROSS CREEK



9. STEELHEAD RESTORATION PLAN

9.1. OBJECTIVES AND SCOPE

The overall objective for steelhead restoration in the Corte Madera Creek Watershed is to improve creek water quality and habitat conditions to increase productivity of salmonids. However, before embarking on any improvement in the Corte Madera Creek Watershed, with regard to steelhead/rainbow trout, specific objectives need to be defined. Are we trying to restore the watershed to conditions which existed decades or even a hundred years ago? This would not be a practical objective, as its success would never be achieved, due to the human-caused impacts which have occurred and will continue to occur in this watershed. The fact that a steelhead/rainbow trout population exists in the heavily-impacted Corte Madera Creek Watershed is testament to the durability of this species. Durable as the species is, though, we must be practical and acknowledge that conditions are not, and never will be, the same as they were years ago. However, if the community works together and adequate funding becomes available to implement habitat improvement measures and continue the necessary scientific studies, I believe we, as a community, can not only improve habitat conditions, but demonstrate an increase in steelhead/rainbow trout populations in the Corte Madera Creek Watershed. Thus, the objective presented here is not to restore the watershed to "how it once was", but to improve or restore it to some extent. The degree to which the watershed improves will be directly dependent both on community involvement and scientific studies which will enable us to determine both the causes of, and solutions to, problems, with regard to steelhead trout habitat and populations. Two examples illustrate the importance of both science and the community involvement.

For a steelhead rehabilitation project to be successful, one must first identify the sources of the problems and limiting factors to the fish, and tailor the solutions (restoration) to rectifying or reducing the problems, if possible. Although there are a number of man-made dams in the creeks and a few large woody debris jams, most are probably not passage barriers for the anadromous steelhead. Some of the dams are low enough that we can be confident that they are not barriers; others are so high that they definitely are barriers to salmonid migration. However, without spawning studies to determine when and where the fish immigrate and spawn, we do not know which, if any, of these dams, actually prevent or impair immigration. We do not want to repeat the mistakes of the 1960's and 1970's, when resource agencies required that all potential barriers be removed from our rivers and creeks. The results of this state-wide creek "clean up" were disastrous for salmonids, as excellent physical habitat in the form of woody debris was removed from rivers and creeks all over the state. Thus, before removing any dams or other potential barriers, no inexpensive proposition, we need to know whether or not there is a need to remove them; are they a problem for the trout? If they are, restoration measures can be designed to remove the problem and help fish passage. And, if any of the potential barriers are not a problem to salmonids, time and money are not wasted on unnecessary activities.

Erosion and flood management are big issues for the people who live along or near the creeks in the Corte Madera Creek Watershed. Historically, flood control projects measures resulted in channelization of creeks and annual removal of woody debris and riparian vegetation before the winter rains. It is very important that any measures undertaken to improve steelhead habitat conditions not be sabotaged by measures undertaken to prevent flooding of human homes; the woody debris that is removed is probably home to juvenile, or even adult, salmonids.

One way of viewing steelhead trout restoration in the Corte Madera Creek Watershed which integrates science and public involvement to achieve watershed improvement, is to divide the project into the following phases (see Figure 21):

- Phase I: Undertake Preliminary Baseline Surveys
- Phase II: Steelhead Restoration Plan
- Phase III: Implementation of Restoration Actions Research and Surveys
- Phase IV: Monitoring Results of Restoration Measures
- Phase V: Adaptive Management

This Five-Phase Plan is modeled after CALFED's Comprehensive Monitoring, Assessment, and Research Program (CMARP, 1998). The approach integrates hands-on restoration activities with assessing the needs of the trout. CMARP (1998) states that "Appropriate and timely assessment of monitoring and research data is critical to effective management."

Phase I (Preliminary Baseline Surveys) was completed in 1999. The results of the preliminary baseline surveys provided information necessary to design the Steelhead Restoration Plan (Phase II), including the identification of limiting factors in the watershed. Phase II (Steelhead Restoration Plan) will be started with the submission of the Conceptual Steelhead Restoration Plan. The Plan will be completed as more information is gathered. Phase III (Implementation of Restoration Measures/Research and Surveys) will evolve over time. It will include both hands-on restoration actions and site-specific research and surveys, both of which will be dependent upon what the community wishes and budgetary constraints (Table 7). One possible type of research endeavor would be a study to determine whether or not water temperature is limiting to steelhead and/or rainbow trout (Figure 22). Phases IV (Monitoring Results of Restoration Measures) and V (Adaptive Management) will be works- in-progress. They will consist of future monitoring efforts to assess the relative success of the restoration efforts, and continual re-evaluation, and adaptation (Adaptive Management). If, after evaluating the results of a monitoring effort, a limiting factor is shown to be non-limiting, then no restoration activities will be needed. If, on the other hand, the factor is shown to be limiting to salmonids, than restoration activities can be designed to improve salmonid conditions (Figure 21).

FIGURE 21. CONCEPTUAL PLAN TO RESTORE CONDITIONS IN THE CORTE MADERA CREEK WATERSHED

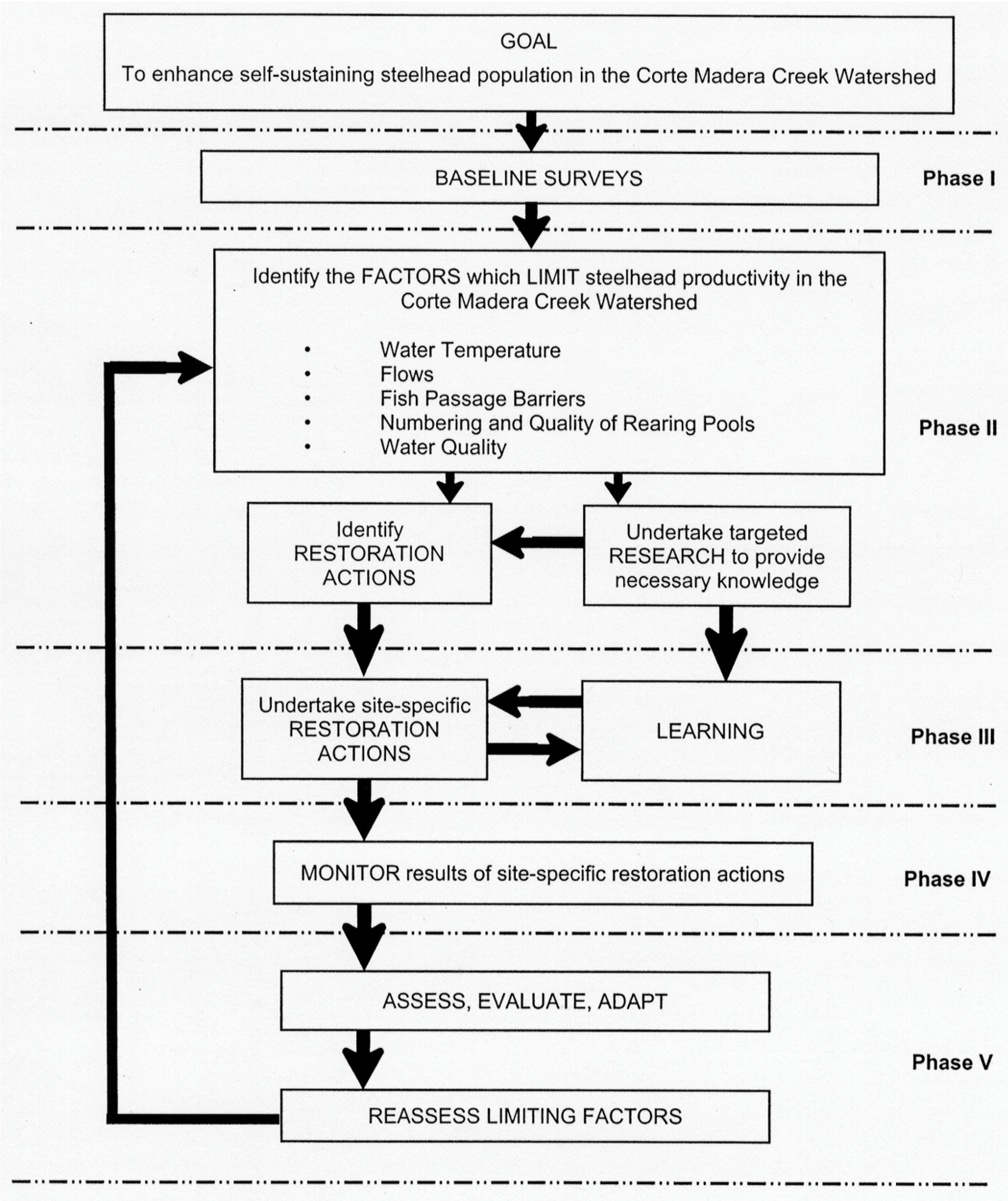
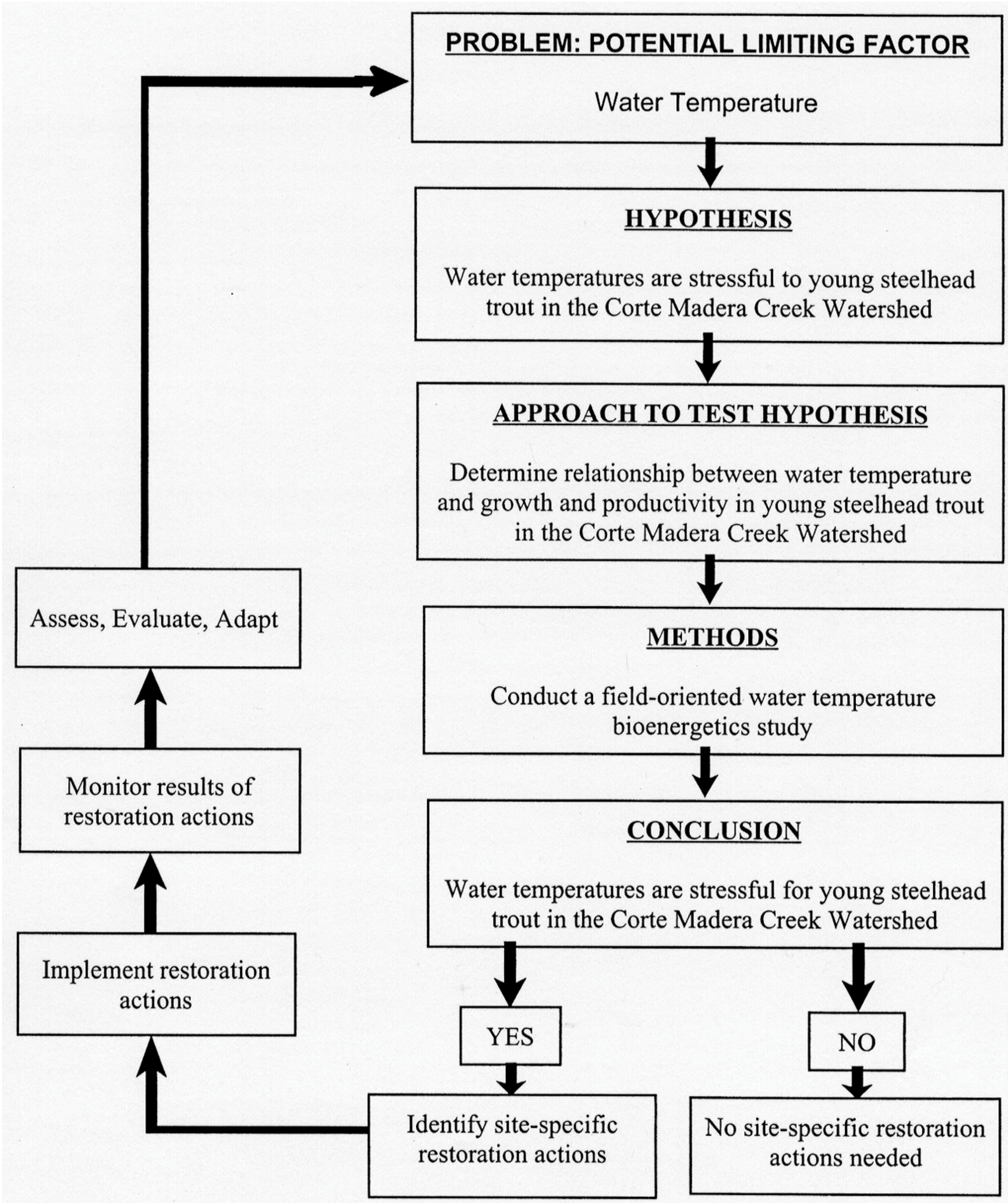


TABLE 7. SAMPLE OF RECOMMENDED RESTORATION ACTIONS AND RESEARCH ACTIVITIES[4]

Potential Limiting Factor	Recommended Restoration Actions	Recommended Research/ Surveys
Lack of Water	• Encourage landowners to stop/reduce diverting of water (diversions/wells) • Encourage natural geomorphic processes • Work with community to enhance groundwater (e.g., reduce impervious surfaces, promoto infiltration of winter rains)	• Identify streamflow requirements for salmonids in each creek • Identify which diversions are operating [1] • Identify locations where hydrologic/geomorphic processes could be modified
Water Temperatures	• Plant appropriate vegetation along riparian corridors • Increase water supply	• Food/Growth/Temperature Bioenergetics Studies • Water temperature monitoring
Fish Passage Barriers	• If warranted, remove barriers • Replace denil fish ladders with more effective structures	• Spawning Surveys • Evaluate adequacy of denil fish ladders
Rearing Habitat	• Remove concrete slabs from creeks [1] • Improve rearing habitat areas • Planting appropriate vegetation along eroded banks • Stream clean-up projects by community	• Productivity (i.e., spring smolt, summer rearing) surveys • Food/Growth/Temperature Bioenergetics Studies • Habitat Studies
Water Quality	• Education of community with regard to problem of pollutants in storm drains • Community should work with MCSTOPP	• Water quality sampling

[4] See Appendix H for list of Stream Reach Units (SRU's) which have diversion hoses and large slabs of concrete in them, and eroded stream banks

FIGURE 22. CONCEPTUAL PLAN TO DETERMINE WHETHER OR NOT WATER TEMPERATURES ARE STRESSFUL TO STEELHEAD AND/OR RAINBOW TROUT IN THE CORTE MADERA CREEK WATERSHED



9.2. PHASE I: UNDERTAKE BASELINE SURVEYS OF THE WATERSHED

To determine if and what restoration actions are necessary, baseline surveys are necessary. The results of such information can be used to assess existing water temperature, physical habitat, and water quality conditions within the watershed. By comparing the results of those types of data with the requirements of the species in question, one is able to identify factors which may be limiting to the steelhead productivity. The 1999 surveys provided much-needed information on the fishery resources conditions in the Corte Madera Creek Watershed. Habitat and water temperature conditions were assessed, and potential factors which may limit salmonid productivity were identified. As the restoration project continues, it is likely that additional baseline surveys and research will be required.

9.3. PHASE II: STEELHEAD RESTORATION PLAN

A steelhead Restoration Plan should have the following elements (Figure 21):

(1) Identification of Objectives;

(2) Determination of existing water quality and habitat conditions and factors limiting steelhead/rainbow trout;

(3) Identification of what restoration measures are possible, from both an economic and practical standpoint;

(4) Implementation of restoration actions;

(5) A Monitor Program to assess the relative success of the restoration actions; and,

(6) If warranted, re-evaluation of restoration actions, and adaptation.

9.3.1. Identification of Objectives

Identification of objectives is the most important aspect of any restoration plan. At the May 8, 2000 meeting of the Watershed Planning Advisory Committee, the group concluded that the overall goal of the restoration plan was, "To enhance a self-sustaining healthy steelhead population in the Corte Madera Creek System". The community needs to build on the conceptual Steelhead Restoration Plan by preparing a more detailed Plan . It should also be understood that the objectives of the community may change with time, as the restoration project evolves.

9.3.2. Determination of Existing Conditions and Factors which Limit Steelhead/Rainbow Trout Productivity

Before we can improve steelhead/rainbow trout conditions and, hence, population size, it is imperative that we know what the watershed provides, with regard to water temperature, water quality, and habitat conditions. From the results of the 1999 surveys (Phase I), we know enough about watershed conditions to be able to identify potential limiting factors. In addition, based on the results of the 1999 surveys, there are some site-specific restoration activities which could be undertaken that would improve habitat conditions immediately. Provided that studies and surveys continue to be functional (i.e., their objective is to identify cause-and-effect mechanisms which affect the salmonids), there really is a wide variety of types of studies/surveys that can be undertaken. The results of these and future studies will enable us to determine existing conditions within the watershed. From that information, we can determine the effectiveness of restoration measures.

9.3.3. Selection of Restoration Actions

The community needs to determine what type of restoration measures it wishes to undertake. To begin to restore the Corte Madera Creek Watershed, there is a wide assortment of activities which could be undertaken (Table 7). It would be prudent to begin with the least expensive options and proceed to more extensive, and hence, expensive, restoration actions (such as buying property to allow the removal of structures too near the creek).

9.3.4. Implementation of Restoration Actions

After selecting restoration measures, they need to be implemented. As the project evolves, so too will the restoration measures undertaken, as part of the adaptive management strategies included in the Restoration Plan (Figure 21).

9.3.5. Monitoring the Results of the Restoration Actions.

To determine whether or not the restoration undertaking has been successful, with regard to steelhead/rainbow trout productivity, the results of the restoration measures should be monitored. This monitoring could be undertaken in several ways. For example, the results of the various fishery resources-related studies which provide data on existing conditions would provide information upon which to base the relative success of the restoration activities. Or, to determine whether or not water quality conditions had improved in a certain area, the community could work with the State Water Quality Control Board; water quality conditions could be monitored in selected areas.

Regardless of what level of monitoring is undertaken, one of the most effective methods for tracking success/failure and having a continual running dialogue between scientists, the community, agency personnel, etc. is to design a *Watershed-Based Database on a GIS system.* Developing such a system should be a priority, not only for monitoring the effectiveness of the steelhead restoration efforts, but for all other efforts implemented as part of the watershed plan.

9.4. PHASE III: RESTORATION ACTIONS/RESEARCH AND SURVEYS

The following potential limiting factors were identified, based on the results of the 1999 surveys and other relevant information:

(1) Lack of water (i.e., stream flows);

(2) High water temperatures;

(3) Fish passage barriers (i.e., man-made dams);

(4) Rearing habitat; and,

(5) Water quality conditions.

The following two general outcomes resulted from 1999 surveys:

(1) The identification of a number of restoration actions which could begin as soon as funding becomes available; and,

(2) Some “data gaps” were identified, for which further research is necessary before one can determine whether or not restoration actions are required.

Each of these is discussed below.

9.4.1. Recommended Restoration Actions

Based on the results of the 1999 surveys, the following types of restoration actions are recommended, as soon as funding becomes available (Table 7):

- Reduce number of diversions;
- Remove numerous concrete slabs from creeks;
- Work with community to reduce water quality problems;
- Plant appropriate vegetation along eroded banks;
- Stream clean-up projects by community; and,.
- Education of the community to enhance watershed, as a whole.

There are dozens of hoses in the creeks that appear to be used to divert water from the creeks. Are these hoses used to pump water out of creek or do they drain swimming pools, or do they drain off roads and/or property into the creeks? Do the owners have permits, and if they are pumping water out of the creek, is this really necessary? Enquiring fish minds want to know! To determine whether or not they would be willing to cease robbing the fish of their water, homeowners need to be educated about the needs of the fish.

Other than the lack of water in the summer and the resultant high water temperatures, the single most problematic issue, with regard to trout habitat, is the quantity of concrete, asphalt, and other garbage in the creeks. The large concrete slabs in the various creeks range in size from one meter to more than 10 meters in length. The creeks flowing through downtown San Anselmo, downtown Fairfax, and Ross are the biggest problem areas. The concrete slabs block flows and provide a haven for roaches and stickleback, but very poor habitat for salmonids.

There are hundreds of channels which ultimately contain runoff from streets into the creeks. This is probably a real problem, with regard to water quality, particularly during the winter months. However, it is the washing of cars with non-biodegradable soap, and washing of paintbrushes, etc. which are summer-related problems. Identification of problem areas and perhaps a community outreach program could be undertaken to help reduce non-point source pollution.

There were a few sites where severe bank erosion was occurring. The community needs to consult with a geologist/geomorphologist and, perhaps, landscaper, and determine what, if anything, could be done to contain them in a "fish friendly" fashion (i.e., vegetative planting rather than rip rap).

Stream clean-up projects need to be undertaken several times a year. Although most of the towns already have some form of fall stream clean-up, a few hours by a handful of volunteers on one day of a weekend is helpful, but insufficient. We now have a photographic database of the major creeks. These photos can be used to identify where the smaller garbage is and what needs to be removed. Water heaters, old pipes, and concrete blocks can all be manually removed with a lot of human power and not much expense. The expensive part of creek clean-up will be the removal of the really big concrete slabs.

It is essential to plan activities that will further educate the public, both about the steelhead/rainbow trout and the factors which affect them. For example, there could be a series of field trips for the public, led by a group of scientists, such as a fisheries biologist, a geologist, and a hydrologist. The focus would be to understand what the trout require, the interaction of the factors which affect trout needs, and how landowners can help the fish. So often I have found that the public believes that all we scientists do are "studies", which have no basis in practical reality. Such field trips would provide the opportunity for the interested public to observe functional fisheries biology, where the surveys and studies focus on cause-and-effect mechanisms, rather than academic science.

It would also be beneficial to involve school children in the importance of protecting and helping the animals in the creeks. Field trips could be scheduled with local schools. The watershed project could be described and students could observe first-hand, ways of improving creek conditions. Perhaps they, too, would become interested in contributing to the restoration effort of the steelhead trout in their creeks, both as children and, later, as adults.

Other restoration actions which may be implemented later include (Table 7):

- Plant appropriate vegetation along riparian corridors to increase shade and cover for salmonids;
- Remove barriers, if warranted, to allow passage by salmonids;
- Replace denil fish ladders with more effective structures, if warranted; and,
- Improve salmonid rearing habitat conditions.

However, before these restoration actions are undertaken, further research is needed to assess the utility and location of such actions.

9.4.2. Data Gaps/Further Research Needs

Based on the results of the 1999 surveys, some "data gaps" were identified. Before one can determine whether or not restoration actions are required, further research is necessary for the following (Table 7):

- Food/growth/temperature bioenergetics studies;
- Spawning surveys/adequacy of denil fish ladders;
- Productivity studies (e.g., smolt trapping, summer rearing);
- Water quality monitoring; and,
- Salmonid streamflow requirement studies.

Steelhead are both state- and federally-listed and, hence, of great importance, with regard to protection. Water temperature requirements are site-specific and data from laboratory studies really should not be used to determine optimal thermal ranges. Having already collected the beginnings of a large thermal database in the watershed, the next obvious step would be to take those data, together with future site-specific studies to determine whether or not the high water temperatures during the spring and summer months were detrimental to trout productivity (i.e., is temperature a major limiting factor in this watershed?). To determine whether or not water temperature is a limiting factor to steelhead and/or rainbow trout, a food/temperature/growth (i.e., "bioenergetics") study (some of which could be done in conjunction with the smolt trapping studies), is necessary.

Is there a passage problem for anadromous steelhead? Where and when do steelhead spawn in the creeks of the Corte Madera Creek Watershed? Do any of the concrete dams in the creeks present a physical barrier to these fish during their spawning immigration? Are the denil fish ladders useful in terms of fish migration? To answer these questions, steelhead trout spawning surveys need to be conducted. In addition, most, if not all, of the denil fish ladders should be replaced with new, more effective passage structures.

What is the relationship between rearing habitat and productivity in the Corte Madera Creek Watershed? How does it compare with other watersheds in Marin or in other areas of the state? To answer these questions, spring smolt trapping studies are needed. In addition, the summer habitat/electrofishing surveys should be continued, as there is so much variability from year to year, with regard to both habitat and populations.

Are water quality conditions in the Corte Madera Creek Watershed suitable for salmonids? Little is known about the water quality conditions in the watershed. To assess water quality conditions, water quality monitoring is needed (Table 8).

The flow requirements for each of the life stages of steelhead and rainbow trout in the Corte Madera Creek Watershed are unknown. To assess flow requirements, several types of site-specific studies could be conducted. For spawning, the Thompson (1972) method would be useful. For rearing, the instream flow incremental methodology (IFIM) has been used (Bovee, 1978). However, unless suitable biological data (e.g., thermal requirements, water quality requirements, habitat requirements) can be integrated into an IFIM, it is of limited value.

9.5. PHASE IV: MONITORING THE RESULTS OF THE RELATIVE SUCCESS OF THE RESTORATION ACTIONS

Monitoring the results of restoration measures will be a process, occurring over many years. In the current funding environment, it is necessary to undertake restoration measures based on the results of scientific studies, with monitoring that will document the effectiveness of the measures we have implemented. Designing a *Watershed-Based Database on a GIS system* should be a priority in developing, undertaking, and monitoring the effectiveness of the steelhead restoration efforts. It would be the most effective method for tracking success/failure and having a continual running dialogue between scientists, the community, agency personnel.

The Watershed-based GIS system could be on a Web site, so that anyone with a computer and modem could access the information at any time. The results of scientific studies, anecdotal information, restoration activities could be depicted in layers of information which could be "pulled up" on the Internet. Examples of types of information which could be posted include:

- Results of past surveys (i.e., the raw data) such as the ones we conducted in 1999, including photographs and whom to contact to ask questions;
- Potential (and actual, once spawning surveys have been conducted) steelhead/rainbow trout spawning areas;
- Examples of good rearing areas for steelhead/rainbow;
- Sites of potential anadromous salmonid migration barriers;
- Restoration activities (past, ongoing, proposed future);
- Dates of meetings, field trips; and,
- Status of Corps of Engineers Corte Madera Creek Flood Control Project

TABLE 8. IMPORTANT WATER QUALITY PARAMETERS TO MONITOR IN THE CORTE MADERA CREEK WATERSHED[5]

Parameter	Reason for Monitoring
Biological Oxygen Demand (BOD)	BOD is a measure of the quantity of oxygen used by microorganisms in the aerobic oxidation of organic matter. When BOD is high, it is an indication that a creek, or area within a creek is stagnant and there is either not much or no free oxygen. Trout do not live well in stagnant water.
Fecal Coliform	Indication of human and/or animal waste products
Herbicides/Pesticides or Specific Heavy Metals	Many of the herbicides/pesticides used on lawns and plants end up in creeks. Such herbicides and pesticides, which contain heavy metals, can be extremely toxic to fishes, particularly trout.
Oil and Grease	Oil and grease flow into the creeks from the streets. If present in sufficient quantities, they can result in asphyxiation of trout and other species within the watershed
Oxygen, Dissolved	Essential for life; low (e.g., less than 5 mg/l) concentrations can stress trout
Nitrates	Although nitrogen is an element needed by all living plants and animals, high nitrate concentrations in creeks can lead to algae blooms which, in turn, decrease the habitat value for trout. Stormwater runoff can carry nitrate-containing fertilizers from laws into the creeks. As a result, water can cease flowing, habitat conditions decline for trout, and other more hardy fishes will replace the trout..
pH	Indication of acid, neutral, or alkaline conditions. Salmonids generally prefer pH of 7-9
Phosphates	Phosphates are part of living plants animals, their by-products, and their remains. High phosphate concentrations are indications of eutrophication. Phosphorus stimulates plant growth and eventually, an entire reach may fill with aquatic vegetation. Such habitat is unsuitable for trout and other more hardy fishes will replace the trout.
Temperature, Water	Water temperature controls the life of trout and all other fishes. Water temperatures which are stressful to trout can lead to decreased survival of a species. Water temperatures should always be measured over time, using continuously operating thermographs in representative habitats within a creek.
Turbidity or some measure of suspended solids	Turbidity is a measure of the relative clarity of water: the greater the turbidity, the murkier the water, and the less habitable for trout. Turbidity increases as a result of suspended solids in the water. High turbidity may be caused by soil erosion, urban runoff, abundant bottom feeders (e.g., carp) that stir up bottom sediments, or algal growth.

[5] When monitoring water quality with the purpose of determining existing conditions for trout, there are a variety of parameters which can be used. Those listed in Table 8 are some of the more important ones. However, regardless of what parameters are chosen, monitoring should only be undertaken as part of a Watershed Plan and a detailed Water Quality Monitoring Plan should be designed as part of that Watershed Plan.

9.6. PHASE V: ADAPTIVE MANAGEMENT

Adaptive Management is a useful tool for watershed restoration. The process of Adaptive Management uses the following incremental approach (Brown et al., 1998):

(1) Defining the problem (s);
(2) Taking action;
(3) Evaluating the benefits of the action; and,
(4) Modifying subsequent actions, as necessary.

Thus, for example, instead of spending time and money on removing dams which may not be passage barriers for anadromous steelhead, the dams are first assessed to determine whether or not they present a problem to the migrating fish. As a result, one might discover that some of the dams were passage barriers, but others were not. One can then remove only those which present a problem to fish migration. Or, the community might spend considerable time and cost planting riparian vegetation with the intent of reducing water temperatures by providing shade. Instead, to determine whether or not such actions are warranted and where such restoration should occur, both temperature monitoring and modeling studies should be undertaken beforehand, Then, if water temperature appeared to be a problem and the results of the water temperature studies demonstrated that the planted vegetation could improve water temperature conditions for salmonids, restoration actions could be undertaken in the watershed. However, if the results of water temperature studies demonstrated that the planted vegetation did not improve water temperature conditions for salmonids, then such restoration actions would not be undertaken. The use of Adaptive Management to enhance steelhead conditions in the Corte Madera Creek Watershed will allow one to either proceed with restoration actions, or to modify the planned actions, if those actions do not appear to be achieving the intended results (Figure 21).

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11. APPENDICES

Appendices are not included in the electronic version of this document.

12. GLOSSARY

Glossary of some terms used in the report[6]

acclimate: Adaptation to slowly changing new conditions

alevin: A young salmonid that still has it's yolk sac attached (pre "fry" stage)

anadromous: Fishes which migrate from fresh to salt water and vice versa

carrying capacity: The maximum number of individuals of a particular species that can be supported indefinitely by a given part of the environment

crustacean: Primarily aquatic, gill-breathing animals, such as shrimp, crabs, and lobsters

euryhaline: Ability to withstand high salinity concentrations

eutrophication: The enrichment of bodies of fresh water by inorganic plant nutrients (e.g., nitrate, phosphate). It may occur naturally, but can also be the result of human activity (e.g., fertilizer runoff, sewage discharge). The biomass of phytoplankton and herbivorous zooplankton increases, and species diversity decreases. The water becomes turbid in the summer, the growth of the large aquatic plants may eventually become suppressed and algal blooms are frequent. The water may be low in dissolved oxygen through the decay of large amounts of organic matter.

fry: Term assigned to the young salmonid that has recently emerged from the gravel (pre "juvenile" stage)

grisle: Male anadromous salmonid that has spent only one year at sea before returning to fresh water.

jack: See "grisle"

juvenile: Term assigned to young salmonid that has reached a given length, the length differs from study to study (after the "fry" stage)

limiting factor: Factor which has the potential to restrict an individual or population

metabolic rate: A measure of the rate of metabolic activity in a living organism. The rate at which an organism uses energy to sustain essential life processes such

[6] Sources:

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as respiration, growth, reproduction, blood circulation, muscle tone, and activity.

milt: Testis or sperm of fishes

natal stream: Stream where fish hatch

parr: See "parr-smolt transformation"

poikilotherm: A "cold-blooded" animal. An animal which has very limited capability in terms of regulating body temperature.

redd: Nest

repeat spawners: Adult steelhead that returns to the ocean and then to the stream to spawn again

resident: Fish which does not migrate to sea (e.g., rainbow trout)

salmonid: Trout and salmon.

smolt: See "parr-smolt transformation"

parr-smolt tranformation (smoltification): Behavioral, morphological, and biochemical changes which transform a darkly pigmented, bottom dwelling freshwater salmonid (the parr) into a pelagic silvery fish (the smolt)

threshold effect: The harmful effect of a small change in environment which exceeds the limit of tolerance of an organism or population, and which becomes evident

threshold value: A critical level or value which must reached before an event occurs

yolk sac: The membranous sac rich in blood vessels which develops around the yolk in the eggs of vertebrates, such as fishes and mammals, and which is attached to the embryo and through which nutrients pass from the yolk.