SAN LORENZO RIVER WATERSHED MANAGEMENT PLAN

FISHERY HABITAT AND THE AQUATIC ECOSYSTEM

TECHNICAL SECTION

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November, 1979

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FISHERY HABITAT AND THE AQUATIC ECOSYSTEM

OF THE SAN LORENZO RIVER WATERSHED

The flow of water, nutrients and organic debris supports an important and diverse biota in the streams of the San Lorenzo Watershed. The overall health of this biologic community is essential for maintenance of the economically important steelhead and silver salmon fishery and for maintenance of water quality through the natural purification processes. The aquatic community in turn is dependent on the character of the Watershed for the maintenance of suitable habitat. Thus the health of stream biota is important as an indication of overall Watershed health.

Several studies have been carried out in the streams of the San Lorenzo Watershed on primary productivity and eutrophication, occurrence of bottom organisms, and the quality and quantity of available fishery habitat. Results of those studies will be presented following a general discussion of the characteristics of stream ecosystem.

GENERAL CHARACTER OF STREAM ECOSYSTEM

A stream carries much more than water from a Watershed. It carries dissolved nutrients, dissolved organic material, and organic debris. These potential food supplies are exploited immediately by organisms that make the stream their home and source of nourishment. They in turn serve as food for other stream organisms. The stream community consists of a wide range of organisms, from microscopic bacteria and diatoms to silver salmon over three feet long. These organisms are linked to each other and the aquatic and terrestrial environment around them by a set of complex relationships that make up the stream ecosystem.

Aquatic Foodchains and Life Cycles

The food and energy that supports the stream organisms comes from two sources: photosynthesis of aquatic plants and, more importantly, the input of dead leaves and other organic material from the terrestrial environment (Figure 1). Most of the instream photosynthesis is carried out by attached algae and diatoms, often microscopic in size. This attached algae may be eaten directly by the animals that scrape it off the rocks or it may be torn loose and transported downstream with other living and non-living organic material (of aquatic or terrestrial orgin), collectively known as detritus. Detritus serves as the main source of energy for the aquatic ecosystem. Detritus ranges in size from large branches to microscopic particles and is utilized in innumerable ways as it passes downstream.

When leaves or other detrital material first enters the stream, it is attacked immediately by fungi and bacteria. The leaf is then broken up and eaten by organisms that get most of their nourishment from the attached fungi and micro-organisms. This breakdown continues until the original

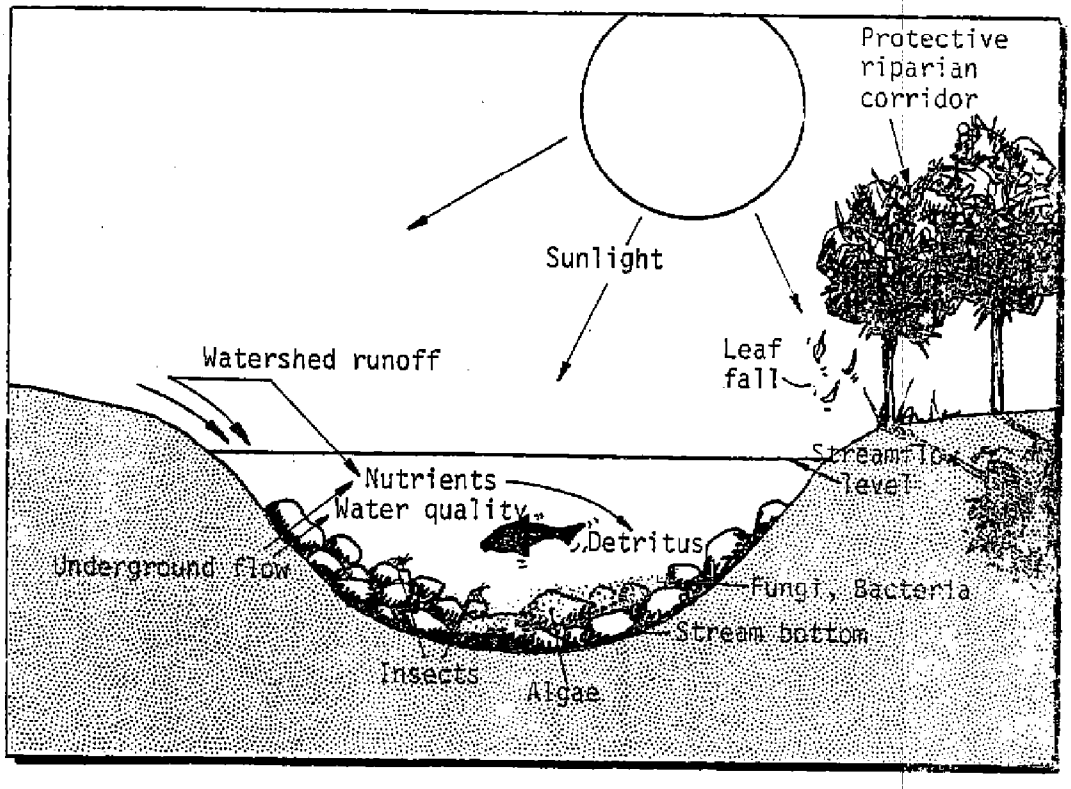

FIGURE 1: AQUATIC ECOSYSTEM

material is fragmented to near microscopic size. Each size class of detritus is eaten by different types of organisms: shredders, scrapers, and filter feeders. These animals are in turn eaten by carnivores or die and become part of the detrital pool. The diet of filter feeders also includes the numerous bacteria which live off dissolved organic matter and nutrients in the stream.

Most of the animals that participate in this breakdown of detritus are aquatic insects, usually immature stages of species that spend their adulthood in the terrestrial environment. Many of the carnivores are also insects. Some of the major insect orders present in the stream are caddisflies, mayflies, stoneflies, beetles, and true flies.

Many of these insects provide food for fish. The two species of fish that are predominant in the San Lorenzo Watershed are the steelhead trout and the silver salmon. Steelhead are predominant. Both are anadromous, hatching and spending their juvenile life in the stream, maturing in the ocean, and then returning to the stream to spawn. Silver salmon migrate upstream to spawn with the first high winter flows. Steelhead generally spawn all winter with peak activity in January and February. Both species move upstream to the headwater areas, mating and laying their eggs in areas of loose gravel. After spawning the salmon die, but many steelhead survive and migrate back to the sea. Some may spawn again.

Two to three months after spawning the young fish emerge from the gravel and begin to feed on insect larva and other small animals. Juveniles of both species generally remain in the streams for a year, migrating to the ocean in March and April. Generally, only about 10 percent of the juveniles survive to migrate to the ocean (Shapovalov and Taft, 1954). Once in the ocean they grow rapidly, nourished by the abundant resources. After two years, when most of the fish return, they have grown from a length of only 4 inches to an average length of 25 inches. The size of the return migration each year may vary as much as 50 percent, due to the variability of stream conditions during spawning and growth of the young fish. The survival of the fish is an uphill battle against great odds. Out of every four thousand salmon or steelhead eggs hatched, there will be on the average only one fish that survives to maturity and returns to spawn (Shapovalov and Taft, 1954).

Other fish that occur in the Watershed are resident rainbow trout, roach, stickleback, sculpin, and the anadromous Pacific lamprey. Altogether about 25 different species have been reported in the San Lorenzo River (Table 1).

Factors of the Stream Environment

The functioning of the stream ecosystem and the distribution of the aquatic organisms is regulated by the various interrelated physical and chemical parameters of the stream environment: current velocity, substrate, discharge, chemical quality, temperature and light availability. Movement of water differentiates stream ecosystems from other aquatic ecosystems. It molds the channel shape, determines the character of the bottom and provides increased food-availability for stream organisms.

TABLE 1

FISHES REPORTED FROM THE SAN LORENZO RIVER

FAMILY	SCIENTIFIC NAME	COMMON NAME
Petromyzontidae	Entosphenus tridentatus	Pacific lamprey
Clupeidae	Clupea harengus pallasi	Pacific herring
Salmonidae	Oncorhynchus gorbuscha	Pink Salmon
	Oncorhynchus keta	Chum salmon
	Oncorhynchus kisutch	Coho salmon
	Oncorhynchus tshawytscha	Chinook salmon
	Salmo gairdneri	Steelhead
Cyprinidae	Hesperoleucus symmetricus	California roach
	Rhinichthys osculus	Speckled dace
Catostomidae	Catostomus occidentalis	Sacramento sucker
Atherinidae	Atherinopsis californiensis	Jacksmelt
Gasterosteidae	Gasterosteus aculeatus	Threespine stickleback
Syngnathidae	Syngnathus californiensis	Kelp pipefish
	Syngnathus griseolineatus	Bay pipefish
Percichthyidae	Morone saxatilis	Striped bass
Embiotocidae	Amphistichus koelzi/	Calico surfperch
	Cymatogaster aggregata	Shiner perch
	Embiotoca jacksoni	Black perch
	Phanerodon furcatus	White seaperch
	Rhacochilus toxotes	Rubberlip seaperch
Cottidae	Cottus aleuticus	Coastrange sculpin
	Cottus asper	Prickly sculpin
	Cottus gulosus	Riffle sculpin
	Leptocottus armatus	Pacific staghorn sculpin
Pleuronectidae	Platichthys stellatus	Starry flounder

Generally, a stream is composed of alternating reaches of fast, rocky, riffles, and slow pools. In riffles, the rocky bottom material provides a wide variety of living conditions for organisms adapted to specific flow velocities. Different faces of the rocks are exposed to different velocities, while the spaces between the rocks and gravel provide protection from high velocities. The rocks provide a solid base for the growth of algae, while the spaces between rocks trap large amounts of detritus. The rapid current through these riffle areas increases the availability of food, nutrients, and dissolved oxygen by the continual transport of these materials past stream organisms. Turbulence of flow over the riffles replenishes the dissolved oxygen in the water. It also induces flow down through the openings between the rocks and gravel allowing the survival of fish eggs and small organisms in the upper parts of the stream bottom. All these factors serve to make riffle areas the most productive areas of the streams. This productivity will be much less in riffle areas where living space is filled and water movement is blocked by the presence of sand and finer bottom materials.

Pools are also important habitat areas. Much of the decomposition of organic debris takes place in the pools, releasing nutrients for downstream transport. Animals that prefer slower flows occur in the pools. Pools are important for fish, providing shelter and resting areas. Generally, an equal distribution of pools and riffles is ideal for fish production.

The seasonal variations in streamflow have very important impact on the stream biota. High flows in winter provide for the flushing of accumulated fine sediment increasing their suitability for shelter, spawning, and the growth of stream invertebrates. Extremely high flows may be detrimental to stream life, due to excessive scour which removes algae, detritus, and invertebrates, and destroys spawning areas. Sufficient baseflows between storms are necessary for the migration and spawning of the anadromous fishes.

Flows in summer are very critical to the stream ecosystem. In the summer, streams shrink in size, temperatures go up, concentration of chemical substances increase, and growth of algae may become excessive. High baseflows moderate these conditions and allow the stream to support a more diverse and productive ecosystem. The amount of living space and productivity is related directly to the amount of flow.

Water quality influences both the organisms that occur in a stream and the total productivity of the stream. The most important stream parameter is dissolved oxygen. In the San Lorenzo Watershed, most aquatic organisms, especially fish, require high levels of dissolved oxygen. Factors that contribute to high dissolved oxygen are low stream temperature, turbulent flows and instream photosynthesis. Factors that lead to a depletion of oxygen are high temperature, still water, and high rates of biological activity, especially decomposition. Generally, in the San Lorenzo Watershed, dissolved oxygen will only approach critically low levels during the summer when temperatures are high, algae growth is extensive, and there is a reduction of turbulence.

Other critical parameters are temperature, pH, total dissolved solids, hardness, sulfate, and iron. Most organisms are limited to a certain range of these parameters. A stream will thus be inhabited by the types of organisms that are best suited to the chemical conditions that prevail there.

The organic and inorganic nutrient content controls the productivity of the stream. The amount of detritus and dissolved organic material provides the main food base for the ecosystem. The type of organic material present is very important. Leaf litter from riparian trees provides much more food than litter from coniferous trees. The levels of nitrogen and phosphorus regulate the amount of algae growth. Higher levels of these nutrients will provide for growth of more algae, supplying more food to the ecosystem. Nutrients also increase the food value of detritus by stimulating the growth of fungi and bacteria. Excessive amounts of either organic materials or nutrients can overload the stream ecosystem, providing an increase in biologic activity that can lead to a reduction in dissolved oxygen and the death of many important organisms. This is known as eutrophication.

A factor influencing the productivity of the stream ecosystem is the amount of light that reaches the stream. More light will allow for more in-stream photosynthesis, increasing ecosystem productivity. Greater exposure to light will also increase stream temperatures. The amount of light is determined by the amount of vegetation shading the stream, the shape of the stream valley, and the clarity of the water. Light availability will be much less in narrow canyons or in streams where suspended sediment makes the water murky.

Condition of the Stream Ecosystem

It is practically impossible to isolate the effects of any one of the environmental factors on the aquatic ecosystem. Organisms are not influenced by any one isolated factor, but by the whole set of environmental factors as they work together. Several terms have been developed to describe the overall condition of the stream ecosystem: diversity, productivity, carrying capacity, and stream health.

Diversity is a measure of the variety of different types of organisms present. Biologic communities with high diversity are generally considered to be more stable and more able to absorb disturbances without significant disruptions. Areas of low natural diversity are usually areas with harsh environments such as hot springs or alpine areas. A reduction in diversity is thus considered to be indicative of an adverse change in the environment so that it becomes unsuitable for the continued survival of some species. In a stream this might be caused by siltation or by a change in the chemical quality of the water.

Productivity is a measure of the rate that biomass is produced in the stream. Primary productivity refers to the rate of plant growth while secondary productivity refers to the growth of herbivores and tertiary

productivity refers to the growth of carnivores. High productivity in the upper levels of the food chain requires high productivity in the lower levels. Overall productivity may be limited by a lack of plant nutrients which limits the primary productivity.

Carrying capacity usually refers to the "living space" for fish provided by the stream. The number of fish a stream can support is dependent on the amount of food available, the amount of flow, depth of flow, and shelter from predators. Surface area is generally one of the most important measures of carrying capacity (Burns, 1971).

Stream health is a general term used to describe the condition of the stream habitat. A healthy stream should generally have high diversity and high but not excessive productivity.

ALGAL GROWTH AND EUTROPHICATION

Many people feel that growth of algae has reached nuisance proportions in many parts of the San Lorenzo Watershed. Excessive algal growth has had adverse impacts on aesthetic value, recreational use and on the quality of water used for domestic supply. On several occasions, the City of Santa Cruz has had to resort to more expensive treatment procedures to remove obnoxious tastes and odors imparted by excessive algal growth in the River.

Excessive algal growth can be indicative of a condition known as eutrophication. Eutrophication signified by excessive plant growth is stimulated by high nutrient concentrations (Golterman, 1975). This definition can be expanded to describe a eutrophic system as one that has a total potential for high concentrations of nutrients (and resultant plant growth), depending on nutrient cycling in sediments and biota (Hynes, 1969). Nutrient enrichment can also lead to intermediate conditions less extreme than eutrophication.

If the potential for algal growth in an area increases due to greater concentrations of nutrients, the few algal species which thrive in enriched conditions will have a competitive edge and predominate (Margalef, 1965). This domination by a few species destroys the natural diversity of the area, which normally helps maintain a stable, healthy ecosystem.

Aesthetic degradation occurs when algal density reaches a level which is highly visible, or when malodorous substances are released into the water. When algal biomass becomes a nuisance, as it has in areas of the San Lorenzo the standing crop is in far greater supply than the substances responsible for the algal growth (Williams, 1964). In this case, the algal mass can be considered a pollutant. In extremely eutrophic conditions, algal growth becomes so excessive that water quality is further jeopardized. Dissolved oxygen levels become depleted by the nocturnal biological oxygen demand of the algae, and nutrient levels can be greatly increased by large scale senescense of algal populations (Wetzel, 1975).

Algal Growth in the San Lorenzo Watershed

In order to investigate the nuisance algal growth and determine whether eutrophication was occurring or likely to occur in the Watershed, the extent of algal distribution, the impacts resulting from pervasive growth and the factors contributing to persistent presence of algae in the San Lorenzo were studied. Most of this work focused on the main River from the Waterman Gap area near the top of the Watershed to Sycamore Grove at the lower end of the Watershed. Work was done both during the extremely dry summer of 1977 when maximum River degradation might be expected, and the summer of 1978 when the flow regimes were in a more normal state.

Species composition, biomass density, and relative diversity of algae were determined for comparison between sample areas and to represent the River system as a whole. Analysis of attached macro-algae (filamentous form) samples is presented in Table 2. At the time of algal sampling, water quality parameters were checked at each station. In addition, a diurnal water quality study which monitored these parameters at three of the algal sample sites was conducted on 25-26 August 1977. The following findings are substantiated by conditions observed during both 1977 and 1978. A detailed discussion of the results can be found in the report prepared by Butler (1978).

Extensive growth of algae was found to be present in many areas throughout the Watershed. However, from 1977 to 1978 there were extreme changes in the distribution of dense algal growth in response to increased flow regimes. In general, there was greater extent of algal growth during more normal flows following the drought. This was observed quantitatively at the algal sample sites and qualitatively throughout the San Lorenzo system. The distribution of algae in the San Lorenzo has not yet caused significantly adverse impacts to the overall aquatic ecosystem. Eutrophication is not occurring. However, in some parts of the River, the character of the aquatic ecosystem has been altered by excessive algal growth and conditions approaching threshold levels. If present conditions persist or worsen, these thresholds could be exceeded, with resultant degradation of the stream habitat.

Areas of very thick filamentous green algal growth occurred in 1977 but they were largely confined to low velocity pools and were comprised of species which thrive in standing water, the Spyrogyra species (Round, 1973). Increased distribution of algae throughout the San Lorenzo in 1978 was due to 1) greater availability of suitable algal habitat (i.e., greater subsurface area), 2) a probable increase in absolute nutrient concentrations resulting from storm wash-off, and 3) a greater availability of nutrients in rapidly moving water (Hynes, 1974) which allows constant nutrient replenishment for algal development. The latter aspect is supported by the 1978 basin-wide succession of algal species which prefer moving water, the Cladophora species (Whitford and Schumacher, 1961).

TABLE 2

ALGAE BIOMASS AND SPECIES COMPOSITION

(EUTROPHICATION STUDY SITES)

STATION	1977 Dry Weight	1977 Dominant Species	1978 Dry Weight	1978 Dominant Species
SLR at Waterman Gap	Negligible, not collected		3.80 gm 15.15	*Cladophora glomerata*
SLR near Boulder Creek	2.0 gm 2.1 5.9 6.6	*Spirogyra elipsospora* *S. ribularis* *S. maxima*	1.92 1.9 5.7 3.02	*Cladophora glomerata*
SLR near Ben Lomond	28.8 4.5 16.5 21.7	*Spirogyra elipsospora* *S. ribularis*	negligible, not collected	*Cladophora sp.*
SLR at Big Trees	12.3	*Rhizoclonium sp.*	0.76 3.36 5.89	*Cladophora* sp. *Oedogonium* sp.
SLR at Sycamore Grove	0.7 4.3 4.6 3.5	*Cladophora* sp. *Spirogyra* sp.	2.5 0.49 0.21	*Cladophora* sp. *Ulothrix* sp.
Upper Zayante	ADDITIONAL SAMPLE SITES		2.13 0.88 1.71	*Cladophora* sp. with *epiphytic* diatoms
SLR at Waterman Gage Station			15.65 15.07	*Cladophora* sp.
Zayante near Woodwardia			8.78 8.92 8.81 7.33	*Cladophora* sp. *Rhizoclonium* sp. much epiphytic diatoms
Bear Creek			11.76 5.87 10.36 17.29	*Cladophora* sp.
Boulder Creek			not sampled	*Cladophora* sp. *Lemanea* sp.
SLR below Boulder Creek			not sampled	*Cladophora* sp.

Most areas of the Watershed showed algal densities and species composition indicative of moderate nutrient enrichment in both years. Conditions in 1977 at the Boulder Creek and Ben Lomond sample sites indicated greater degradation than at other sites on the River. Both of these stations were low velocity pool areas which favored the dense growth of predominantly Spirogyra species. Consequently, the diversity of algal species was lower at these sites than at other areas due to a high degree of dominance by few species. Phytoplankton samples from the Boulder Creek site showed the lowest number of species (56) of any samples (5 station average = 89.2), while having the highest (64%) degree of dominance (5 station average = 47%) (Butler, 1978). Both stations showed the presence of species that have been associated with enriched conditions.

It was also found at the Boulder Creek site that dissolved oxygen levels were depleted to the extent that they would threaten the survival of Salmonid and other cold-water organisms that normally inhabit the River. Although not quite eutrophic, these two areas of the River both showed the greatest impacts of over-enrichment in 1977. In 1978, algal densities were considerably less (particularly at the Ben Lomond site), but diversity of filamentous algae appears to have dropped and water quality parameters did not improve. Therefore, these are still considered problem areas.

Factors Contributing to Algal Growth

Primary factors contributing to the presence of algae in the Watershed are the amount of sunlight reaching the stream, the concentration of nutrients in the water, and the availability of suitable substrate. Algae needs sunlight to photosynthesize and grow. If other conditions are favorable, algal growth will occur whenever adequate sunlight reaches the stream, regardless of season. Removal of streamside vegetation can trigger the rapid growth of algae in an area, as seen in many instances along the River and its tributaries.

Greater distribution and densities of algal communities throughout the San Lorenzo can be traced to recent increases in available nutrients. Carbon, nitrogen, and phosphorus are essential elements in the growth development and maintenance of algal cells. As such, these elements are utilized from the environment in the same ratio as they are present within the algal cells (C:N:P = 106:16:1) (Stumm and Morgan, 1962). In sufficient amounts of any one of these nutrients will limit algal productivity, regardless of the presence of other nutrients in surplus quantities. An increase in concentration of that limiting nutrient will also increase the availability, or utilization, of the other non-limiting nutrients.

In freshwater ecosystems, carbon is abundant as respired CO_2 and organic matter. Phosphorus is available primarily as phosphate ions dissolved in the water or as phosphate particulates adsorbed onto floating matter. In either form, it is utilized rapidly (Hutchinson, 1957) and is often considered the limiting nutrient to aquatic plant productivity. However, in the San Lorenzo Watershed, phosphate is abundant and nitrogen, utilized as nitrate, can be considered the limiting factor to the growth of algae.

The primary source of phosphate in the San Lorenzo River is sedimentary geologic formations. Its presence in the water may be greatly augmented by the high rates of erosion that take place, which introduces phosphate-rich sediment to the stream system. Phosphate levels in the streams have been relatively stable over the past several years. Because nitrate is the limiting nutrient in the Watershed, any appreciable increase in nitrate concentrations will lead to an increase in the availability of both nutrients and result in increased growth of algae. In fact, a general increase in nitrate levels has been taking place over the past five years (See Water Quality Technical Section).

The increased nitrate levels could result from the movement of inadequately treated waste water into the River and other streams. (This is a source of various forms of nitrogen which are readily oxidized to nitrate by the action of turbulent water and oxidizing bacteria.) This is indicated by both water quality data and by the chronic presence of noticable algae. The algal density and species composition has been indicative of over-enrichment in the heavily developed areas such as Boulder Creek and Ben Lomond. In addition, both the concentration of nitrate and the extent of algal distribution increase in a downstream direction as the River flows through developed areas. However, as the River flows through the undeveloped area of Henry Cowell State Park, nutrient influx is minimal and the River is able to cleanse itself. As a result, the area at Sycamore Grove showed much lower concentrations of nitrate and a much reduced density of algal growth with indication of greater species diversity. It appears that excessive growth of algae is closely related to the extent of impact to the stream.

In conclusion, the presence of excessive algae can probably be related to increases in nutrient enrichment from human activities. If nutrient levels continue to increase, the present nuisance of ubiquitous algae will worsen and degradation of the aquatic ecosystem by eutrophication will ensue.

Stream Bottom Organisms

Studies of streambottom organisms (benthic invertebrates) have produced valuable information concerning overall water quality in streams of the San Lorenzo Watershed. The number of organisms present (productivity), variety of species present (diversity) and types of species present are all indicative of the long range water quality, as it influences the health of the stream ecosystem. The productivity of these food-organisms is also important for overall fishery productivity.

Studies have been done on Bear, Zayante, Fall, Bean, and Carbonera Creeks as well as the San Lorenzo near Waterman Gap, above Boulder Creek, and in Henry Cowell State Park. All of the studies utilized consistent and semi-quantitative sampling techniques. From these studies benthic communities can be analyzed and comparisons between different sample areas can be drawn.

Collection of benthic organisms within several square foot areas at sample sites was done with a Surber sampler. This allowed a determination of population numbers, species composition and diversity, with biomass values determined in some of the studies. The accuracy of the results is limited somewhat by the small numbers of samples taken on each creek, but larger sample numbers would have been prohibitive given scope of the studies and size of study areas. Sample sites were chosen which best represented the entire creek or stream reach.

Sampling times for the four benthic studies were split between spring (Ricker and Harvey, 1975; Johnson and Butler, 1977) and autumn (Fitzgibbons and Jansen, 1976; Ricker, 1976). Differences in results due to seasonal changes in benthic populations should be considered when comparing these studies. Results of these studies are presented in Table 3.

The seasonal variation is determined by the life history of the insects, which make up most of the benthos. Most species hatch from eggs in late summer and early fall. At that time they are quite small and relatively numerous. As winter passes, the larvae grow larger and many individuals are lost to competition and predation. In late spring and early summer most adults emerge briefly to reproduce and repeat the cycle. This life cycle lasts one year for most species. The data reveals a slight temporal variation in numbers of individuals and species due to the seasonal population fluctuations. This is particularly evident on Bear Creek between fall of 1976 and spring of 1977. However, results from the same sample areas over different times of the year are very similar and can be readily compared.

The studies indicate generally healthy aquatic communities with no adverse impacts from degradation of chemical quality (except on Carbonera Creek). However, major impacts from excessive sedimentation were observed on a number of streams. The difference in populations between the upper and the lower sections of Bean Creek shows the influence of substrate on the benthic community. The upper portion was rocky throughout, with little infilling of sand. Downstream, much more sediment was present and often filled the spaces between bottom gravels. The number of individuals and the diversity were both sharply reduced wherever the proportion of sand in the bottom material increased.

Species composition also changed downstream in Bean Creek due to sedimentation. The proportion of caddisflies (Trichoptera) dropped from 52 percent to 19 percent and the proportion of mayflies (Ephemeroptera) increased from 39 percent to 58 percent. Many caddisflies are filter feeders, capturing food in nets spun among the bottom gravels. When these openings in the gravel become filled with sand as in the lower area, the net-spinners are eliminated. A sparsity of caddisfly larvae (13 percent) was apparent at the lower Bean sample area again in 1977. At the same time there was a predominance of blackfly (Similiid) and midge larvae (Chironomid); a condition which Usinger (1956, p.36) cites as characterizing highly turbid or low quality water.

TABLE 3

DATA FROM SAMPLING OF BENTHIC INVETEBRATES

	Creek	Number of Samples	Number of Individuals per Square Foot		Number of Species per Square Foot		Diversity[1]		Biomass (gm)		SOURCE
			Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Stan. Dev.	
AUTUMN STUDIES	Bear Creek	4	302	121.5	19.5	4.04	1.62	.14	.70	.27	Fitzgibbons and Jansen, 1976
	Fall Creek	4	65.5	15.8	12.1	3.30	2.29	.38	.08	.01	
	Upper San Lorenzo River	4	283.7	143.0	17.6	2.89	1.90	.45	1.00	.59	
	Zayante Creek	4	113.5	27.8	18.0	.82	1.96	.01	.40	.39	
	Carbonera Creek	3	80	26.61	9.7	1.89	1.47	.33	-	-	Ricker, 1976
SPRING STUDIES	Bean Creek[2] Upper	16	28.75	13.11	8.5	2.48	1.70	.37	-	-	Ricker and Harvey, 1975
	Lower	16	36.44	24.9	8.2	3.72	1.55	.50	-	-	
	Carbonera Creek (A)	3	84.7	7.09	9	2.0	1.51	0.42	0.34	0.27	JOHNSON AND BUTLER, 1977
	Carbonera Creek (B)	3	174	66.7	13	3.51	1.84	0.27	0.97	1.07	
	Upper San Lorenzo (A)	2	50	9.9	13.5	3.59	2.30	0.19	0.44	0.13	
	Upper San Lorenzo (B)	2	137	85.6	18.5	0.71	2.54	0.16	1.26	0.35	
	Zayante Creek	3	188	102.0	16.6	4.04	2.04	0.09	0.29	0.20	
	San Lorenzo River at Waterman	3	50	13.2	9.6	0.58	1.75	0.02	0.62	0.37	
	San Lorenzo River at Big Trees	3	419	282.2	16.7	3.06	2.11	0.34	0.84	0.73	
	Bear Creek	3	93.6	43.8	12.3	0.58	2.04	0.29	1.46	0.96	
	Bean Creek	3	82.6	42.0	12.3	1.53	1.78	0.53	0.14	0.06	
	Fall Creek	3	48	18.03	16.3	1.53	2.57	0.12	-	-	

[1] $\text{Diversity} = \sum\left(\frac{ni}{N} \times \left(\frac{\ln ni}{N}\right)\right)$

[2] Bean Creek (1975) samples were taken in a variety of bottom and velocity conditions (0.5-2.5 feet/sec.), probably resulting in a lower average diversity value. All other sites were sampled at approximately uniform flow regimes (1.0 foot/sec).

Similar reductions in caddisflies were found in Zayante and Carbonera Creeks. Zayante Creek, with extensive sedimentation, contained only 14 and 8% of filter-feeding caddisflies in the 2 sample years. Carbonera Creek had the lowest diversity index during both study periods, dominated by 71% midge (Chironomid) larvae in 1977. The low diversity and high percentage of this generalist, Omnivorous Taxa indicates that specialist organisms have been eliminated and suggest poor chemical water quality (Usinger, 1956). This may be due to an undetermined natural water quality limitation or the runoff of toxic materials from the urban and industrial areas of Scotts Valley.

Samples areas which had less impact from sedimentation supported larger caddisfly populations and greater population diversities. In Bear Creek, Fall Creek and upper San Lorenzo caddisflies made up 32, 35 and 45% of the benthic community, respectively.

Fall Creek had the highest diversity values of all tributaries in both spring and fall studies. However, low numbers of individuals and low biomass in Fall Creek indicates relatively low levels of productivity. This creek drains an undisturbed Watershed underlain by granitic rock and has very low levels of nitrate and phosphate in the water as compared to other creeks which drain sedimentary rock and have been influenced by human development. These nutrients normally stimulate the growth of algae, bacteria, and fungi, the basis of the food web for benthic invertebrates.

Many benthic insects derive much of their nourishment from the bacteria and fungi which grow on floating detritus (Hynes, 1970). The bacteria and fungi greatly enrich their substrate, the floating organic detritus, by taking up dissolved nutrients from the water. Though there is no lack of detritus in the heavily forested Fall Creek Watershed, inherently low levels of dissolved nutrients probably inhibit bacterial and fungal productivity, which in turn limits benthic invertebrate populations. An increase of nutrients in the water would probably lead to an increase in the amount of food available to the benthic insects.

The Upper San Lorenzo (above Boulder Creek) sample sites appear to be suitable habitat for a stable benthic invertebrate community. A high diversity of organisms reflects a very even species composition, while moderate numbers of individuals and the absence of domination by any particular feeding class indicates relatively undisturbed conditions. Bear Creek showed similar stable conditions with moderate numbers of individuals. Both Bear Creek and San Lorenzo above Boulder Creek sample areas had low or moderate percentages of sediment in the bottom composition.

The 1977 reconnaisance study revealed few anomalies in the benthic communities throughout the San Lorenzo system. Most notably, there

were reduced numbers of individuals and low diversity levels at the Upper San Lorenzo site, an area which had little sedimentation and apparently favorable habitat. Very high numbers of individuals were observed in the San Lorenzo-Henry Cowell samples. This general increase in productivity from the headwaters above Boulder Creek downstream to Henry Cowell Park may result from concurrent increases of influent nutrients in a downstream direction. In general, the 1977 follow-up report shows a consistency throughout the Watershed, confirming observations from earlier studies.

From these studies, generalizations can be made concerning the size and character of benthic populations in the San Lorenzo Watershed. Streams that drain areas of sedimentary rock (especially older rock types) and that have high nutrient levels can be expected to have higher productivity and larger populations than streams that are low in nutrients. Both diversity and productivity will be reduced where sedimentation has occurred. Influences on benthic invertebrates which have not yet been clarified are the influence of predation, bottom scour during storms, and variations in streamflow.

FISHERY PRODUCTIVITY

The San Lorenzo River and its tributaries have supported the largest anadromous fishery of south of San Francisco Bay. It was estimated that in 1964 the annual run consisted of 20,000 steelhead rainbow trout and 2,500 to 10,000 silver salmon (Johnson, 1964). The River is currently the southernmost stream which supports a regular run of silver salmon. An estimated 50,000 angler hours a year are spent on the River, attracting many fishermen from outside the County (Johansen, 1975). In a normal year the River and its tributaries provide more than 80 miles of stream habitat (Murphy, 1948). The River has been regarded as the fourth most fished steelhead stream in the State (California Department of Fish and Game, 1965).

The San Lorenzo fishery has value to both the individual fisherman and the County's economy. A method developed in Oregon to calculate the value of the fishery can be applied to the San Lorenzo (Kunkel and Janick, 1976). It was determined that each angler-day was worth $28. Correcting for inflation brings the value up to $33 per day. (This value represents the value to the fisherman, not what is actually spent). If an estimated average of 1.75 hours per angler-day are spent fishing, the average number of angler-days on the San Lorenzo River would be 28,700 providing for an overall value of $947,100. (There is no data to relate angler hours to angler-days on the San Lorenzo River). Inclusion of the value to the ocean fishery would bring the total value of the San Lorenzo fishery to over one million dollars.

The following sections will discuss the overall condition of the fishery, the impacts of sedimentation, and the impacts of reduction in streamflow.

Condition of the Fishery

The amount of fish the River system supports is quite variable. Each annual run consists of fish from three or four year classes (Shapovalov and Taft, 1954). The size of the run thus depends on the relative productivity over the previous several years. Productivity is dependent on the success of spawning and the subsequent availability of adequate nursery area in the River system for the growth of the juvenile fish.

The amount of spawning success is dependent on the size of the run, the accessibility of the streams and the suitability of the bottom for spawning. During dry years much of the potential spawning area may be limited due to insufficient flows for upstream migration. During the drought of 1975-77 the size of the runs was very low and fish were able to reach only an estimated 50% of their normal spawning areas. Accessibility may be further limited by the presence of log jams or other impassable barriers. Spawning success may also be limited by siltation of the stream bottom resulting from accellerated erosion landslides or the lack of high flows which usually flush fine material out of the spawning beds. Shapovalov and Taft (1954) found that siltation of spawning gravels would reduce the survival rate by up to 85%.

Once the young fish hatch and emerge from the spawning bed, they require adequate food, shelter and living space as they grow to sufficient size for migration back to the sea. Generally they spend at least one summer in the stream. Mortality during this time is usually about 90%. (McNeil and Bailey, 1975). Thus the availability of nursery area is a very important factor in determining the overall fishery productivity of the system. The carrying capacity may be limited by sedimentation, low flows, high temperatures, low dissolved oxygen levels, lack of food or intense predation.

Carrying capacity of the overall system is important as the fish move out from the spawning areas into any suitable nursery area. A stream segment may offer poor spawning conditions but still be very important for providing nursery area. This is especially true of the main River which supports a good many juveniles which move downstream when the headwaters dry up in the summer (Pintler, 1956).

The large number of variables affecting fishery productivity often leads to a normal variation in productivity of 50% from year to year (Burns, 1971). In the San Lorenzo River Watershed, it is felt that the primary limitation to fishery productivity is the availability of habitat for juveniles. Because each female fish produces about 6,000 eggs, the streams can be saturated with young relatively easily. The amount of spawning success would limit productivity to some extent during dry years when low flows prevent irregation and spawning in areas of otherwise suitable habitat. If the size of the runs decline further than they already have, spawning success could limit overall productivity. This would be aggravated by siltation which greatly reduces survival of the eggs.

Trends in the Fishery

Until recently overall size of the runs has not been directly measured. Relative estimates have been based on creel census information which allow an estimate of the relative population based on the numbers of fish caught. Estimates have also been made based on the amount of available habitat in the River system. In 1964, it was estimated that the annual run consisted of 20,000 steelhead and 2500-10,000 silver salmon (Johnsen, 1964).

In the last three years, runs have been measured directly at a fish trapping facility in the Felton Diversion Station at Felton. However, precise estimates of the runs have been somewhat hampered by periods when the dam was collapsed. In the dry year of 1976-77, only 174 silver salmon and 1614 steelhead were counted. This was less than the total 1970-71 catch of 383 silver salmon and 1816 steelhead (Johansen, 1974).

In 1977-78, the counting operation was suspended in mid-winter due to high flows. However, measurements made in the early winter indicated that the run was only about twice the size of the previous winter's run despite the presence of high flows. This rate should put the steelhead run at about 3,000 fish. This low estimate is supported by the reports of fish and game wardens who observed few fish in the tributaries. Counting did last long enough to measure the entire silver salmon run which consisted of only 182 fish.

In 1978-79, only three silver salmon and 537 steelhead were counted. Based on observed migration rates it was estimated that approximately 100 silver salmon and 50-100 steelhead passed the station uncounted when the dam was down. The total run is thus estimated at 625 steelhead and 100 silver salmon. These low numbers were echoed by anglers who felt that this was the worst year yet. Based on a rough angler survey, probably 190-285 fish were caught during the season. This represents a major reduction from the 1500 fish caught in previous years. The catch also amounted to 21-28% of the total run.

The decline in the runs can be attributed to the drought and to excessive sedimentation. While the drought was probably responsible for the lower numbers in 1976-77 and 1978-79, the run of 1977-78 should have been influenced by the drought as it was made up of fish which went to sea at the beginning of the drought. These figures represent an 80-90% reduction in the size of the runs as originally estimated in 1964. This reduction can be attributed primarily to sedimentation. The impacts of both sedimentation and reduced streamflows will be discussed in subsequent sections.

Contribution of Individual Tributaries

Efforts have been made to assess the contribution to the fishery of the various tributaries and segments of the River. This has been done through studies and stream surveys conducted primarily by personnel of the State Department of Fish and Game. These surveys have revealed a good deal of variability in productivity from year to year. One year a stream may offer very good spawning and nursery and then another year it may be very limited by log jams or siltation. The information for the San Lorenzo was compiled by Benkman (1976), who has presented a good summary of the history and condition of the San Lorenzo fishery.

TABLE 4 - FISHERY PRODUCTIVITY OF THE SAN LORENZO WATERSHED

Stream	Overall[1] Length	Length for[1] Spawning	Spawning[2] Condition	Nursery[2] Suitability	Contribution[3] in 1974	Limiting[2] Conditions
San Lorenzo River	26	22	Poor	-	-	Siltation (1972)
Upper portion	-	-	Good	-	23%	Siltation
Bear Creek	8	7	Poor (Potentially good)	Good	7%	Siltation
Deer Creek	4	3	Poor (Potentially good)	Good	-	Siltation
Fall Creek	5	3.5	Good	Moderate	-	Log jams Food
Boulder Creek	7	3	Poor	Moderate	8%	Siltation Large boulders
Love Creek			Poor	Moderate	2.7%	Low flow
Newell Creek	7	3	Poor	Poor	2.2%	Siltation
Zayante Creek	10	7.5	Moderate	Good	18%	Siltation
Bean Creek	6	3.75	Good	Good	20%	Siltation
Kings Creek	6	4	Good	Moderate	13%	Low flows
Two Bar Creek	3	2	Moderate	Poor	.4%	Low flows
Carbonera Creek	7	5	Poor	Poor	.2%	Siltation Pollution Food
Branciforte Creek	8	7.5	Poor	Poor	2%	Siltation

[1]Murphy, 1948

[2]Information taken from 1974 surveys by Dennis Johnson and John Yoakley, supplemented by more recent surveys by the Office of Watershed Management. (1976) (Johnson and Yoakley, Department of Fish and Game)

[3]Estimated by Benkman (1976) from stream survey information by Dennis Johnson and John Yoakley in the fall of 1974.

The most recent comprehensive survey was done in the fall of 1974. Estimates of fish populations made then provide an indication of the relative contribution of each tributary to the overall fishery at that time. This and other information is shown in Table 4. This table should only be considered a general indication of conditions on the River as much of the information is based on the subjective observations of different observers. In addition, conditions may change from year to year.

Impacts of Sedimentation

Sedimentation is the major cause of the fishery decline in the San Lorenzo Watershed. It has clogged spawning gravels, reduced food production in the stream and reduced the amount of habitat available for fish.

Excessive sediment in spawning areas has been found to reduce the number of fish emerging from the spawning gravels by up to 85%. (Shapovolav and Taft, 1954). Observations of insect production on streams of the San Lorenzo Watershed show biomass to be 75-90% lower on silted reaches of Bean, Zayante, and Carbonera Creeks as compared to the UpperSan Lorenzo(B) (see Table 3). Where the rocks became completely surrounded by sand, researchers in Idaho found that the number of young fish that could be supported was reduced by 90% (Bjornn, 1977).

Excessive sedimentation is widespread in the streams of the San Lorenzo Watershed. The Department of Fish and Game surveys on the main River show that the percentage of bottom classified as silt measured from 8% in in 1966 to 65% in 1972. The amount of gravel present dropped from 20% to 2% (Lang, 1972). Conditions have not improved since then. Other surveys have pointed out the presence of excessive amounts of silt in all of the tributaries but the relatively undisturbed Fall Creek (see Table 4). (See the Erosion and Sediment Transport section for a further discussion of excessive erosion and sedimentation.)

Effects of Reduced Streamflow on the Fishery

Although sedimentation is probably the primary cause for the current drop in fishery productivity, reductions in streamflow can directly reduce the quantity of available habitat and the ability of fish to utilize that habitat. Anadromous fish need relatively high winter streamflows for upstream migration, spawning and the flushing of fine sediment from stream bottom gravels. Moderately high spring flows are needed for incubation of eggs and the seaward migration of young fish in late spring. Moderate flows are needed throughout the year to provide sufficient living space for the growth of juvenile fish.

The relationships between streamflow and available habitat in the San Lorenzo Watershed were determined from field measurements used in conjunction with a computer model developed by the U.S. Fish and Wildlife Service. Results from the model have been used to describe overall habitat availability and to assess the impacts of natural and man-induced reductions in flow.

Techniques for Habitat Assessment

Following a review of generally available techniques for fishery habitat assessment, it was decided that the system developed by the U.S. Fish and Wildlife Service Cooperative Instream Flow Group would be the most appropriate for the project. This system provides for a computer-assisted analysis of relatively straight-forward field measurements. Although it still has some areas that need work, their techniques appear to be the state-of-the-art in quantitative, objective assessment of available habitat.

The system currently being developed by the Instream Flow Group consists of two models: IFG4 and HABITAT. The IFG4 model utilizes several sets of hydraulic data (depth and velocity) measured at different flow levels, to simulate the hydraulic condition across a stream cross-section for a wide range of flow volumes.

The HABITAT model utilizes the output from IFG4 to determine the amount of "weighted usable habitat" for the discharges of interest. For each "slice" of the transect, HABITAT utilizes the values for depth, velocity, and substrate character to assign that slice a weighted habitat value. The suitability for supporting a given life stage is determined by comparing the hydraulic parameters to a set of habitat suitability curves, which delineate the value of a given type of habitat for a given life state of the particular species. These curves have been developed by the Instream Flow Group from a compilation of field observations which indicate the type of habitat where the fish are most likely to be found. The weighted amount of suitable habitat for all sections of the study reach is summed up by the model to provide the total area of "weighted usable habitat" per thousand feet of stream length for that particular flow. Habitat values are computed for a range of discharges to show the fluctuation of available habitat in response to changes in discharge.

This technique was applied to eight stream reaches in the San Lorenzo Watershed: San Lorenzo Rover above Boulder Creek (Waterman Gap); San Lorenzo River at Henry Cowell State Park; Bear Creek; Boulder Creek; Fall Creek; Zayante Creek below Mountain Charlie Creek (just below proposed Zayante damsite); and Zayante Creek above Felton.

On each stream, a study reach was selected that appeared to be representative of conditions on that stream. Factors that were considered were: channel morphology, pool and riffle frequency, substrate character,

size of pools, and stream gradient. Assistance from a fisheries biologist with the Department of Fish and Game was available in the selection of the upper study reach on Zayante Creek. On each study reach, three to six transects were laid out across the reach. These were designed to be representative of each habitat type present: pool, glide, riffle, and head of riffle. Care was taken to ensure that no habitat type was over-represented.

Field measurements were taken at each study reach three times in May, July, and late September of 1978. The range of flows assessed varied from 74 cfs to 14 cfs on the San Lorenzo River at Cowell Park, and from 5.5 to 0.5 cfs at the Upper Zayante Creek station.

The field data was fed into the IFG4 model. After the initial output from this model was verified, the HABITAT model was run. This provided values of available habitat for coho (silver) salmon (spawning, incubation, and fry) and for steelhead (adult, spawning, incubation, fry and juvenile nursery). Values of habitat were provided for the normal range of flows to be expected from very dry years to normal years. This allowed the construction of curves relating availability of habitat to flow for all flow levels. An example is shown in Figure 2.

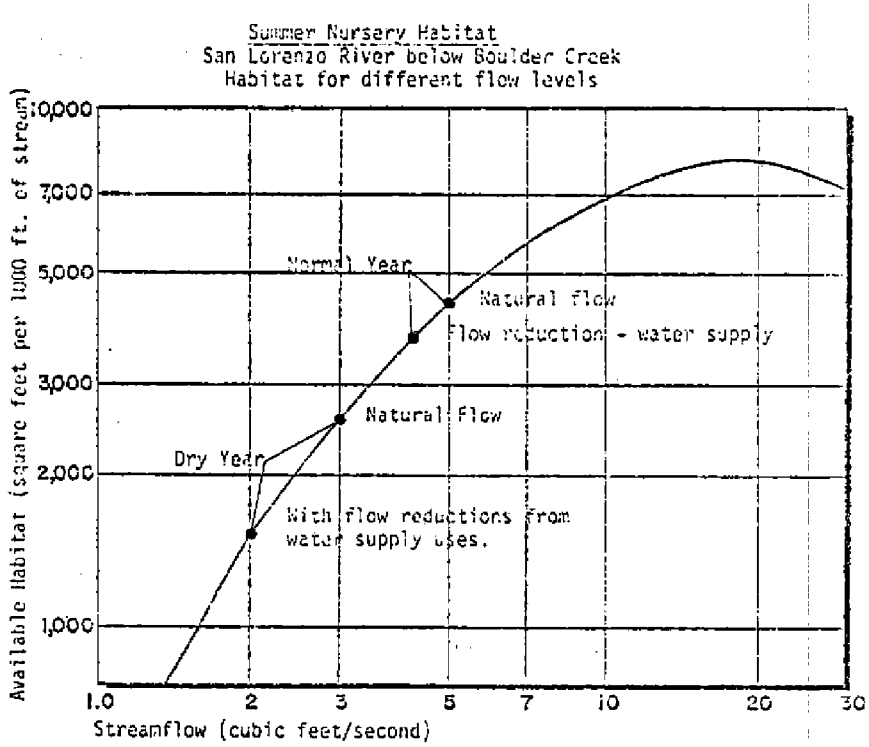

FIGURE 2: Relationship of Habitat to Streamflow.

Limitations of Technique

This technique determines the relative quantity of available habitat as affected by changes in flow. It does not appear to deal effectively with changes in quality of the substrate. Improvement of substrate should result in significantly greater increases in suitable habitat than indicated by the model. The model also does not take into account other aspects of habitat quality such as shelter or food production. Despite these limitations the findings provide a good first approximation of the relative changes in available habitat resulting from natural or human-induced changes in streamflow.

Overall Habitat Conditions

The relationship between streamflow and habitat at the different stations was compared to existing streamflow conditions to determine the amount of existing available habitat (Table 5). Flow conditions were taken from those derived in the Hydrology Technical section. Available habitat is shown for different levels of flow: normal years (50% flow), moderately dry years (once-in-four years, 75% flows), and dry years (once-in-ten years, 90% flows).

In order to describe habitat availability throughout the entire River system (above Henry Cowell Park) each station measured was considered to be representative of a given length of stream, possibly including reaches of other similar streams. Thus, the upper Zayante Creek station was considered to be representative of Zayante Creek above Lompico Creek, Kings Creek, upper Bear, upper Boulder, and upper Bean Creeks. For each station the amount of habitat was multiplied by the total amount of stream length represented by that station. These figures were added to get total amount of habitat area for the whole River system (Table 5). This was done for different flow levels to see relative changes in the available habitat.

Natural variations of flow in the San Lorenzo Watershed cause wide fluctuations in the amount of fish habitat available from year to year. For the River system as a whole, total spawning habitat is reduced by 70 percent; and total summer nursery babitat is reduced by 50 percent during the drier years that occur on the average once every 10 years. The degree of habitat fluctuation on each stream depends on the natural flow pattern of the individual stream. Streams that receive greater amounts of groundwater during the summer show smaller drops in streamflow and, thus, smaller habitat reductions. Fall Creek, Zayante Creek, lower Bean Creek and the lower portion of the River generally experience reductions of 40 percent in September juvenile nursery habitat during dry years (1 year in 10). Lower Boulder Creek and the mid portion of the River experience dry year habitat reductions of about 60 percent (Figure 2). The upper River, Kings Creek, Bear Creek, upper Boulder Creek, upper Zayante Creek, and upper Bean Creek, all experience low-year habitat reductions in excess of 75 percent. Habitat loss during very dry years (such as 1975-77) is much greater than that during

TABLE 5

JUVENILE/NURSERY HABITAT AVAILABLE AT EXISTING FLOW REGIMES

CREEK	JULY						SEPTEMBER						Number of Stream Miles Represented By Station[c]
	50% Flow		75% Flow		90% Flow		50% Flow		75% Flow		90% Flow		
	Flow[a]	Hab.[b]	Flow	Hab.	Flow	Hab.	Flow	Hab.	Flow	Hab.	Flow	Hab.	
San Lorenzo above Boulder Creek (Waterman Gap)	1.20	1150	.73	510	.49	280	.63	410	.40	200	.26	100	7
Bear Creek	2.14	800	1.20	350	.66	120	1.17	280	.65	120	.45	68	5
Boulder Creek	2.51	3000	1.65	1600	1.03	920	1.58	1600	1.08	950	.74	650	3
San Lorenzo below Boulder Creek	7.08	5300	4.33	3700	2.57	2350	4.17	3700	2.69	2400	1.91	1600	8
Fall Creek	2.75	2300	1.87	1750	1.29	1350	1.86	1750	1.36	1360	1.00	1100	6
Zayante Creek below Mountain Charlie	1.00	530	.50	260	.26	82	.60	280	.36	140	.22	65	20
Zayante Creek at Woodwardia	3.31	2400	2.52	1800	1.95	1400	2.51	1800	2.07	1400	1.70	1150	6
San Lorenzo at Henry Cowell	25.12	4700	17.45	3800	12.59	2600	17.4	3800	13.30	3200	10.20	2300	8
Total River System[d]	-	-	-	-	-	-	-	497[d]	-	-	-	250[d]	62

SPAWNING HABITAT AVAILABLE AT EXISTING FLOW REGIMES

CREEK	JANUARY						MARCH						Number of Stream Miles Represented By Station[c]
	50% Flow		75% Flow		90% Flow		50% Flow		75% Flow		90% Flow		
	Flow[a]	Hab.[b]	Flow	Hab.	Flow	Hab.	Flow	Hab.	Flow	Hab.	Flow	Hab.	
San Lorenzo above Boulder Creek (Waterman Gap)	5.00	120	1.7	9	1.20	0	12.6	800	2.9	29	1.4	6	7
Bear Creek	12.60	210	3.9	0	2.30	0	21.4	600	10.2	140	4.9	10	5
Boulder Creek	14.10	11	4.2	0	2.60	0	22.9	95	11.0	0	5.5	0	3
San Lorenzo below Boulder Creek	41.70	950	13.0	80	6.80	0	69.2	1350	32.6	650	16.2	135	8
Fall Creek	7.60	430	4.1	100	2.95	62	11.5	600	7.1	400	4.7	200	5
Zayante Creek below Mountain Charlie	4.27	48	2.0	1.74	1.3	0	11.2	460	4.0	40	1.8	0	20
Zayante Creek at Woodwardia	9.60	110	4.7	12	3.8	6	14.1	450	8.3	60	5.8	25	6
San Lorenzo at Henry Cowell	89.10	3300	38.1	1300	25.1	300	145.0	2000	71.3	3200	44.7	1700	8
Total River System[d]	-	-	-	-	-	-	-	267[d]	-	-	-	84[d]	62

a. Flow (cfs) Percentage indicates the frequency that the Flow is exceeded (ie. a 90% flow is a low flow that occurs 10% of the time in that month (or the monthly average is that low once in ten years); a 50% flow is a normal flow).

b. Habitat (Ft^2/1000 Ft of Stream).

c. Each station was considered to be representative of a certain amount of stream length on that stream and on other comparable streams.

d. Includes that part of the river system above Eagle Creek, habitat given in thousands of square feet.

normal dry years. During this recent dry period in upper Zayante Creek, the juvenile habitat was 96 percent less than that available under normal flows. During dry winters fish are unable to reach upper Watershed streams, and habitat in the main River and lower portions of the tributaries becomes all important for fishery survival.

This investigation pointed out that the natural stream flows exceed the instream flow needs only during the wet winter months. During the summer flows are always well below the optimum. Any further decrease in flow will lead to a direct reduction in habitat. Generally, the proportionate reduction in habitat is greater than the reduction in flow. On the San Lorenzo River below Boulder Creek a 50% flow reduction from 3 cfs to 1.5 cfs results in a 60% reduction in habitat from 2500 square feet per thousand feet of stream length to 1000 square feet per thousand feet (Figure 2).

Impacts of Water Supply Projects

Information from the computer model was used to assess the impacts on fishery habitat resulting from water supply projects. Figures on the amount of water taken from the streams were added to the existing flow levels to determine how much habitat would be available without the stream diversions. These figures are shown in Table 6. (Determination of water use and flow figures is discussed in the Hydrology Technical section.) The figures on habitat change were extrapolated to the whole River system, using the same technique as discussed previously.

Stream diversions have caused the following reductions in fishery habitat: a 40 percent reduction in summer nusery habitat on lower Boulder Creek; a 20 percent reduction in summer nursery habitat on the mid portion of the River, lower Bear Creek, lower Fall Creek, and lower Zayante Creek; and a 40 percent reduction in dry years (1 in 10) spawning habitat on lower Fall Creek and the middle portion of the River. These reductions represent a 10 percent decrease in overall summer nursery habitat for the Watershed during normal years, and a 20 percent reduction in the habitat that would be available in dry years without removing water for water supply. During dry years, these human-induced reductions further reduce habitat that has already been decreased by at least 50 percent by natural, seasonal drops in streamflows.

Although the Felton Diversion Dam operates during periods when there is normally more than adequate flows, it can have adverse impacts on upstream migration and spawning during dry winters. A survey of downstream conditions by state fisheries biologist, Paul Chappell indicated that the minimum bypass requirement of 20 cfs was not adequate to allow migration over the very shallow riffle areas in Henry Cowell Park. At 20 cfs these riffles serve as partial barriers to migration; at 12 cfs they are complete barriers. Chappell's conclusion was that a minimum flow of 40-50 cfs is needed to preserve the anadronous fishery of the River. Fish counting

TABLE 6 IMPACTS OF CURRENT WATER USE ON FISHERY HABITAT

Stream	March Spawning Habitat								September Juvenile Habitat							
	50% Flow[a]	Flow Red.[b]	Existing Habitat[c]	Potential Habitat[c]	90% Flow[a]	Flow Red.[b]	Existing Habitat[c]	Potential Habitat[c]	50% Flow[a]	Flow Red.[b]	Existing Habitat	Potential Habitat	90% Flow[a]	Flow Red.	Existing Habitat[b]	Potential Habitat[c]
Bear Creek[d]	21.4	.25	600	600	4.9	.26	10	10	1.2	.26	220	280	.45	.26	10	68
Boulder Creek	14.1	1.9	95	115	1.5	1.9	0	0	1.6	1.0	1600	3200	.7	.5	650	1105
San Lorenzo Below Boulder Creek	69.2	2.8	1350	1350	6.8	28	135	230	4.2	1.4	3700	4600	1.9	.7	1600	2500
Fall Creek	11.5	.9	600	600	4.7	.9	130	200	1.9	.9	1750	2200	1.0	.9	1000	1700
Zayante Creek at Woodwardia	14.1	.25	450	450	5.8	.25	25	450	2.6	.25	1800	2250	1.7	.25	1150	1800
San Lorenzo at Henry Cowell[d]	145	24.6	2700	2000	44.7	24.6	110	1700	17.4	3.2	3800	4800	10.2	2.1	2300	2800

[a]Flow (in cubic feet per second) percentage indicates the frequency that the flow is exceeded under current conditions and water use patterns.

[b]Flow reduction (cfs) is the amount of water that is currently being taken from that stream for water supply (see Hydrology Technical section for a discussion of the figures)

[c]Existing habitat is the amount of habitat (in square feet per thousand linear feet) under existing flow conditions. Potential habitat is that amount that would be available if natural flows were not currently reduced by stream diversions.

[d]For Bear Creek and San Lorenzo River at Henry Cowell. March potential habitat represents the amount that is currently there and existing represents the amount that will be there when recently issued water permits are exercized. The flow levels shown are those that exist prior to the diversion.

records also indicate the reduced migration at low flows. In 1978-79 only 32 fish out of the total run of 600 migrated past Felton when the flows were less than 40 cfs. Use of the computer model further indicated that an increase in downstream flow from 20 cfs to 40 cfs would increase spawning area from 110 square feet per thousand feet to 3300 square feet per thousand feet.

More work should be done to determine a better release schedule from the Felton Diversion Dam. During the drought the minimum release was reduced to 10 cfs when the natural flows dropped below 20 cfs. If it was confirmed that this would have little impact on the fishery (in particular downstream egg incubation) this condition could be permanently incorporated into permit conditions. Similarly, terms for increasing the minimum bypass to 40 cfs during periods of fish movement should also be incorporated into the permit terms.

Construction and operation of Loch Lomond reservoir has resulted in some adverse impacts on the fishery. Dam construction eliminated 3.5 miles of upstream habitat. This represents a reduction in overall habitat in the River system of 3-5% of the spawning habitat and 1-2% of the juvenile nursery habitat, depending on whether the habitat was more similar to that at the upper San Lorenzo River or to that on upper Zayante Creek.

The downstream reduction in winter flows has reduced sediment scour and has inhibited upstream fish migration for spawning unless the dam spills (which it does about once every 3 years) the upper .7 mile below the dam is inaccessible for spawning. The lower .9 mile is accessible, but is of very low quality due to sediment accumulation.

Operation of the reservoir requires the constant release of 1 cfs. Although this is a significant reduction of winter flows, it does represent about a doubling of pre-project summer flows. This has increased flows and habitat in the main part of the River. The increase in habitat represents about 12,000 square feet of normal September nursery habitat and about 5500 square feet of dry September nursery habitat. This amounts to 2-2.5% of the total habitat in the River system. This project should be investigated to determine if measures to enhance habitat could be developed.

Future Management

The fishery model should be used in conjunction with more in-depth studies of flow needs to better manage stream resources. Some modification of existing water projects may yield significant benefits. All new projects should be preceded by detailed assessments in order to determine the flows necessary to maintain or enhance fishery productivity. This is currently being done for the proposed Zayante reservoir project (Kelley, 1979).

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