BEFORE THE STATE WATER RESOURCES CONTROL BOARD

In the Matter of the State Water Resources Control Board (State Water Board) Hearing to consider Monterey Peninsula Water Management District's (MPWMD) Petitions to Change Permits 7130B and 20808 (Applications 11674B and 27614)	Hearing Date: September 24, 2007 Carmel River in Monterey County

EXHIBIT KU-3

MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

Dettman and Kelly 1986 Assessment of the Carmel River Steelhead Resource Volume 1 Biological Investigations, Prepared for the MPWMD

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ACKNOWLEDGEMENTS

This report was prepared by D. W. Kelley and D. H. Dettman, but a number of others helped gather information and make analyses. Dr. Stacy Li collected and analyzed most of the information on the upstream migration of adult steelhead over shallow riffles at various flows, and participated with David Dettman in much of the field work regarding juvenile rearing and downstream emigration. Jerry Turner developed the analysis relating the historical accounts of adult steelhead in the San Clemente fish ladder with streamflows and also participated in some of the field work. W. C. Fields, of Hydrozoology, designed and conducted the studies on the food for downstream migrating juveniles. Dr. Fred Theurer, of the US Fish & Wildlife Service at Fort Collins, Colorado, assisted Dr. Li in the application of Theurer's water temperature model to predict the stream water temperatures at various flows along the Carmel River. We have frequently referred to William Snider's previous work on the Carmel River for the Department of Fish and Game.

We are grateful to these men and to the staffs of the Department of Fish and Game and Monterey Peninsula Water Management District for the assistance that they have given us.

CHAPTER I. INTRODUCTION AND SUMMARY

The Carmel River flows out of the Ventana Wilderness Area through the long Carmel Valley into Monterey Bay. The river is an important natural resource, not only because it provides a water supply for people who live in the Carmel Valley and on the Monterey Peninsula, but also because of its scenic and ecological values. These two important uses are in conflict. The purpose of this report is to help resolve that conflict by providing all parties with additional knowledge and understanding and by using it to evaluate water development alternatives.

One of the most important and most affected resources of the Carmel River is its steelhead run. The steelhead, Salmo gairdneri, a large fish of the salmonid family, spend their adult years in the Pacific Ocean and return to spawn in the streams where they were born. They have been engaged in this migration since the end of the last ice age.

Once abundant in almost all West Coast streams and rivers from Mexico to Alaska, steelhead populations have been greatly reduced; primarily, by the construction of dams and diversions, the reduction of streamflow, the loss of riparian vegetation, and the accumulation of sand in stream bottoms. The Carmel now supports the southernmost major steelhead run remaining in North America. The California Department of Fish and Game (CF&G) has estimated that an average of 2000 adult steelhead enter the river to spawn each winter and spring (Snider 1983).

This Volume 1 of our final report describes what is known about the steelhead resource and its relationship to streamflow. Our assessment is based on our field investigations that began in the winter of 1981-82, and the work of many others who are concerned with this problem.

Trial Minimum Flow Schedules

This work was done for the Monterey Peninsula Water Management District (MPWMD) to help evaluate the desirability of alternative approaches to augmenting water supplies for the Monterey Peninsula. To that end, we have developed a set of trial minimum flow schedules for maintenance of habitat and a wild steelhead run in the Carmel River.

The schedules are not proposed as minimum flow standards but only as first inputs to hydrological models. They are the beginning of our work with the project hydrologists to make each of the alternatives as compatible as possible with the steelhead resource and still meet the water supply objectives. The following biological findings were important to their development.

(1) During the adult migration, which takes place from January through March, a flow of at least 200 cfs for a week or so appears necessary to allow large numbers of steelhead to reach the middle and upper Carmel River and

tributaries above San Clemente Dam. All but a very small portion of the habitat for juvenile rearing is above San Clemente Dam and the steelhead run depends upon the number of adults that reach it.

Our "normal or better years" schedule calls for the maintenance of a minimum 200 cfs into the lagoon for 2 days in January, and 7 days in both February and March. In drier years, the fish migration to the habitat above San Clemente would be delayed until February or even March unless angling was further restricted. In critically dry years the schedule provides no streamflow releases for upstream migration. Such years are rare but when they do occur, we believe it better that steelhead remain in the sea, resorb their eggs, and return to spawn the following year at a larger size.

(2) Smaller flows down to about 50 cfs bring adult steelhead into the lower Carmel River. A flow of 75 cfs at Robles del Rio appears necessary to allow adults undelayed passage over the shallow riffles that might otherwise block them from spawning habitat. A flow of 75 cfs will also provide spawning habitat in the lower Carmel River for almost 1000 female steelhead.

Our "normal or better years" schedule calls for maintaining a minimum 75 cfs flow through January, February, and March, in "dry" years only in March, and in "critical" years not at all.

(3) The downstream emigration of juveniles from above San Clemente Dam begins in mid- or late winter and is usually over in early June. Flows during April and May are extremely important and, up to a total of about 15,000 acre-feet, are well correlated with counts of adult steelhead made in the San Clemente fish ladder 2 years later, when about 70 percent of the downstream migrants return as adults. A decline of streamflow during April and May to below about 20 cfs for any significant length of time appears to be very detrimental.

The schedule calls for a minimum of 40 cfs throughout all of April and May during "normal or better" years, and reductions in drier years. Our analysis suggests that April and May are periods when maintaining streamflows as high as possible is likely to have the greatest benefit to the steelhead population, with the least cost to the water supply, of any alternative. The combination of maintaining good spring flows with reducing the amount of sand in the stream and increasing the riparian vegetation, should have a powerful beneficial effect upon the steelhead run. Because of the cost effectiveness of spring flows and the fact the flows in the spring of dry years are needed by juveniles born the previous wetter years when there may have been a lot of spawning, we have not reduced the spring flows of the drier years to the same degree that we have the flows for upstream migration.

(4) Streamflows below Robles del Rio in the lower Carmel River have for many years ceased, or nearly ceased, almost every summer or fall, and throughout most of its length the stream has dried up. The large amount of excellent spawning habitat that exists between the dam and Schulte Road has been largely wasted. Most of the progeny of adults that spawn there are consumed by birds or die from other causes. Many older juveniles that

migrate down from the middle and upper river but do not reach the sea by early June, are also trapped as they cease emigration when the stream warms up. They too are lost when the stream dries up. We have estimated that maintaining 5 cfs at the Narrows will rear about 51,000 steelhead throughout their first year, 20 cfs will rear 93,000, and 40 cfs will rear 135,000 fish.

Our schedule includes a minimum 20 cfs year around flow at the Narrows in all types of years. In "normal or better" and "below normal" years, the schedule also requires that a minimum of 5 cfs reach the Carmel Lagoon.

Predicting Project Effects

We have converted these trial flow schedules into sets of operating "rules" that are currently being used to predict instream flows likely to occur if the project is built and if it is not built. These instream flows will differ from the above schedules in that they will include reservoir spills, releases of water for groundwater percolation and direct river diversions, and natural runoff not captured behind New San Clemente Dam. The reader is again cautioned to not think of these schedules as instream flow recommendations. They are only guidelines to help the hydrologist design and operate a model of the project in a way that is as compatible as possible with both fish production and municipal water supply. Repeated trial runs and modification of operating rules will be necessary. Once instream flows can be predicted with the models, we will use those flows and the biological information contained in this report to evaluate the effect of each alternative and develop instream flow standards for the project. That evaluation will be reported in Volume 2 of this series.

CHAPTER II. UPSTREAM MIGRATION OF ADULT STEELHEAD

Upstream migrating adult steelhead must pass into and through the Carmel Lagoon and move upstream some 18.5 miles to reach the fish ladder at the existing San Clemente Dam. There is good spawning habitat below San Clemente Dam, but most of the young produced there perish when the stream dries up the following summer. On reaching San Clemente Dam, the adult upstream migrants must climb an 85-foot-high ladder and pass through the existing small San Clemente Reservoir. Once in the reservoir, some migrate up San Clemente, Cachagua, and Pine creeks to spawn and some continue 5 miles up the Carmel River to Los Padres Dam. There is no ladder over Los Padres Dam, but the adult fish are trapped at its base and driven in a truck to be released in Los Padres Reservoir. Those fish continue their migration to the headwaters of the Carmel River. After spawning, the adult fish return to the ocean if they can. The following account describes what we have learned about these migrations.

The Carmel Lagoon

Adult steelhead now congregate in Carmel Bay and move upstream in response to the first heavy rains that break through the sand barrier at the river's mouth. In 1982, high waves swept seawater into the lagoon on October 30. The lagoon was dredged open by Monterey County on November 13 in anticipation of high streamflows following storms.

On November 25, David Dettman interviewed several fishermen on the river who reported that they had seen several adult fish in the lagoon on November 20 and 25. These fish probably moved into the lagoon in response to high flows on November 18 and 19. Following another storm in late November a few more adults moved into the lagoon and, when flows receded, a few of these were observed lying under the willows growing along the left bank in the upper part of the lagoon. As streamflow receded in early December, outflow at the lagoon gradually declined and a check of the lagoon on December 20 showed the mouth was closed. The closing sandbar was breached for the last time during a storm on December 21, and the lagoon then remained open to the ocean until the sandbar closed it again in mid-July.

At the present time the lagoon is too shallow to hold large numbers of adult steelhead (Appendix A). If the lagoon was deeper, as it reportedly was in years past, the adult fish might assemble there before migrating upstream but the value of doing this, other than to anglers, is unknown.

During our field investigations in 1982, we found no evidence that the sandbar which closes the river mouth was detrimental to upstream migrating steelhead. This may not be true in all years. In some years such as 1984, when flows between storms in January, February, and March drop below about 100 cfs, the sandbar blocks the connection between the ocean and the lagoon. This reduces opportunities for upstream migration and may result in excessive catches when adults migrate into the lagoon all at once, following the next storm or series of high tides.

Flows Needed for Adult Migration Through Problem Riffles

During the winter of 1981-82 we repeatedly walked the Carmel River from the lagoon to San Clemente Dam to locate and observe how streamflows affected the shallow riffles that constrain adult steelhead migration at low flows. We selected five riffles where large amounts of cobble and gravel had accumulated as representing the most difficult conditions for adult steelhead passage (Figure II-1). We measured the depths of water at 3-foot intervals across the shallowest part of each riffle at different streamflows. Velocities were never high enough to constrain steelhead passage.

We first estimated the flows needed for steelhead migration through these riffles with the method developed for small Oregon streams by Thompson, (1972).

> "To determine the flow to recommend for passage in a given stream, the shallow bars most critical to passage of adult fish are located and a linear transect marked which follows the shallowest course from bank to bank. At each of several flows, the total width and longest continuous portion of the transect meeting minimum depth and maximum velocity criteria are measured. For each transect, the flow is selected which meets the criteria on at least 25 percent of the total transect width and a continuous portion equaling at least 10 percent of its total width. The results averaged from all transects is the minimum flow we have recommended for passage. I might caution that the relationship between flow conditions on the transect and the relative ability of fish to pass has not been evaluated."

The "Thompson Method" is widely used, and by making such measures and observing steelhead passage in Soquel Creek near Santa Cruz we have found it reasonably accurate on that stream. On the Carmel riffles, however, Thompson's criteria was met at such a wide range of flows that we believe the method is inappropriate. At three of the five riffles we selected as the most difficult Thompson's criteria was met with < 60 cfs, but at the Paso Hondo Riffle it was never met at any flow that we measured (Figure II-2, Table II-1). A linear extrapolation of our data at the Paso Hondo riffle results in an estimate that it would take a flow of 220 cfs at Robles del Rio to meet Thompson's criteria.

Thompson's criteria requires that 25 percent of the width be passable. There is no reason to believe (and Thompson did not imply) that upstream migrating steelhead recognize whether the channel they are passing through is any certain percentage of the length of a transect across the riffle. We believe passage is more related to the actual width and depth of the channel through the shallow riffles. To improve our understanding of this we plotted the width of 0.6' or deeper channels created through these riffle transects by various streamflows at Robles del Rio (Figure II-3). We selected a channel width of 5 feet as the minimum worthy of consideration for steelhead passage (Table II-1). Providing a deep enough channel 5 feet wide at the Paso Hondo Riffle required a Robles del Rio flow of 79 cfs.

We attempted to observe steelhead migrating over these riffles but

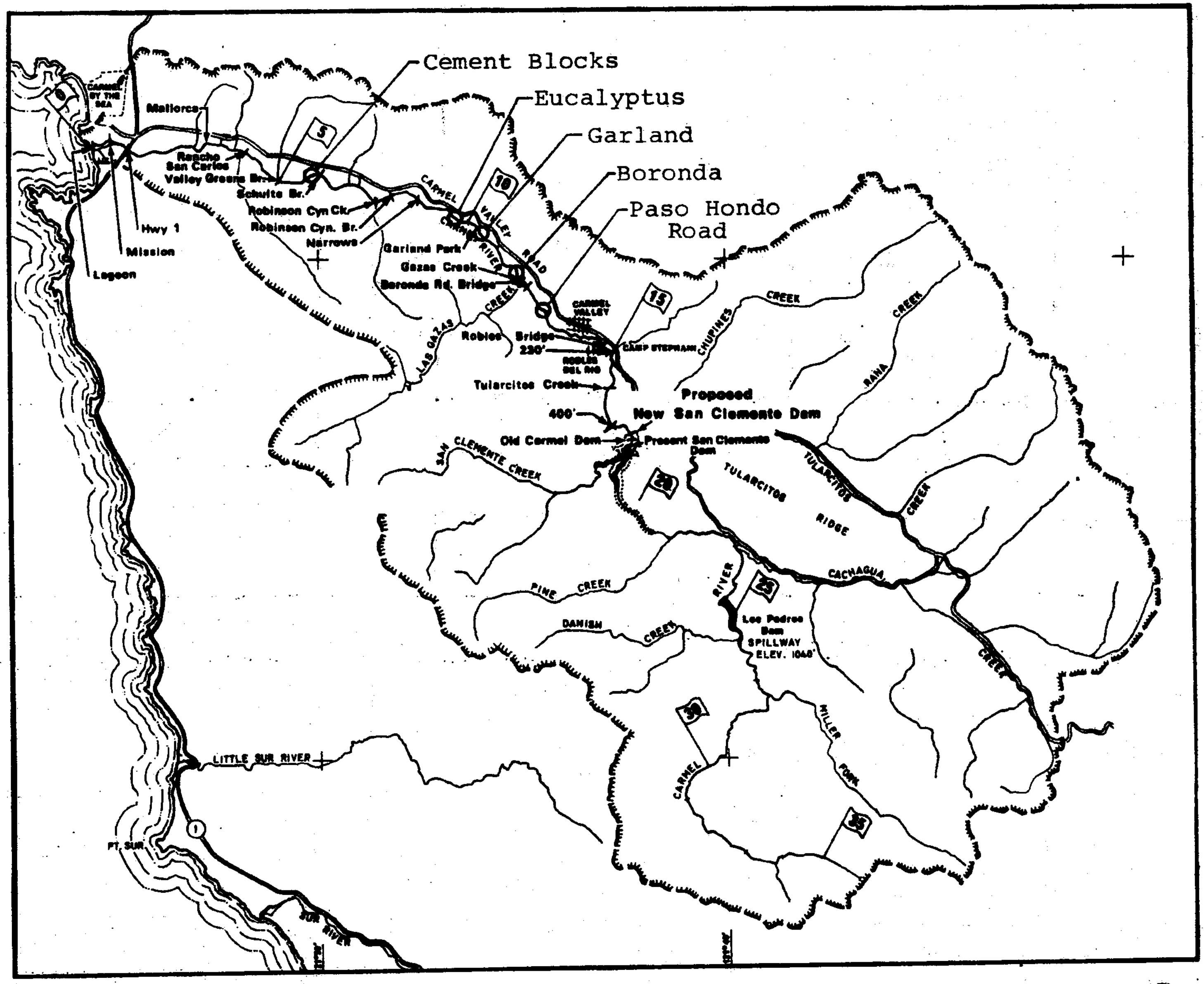


Figure II-1. Location of shallow riffles impeding upstream passage of adult steelhead at low flows during December 1981-March 1982. Base map from US Corps of Engineers. Flags indicate miles from mouth.

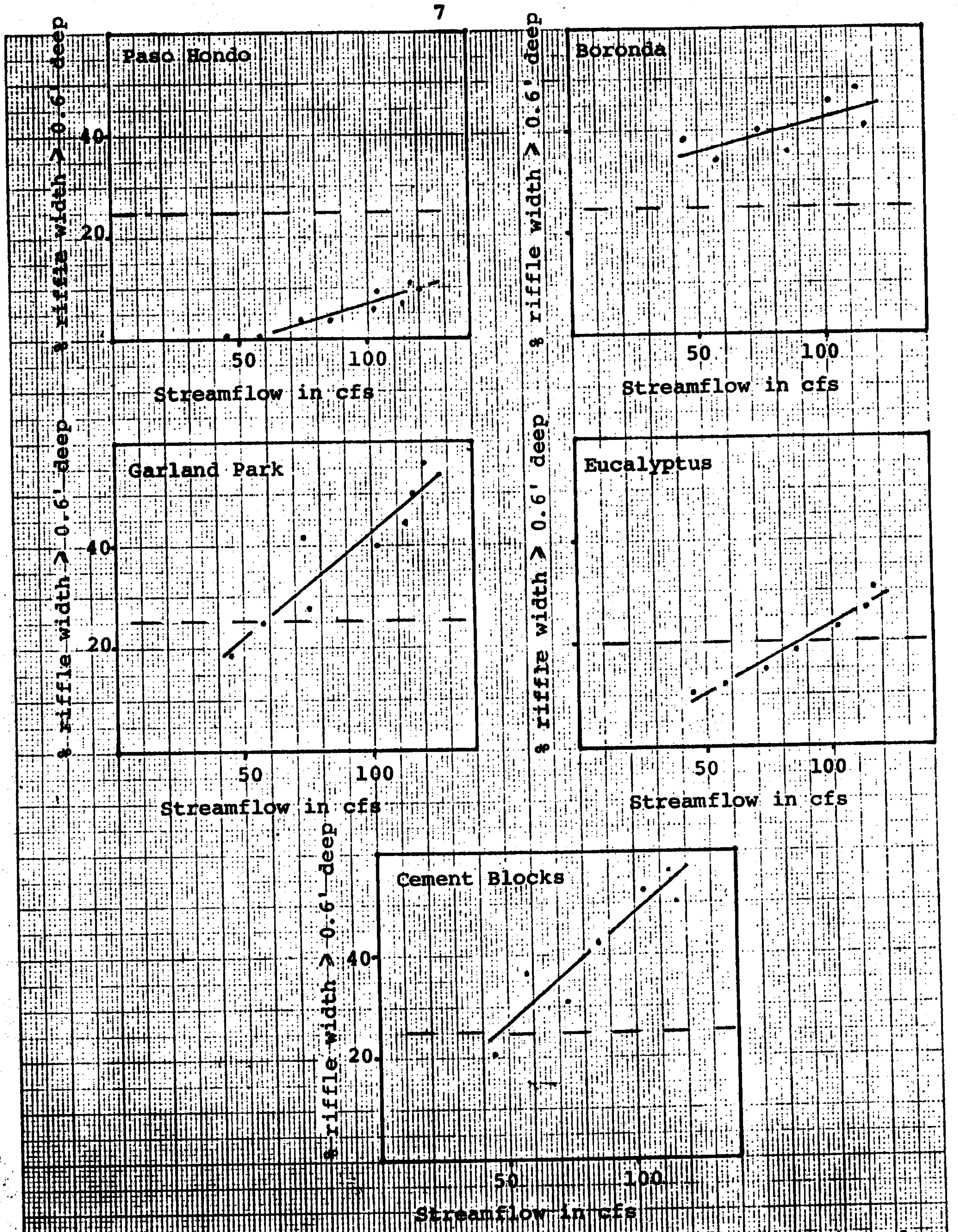


Figure II-2. Relationship between streamflows at Robles del Rio and percent of riffle widths deep enough for steelhead passage. Dash line indicates 25% of riffle width (Thompson's criteria). Carmel River, Dec. 1981-March 1982. Thompson's criteria was never met at the Paso Hondo riffle where the streambed was continuously moving.

Table II-1. Equations relating streamflow at the USGS Robles del Rio gage and water deep enough for steelhead migration through problem riffles.

LOCATION	EQUATION	Flows required at Robles del Rio to provide depth 0.6' over 25% stream width (Thompson's criteria)
Paso Hondo	% = - 8.13 + 0.15 (flow)	(220.8)
Boronda	% = 29.70 + 0.13 (flow)	<40
Garland Park	% = 1.11 + 0.41 (flow)	58.2
Eucalyptus	% = - 2.83 + 0.26 (flow)	107.0
Cement Block	% = 5.03 + 0.43 (flow)	46.4
LOCATION	**EQUATION**	**Flows required at Robles del Rio to provide depth 0.6' over 5' stream width**
Paso Hondo	width = -12.3 + 0.22 (flow)	78.6
Boronda	width = 19.0 + 0.10 (flow)	
Garland Park	width = 2.9 + 0.09 (flow)	(23.3)
Eucalyptus	width = - 1.0 + 0.30 (flow)	(19.9)
Cement Block	width = - .03 + 0.31 (flow)	(16.2)
LOCATION	**EQUATION**	**Width in feet of channel 0.6' or deeper at 75 cfs at Robles del Rio**
Paso Hondo	Same as above	4.2
Boronda	do	26.5
Garland Park	do	9.6
Eucalyptus	do	21.5
Cement Block	do	23.2

Values in brackets are extrapolated values.

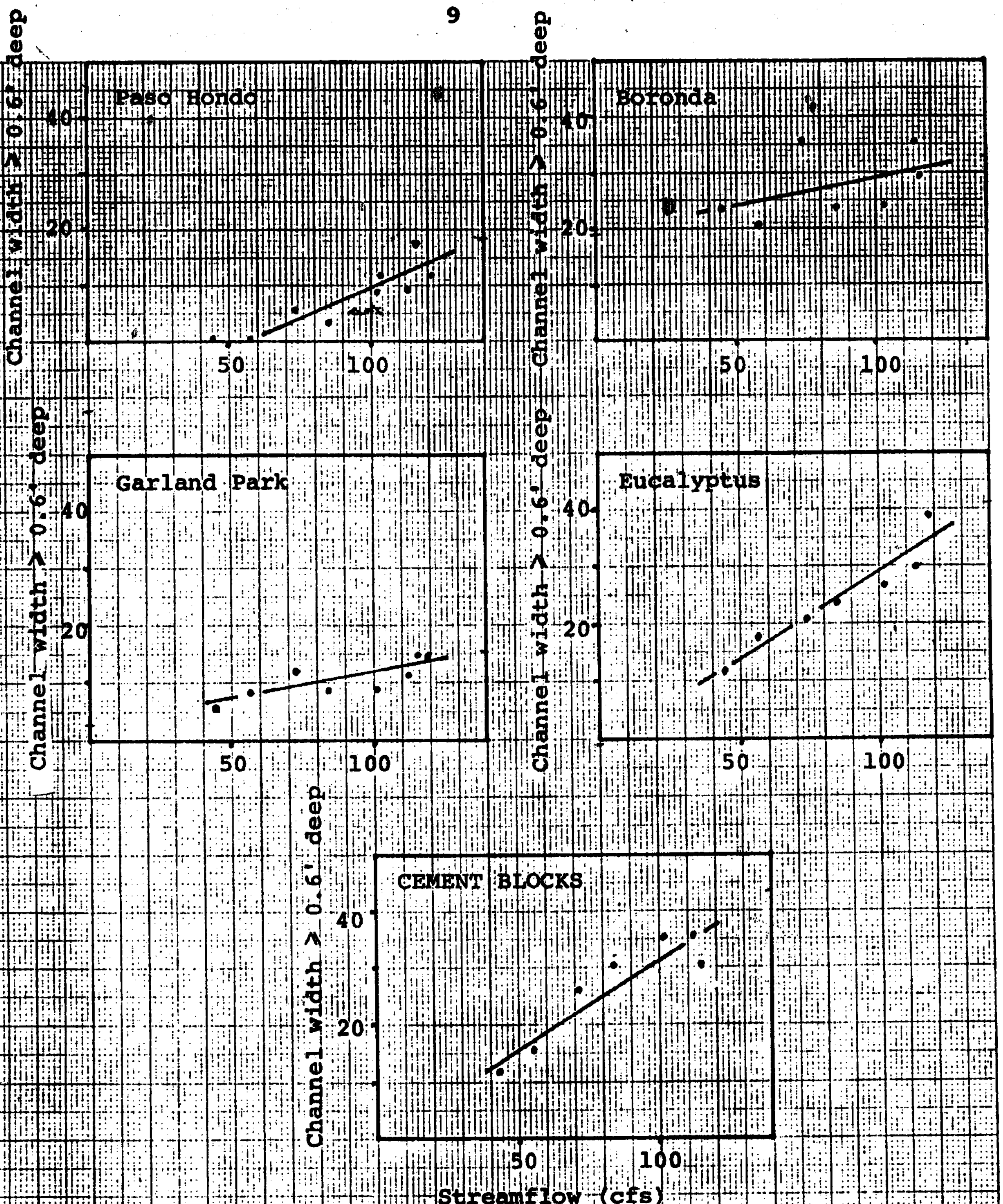


Figure II-3. Relationship between streamflows at Robles del Rio and widths of channel deep enough for steelhead migration over shallow riffles. Carmel River, 1981-82.

because of the high flows during the migration this year, were unable to do so. We did judge each riffle at each observed flow as "easy", "time consuming", and "difficult" for passage (Table II-2). We judged the Paso Hondo Riffle as "difficult" at flows of 86 cfs and less, and as "time consuming" at flows up to 283 cfs. We thought that steelhead could easily pass all the other riffles when flows were above 58 cfs at Robles del Rio.

The riffle at Paso Hondo was a special but not unique problem. It was a large deposit of cobble, gravel, and sand that extended diagonally across the river. At all but low flows the bed was constantly changing, and often as flows increased the streambed at the lip of the riffle built up. Although Paso Hondo was the worst example of this, most of the scatter in the data points for the Paso Hondo, Boronda, and Garland Park Riffles is due to such mobile beds. With additional bedload any of these could become as critical as the Paso Hondo Riffle in future years.

We calculated that under 1982 streambed conditions, 75 cfs at Robles del Rio would provide channels 10 feet or wider and deep enough for comfortable steelhead passage through all but the Paso Hondo Riffle where the suitable channel would be about 4 feet wide (Table II-1). Under those conditions steelhead might refuse, or at least be delayed at, the Paso Hondo or similar riffles created by the moving streambed.

Comparing Historical Flows and Migrations

To further assess the problem of flows needed for upstream migration, we examined the historical records of flow and fish counts at the San Clemente Dam. The Cal-American Water Company made twice daily counts of the steelhead in the fish ladder during the migration seasons from 1954 to 1973 and continuous counts in 1974 and 1975. We were able to obtain only the records for 1962, and from 1964 to 1975. The twice daily counts are not a measure of the total number of steelhead passing the dam but they do appear to be a good annual index of the abundance of fish that migrated past San Clemente Dam.

The fish arrive at San Clemente Dam in waves (Figure II-4). We compared each wave or group of fish with the flows that existed at the time of their movement. We defined groups of fish as being separated either by 5 days with no fish counted at the ladder and/or by an increase in the moving average of 4 days of counts. Using these criteria, we distinguished 38 spawning groups over this 13-year period. They are delineated by small arrows on Figure II-4. We did not include the spawning group in the last half of 1971 because counts during that period appear to have been done in a different manner and we do not believe the data is comparable. There were 17 fish counted over the ladder in March 1972, but we do not have the daily count for that month. Examination of Figure II-4 suggests that relatively large flows (200 cfs or more) that were sustained for a week or so coincided with large counts of steelhead at San Clemente. While such flows did not always produce large numbers of fish, lower flows attracted large numbers of fish only in March and April of 1964.

Table II-2. Dettman's and Li's judgments of the ease of adult steelhead passage over representative shallow riffles in the Carmel River at various flows measured at Robles del Rio during the winter and spring of 1981-82.

Streamflow at Robles del Rio	Paso Hondo	Boronda	Garland Park	Eucalyptus	Cement Blocks
283	time consuming				
185	time consuming	easy			
121	time consuming	easy	easy	easy	easy
117	time consuming	easy	easy	easy	easy
114		easy	easy	easy	easy
104	time consuming				
103	time consuming	easy	easy	easy	easy
102					
86	difficult	easy	easy	easy	easy
74	difficult	easy	easy	easy	easy
58	difficult	easy	easy	easy	easy

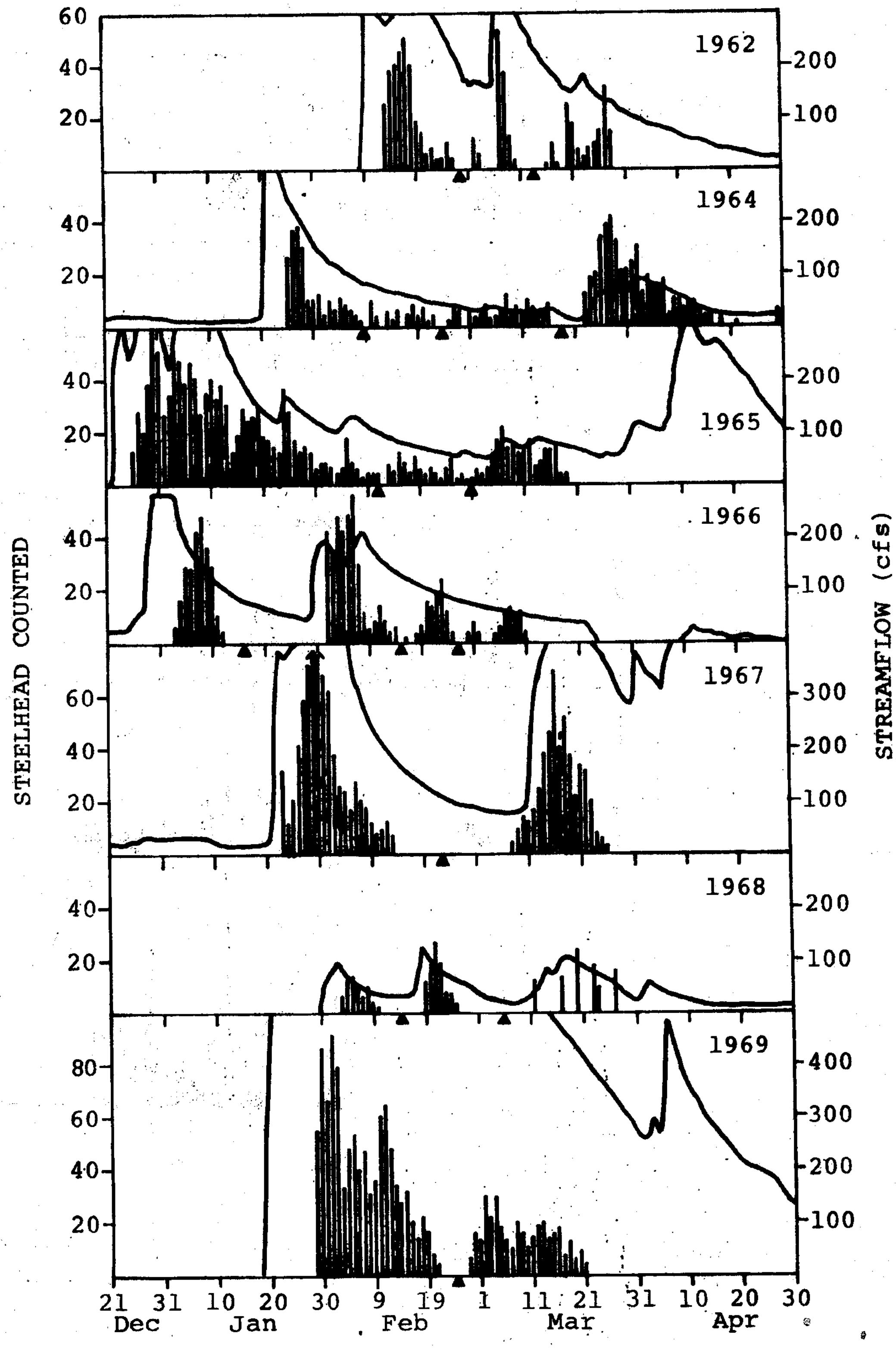


Figure II-4. Number of adult steelhead counted twice daily in the fish ladder at San Clemente (vertical bars) compared with daily streamflow in the Carmel River at Carmel (line). Fish arrive in waves or spawning groups and usually appear to do so in response to sustained flows of 200 cfs or more.

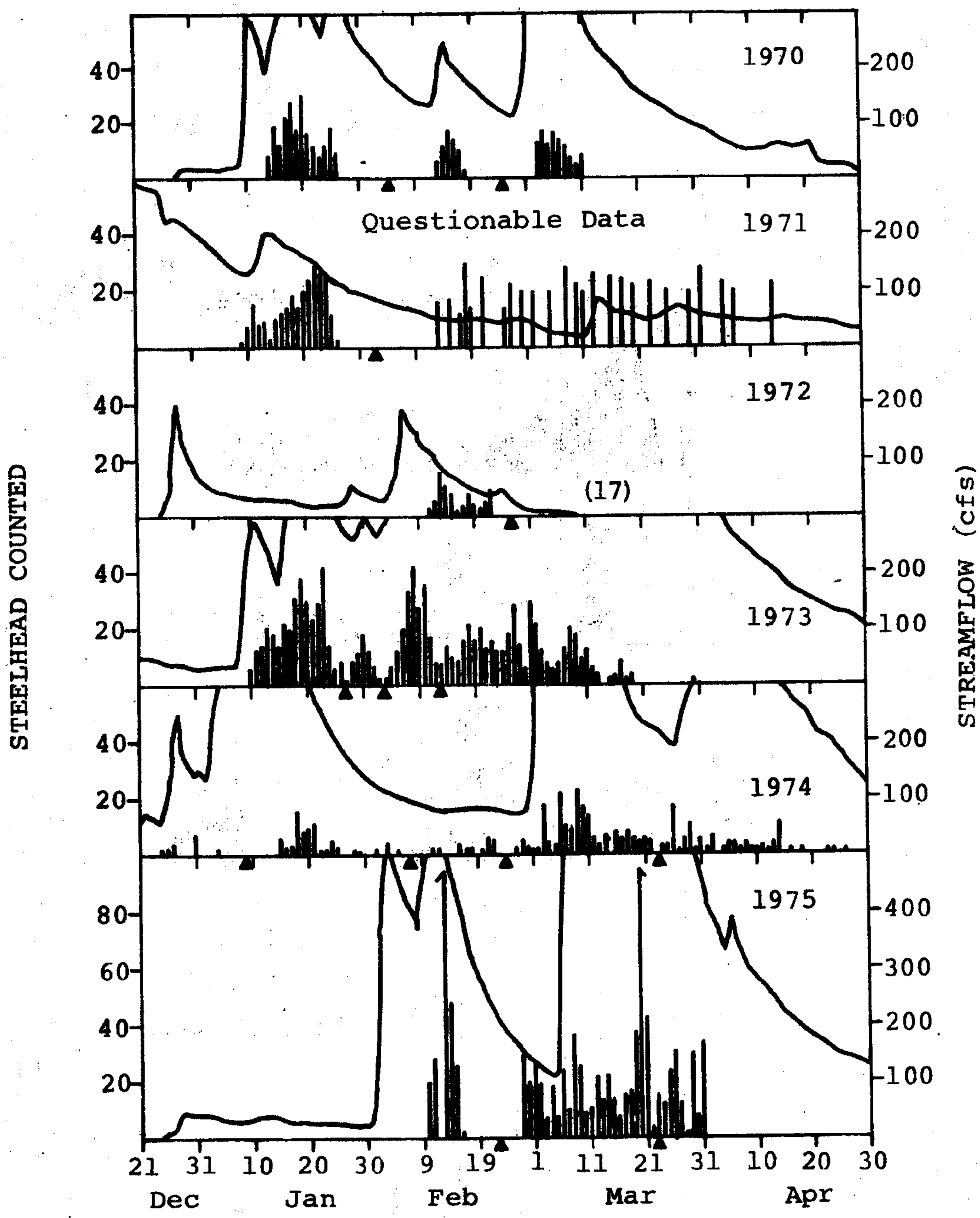


Figure II-4. (continued) Number of adult steelhead counted twice daily in the fish ladder at San Clemente (vertical bars) compared with daily streamflow in the Carmel River at Carmel (line). Fish arrive in waves or spawning groups, and usually appear to do so in response to sustained flows of 200 cfs or more.

We plotted the mean daily counts for each of the spawning groups against the average of the daily flows at the USGS gage at Carmel on the days each spawning group was counted through the ladder (Figure II-5). There is a great variation in the way spawning groups appeared to respond to various levels of streamflow, but a general trend for more fish to arrive during periods of higher flow is obvious. This relationship is statistically significant.

The last spawning groups in each year accounted for a great deal of the variability that is observed in this relationship. While fish are more inclined to migrate on lower flows as they approach the end of their spawning time, the actual number that pass in March and April depends largely upon whether they have been held up below by low flows in January or February.

If we omit this last group, the correlation coefficient of the relationship between flow and group size is 0.71. Over 50 percent of the variability in the mean daily counts of all but the last group can be accounted for by the flows at the time the fish were passing the ladder.

Over 95 percent of the steelhead counted during these 13 years migrated over the dam during January, February, and March. Only a few fish moved over the ladder in December or in April. As another way of examining the flows needed for upstream migration, we plotted the total flow for January, February, and March each year with the total size of the steelhead run at the fish ladder (Figure II-6). The results are significant at the 5 percent level utilizing the data for all years.

We believe the low fish counts in 1962, 1970, and 1974, all years of high winter flow, resulted from low flow conditions for downstream smolt migration in the springs of 1960, 1968, and 1972 (See Chapter V). If we ignore these three data points, there appears to be a steady increase in the size of the steelhead run at the ladder with higher flows--up to about 26,000 acre-feet. Additional flows above this level did not increase the steelhead run.

We believe that angling may be the factor causing the relationship between counts at San Clemente Dam and runoff in January, February, and March. The results of our 1984 survey of the Carmel River steelhead fishery indicate that anglers captured over 95 percent of the steelhead that ran into the river in December, January, and February (Appendix F). Flows in January and February were high enough to attract fish into the river, but low enough to cause fish to hesitate in the lower river. This hesitation, combined with excellent water clarity and streamflows for fishing, resulted in high angler success and a large catch. Based on these results, we believe a smaller portion of the steelhead run reaches San Clemente Dam in low water years because anglers catch most of the fish that are migrating in January and February.

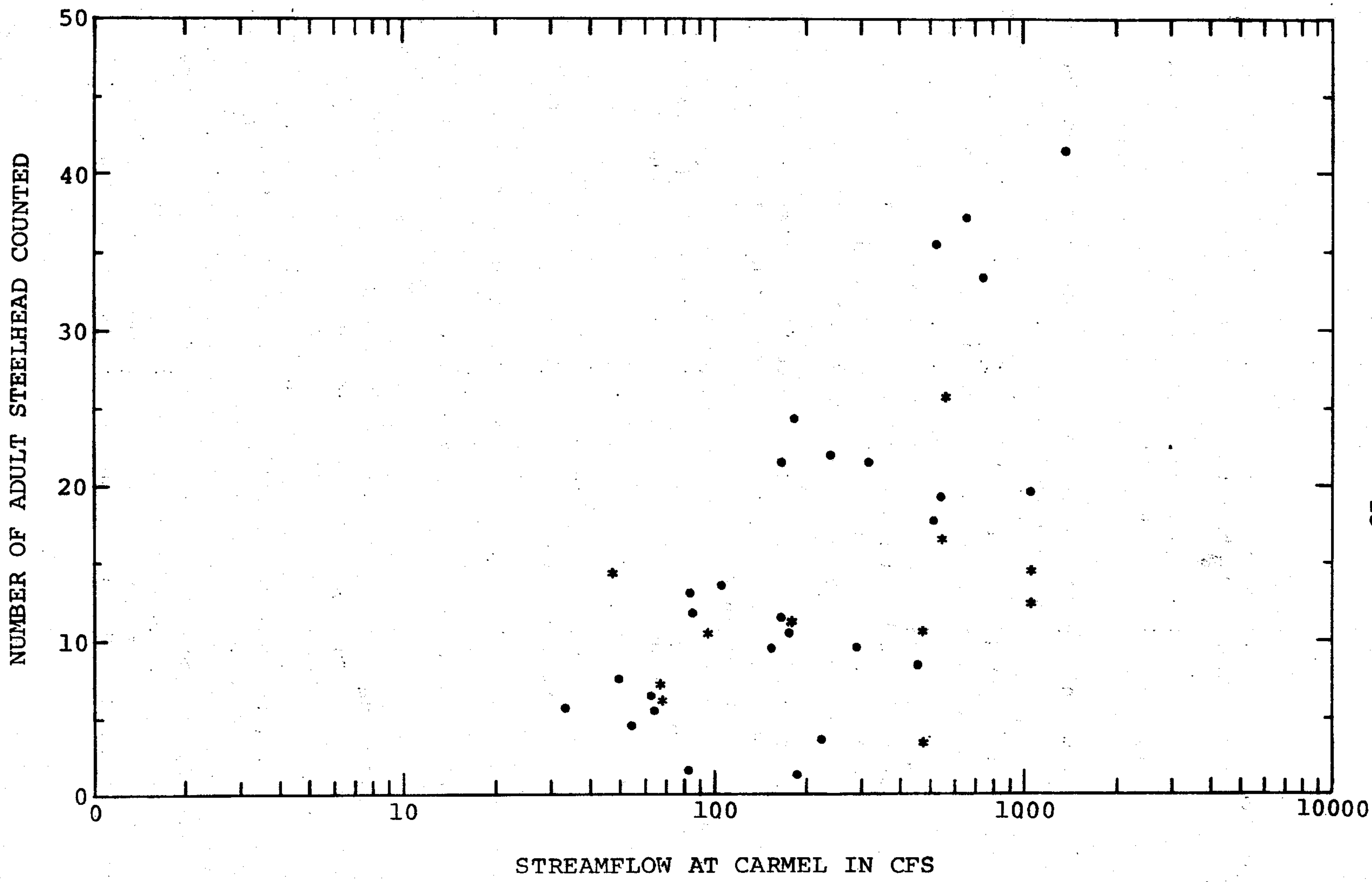


Figure II-5. Relationship between average daily count of steelhead spawning groups passing San Clemente Dam and the average daily flow of the Carmel River at Carmel during their passage. R = 0.54; significant at 1% level. * indicate last spawning group of the year.

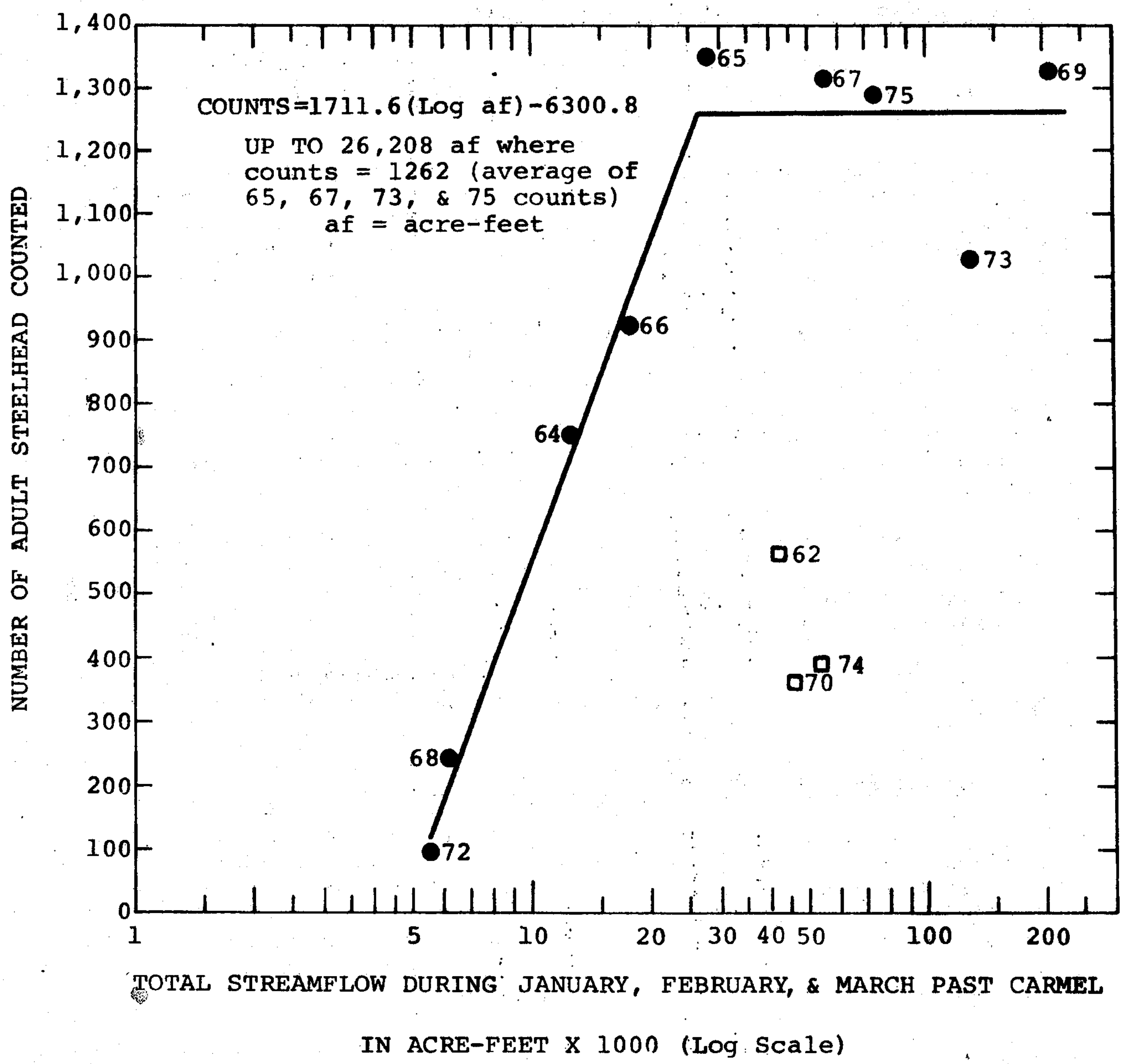


Figure II-6. Relationship between the total steelhead counted in the San Clemente fish ladder each year from 1962 to 1975 and the total acre-feet of flow passing Carmel in January through March in the same year. □, Years 1962, 1970, and 1974 are poor year classes because of low spring flows two years earlier when most juveniles were emigrating. During this 12-year period, larger winter flows (up to about 26,000 acre-feet) usually attracted more fish upstream into the ladder. Relationship developed using data shown by ●.

Length of Time Needed for Upstream Migration

Comparing the historical daily flows with arrival of the first steelhead at San Clemente suggests that the length of time required to reach the fish ladder varied from 1 to 10 days following an increase in flow (Table II-3). A few fish arrived at the ladder one day after an increase from flows too low for passage in January 1967 and did so again in January 1973. However, it required 10 days to reach the ladder in January 1969 and 9 days in February 1975. The average time to reach the ladder, following an increase in flow, was 4 days. The data is evidence that, with high flows, fish can reach the dam in a few days. It is not evidence that they usually travel that fast.

Upstream Passage Through San Clemente Dam and Reservoir

The San Clemente fish ladder was built in 1921 and at 85 feet is the highest ever built in California. There have been no studies to describe its efficiency, but we know of no reason to believe that, when properly operated, it is a significant impediment to fish that reach the base of the San Clemente Dam and want to proceed further upstream. The ladder apparently works well.

The 790 acre-feet, 33 surface acre, San Clemente Reservoir fills within a few days after the first storms and should not significantly delay upstream migrating steelhead that wish to proceed upstream in the Carmel or into Pine or San Clemente creeks to spawn.

At flows that existed during the 1982 spawning season, there were no barriers in the 5.5-mile reach from San Clemente Reservoir to Los Padres Reservoir.

Upstream Passage - Los Padres Dam and Reservoir

The Los Padres Dam, built in 1949, is 148 feet high and currently stores approximately 2000 acre-feet of water. There is a fishway at its base which leads migrating steelhead into a trap. That trap is operated by the Cal-American Water Company under agreement with the Department of Fish and Game. Fish trapped there are trucked around the dam and placed in Los Padres Reservoir where they can continue their migration upstream to spawning areas in the upper Carmel River and its tributaries.

The few records of steelhead trucked around Los Padres Dam describe the numbers as being very much less than even the partial counts of steelhead in the San Clemente ladder (Table II-4). One reason for the low returns to the trap may be that the trap itself is inefficient in collecting fish that arrive at Los Padres Dam. It was reconstructed in 1981 to be more attractive to the adult migrants, but the low numbers of fish that have been trapped since suggest that the problem may not have been solved. The low runs to the Los Padres trap could also be caused by high mortality of juvenile steelhead migrating downstream over the Los Padres Dam. This problem is discussed in the Chapter V on Downstream Migration.

Above Los Padres Reservoir the steelhead have access to 14.4 miles

Table II-3. Days required for adult steelhead to reach ladder after first major flow increase of Carmel River at Carmel.

	First Flow Over 90 cfs		First Fish Arrival			
YEAR	DATE	FLOW	DATE	#FISH	TEMP	DAYS
61/62	Feb 9	330*	Feb 13	25		4
63/64	Jan 21	482	Jan 25	18	45°	4
64/65	Dec 24	315	Dec 26	12	52°	2
65/66	Dec 29	387	Jan 3	5	44°	5
66/67	Jan 22	570	Jan 23	31	44°	1
67/68	Jan 31	93	Feb 3	6	41°	1**
68/69	Jan 19	2840	Jan 29	53		10
69/70	Jan 10	407	Jan 14	8		4
70/71	Dec 1	103	Jan 9	2		***
71/72	Feb 6	196	Feb 11	3		5
72/73	Jan 9	188	Jan 10	6	43°	1
73/74	Dec 1	407	Dec 19	2		***
74/75	Feb 1	121	Feb 10	20		9
						x 4.18

* Carmel River at Robles - only data available.

** In 1968, flows were < 10 cfs until December 31 when they suddenly rose to 64 cfs at Carmel. Flow did not reach 90 cfs until February 2, but fish could have started their migration on December 31.

*** High flow early in December - but fish may not have wanted to migrate that early.

Table II-4. Counts of adult steelhead at the San Clemente fish ladder and of steelhead trapped and passed over Los Padres Dam. The 1949-73 counts in the San Clemente ladder are the sum of twice-daily counts of fish in the entire length of ladder made by shutting off the flow. The 1974-84 counts are totals made by automatic counter as the fish entered San Clemente Reservoir.

YEAR	San Clemente Ladder	Los Padres Trap
1949	no data available	147
50	no data available	124
51	no data available	154
52	no data available	86
62	566	558
64	759	
65	1350	
66	915	
67	1314	
68	246	
69	1336	
70	362	
71	769	
72	94	
73	1022	
74	395	
75	1287	9
82		125
83		160
84	380	51
85		27
86		42
average	771	135

CHAPTER III. SPAWNING AND SPAWNING HABITAT

Successful reproduction is, of course, necessary for continuation of any steelhead resources. Success depends upon upstream migration which we have described in Chapter II, and upon the right combination of streamflow and stream bottom conditions for nest building, egg incubation, and fry emergence.

Female steelhead select sites for digging their nests usually in moving water of glides at the lower ends of pools and at the heads of riffles. They are adept at choosing areas where ample movement of subsurface water occurs and where dissolved oxygen, water depths, and velocities remain high as streamflow declines.

Previous studies in Oregon and California have shown most steelhead dig their nests where depths are about a foot and velocities are about 2 ft/s, but there is significant variation. If eggs are to hatch, gravel must be large enough to resist movement during succeeding high flows, but it must be small enough to move downstream when the combined forces created by high water velocity and digging action of the female lifts the gravel off the stream bottom. Estimates of the size of gravel used by steelhead range from about 0.5" to 4" (12-100 mm). When possible they avoid sand and larger cobble.

The Spawning Season

To assess when steelhead begin spawning below San Clemente Dam we searched the Carmel River throughout the migration season trying to locate nests.

During December 2-5, 1982, biologist David Dettman hiked 14.4 miles along the Carmel River from the mouth to Rosie's Bridge (Esquiline Road). He found ample areas where steelhead could have spawned in late November when mean daily flows vary from 66-378 cfs. But even though fishermen had reported catching fish as far upstream as Rosie's Bridge, and the water was low and clear, he found no steelhead nests. High flows prevented further searches for nests until February.

On February 13 and 14, biologists Don Kelley and Stacy Li searched several reaches of the Carmel River below Rosie's Bridge downstream to Schulte Road when the stream was again low and clear. Although they found abundant spawning gravel throughout the stream, they saw only two nests, both at Garland Park (Figure III-1).

During a search that began on February 22 and continued through March 11, 1982, biologists Stacy Li and David Dettman located 218 steelhead nests in the Carmel River from San Clemente Dam downstream to Riverside Trailer Park below Meadows Road. They observed several females below Rosie's Bridge and at Garland Park as late as March 22-24, 1982. We concluded that in 1982 little spawning occurred in the Carmel River before mid-February and that most of the steelhead spawned from late February and through March.

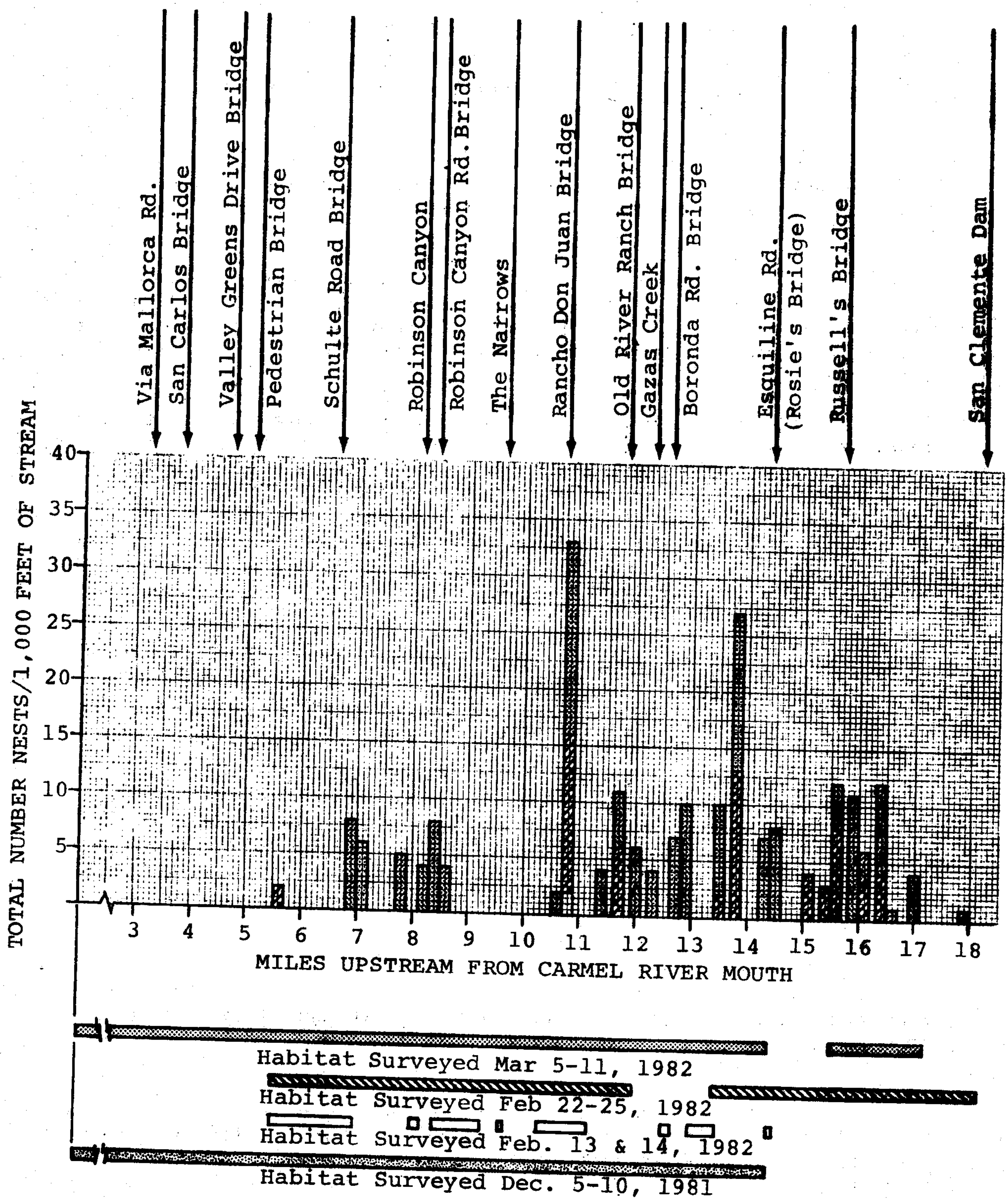


Figure III-1. Distribution of steelhead nests, and date and location of searches, in lower Carmel River, 1992-83 water year.

Distribution of Steelhead Nests in the Lower Carmel River

During the 1982 spawning season steelhead spawned in the 12.5-mile reach of the Carmel River below San Clemente Dam. Nests were most abundant in the 9.5-mile reach above the Narrows where 183 (or 83%) of the nests were located. Thirty-five of the remaining 37 nests were in the 2.5-mile reach from Robinson Canyon Bridge to Schulte Road. Over one-quarter of the nests were concentrated in two locations, Garland Park and below Powell's Hole downstream of Rosie's Bridge. Only two nests were found below Schulte Road.

Many of the nests below Robinson Canyon Road were built in gravel that met the criteria for spawning gravel, but were subsequently threatened by shifting sand that moves through the reach at relatively low flows. Matt Kondolf, who has studied the streambed movement, estimates that sand movement through the reach at Schulte Road varies from 15 ton/day at 40 cfs to 55-95 ton/day at 225 cfs. In the reach above Schulte Road where steelhead were spawning, 5 tons of sand/day would be equivalent to about 1 cubic foot of sand per day per foot of stream width. This quantity is probably sufficient to fill the spaces between gravel in the nests and severely reduce fry emergence. The high sediment transport rates at low flows and the fact that much of the sand carried at high flows settles out as flow declines, led us to conclude that high sand concentrations probably limit successful fry emergence in the reach below Schulte Road.

Nests were absent from the 1.5-mile reach between the lower boundary of Garland Park and the old gravel pit adjacent to Robinson Canyon Road Bridge. This was despite the presence of ample good quality spawning gravel throughout the reach.

Definition of Spawning Habitat

To estimate the amount of spawning habitat in the Carmel River we developed a set of criteria based upon measurements of depth, velocity, and substrate composition at nesting sites.

Depth and Velocity

After steelhead finish digging their nests and burying their eggs, they leave a small mound of gravel with eggs buried at its base and a depression immediately upstream. We measured depths and velocity of water over the top of the mound and immediately upstream in the depression. At the time of our surveys, water depths average 1.3 feet in the depression and 0.9 foot over the top of the gravel mound (Figures III-2 and III-3). Mean water velocity averaged 2.0 ft/s over the depression and 2.6 ft/s over the nest mound. We observed fish building nests in water as shallow as 0.5 foot and as slow as 1.2 ft/s (Figures III-4 and III-5).

Substrate Size

During nest construction, silt, sand, and usually small gravel is washed downstream. We therefore measured streambed composition adjacent to

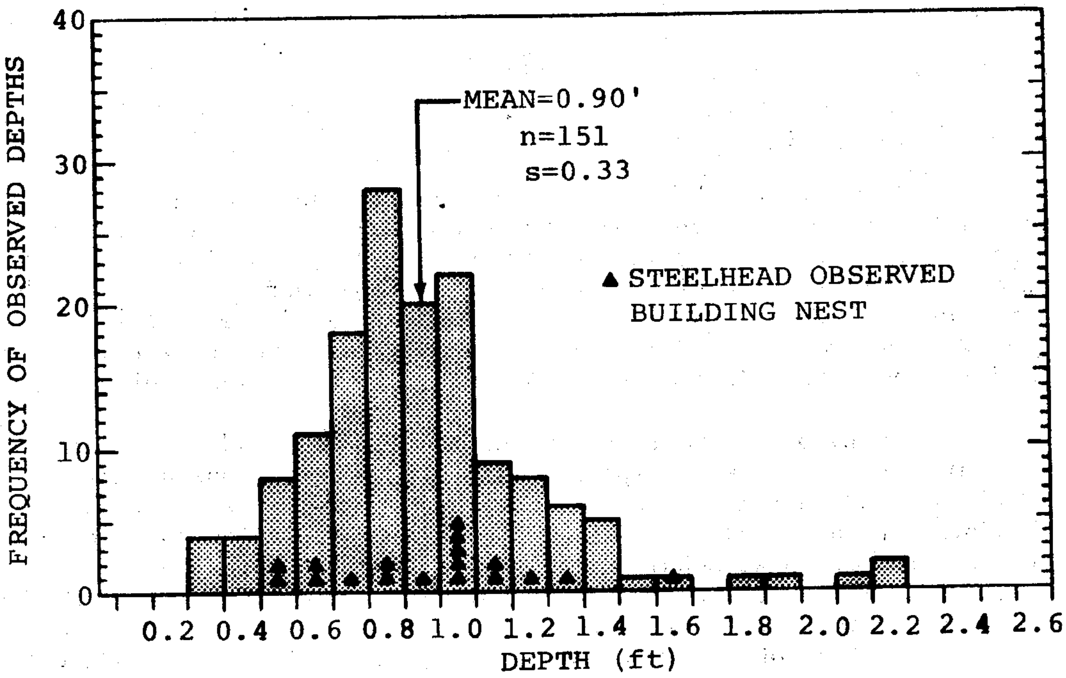


Figure III-2. Depth of water over top of steelhead nests in Carmel River below San Clemente Dam, February 22-March 10, 1982. Streamflow at time of measurement ranged from 150-230 cfs at Robles del Rio USGS gage.

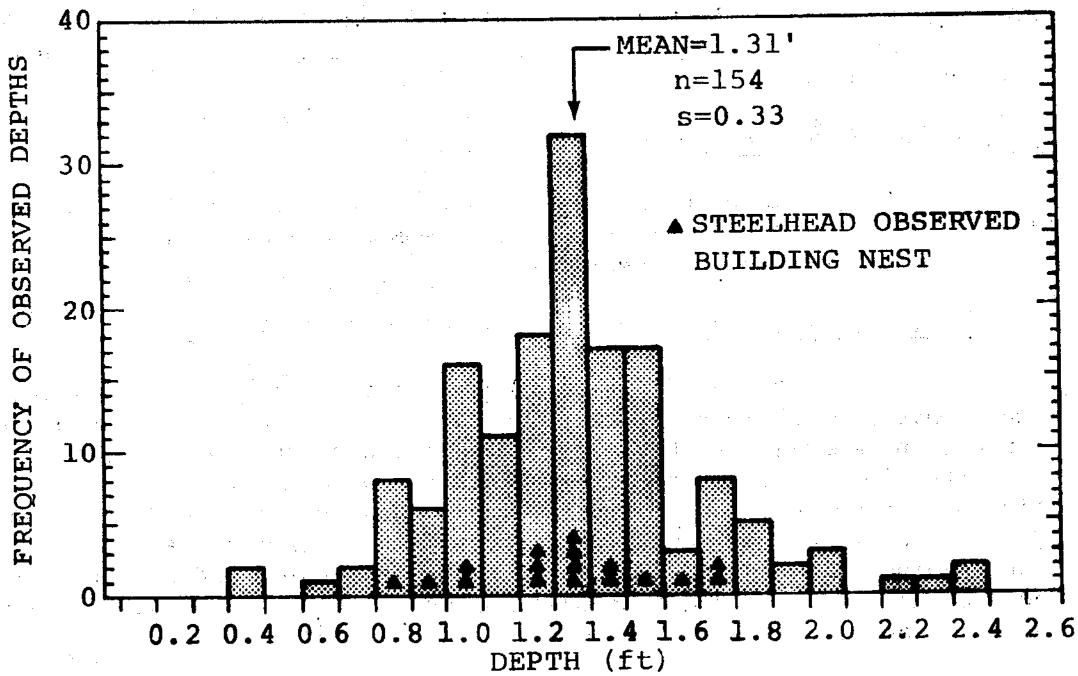


Figure III-3. Depth of water to bottom of depression in steelhead nests in Carmel River below San Clemente Dam, February 22-March 10, 1982. Streamflow at time of measurements ranged from 150-230 cfs at Robles del Rio USGS gage.

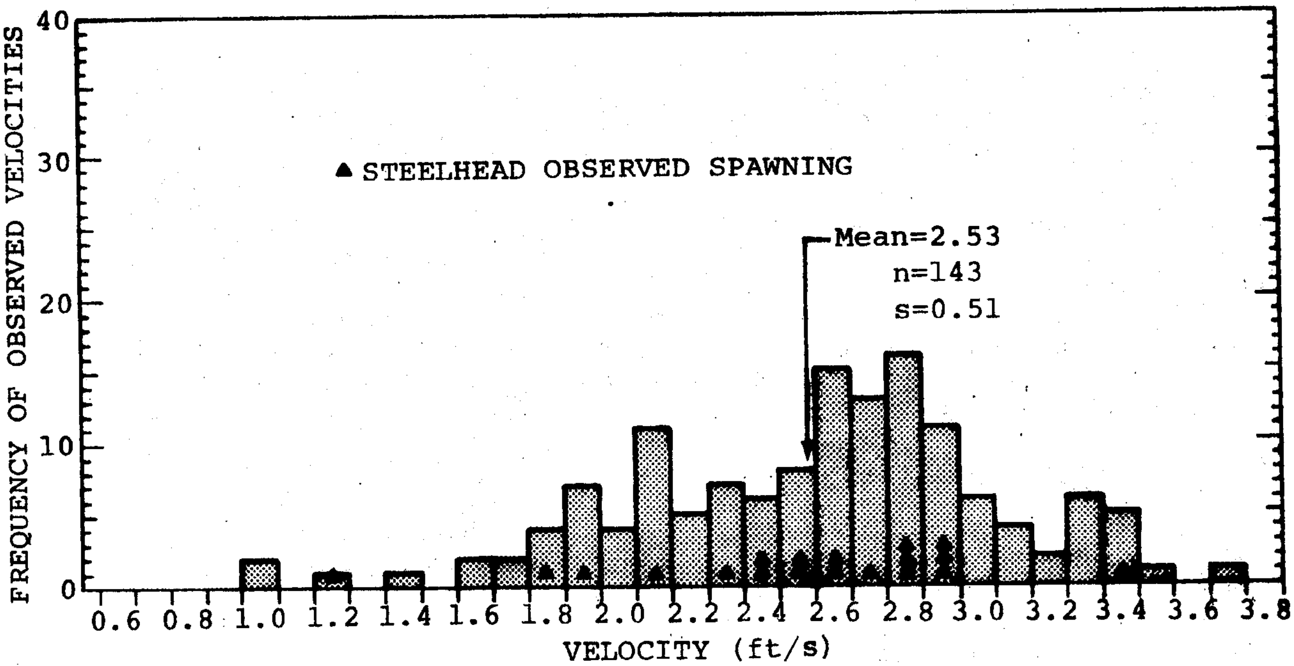


Figure III-4. Velocity of water over top of steelhead nests in Carmel River below San Clemente Dam, Feb. 22–March 10, 1982. Streamflow at time of measurement ranged from 150-230 cfs at Robles del Rio USGS gage. Velocity measured at 0.6' depth from water surface.

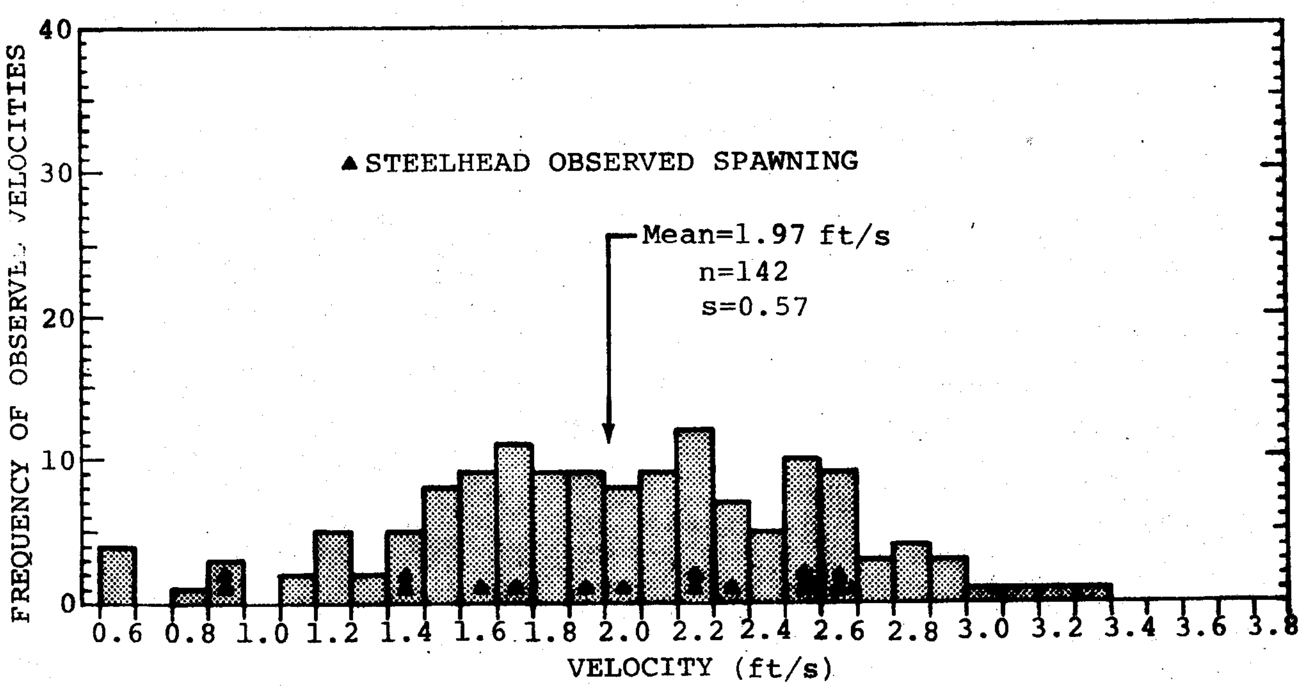


Figure III-5. Velocity of water over depression in steelhead nests in Carmel River below San Clemente Dam, Feb. 22-Mar. 10, 1982. Streamflow at time of measurements ranged from 150-230 cfs at Robles del Rio USGS gage. Velocity measured at 0.6; depth from surface of water.

nest as an indication of streambed composition chosen by the fish. Over 80 percent of the gravel and cobble adjacent to 15 nests we measured ranged from 22-90 mm. Although larger cobble and small boulders were abundant in the Carmel River below San Clemente Dam, steelhead built their nests where smaller cobble and gravel was predominant. Orcutt et al. (1968) found that 75 percent of the spawning gravels ranged from 13-101 mm in diameter and that steelhead rarely utilized cobble larger than 152 mm in diameter. Dettman measured gravel adjacent to 15 steelhead nests (Figure III-6) and concluded that the size of gravel and cobble utilized by steelhead in the Carmel River is similar to sizes utilized elsewhere.

Criteria for Measuring Spawning Habitat

Previous studies reviewed by Smith (1973) have used minimum depths and velocity criteria for steelhead spawning habitat that are skewed toward the low end of the range of observed depth and velocity. We believe that using minimum or lower depth or velocity criteria is likely to overestimate the amount of spawning habitat at a given flow. We selected a depth of 0.9 foot and velocity of 2.0 ft/s from Figures III-3 and III-6 as the lowest criteria we would use for deciding whether or not a portion of the stream was suitable for spawning. At flows we measured, depths and velocities were never high enough to preclude spawning.

We used the distribution of gravel and cobble sizes of Figure III-6 as the criteria for determining whether or not the substrate in each portion of the stream was suitable for spawning habitat. Based upon this distribution, 75 percent of the gravel larger than 8 mm in diameter should be in the 22-90 mm size range, with more than half 22-64 mm in diameter.

Size of Steelhead Nests in the Lower Carmel River

The size of steelhead nests in the Carmel River ranged from 5-70 square feet and averaged 25.1 square feet (Figure III-7). We found no instances where the size of the nest was limited by a lack of available gravel and, with few exceptions, all nests were located in areas where ample additional habitat was available, but not used. Only between San Clemente Dam and Tularcitos Creek, were all of the available nesting sites used.

Spawning Habitat in 1982

Streamflow in the Carmel River below San Clemente Dam was adequate for spawning throughout January, February, and March. Streamflow at the Robles del Rio USGS gage never dropped below 100 cfs during these months, and 80 percent of the time mean daily flows were greater than 150 cfs. As we located nests during the period February 11-March 5, 1982, we also measured potential spawning habitat in the vicinity of each nest and in areas we judged suitable for spawning but where we found no nests.

In 1982, we measured 104,000 sqft of spawning habitat in reaches where steelhead were actually spawning and an additional 74,000 sqft in reaches where no fish spawned that year. Using our estimate that the mean

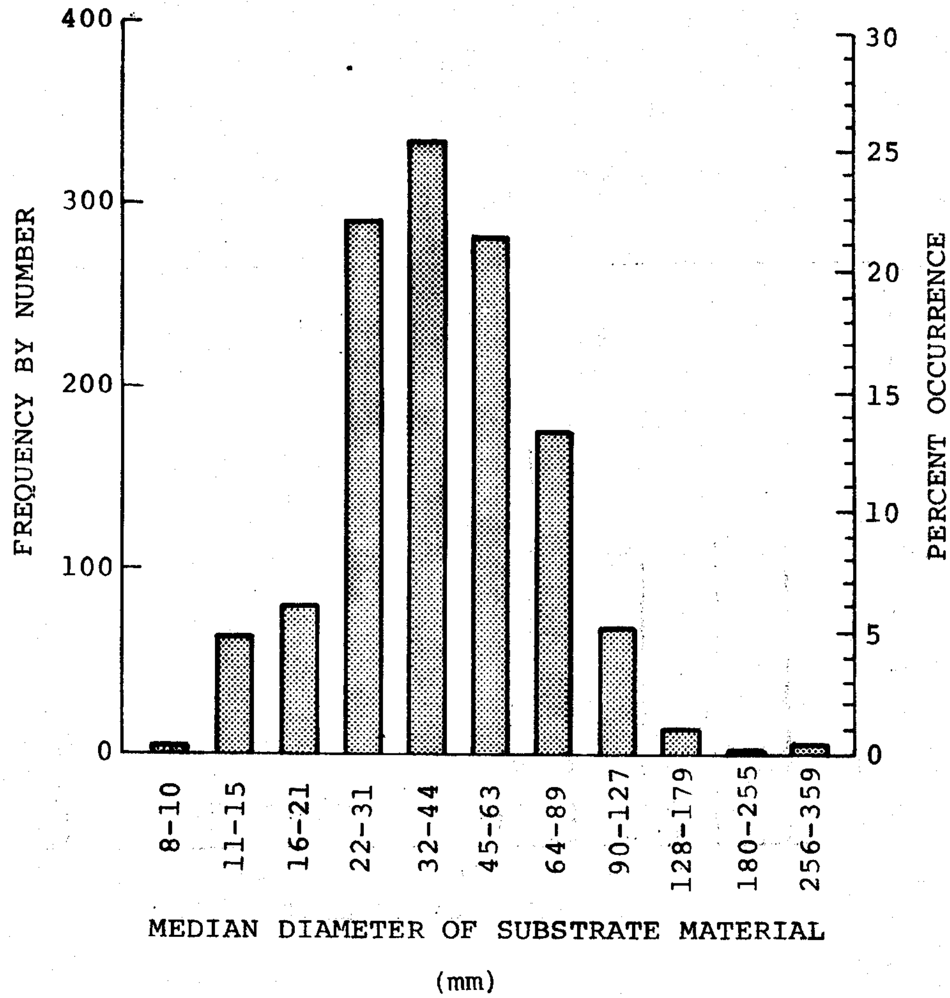


Figure III-6. Size class composition of substrate mixture directly adjacent to 15 steelhead nests in the Carmel river between Robinson Canyon and San Clemente Dam. Based upon median diameter measurements in a 3 square foot sample of surface gravels and cobble with diameters ⩾ 8 mm.

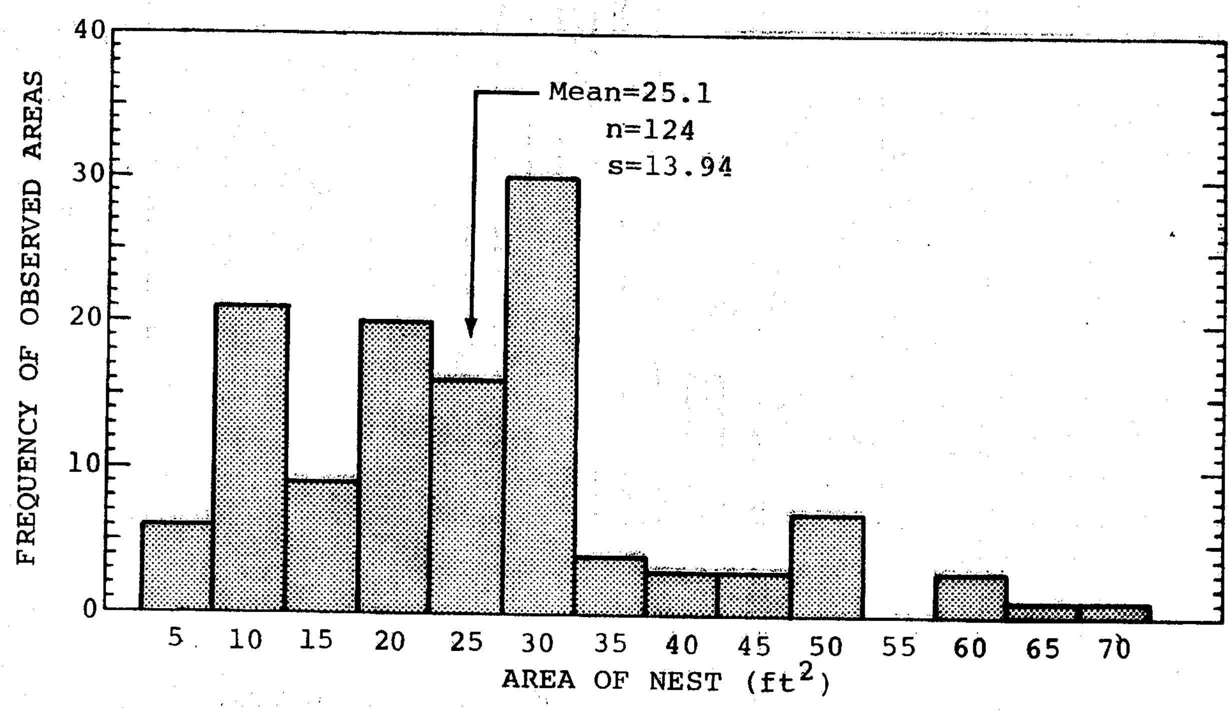


Figure III-7. Size of steelhead nests in Carmel River below San Clemente Dam, February 22 - March 10, 1982.

nest area occupied 25 sqft and assuming each female needs another 25 sqft to minimize disturbance from adjacent females, we divided the amount of spawning habitat by 50 square feet/nest to calculate that the Carmel River could support a spawning population of 4000 fish if they used only the reaches where we observed spawning, and 7000 fish if they used all that we defined as being available at 188 cfs, the mean flow during our observations.

How representative was the amount of spawning habitat in 1982? During the 1982 spawning season flow ranged from 220 cfs to 165 cfs. Based upon reconstructed Carmel River flows (USCE data) the median March flow is 173 cfs. This median flow is very close to the average flow (188 cfs) during our spawning habitat measurements. We concluded that the amount of spawning habitat available in 1982 (or more than that) has been available in about one-half the years. There are excellent steelhead spawning opportunities below San Clemente Dam and in most years there is far more spawning habitat than there are fish to use it.

The Effect of Streamflows on Spawning Habitat in the Lower Carmel River

We measured available spawning habitat in five, 400-foot-long reaches at three flows. For these measures we chose the reaches that were used by spawning steelhead and represented different stream widths and channel slopes as follows.

wide channel/low slope-- glides at Garland Park and below Robinson Canyon Bridge;
wide channel/high slope-- run and riffle below Manor Well;
narrow channel/low slope-- glides below Powell's Hole;
narrow channel/high slope--run and riffle below Cal-Am Filter Plant.

In each reach we measured depths and surface water velocity over all discrete patches of suitable spawning gravel. Later, when we had developed the previously described criteria for depth and velocity we eliminated or included the area of these discrete patches in a summation of available habitat in each reach and at three flows (Table III-1).

Figure III-8 illustrates the data in column 5 of Table III-1 and the relationships between available habitat and streamflow in these reaches. As one would expect, where the channel is wider, the amount of spawning habitat increases more rapidly with increasing flows. We could not determine any relationship for the Garland Park reach due to the major substrate changes that occurred following storms in early April.

Using this data, we calculated the effect of streamflow on spawning habitat in these four reaches as a percent of habitat available at 150 cfs (Figure III-9). Based upon these relationships, we calculated the amount of spawning habitat that would exist at 150 cfs in the other locations where we found steelhead nests (Table III-2), and also in locations where we judged habitat suitable for spawning but where we found no nests (Table III-3). To do so it was necessary to classify each location in Table III-2 by stream width (narrower/wide) and slope (steep/shallow) and match these designations

Table III-1. Measurements of spawning habitat area in five 400-ft reaches of the Carmel River between Schulte Road and San Clemente Dam, March-June 1982.

REACH	DATE	Streamflow (cfs) at Robles del Rio	Area in reach with suitable depth <u>or</u> velocity (ft^2)	Area in reach with suitable depth <u>and</u> velocity (ft^2)
Below Cal-American	3/ 9/82	150	2,850	2,850
Water Company	5/30/82	77	105	105
Filter Plant	6/ 9/82	58	96	96
Below Powell's	3/ 5/82	195	2,020	1,722
Hole	5/30/82	77	560	560
	6/ 9/82	58	337	112
Above Footbridge	3/ 9/82	150	16,450	1,500[1]
in Garland Park	5/30/82	71	3,940	3,849
	6/ 9/82	58	2,820	1,179
Below Robinson	3/ 9/82	150	16,450	16,450
Canyon Road	5/30/82	77	11,280	10,213
Bridge	6/ 9/82	58	5,300	2,860
Below Cal-American	3/ 9/82	150	6,500	6,500
Water Company	5/30/82	77	1,384	1,168
Manor Well	6/10/82	56	1,630	1,087

1 Major channel changes during April 6-7, 1982 reduced habitat available at 150 cfs.

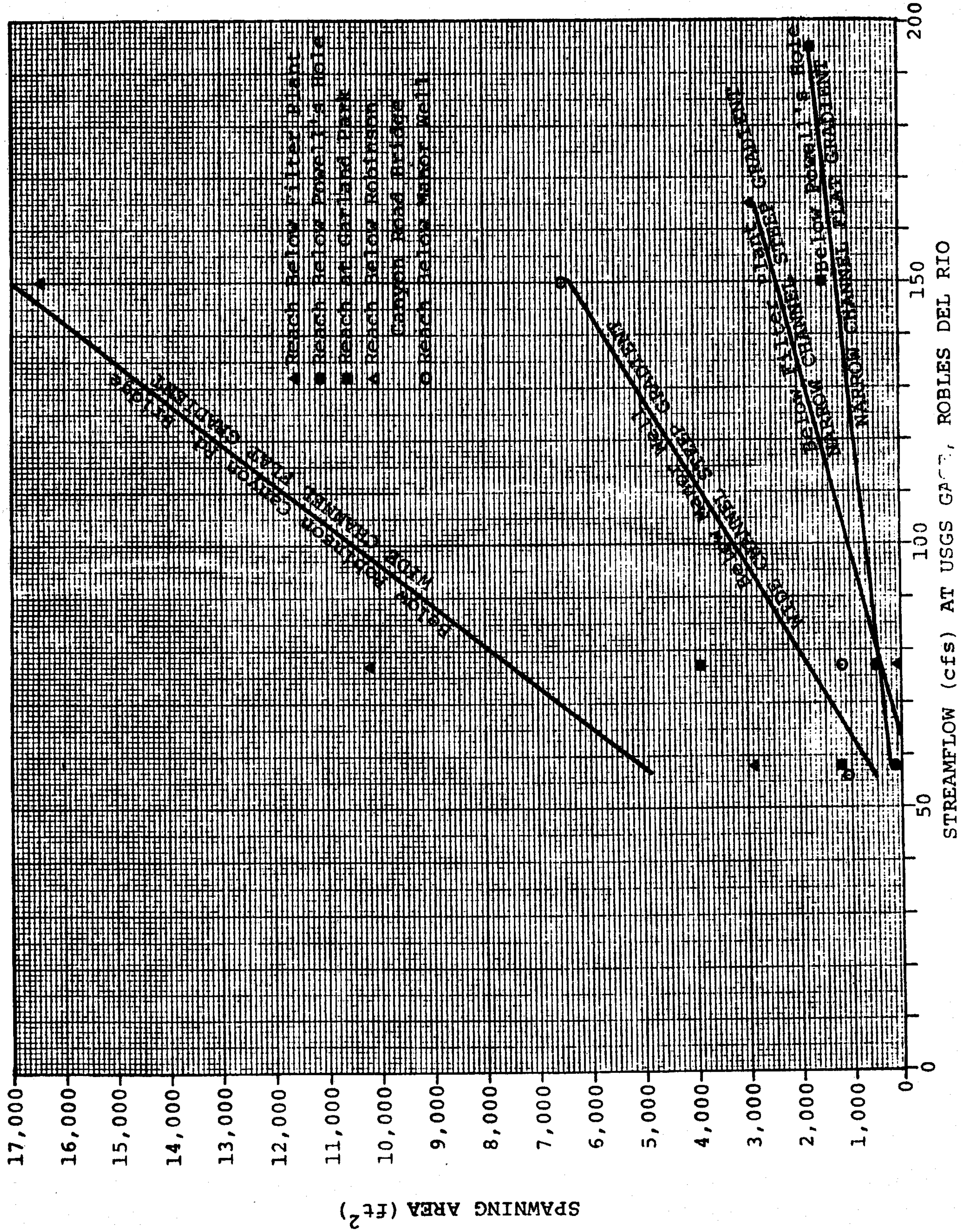


Figure III-8. Relationship between amount of steelhead spawning habitat and streamflow at five stations on Carmel River below San Clemente Dam. Streamflow measured at USGS gage (Robles del Rio).

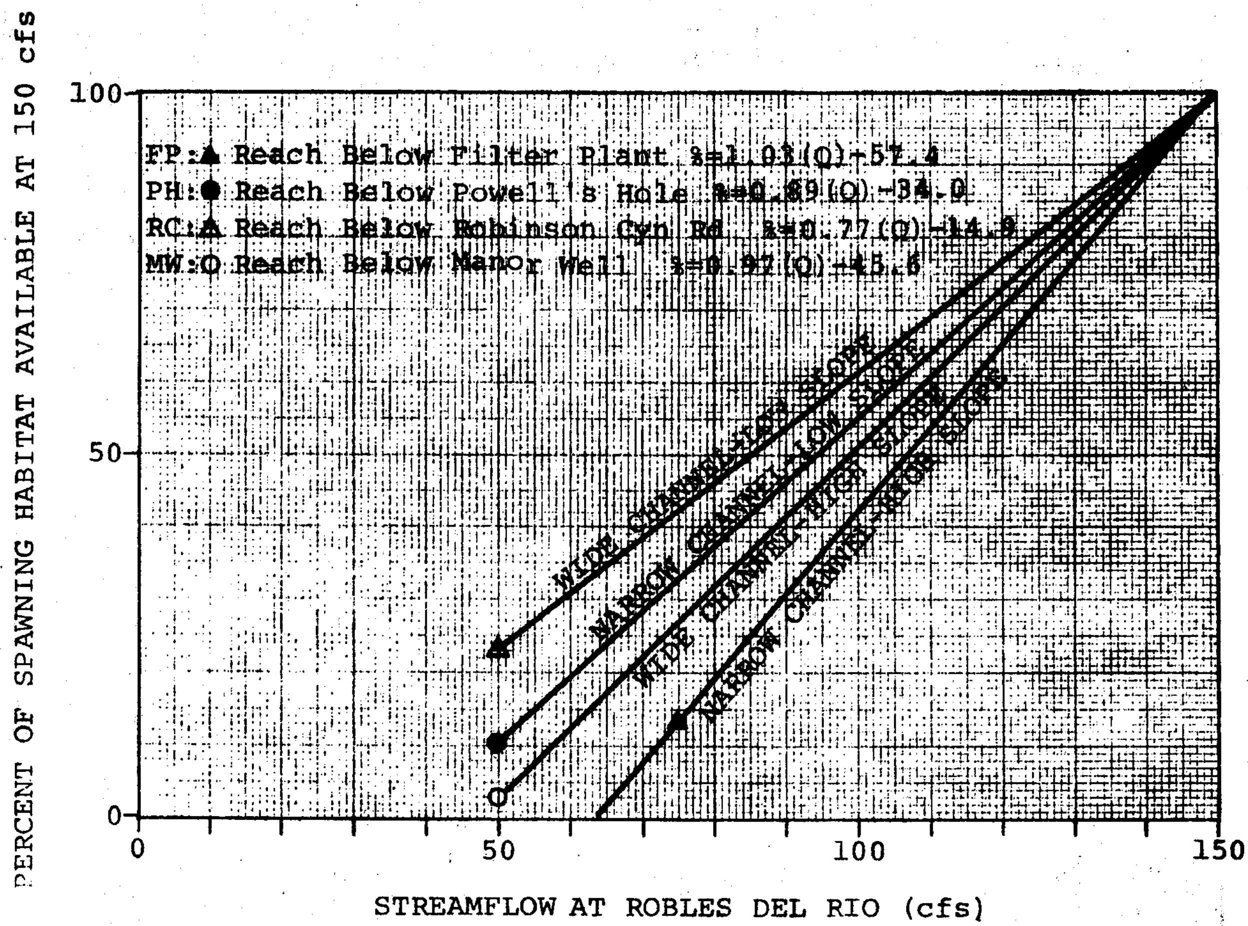


Figure III-9. Relationship between percent of spawning habitat available at 150 cfs and streamflow at four stations on the Carmel River below San Clemente Dam. Streamflow measured at USGS gage at Robles del Rio.

Table III-2. Spawning habitat area in the Carmel River at various streamflows, and in locations where steelhead spawned in 1982.

Distance From Mouth (miles)	Spawning area (sqft)	Streamflow at Robles del Rio (cfs)	Function From Figure III-9	Spawning Habitat Area at Various Streamflows				
				150	125	100	75	50
14.3	730	195	PH	521	405	288	172	56
13.8	1215	195	FP	847	604	386	168	0
13.5	1380	195	PH	984	764	545	325	105
13.5	600	195	FP	418	298	191	83	0
12.9	1800	195	PH	1284	997	711	424	137
12.9	3523	195	PH	2513	1952	1391	830	269
12.3	720	185	FP	541	386	247	107	0
12.3	540	185	FP	406	290	185	81	0
12.0	8040	185	MW	5999	4545	3088	1632	176
11.7	4645	185	MW	3392	2570	1746	923	99
11.4	2000	185	MW	1492	1130	768	406	44
10.8	1500	185	MW	1119	848	576	304	33
10.8	2490	160	MW	2269	1719	1168	617	66
10.8	3200	160	RC	2973	2403	1834	1264	695
10.6	720	160	MW	656	497	338	178	19
17.0	214	165	FP	190	136	87	38	0
17.0	252	165	FP	224	160	102	44	0
16.4	196	165	FP	174	124	79	35	0
16.1	62	165	FP	55	39	25	11	0
15.9	2850	165	FP	2532	1807	1155	503	0
15.6	900	165	PH	794	617	439	262	85
13.8	1920	195	PH	1370	1064	758	452	146
Total above Narrows				27983	23355	14888	8859	1930
8.6	3100	160	RC	2880	2328	1776	1225	673
	10850	160	RC	10080	8148	6217	4287	2357
	6300	150	RC	6300	5092	3886	2679	1473
	10150	150	RC	10150	8204	6261	4317	2373
8.2	7700	150	MW	7700	5833	3964	2095	226
8.2	9120	150	MW	9120	6909	4695	2481	267
7.8	3650	150	MW	3650	2765	1879	993	107
7.8	3200	150	MW	3200	2424	1647	871	94
7.1	2400	150	MW	2400	1818	1236	653	70
6.9	6500	150	MW	6500	4924	3346	1768	190
6.9	2100	150	PH	2100	1631	1162	693	224
Total between Shulte Road and Narrows				64080	50076	34293	22062	8054
Total above Schulte Road				92063	73431	49181	30921	9984

Table III-3. Spawning habitat area at various streamflows and in locations judged suitable for spawning, but where no steelhead nests were found in 1982 and total used and unused habitat.

Approximate distance upstream from Carmel River mouth (mi.)	Spawning Habitat Area Measurement (ft²)	Streamflow (cfs) associated with spawning habitat area	Function from Figure III-9	SPAWNING HABITAT AREA AT VARIOUS STREAMFLOWS 150	125	100	75	50
16.6	240	165	FP	213	152	97	42	0
15.6	216	165	FP	192	137	88	38	0
12.5	1,400	195	PH	999	776	553	330	107
12.7	850	195	FP	593	423	270	118	0
12.0	625	185	PH	476	370	263	157	51
11.7	2,095	185	PH	1,596	1,240	883	527	171
10.7	1,100	160	MW	1,002	759	516	273	29
10.7	3,625	160	RC	3,368	2,722	2,077	1,432	787
10.6	600	160	FP	559	399	255	111	0
10.6	3,550	160	PH	3,259	2,531	1,804	1,076	348
10.6	625	160	PH	574	446	318	190	61
10.6	5,900	160	RC	5,481	4,430	3,381	2,331	1,281
UNUSED HABITAT ABOVE NARROWS				18,312	14,385	10,505	6,625	2,835
8.6	3,300	160	FP	3,073	2,193	1,401	610	0
8.6	4,000	160	MW	3,645	2,761	1,876	992	107
8.6	11,050	160	MW	10,069	7,628	5,184	2,739	295
8.7	3,500	160	MW	3,189	2,416	1,642	868	93
8.4	4,400	150	RC	4,400	3,557	2,714	1,871	1,029
8.4	5,400	150	RC	5,400	4,365	3,331	2,297	1,263
7.1	13,200	150	MW	13,200	10,000	6,795	3,591	387
6.9	8,175	150	MW	8,175	6,193	4,208	2,224	240
UNUSED HABITAT BETWEEN SCHULTE ROAD AND NARROWS				51,151	39,113	27,151	15,192	3,414
UNUSED HABITAT ABOVE SCHULTE ROAD				69,463	53,498	37,656	21,817	6,249
TOTAL ABOVE NARROWS including areas from Tables III-2 and III-3				49,065	37,740	26,612	15,484	4,765
TOTAL BETWEEN SCHULTE RD & NARROWS including areas from Tables III-2 & III-3				115,231	89,189	63,220	37,254	11,468
TOTALS ABOVE SCHULTE RD including areas from Tables III-2 & III-3				164,296	126,929	89,832	52,738	16,233

with the appropriate relationship shown in Figure III-9. After estimating potential habitat at 150 cfs we then calculated habitat at a series of flows down to 50 cfs (Tables III-2 and III-3).

Using the estimates in Tables III-2 and III-3, we calculated the relationship between total spawning habitat area and streamflow in the Carmel River, between the Narrows and San Clemente Dam and in the reach from the Narrows down to Schulte Road (Figure III-10). There is more spawning habitat between the Narrows and Schulte Road because the channel there is wider and has more suitable gravel. In spite of good spawning habitat, success of reproduction in this lower reach is probably low because of high bedload movement that damages the eggs. Because of this problem we have used the curve relating spawning habitat to streamflow in the reach between the Narrows and San Clemente Dam to recommend streamflow releases from the base of the new San Clemente Dam. A flow of 75 cfs would provide about 50,000 sqft of spawning habitat (1000 nest sites).

Comparison of Our Results with US Fish & Wildlife Service 1979 Survey of Spawning Habitat

In the spring of 1980, the US Fish & Wildlife Service conducted an instream flow study on the Carmel River. Measurements of stream width, depth, velocity, gradient, and substrate were made three-quarters of a mile below San Clemente Dam and at Garland Park when flows were 32, 100, and 181 cfs at Highway 1 (USF&WS 1980). These measurements were converted through the use of the IFG4 and HABTAT models into predictions of "weighted usable spawning habitat" at flows up to 400 cfs.

The study estimated that very little habitat was available below flows of about 50 cfs, and that it increased up to flows of 100 cfs in the reach below San Clemente Dam, and 150 cfs at Garland Park. Within those ranges the predicted rate of change with increasing flow is about the same as the one we have described. The Fish & Wildlife Service estimated that above those levels the amount of spawning habitat was added more slowly by increasing flows. Maximum levels were achieved at about 200 cfs and above there they estimate the habitat declines. We made no prediction of the amount of spawning habitat that would exist above 150 cfs.

Aside from the above, comparison between our work and that of the US Fish & Wildlife Service is difficult. Their measures of streamflow were at Highway 1 whereas ours were at Robles del Rio, and there is often not a good correlation between the two locations. Their "weighted usable habitat" is a calculated index and should not be compared with our measures of spawning habitat in each 400-foot section or estimate of the total amount available.

Spawning Habitat Above Los Padres Reservoir

A portion of the steelhead population in the Carmel River annually migrates to the base of Los Padres Dam, where fish are trapped and carried over the dam to spawn in tributaries above there.

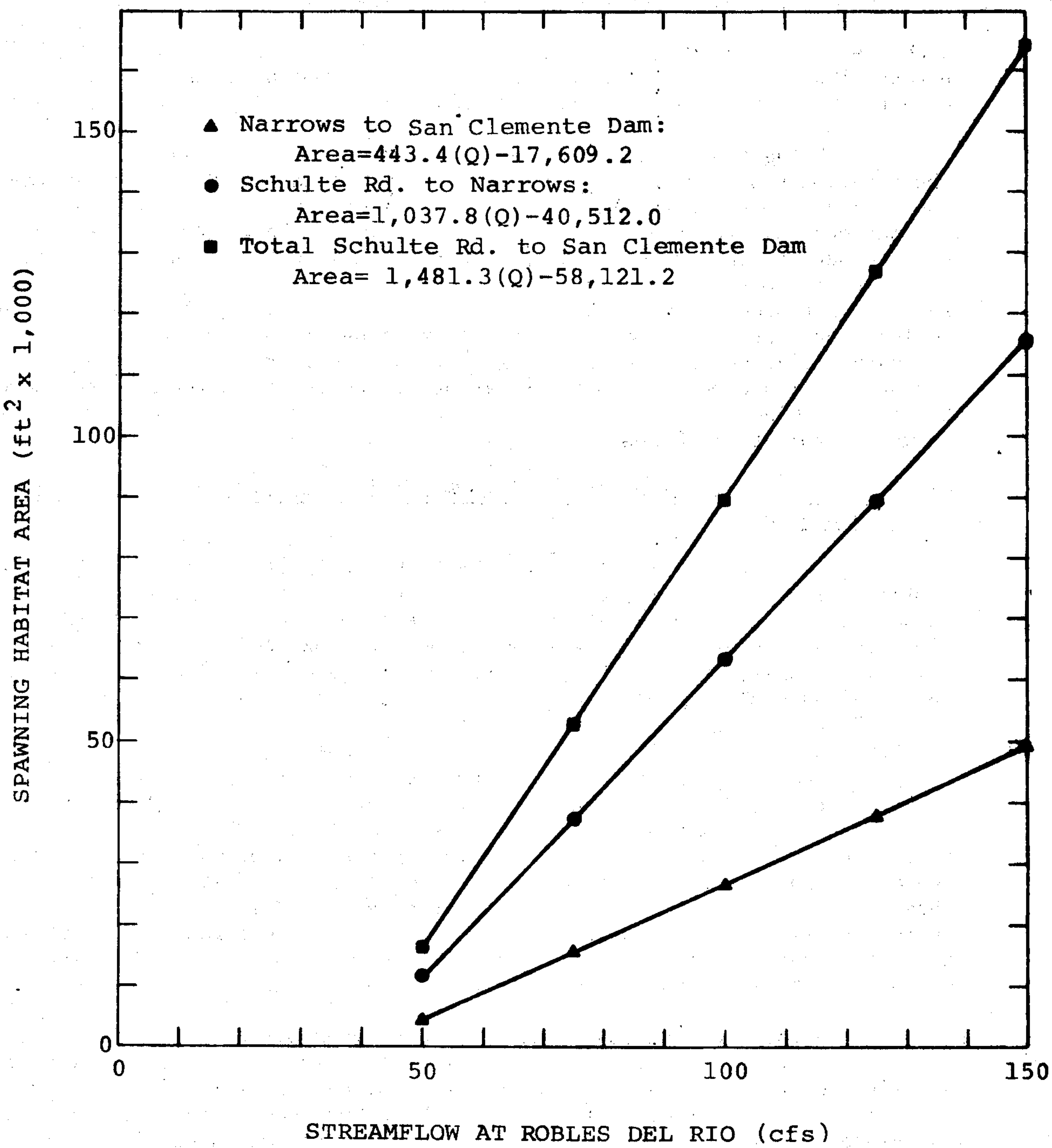


Figure III-10. Relationship between steelhead spawning habitat area and streamflow in the Carmel River during 1982. Streamflow measured at Robles del Rio USGS gaging station.

Snider (1975) surveyed the upper Carmel River basin and concluded that steelhead had access to 17.7 miles of stream above Los Padres including 1.7 miles of Danish Creek, 5.7 miles of Miller Fork, and 10.3 miles of the mainstem of the Carmel River. We did not have time to locate the barriers on Danish Creek and Miller Fork, but we found an additional mainstem barrier that prevents steelhead from utilizing 3 miles of stream habitat included in the 10.3 miles that Snider estimated was available. This barrier, a 46-foot bedrock falls is located approximately 500 feet above where Ventana Mesa Creek flows into the Carmel River, and completely blocks the upstream migration of all fish.

Using Snider's estimates of the stream habitat accessible to steelhead in Danish and Miller Fork, together with our estimates of the amount of habitat available in the mainstem, we calculate that a total of 14.4 miles of stream is available to steelhead adults above Los Padres Dam.

During late October 1982, biologists David Dettman, Stacy Li, and Gary Stern measured the area of all spawning gravel in 12 representative sections covering 30 percent of the total stream mileage available to steelhead above Los Padres Reservoir. They did not include spawning gravels located high on exposed portions of gravel bars. Our observations on other streams have shown that steelhead avoid such places, presumably because of egg stranding when flows decline. They did measure patches of gravel located in shallow water adjacent to stream edges, and some exposed patches close to the water which they believed would provide spawning habitat at winter flows.

They measured 37,347 square feet of spawning habitat in 23,060 feet of the Carmel River and its tributaries above Los Padres Reservoir. We calculated the total spawning habitat above Los Padres Reservoir by: estimating the spawning area per foot of stream for each reach; multiplying this estimate by reach length; and, summing the total habitat in each reach (Table III-4). In this way, we estimated that there was a total of 90,507 square feet, and there was room to accommodate about 1800 female steelhead or a total run of 3600 fish. Based upon this evidence we concluded there was excellent spawning habitat above Los Padres Reservoir and that other factors limit the return of adults to the trap at the base of the Los Padres Dam.

Table III-4. Summary of steelhead spawning habitat measured in 12 reaches of Carmel River above Los Padres Reservoir and estimates of total spawning habitat above Los Padres Reservoir.

STREAM	REACH	Length of Reach (ft)	Portion of Reach Surveyed (ft)	Spawning Habitat Measured in Portion of Stream Surveyed (ft^2)	Estimate of Total Spawning Habitat in Reach (ft^2)	Potential Number of Steelhead Nests[1]
CARMEL RIVER	Above Danish Creek confluence	8078	3009	4738	12719	254
	Above Bluff Camp	5174	1785	2325	6739	135
	Above Bruce Fork	3960	1828	2972	6438	129
	Above Sulphur Springs	6178	2733	2419	5468	109
	1/4 mile downstream Buckskin Flat Camp	4540	1811	6970	17473	349
	Above Buckskin Flat Camp	4720	3234	12643	18452	369
	Reach adjacent to Bench Mark #1744	4171	489	133	1134	23
MILLER FORK	Reach begin 200 ft above confluence with Carmel River	5280	1117	156	737	15
	Reach ≈1.5 mi above confluence with Carmel River	5544	1908	1770	5143	103
	Reach upstream of Clover Basin Camp	3168	1503	1065	2245	45
	Reach upstream of Miller Canyon Camp	16104	1201	620	8313	166
DANISH CREEK	Upstream of Carmel R. trail crossing	8976	2442	1536	5646	113
Totals above Los Padres Res.		75893	23060	37347	90507	1810

[1] Number of potential nests based upon assumption that each steelhead nest occupies 50 sqft, except where discontinuous patches of gravel may provide suitable substrate for single nests.

CHAPTER IV. JUVENILE REARING

After hatching and emerging from their gravel nest, young steelhead distribute themselves in suitable places and begin feeding on small invertebrates that are drifting downstream with the current. They first occupy the shallow, quiet water along the stream edge but, as waters warm and they grow larger, young-of-the-year steelhead in the central coast waters of California move into relatively shallow (0.25-1.0') water flowing at 0.5-1.5 ft/s over rough, cobble bottomed runs, glides, and riffles. Yearling steelhead prefer deeper water and are usually more abundant in pools or deep runs and riffles where obstructions in the form of roots, logs, or boulders provide resting habitat adjacent to more swiftly (1-3 ft/s) flowing water.

Measuring Rearing Habitat and The Rearing Index for Young-of-the-year Steelhead

For several years we have been developing and testing a "Rearing Index" (RI) as a measure of the quality and quantity of rearing habitat. We have developed methods which:

1. Can be used by trained biologists to efficiently and accurately assess long reaches of the stream at reasonable cost.

2. Can be used to compare one reach to another and one stream to another.

3. Are sensitive to the combined effects of streamflow and the accumulation of sand in stream bottoms--two major variables influencing salmonid production in most California streams.

4. Recognizes that these and other important variables used to assess rearing habitat do not usually influence fish independently. Substrate conditions, for instance, greatly affect the way fish respond to velocity.

5. Can be translated into estimates of potential fish population.

6. Encourages more thought and understanding of the stream ecology. Does not require such complex computer analyses that the methods are mechanically and thoughtlessly applied.

In previous studies on Zayante and Lagunitas Creeks, Kelley and Dettman (1980, 1981) found that measures of cobble embeddedness, cobble abundance, depth, and velocity were important for rating habitat of young-of-the-year 0+ age steelhead. We assessed these same variables to rate young-of-the-year habitat in the Carmel River.

Assessing the habitat at a particular flow begins by having a biologist, trained in the method (in this case, Dettman, Li, or Stern), wade slowly upstream, grading segments or patches that are small enough (usually smaller than room size) and homogeneous enough to be judged as no, poor, fair, good, or excellent habitat and rating them as 0, 1, 2, 4, or 8, respectively. The character and area of each patch, its length, width, and quality, as well as the principal constraints to better quality are recorded on a field form (Figure IV-1). The water must be clear enough to see the bottom.

We usually find it convenient to first eliminate from consideration that part of the patch which is simply not habitat. This often eliminates very shallow quiet edges, where very small steelhead are often abundant early in the spring but leave within a few weeks after their emergence from the gravel, segments with sandy or bedrock bottoms in shallow water, or cataracts. The remainder of each patch is then judged according to its depth, substrate, and surface velocity. For each patch the biologist estimates mean depth, the percent of the bottom covered with cobble, the average degree to which that cobble is embedded in sand, and, finally, surface water velocity. This information is combined as illustrated in Figure IV-2 to produce a grade of excellent (8), good (4), fair (2), poor (1), or zero (0), or sometimes a level in between.

Figure IV-2 illustrates that the way each of the three variables influences the grade is often dependent upon the other two variables. No amount of cobble will produce a good grade of habitat if it is highly embedded in sand. A bottom half covered with cobble only moderately embedded in sand will score a "fair" grade unless the velocity is so high that young steelhead avoid it. A patch where half or more of the bottom is covered with unembedded cobble will score a high grade unless velocity is very low (0.5 ft/s). There are many permutations and, while the method is at first confusing to describe, we have found it easy to use with a bit of practice. We ordinarily grade each patch in the field as the variables are estimated.

The presence of undercut banks, logs, boulders, or submerged vegetation modifies this base evaluation. In the Carmel River occasional patches of submerged vegetation or submerged logs, or willow roots sometimes provide good quality habitat in pools where sand concentrations are high. In such cases the habitat rating is modified upward by the biologist doing the grading.

The data recorded on the field form are then used to calculate a RI for the the total reach by multiplying the area of each patch of habitat times its habitat rating, summing the products, and then dividing the sum by the total length of the reach being assessed. The RI is therefore a measure of both quality and quantity of habitat per linear foot of stream.

This approach and the criteria for judging young-of-the-year habitat has been tested by comparing a wide range of RIs with populations of young-of-the-year steelhead in Lagunitas Creek, Marin County. The stream was fully saturated with fry in the spring and we found excellent correlations between our Rearing Indexes in 13 riffles and glides and the late summer and early fall young-of-the-year steelhead populations (Figure IV-3).

JUVENILE STEELHEAD HABITAT SURVEY

Stream Carmel R Date 30 Jun 1982 Time ______

Location Boronda to Paso Hondo

USGS Gage 3.41 House / 3.38 LB Measured Flow ~20

Observer DHD Sheet 1 of 12

Character	Length	Width	Area	Quality	QualxArea	Y/Y Constraints Depth	Emb	Vel	CbAb	Yearling Constraints Depth	Vel	Rough	Cover	RifDst	Notes
G1	53	8	424	8/1	3392 424					✓	✓		✓		
		14	742	6/0	4452 0		✓								
		9	477	1/0	477 0	✓	✓	✓							
		10	530	0/0	0 0	✓	✓	✓	✓						
G1	35	42] 6	210	0/0	0 0										
	12	3	36	8/1	288 36										
	18	8	144	6/1	864 144		✓								
	2	2	4	2/0	8 0		✓	✓							
	16	6	96	4/0	384 0			✓							
		R	980	4/0	3920 0		-								
Run/Rf	22	11	242	1/0	242 0	✓		✓							
	[12	3	36	0/0	0 0										
	10		30	4/0	120 0										
		5	110	4/0	440 0			✓							
	[9	5	45	8/0	360 0										
	13		65	8/2	520 130					✓					
		8	176	6/2	1056 352	✓									
		6	132	4/0	528 0	✓	✓								
		3	66	0/0	0 0										
Rf	40	33] 11	440	8/6	3520 2640										
		6	240	4/0	960 0	✓	✓								
		3	120	1/0	120 0										
		4	160	4/1	640 160			✓		✓	✓				
	8	6	48	1/0	48 0										
		R	312	0/0	0 0										
Sums	150		5,865		22,339 3886										

Figure IV-1 . Example of field form used to record the lengths and widths of habitat patches and the quality and constraints of young-of-the-year and yearling steelhead habitat in those patches.

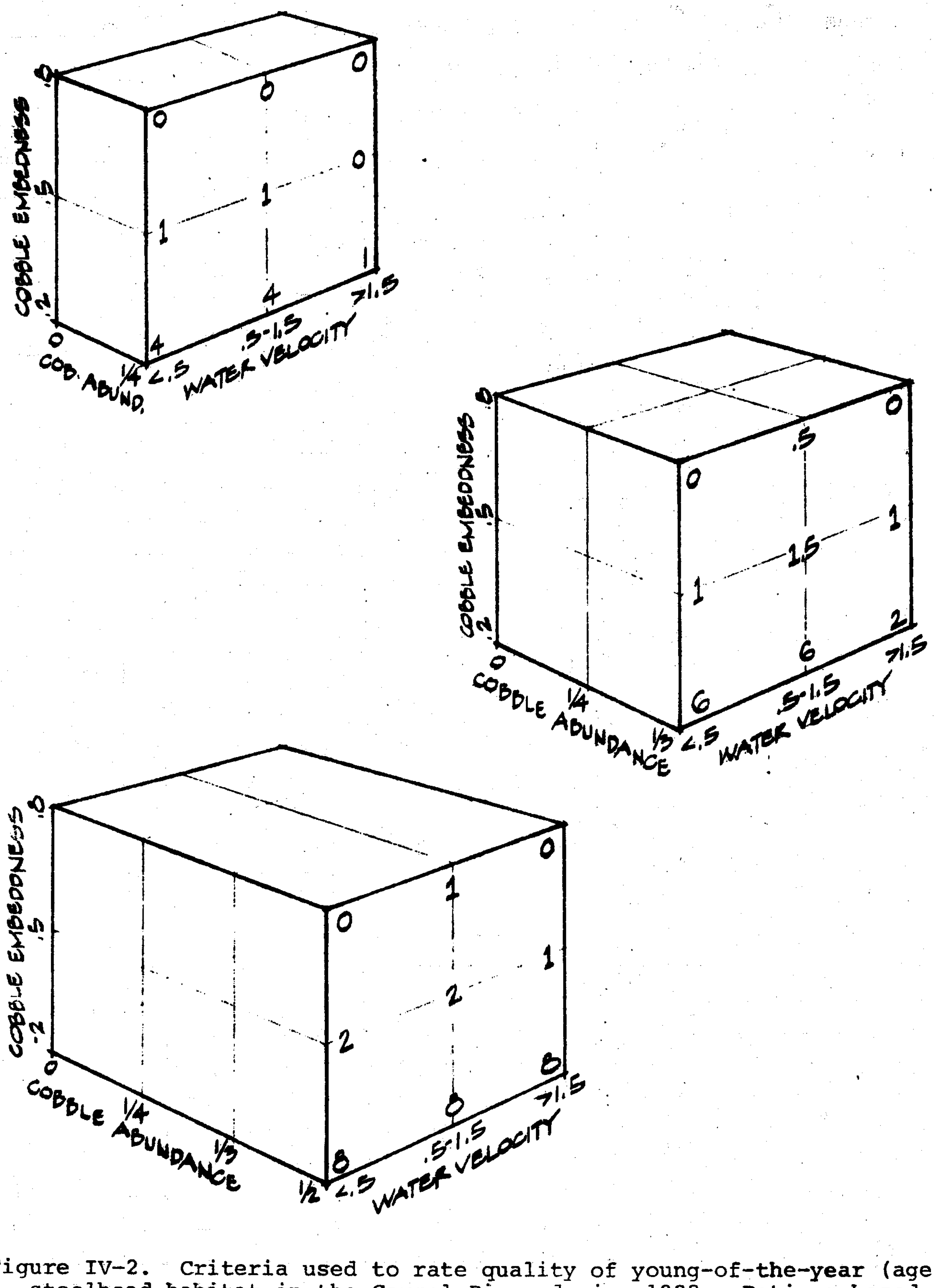
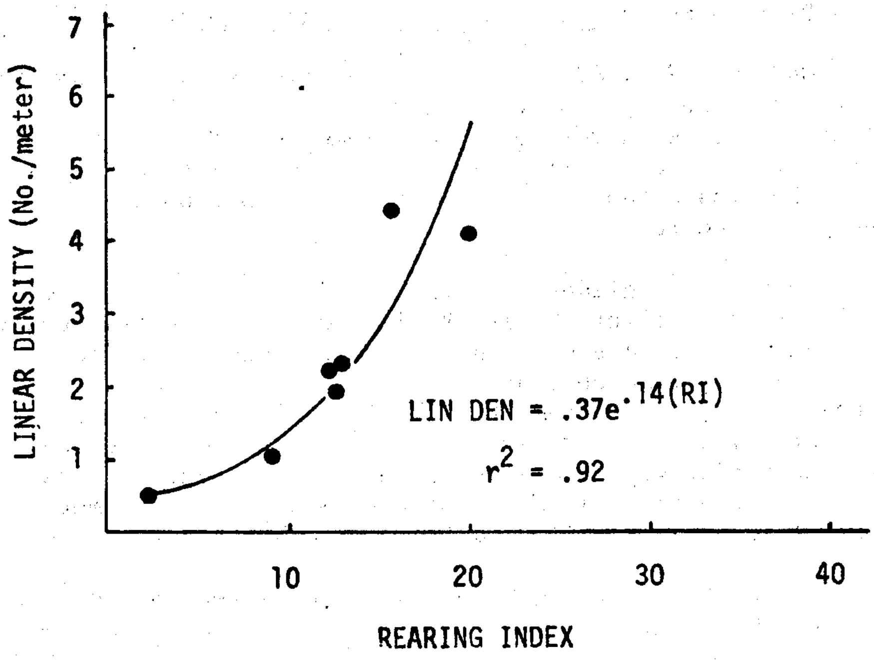


Figure IV-2. Criteria used to rate quality of young-of-the-year (age 0+) steelhead habitat in the Carmel River during 1982. Ratings based on the combination of the three illustrated variables are then modified by the presence of submerged logs, undercut banks, etc.



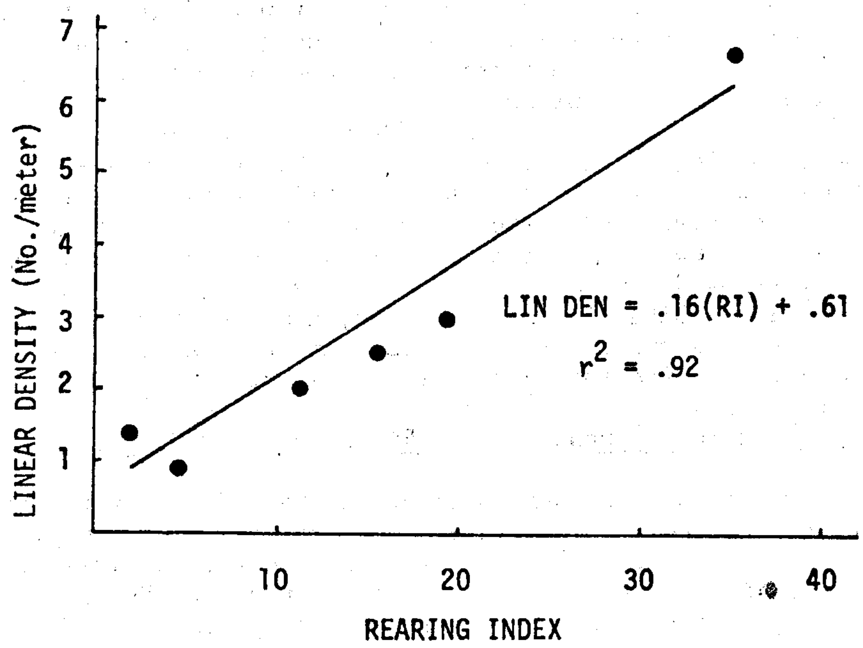


Figure IV-3. Relationship between indexes of rearing habitat and young-of-the-year steelhead population density in riffles (top) and glides (bottom) of Lagunitas Creek. Data from August 27-31, 1979 survey by D. W. Kelley and D. H. Dettman (1980) for the Marin Municipal Water District, Marin County, California.

Measuring Rearing Habitat and the RI for Yearling Steelhead

On June 12, 1982, when the streamflow at Robles del Rio was 40-42 cfs and again on June 22-23, D. Dettman, S. Li, and G. Stern dove in three reaches of the Carmel River below San Clemente Reservoir to observe the behavior of steelhead yearlings and to develop criteria for measuring their habitat. They found that cobble on the stream bottom is not much used by yearling steelhead for cover.

In riffles, glides, and runs, boulders and submerged logs provided nearly all of the shelter (Table IV-1). The yearlings were nearly always observed taking advantage of much reduced current velocities behind these objects. They observed no yearlings in water < 0.9' deep and found fish always near the bottom of the stream (Figure IV-4) where water velocity was lower (Figure IV-5). Water temperature was 3^{o}-8^{o} C cooler near the bottom, probably because of groundwater seepage. On the basis of these observations, they developed the criteria subsequently used to grade summer habitat for these age 1+ or what we call "yearling" steelhead (Figure IV-6).

The RI for yearling steelhead is measured in the same way as the RI for young-of-the-year.

The validity of the RI for yearling steelhead has been tested only on the Tucannon River in Southeastern Washington (D. W. Kelley & Associates 1982). We had intended to test the RI for yearling steelhead in the upper Carmel River during 1982, but could not because the habitat there was not fully seeded. Testing in the Lower Carmel was impossible because the stream ceased to flow during the summer and the fish were lost. In any case, use of an RI for yearlings appears inapproppriate on the Carmel because most steelhead leave the stream and enter the ocean in one year. The RI for young-of-the-year is more relevant here.

In the following sections of this Chapter, we describe the different environmental factors which influence juvenile steelhead rearing habitat in the upper Carmel River and tributaries above Los Padres, in the Carmel River and tributaries between San Clemente Dam and Los Padres Dam, and the lower Carmel River below San Clemente. We describe the quality and quantity of juvenile rearing habitat in these reaches, compare it with the fish populations we measured in 1982, and estimate the capacity of the habitat to rear juveniles at different levels of streamflow.

Juvenile Rearing in the Upper Carmel River and Tributaries

Most of the steelhead habitat in the Carmel River above Los Padres is within the confines of the Ventana Wilderness Area. The river's flow is unregulated, roads have not caused erosion, and the physical steelhead habitat probably looks much like it did before the arrival of European man. The river's configuration is controlled by its steep gradient (320 ft/mile), numerous bedrock outcrops, and large boulders that have lodged in the channel. Deep pools, separated by short, shallow glides and long, cobble/boulder riffles and runs are numerous throughout the upper Carmel River. The stream

Table IV-1. Number of times yearling steelhead were observed using various kinds of cover in riffles, pools, glides, and runs of the Carmel River below San Clemente Dam, June 22 and 23, 1982 (in parentheses), and total number of fish observed there. Boulders and submerged logs were the principal cover except in pools where submerged vegetation was important.

	Boulders	Submerged Logs	Submerged Vegetation	Turbulent Water	Other
Riffles	(11) 15	(3) 3	(0) ---	(2) 2	(1) 2
Pools	(1) 1	(1) 1	(4) 102	(1) 15	(0) --
Glides below Pools	(12) 12	(0) --	(2) 2	(0) --	(0) --
Runs	(14) 114	(1) 100	(1) 1	(1) 1	(8) 8

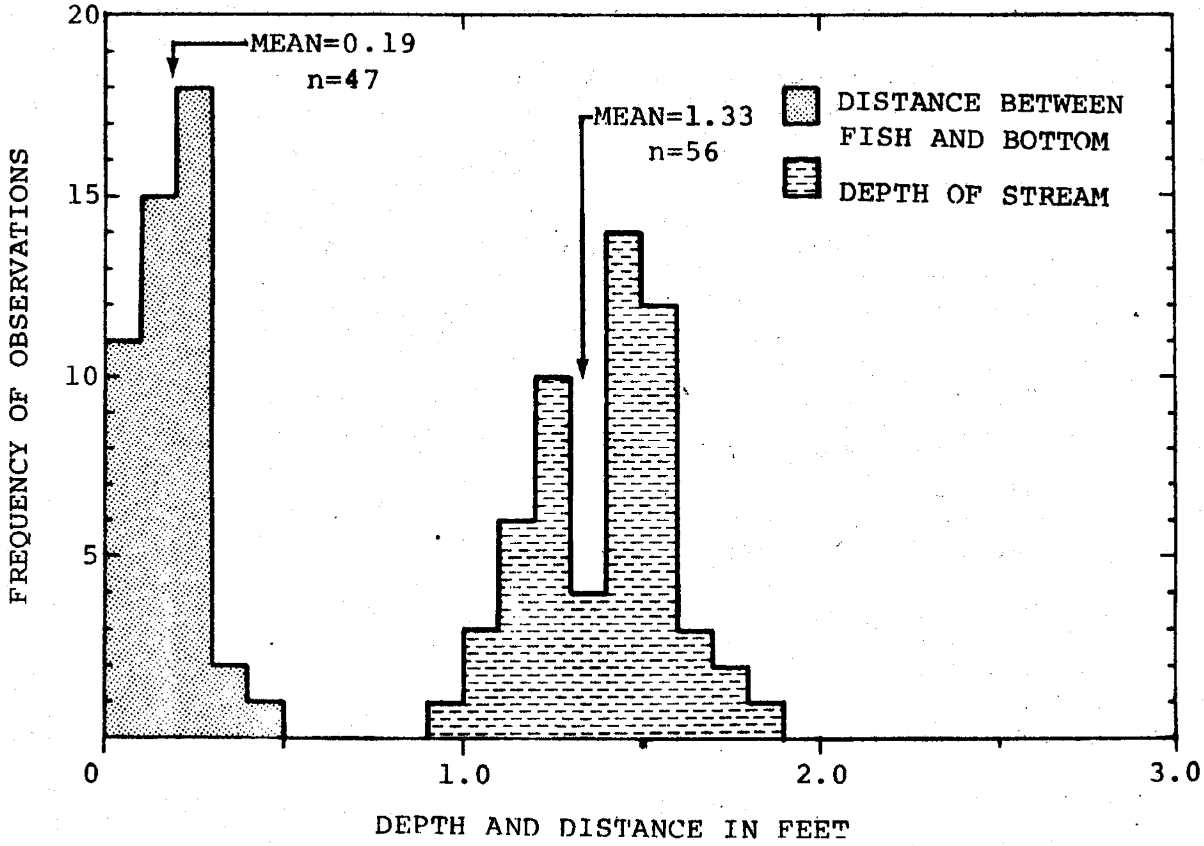


Figure IV-4. Depth of stream where yearling steelhead were observed and distance between fish and stream bottom. Yearlings were always near the bottom and were never observed in water < 0.9' deep. Carmel River, June 22, 23, 1982.

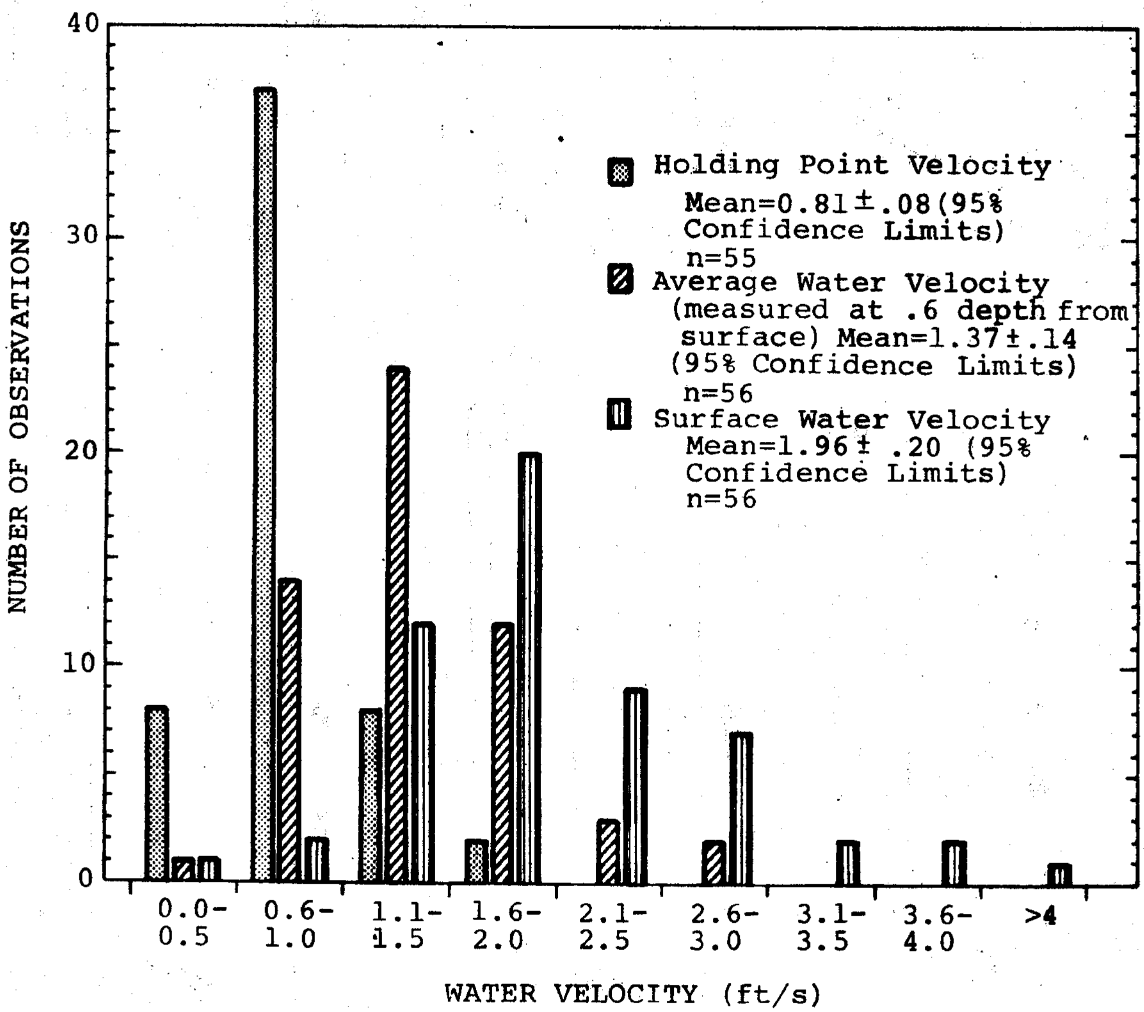


Figure IV-5. Water Velocity at surface, average in water column and at point where yearling steelhead were holding (focal point), Carmel River, June 22-23, 1982. The fish utilized the lower velocities behind boulders and submerged logs.

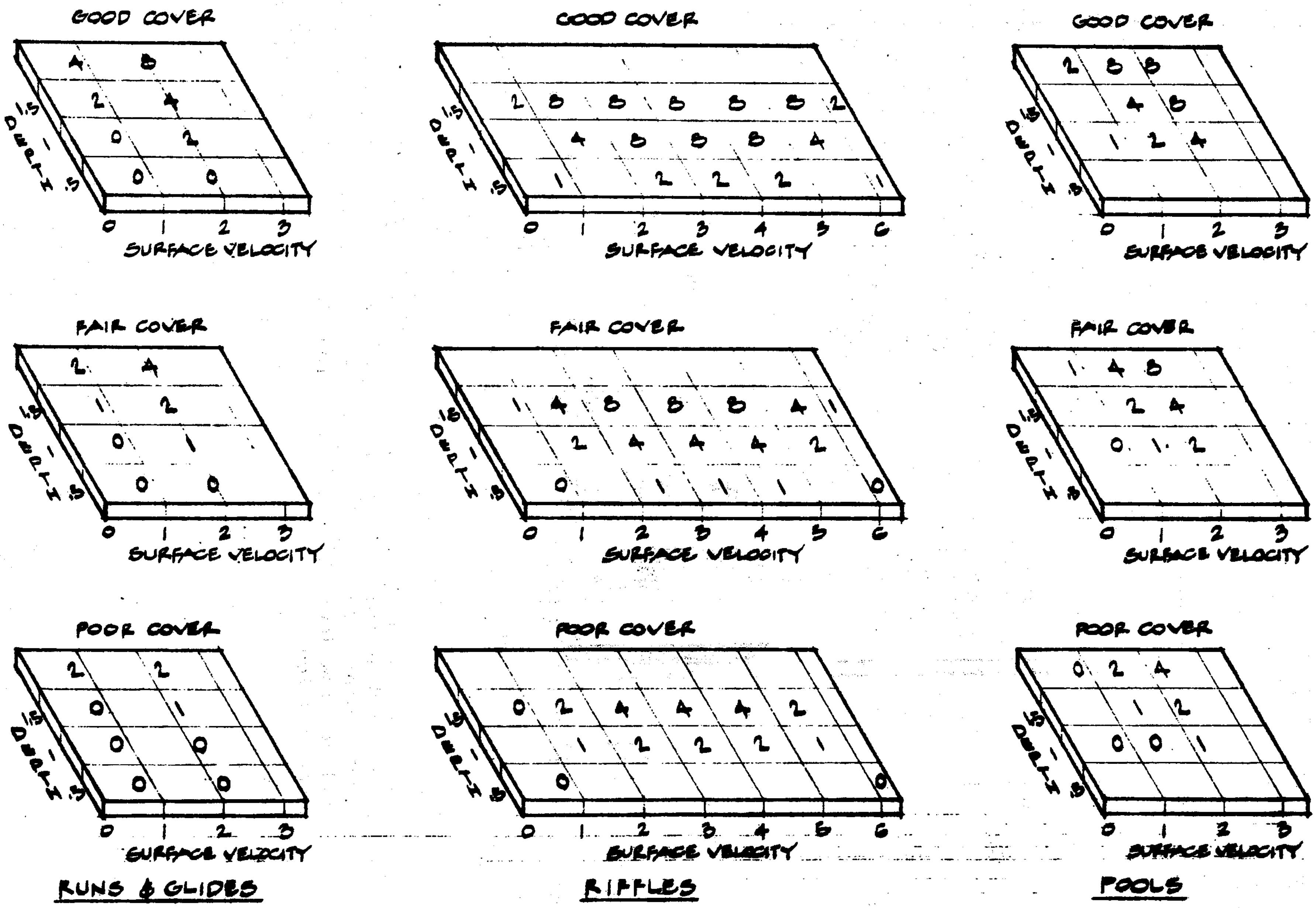


Figure IV-6. Criteria used to rate quality of yearling habitat in runs, glides, riffles, and pools in the Carmel River during 1982. In glides, quality rating is changed according to the following criteria: Distance to riffle is <25 feet, add one quality rating; 25-100 feet, no change; >100 feet, change quality rating to zero.

surface is heavily shaded by a dense canopy of riparian trees, including white alder, sycamore, big leaf maple, California bay laurel, canyon live oak, and sometimes by steep canyon walls.

Quantity and Quality of Habitat

During October 1982 we measured the quantity and quality of steelhead rearing habitat and developed juvenile Rearing Indexes for the seven sections of the mainstem of the upper Carmel River, four sections of the Miller Fork, and one section of Danish Creek (Figure IV-7). The sections covered 31 percent of the habitat available to adult steelhead above Los Padres Dam.

Ninety-seven percent of the stream was habitat for young-of-the-year (0+ age) steelhead and 81 percent was habitat for yearlings (1+ age). In all reaches measured, the quality of this habitat was much better than average for both young-of-the-year and older steelhead (Table IV-2). The average young-of-the-year Rearing Indexes ranged from 2 to 5 times as high as RIs we have measured in other coastal streams at similar flows.

Based upon these measurements, we concluded there are 14.38 miles or 423,000 sqft of good-excellent rearing habitat above Los Padre Reservoir. Because the watershed is almost entirely within the Ventana Wilderness Area the rearing habitat will probably remain in this condition.

The Fish Population in 1982

Snider (1983) estimated the abundance and standing crop of the juvenile steelhead above Los Padres Reservoir in 1973 and 1974 and based his calculation that the average steelhead run was about 2000 fish on those estimates. To assess whether or not the population had changed significantly since that time and to help us predict the potential steelhead population that could be supported by this habitat, we measured the fish population in eight sections in the mainstem Carmel River and Miller Fork (Figure IV-7). In each section we estimated rainbow trout numbers, age, size, and density, and population biomass and standing crop by:

(1) Setting block nets at the upstream and downstream ends of each station;

(2) Making several passes through each station with a backpack electrofisher;

(3) Anesthesizing fish after each pass, measuring the length of each fish, and weighing and taking scales from a representative sample;

(4) Using standard techniques (Ricker 1975) for estimating population from catch per unit efforts and cummulative catch data and age-length relationships, we calculated age specific abundance and density in each reach (Table IV-3);

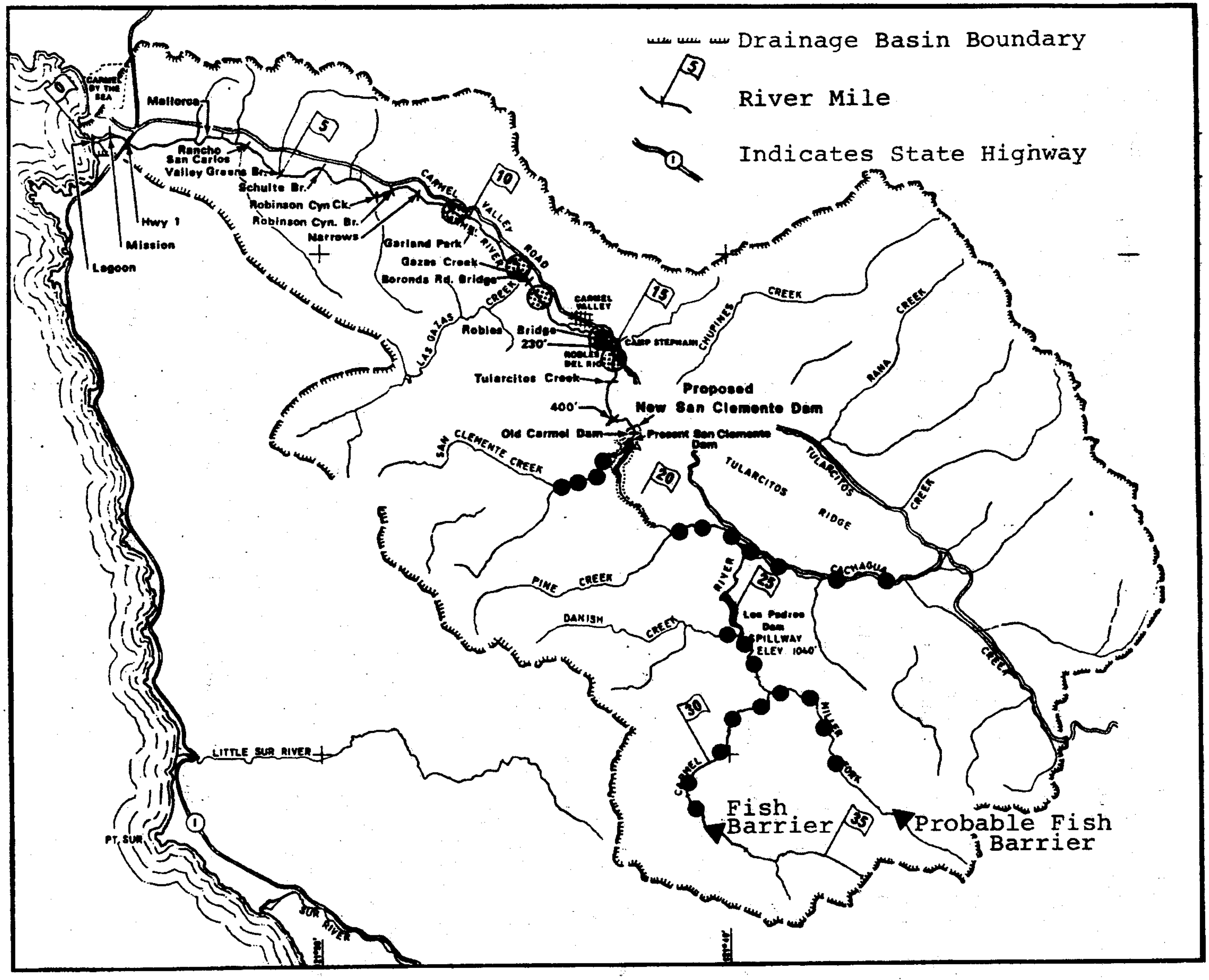


Figure IV-7. Locations of sections used to assess juvenile steelhead rearing habitat in the Carmel River Basin, June-October 1982.

Table IV-2. Location and amount of juvenile steelhead rearing habitat in Carmel River basin above Los Padres Reservoir. Habitat surveyed Oct. 18-26, 1982.

TRIBUTARY	LOCATION OF STREAM REACH	Length of Section (mi)	Approximate streamflow at time of survey (cfs)	Location: Distance from confluence of Danish Creek and Carmel River to beginning of Section surveyed (mi)	Length of Section measured (ft)	Total surface area (ft^2)	Mean width (ft)	YOUNG-OF-THE-YEAR STEELHEAD: Habitat area (ft^2) and percent of total surface	YOUNG-OF-THE-YEAR STEELHEAD: Mean quality of habitat (0-8)	YOUNG-OF-THE-YEAR STEELHEAD: Rearing Index	YEARLING AND OLDER STEELHEAD: Habitat area (ft^2) and percent of total surface	YEARLING AND OLDER STEELHEAD: Mean quality of habitat (0-8)	YEARLING AND OLDER STEELHEAD: Rearing Index
Carmel River, main fork	Danish Creek to Bluff Camp.	1.53	-10	0.28	3,009	67,600	22.5	65,365(97)	4.9	106.9	47,629(70)	4.1	64.5
"	Bluff Camp to Bruce Fork.	0.98	-10	1.33	1,785	40,959	22.9	39,543(97)	5.1	112.0	26,381(64)	4.9	72.0
"	Bruce Fork to tributary above Sulphur Springs.	0.75	~ 7	2.46	1,828	41,288	22.6	38,315(93)	5.1	107.3	33,339(81)	4.6	84.5
"	Tributary above Sulphur Springs to tributary below Buckskin Camp.	1.17	~ 6	3.22	2,733	56,575	20.7	56,175(99)	4.5	93.0	52,788(93)	3.9	75.7
"	Tributary below Buckskin Camp to right bank tributary above Buckskin Camp.	0.86	~ 5	4.28	1,811	41,506	22.9	39,672(96)	5.8	126.1	33,467(81)	4.3	79.4
"	Right bank tributary above Buckskin Camp to tributary below Bench Mark 1743.	0.90	4-5	5.42	3,234	68,293	21.1	67,525(99)	5.2	109.4	65,885(96)	4.0	81.6
"	Tributary below Benchmark 1743 to Barrier above Ventana Mesa Creek.	0.79	~ 4	6.17	489	8,621	17.6	8,148(95)	5.4	90.5	6,217(72)	2.6	32.9
	SUBTOTAL	6.98			14,889	324,842		314,743(97)			265,706(82)		
	MEAN								5.1	106.5		4.1	70.1
Miller Fork, Carmel River	Confluence with Carmel River to Meadow 1 mile upstream.	1.00	~2-3	2.15 (0.05)*	1,117	14,773	13.2	13,705(93)	4.1	50.8	9,726(66)	3.7	32.0
"	Meadow to Clover Basin Camp.	1.05		3.35 (1.25)	1,908	20,824	10.9	19,368(93)	4.4	44.7	16,287(78)	3.7	31.4
"	Clover Basin Camp to Miller Canyon Camp.	0.60	~2-3	4.15 (2.05)	1,503	20,098	13.4	20,063(100)	6.2	82.4	18,100(90)	4.7	56.8
"	Miller Canyon Camp to probable barrier below China Camp.	3.05	~ 1	4.94 (2.84)	1,201	12,585	10.5	12,151(97)	5.4	54.2	7,775(62)	4.0	25.8
	SUBTOTAL	5.70			5,729	68,280		65,287(96)			51,888(76)		
	MEAN								5.0	58.0		4.0	36.5
Danish Creek	Confluence with Carmel River to barrier upstream.	1.7	~ 2	0.0	2,442	30,010	12.3	29,275(99)	4.7	57.0	23,420(78)	3.5	33.8
	OVERALL TOTALS	14.38			23,060	423,132		409,305(97)			341,014(81)		
	MEAN								5.1	86.2		4.0	55.9

* Distance from confluence of Miller Creek and Carmel River to the beginning of reach surveyed.

Table IV-3. Population density of steelhead and resident rainbow trout in the upper Carmel River. Based on multiple passes of electrofishing gear.

SECTION	No. of passes electro-fisher	Total fish collected	Length of section in feet	Area of section in ft²	0+ age		1+ age		≥2+ age		All Ages	
					n/ft	lbs/ac	n/ft	lbs/ac	n/ft	lbs/a	n/ft	lbs/a
Run below confluence with Miller Canyon	3	98	122	3513	0.615	8.50	0.139	7.84	0.049	8.73	0.803	25.07
Miller Fork, Reach 1	3	62	106	1261	0.292	10.51	0.189	23.43	0.104	41.08	0.585	75.02
Miller Fork, Reach 2	4	53	118	1935	0.288	7.66	0.102	10.96	0.059	15.59	0.449	34.21
Carmel River above Bruce Fork #1	3	76	110	2178	0.364	8.11	0.227	21.47	0.100	29.05	0.691	58.63
Carmel River above Bruce Fork #2	4	71	133	3032	0.218	5.08	0.263	18.35	0.053	10.96	0.534	34.39
Carmel River below Buckskin Camp	3	113	209	5288	0.435	8.64	0.086	5.52	0.019	4.01	0.540	18.17
Carmel River above Buckskin Camp	3	118	118	2434	0.583	15.06	0.115	13.01	0.058	17.02	0.756	45.10
Carmel River near Hidden Valley Camp	3	42	42	1886	0.272	7.75	0.130	10.78	0.054	14.70	0.456	33.23
TOTAL		633		MEAN	0.383	8.91	0.156	13.92	0.062	17.64	0.602	40.48

(5) Using length-weight relationships and length tallies for fish in each station, we calculated biomass and standing crop estimates for each age group (Table IV-3).

By multiplying mean density estimates in each reach from Table IV-3 by the stream length available to steelhead (Table IV-2) we calculated that there were 45,630 steelhead or rainbow trout, including 29,079 young-of-the-year and 16,551 age 1+ and older fish, in the population during October 1982 (Table IV-4). Except for three young-of-the-year brown trout, we took no other fish.

In October 1982, total steelhead and resident rainbow trout population weight averaged 40.5 pounds per acre (Table IV-4). Despite a twofold increase in fish numbers in 1982 compared to 1973 and 1974, the population weight in 1982 was only 15-20 percent greater than in 1973 and 1974. And, in spite of our finding many more older resident fish in 1982, the average fish was larger in 1973 and 1974.

Many of these older fish we found were resident rainbow trout--not steelhead. The gonads of 78 percent of the 1+ and older fish that we examined and 19 percent of the 0+ age fish, were developing milt or eggs. Since these fish were all much too young to be sexually mature steelhead, we took this as evidence that they were resident rainbow trout. On that basis, we estimated that approximately 19 percent of these age 0+ fish and 78 percent of the 1+ -year-old fish were resident rainbow trout. We concluded that while the total trout population had increased since the early 1970s, most of the increase was due to a larger resident rainbow trout population.

The population density is low for such good habitat. We compared the combined numbers of age 0+ trout per foot of stream at various RIs in the Upper Carmel River to population estimates from Lagunitas and Zayante Creeks where we were reasonably sure the habitat was fully seeded. The populations were less than half of what we found on the other streams at similar RIs (Figure IV-8). This, combined with the fact that only 13 male and 37 female steelhead were passed over Los Padres Dam in the winter and spring of 1982, leads us to conclude that the habitat of the Upper Carmel and its tributaries was not fully seeded. We believe that this explains why there was no relationship between the RIs and the fish population in various sections of the upper Carmel River.

Rearing Capacity

We made two independent estimates of the capacity of the Upper Carmel habitat to rear steelhead. We estimated the capacity of the streams to rear steelhead through their first summer from Rearing Index measurements. We also estimated the population that would have been there if the total steelhead and trout populations that we found in 1982 were all steelhead.

Rearing Index Method

This method of predicting the stream's potential for rearing

Table IV-4. Comparison of fall steelhead/rainbow trout populations in 1973, 1974, and 1982 in the Carmel River above Los Padres Reservoir.

	STEELHEAD & RESIDENT TROUT				STEELHEAD ONLY[1]			
	Nos. in Population			STANDING CROP #/ACRE	Nos. in Population			STANDING CROP #/ACRE
	Age 0+	Age ≥1+	Total		Age 0+	Age ≥1+	Total	
1973[2]	17965	2685	20650	33.0	-----data not available-----			
1974[2]	15077	2661	17738	35.2	-----data not available-----			
1982	29079	16551	45630	40.5	23554	3834	27388	

[1] Estimated by analyzing gonads.

[2] Estimate from Snider (1983)

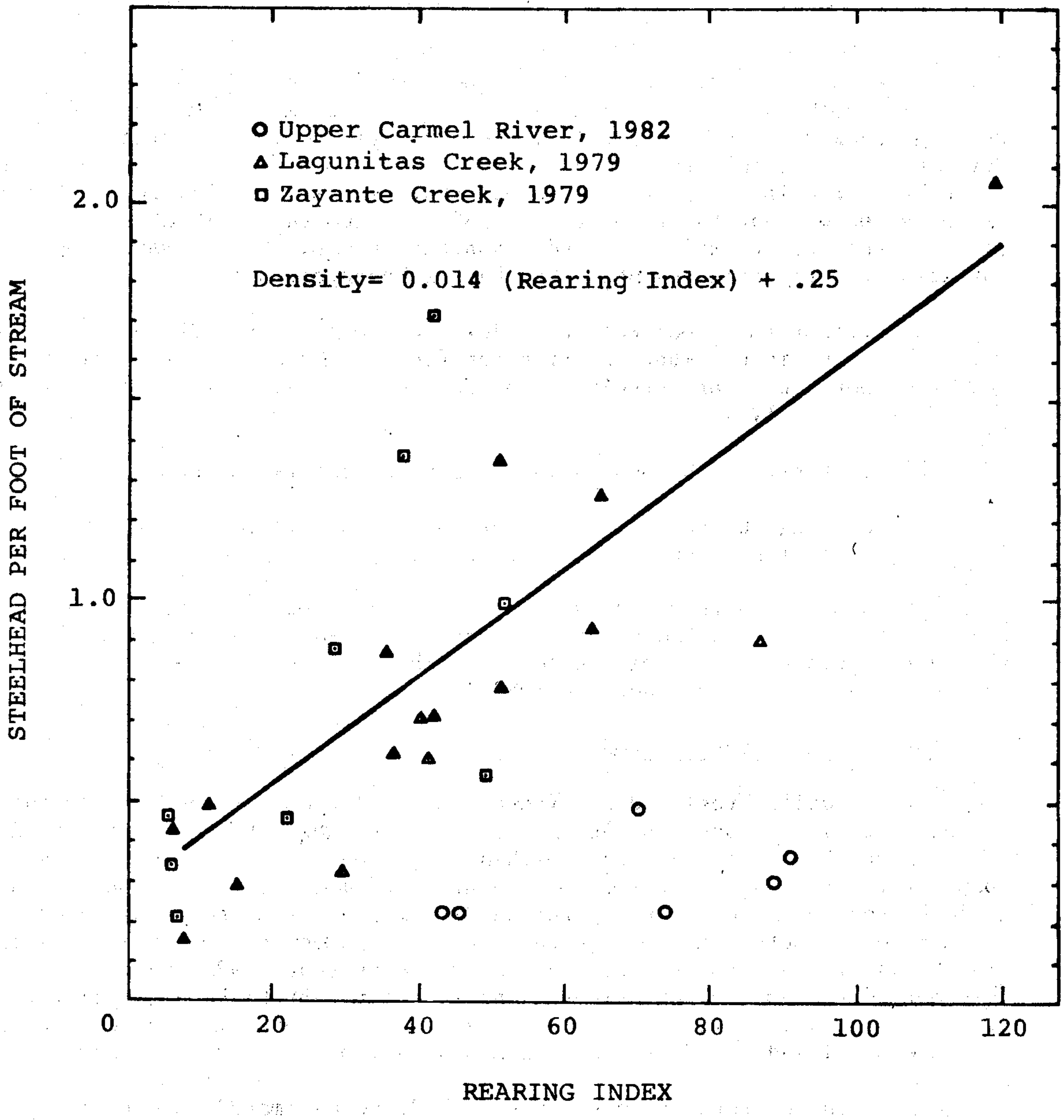


Figure IV-8. Relationship between age 0+ juvenile steelhead population density and rearing habitat index in Lagunitas and Zayante Creeks, and in the upper Carmel River above Los Padres Dam. The relationship we used to estimate capacity of the Carmel River to rear juvenile steelhead through their first summer and fall is based upon data collected in Lagunitas Creek, Marin County and Zayante Creek, Santa Cruz County during fall 1979.

juvenile steelhead relies upon a curve that relates measurements of our Rearing Index to steelhead population density per length of stream. Developing such a calibration curve requires measures of RI and population in a number of rearing habitats that have been fully seeded. Since the Upper Carmel River was not fully seeded in 1982, we used the calibration curves for young-of-the-year from Zayante and Lagunitas Creeks. We estimated the potential rearing capacity above Los Padres Reservoir by:

(a) transforming our Rearing Index measurements in each section (Table lV-4) into numbers of fish per foot of stream with the relationship between RI and steelhead per foot of Lagunitas and Zayante Creeks in Figure IV-8.

(b) multiplying the population density by the reach length, and

(c) summing the potential populations in each reach to estimate the overall rearing capacity (Table IV-5).

Based upon this analysis, using the RIs, we estimate the Carmel River above Los Padres Dam had the potential to rear about 100,000 young-of-the-year steelhead—more than twice the number of combined steelhead and resident trout that were there in 1982.

Total Fish Biomass Method

Juvenile steelhead comprised only 32 percent of the total trout weight or biomass above Los Padres Reservoir in 1982. We reasoned that if the habitat were fully seeded with steelhead fry each year, they would have a competitive advantage over resident rainbow and most resident trout production would be shunted into juvenile steelhead biomass. As a second approach to estimating the potential rearing capacity we assumed that potential steelhead biomass equals the sum of steelhead and resident trout 1982 standing crops. This method probably underestimates the actual potential because prior to our October fish population estimates, fishermen harvested some resident and juvenile steelhead and decreased the standing crop by an unknown amount.

With the total Fish Biomass Method, we estimated potential capacity to rear juvenile steelhead by:

(1) Calculating the biomass of fish in grams per foot of stream for each section measured by dividing the total biomass estimate by section length and then averaging the eight estimates. The result was 7.79 g/ft.

(2) Multiplying 7.79 g/ft by the total stream length (75,983) above Los Padres to estimate total steelhead and trout biomass. The result was 590,206 grams.

Table IV-5. Capacity of Carmel River above Los Padres Reservoir to rear juvenile steelhead through their first summer with 1982 streamflows and channel bed conditions. Population density estimates are based upon the relationship in Figure IV-8 and measurements of rearing indexes in the Carmel River above Los Padres Reservoir (Table IV-1).

STREAM AND REACH	Length of Reach (ft)	Rearing Index	Estimated (no/ft)	Estimated Capacity
Carmel River, Danish Creek to Bluff Camp	8,078	106.9	1.75	14,109
" Bluff Camp to Bruce Fork	5,174	112.0	1.82	9,406
" Bruce Fork to Sulphur Springs	3,960	107.3	1.75	6,938
" Sulphur Springs to Buckskin Camp	6,178	93.0	1.55	9,588
" Buckskin Camp to Tributary above Buckskin	4,540	126.1	2.02	9,150
" Tributary above Buckskin to Bench mark 1743	4,720	109.4	1.78	8,409
" Bench Mark 1743 to Barrier above Ventana Mesa Creek	4,171	90.5	1.52	6,327
TOTALS Main Stem Carmel River Above Los Padres Dam	36,821			63,927
Miller Fork, confluence with Carmel River to Meadow 1 mile upstream	5,280	50.8	0.96	5,075
Miller Fork, Meadow to Clover Basin Camp	5,544	44.7	0.88	4,855
" Clover Basin Camp to Miller Canyon Camp	3,168	82.4	1.40	4,447
" Miller Canyon Camp to probable barrier below China Camp	16,104	54.2	1.01	16,246
TOTALS Miller Fork	30,096			30,623
Danish Creek, confluence with Carmel River to barrier upstream	8,976	57.0	1.05	9,407
TOTALS in Carmel River above Los Padres Reservoir	75,893			103,957

(3) Apportioning total potential steelhead biomass (590,206 g) into representative age groups, that is,

Biomass total = $N_o(w_1) + N_1(w_2)$

where N_o = Number of age 0+ steelhead in sample = 337

N_1 = Number of age 1+ steelhead in sample = 44

N_2 = Number of age 2+ steelhead in sample = 6

$\bar{w}_o$ = Mean weight of age 0+ steelhead = 4.71 g

$\bar{w}_1$ = Mean weight of age 1+ steelhead = 17.42 g

$\bar{w}_2$ = Mean Weight of age 2+ steelhead = 52.13 g

(4) Specifying N_1 and N_2 in terms of N_o by calculating ratios,

$\frac{N_1}{N_o}$ and $\frac{N_2}{N_o}$ from steelhead numbers in each age group (Table IV-3).

$$\frac{N_1}{N_o} = \frac{44}{337} = .131; \quad N_1 = .131(N_o)$$

$$\frac{N_2}{N_o} = \frac{6}{337} = .018; \quad N_2 = .018(N_o)$$

(5) Solving the biomass equation for N_o and then estimating N_1 and N_2

$$\text{Biomass total} = N_o(\bar{w}_o) + N_1(\bar{w}_1) + N_2(\bar{w}_2)$$

$$(590{,}206\text{g}) = N_o(4.71\text{g}) + .131(N_o)(17.42\text{g}) + .018(N_o)(52.13\text{g})$$

$$= N_o(7.93)$$

$$N_o = 74{,}424$$

and

$$N_1 = .3.(N_o) = 9{,}750$$

Based upon this analysis, we estimate that the Carmel River above Los Padres Reservoir could support 84,769 juvenile steelhead including 73,776 young-of-the-year, 9,665 yearlings, and 1,328 2-year-olds.

* * * * * *

The two methods predict that the capacity to rear young-of-the-year steelhead ranges from about 74,000 to 100,000 if the habitat were fully seeded with steelhead fry and if there were no population of resident fish inhabiting the stream. Should the California-American Water Company in cooperation with CF&G succeed in passing more fish over Los Padres Dam, the resident fish will probably continue to inhabit the river but will probably comprise only a minor part of the total population.

Juvenile Rearing in the Carmel River Between San Clemente Reservoir and Los Padres Dam

The Carmel River between Los Padres Dam and San Clemente Reservoir is used to convey water released from Los Padres and diverted at San Clemente Reservoir. A 5 cfs minimum streamflow is maintained below Los Padres Dam throughout the dry season. Due to variation in natural accretion, the augmented dry season flows in this reach vary from about 8 cfs in dry years to 15 cfs in wet years.

In dry to average years late summer and fall stream temperatures immediately below Los Padres Dam warm to 20°-24° C, because epilimnetic water is drawn into the release at the base of Los Padres Dam. This is too warm for good trout or steelhead production. Stream temperatures in this reach were cooler during 1983 because Los Padres Reservoir was kept full and the downstream release made with colder water from its lower depths. In years when Los Padres is lowered and warmer water is released, it may cool as it flows through the densely shaded reach below Los Padres Reservoir.

The river's configuration in this reach is controlled by bedrock outcrops and large boulders. The substrate is a large cobble/boulder mixture. Gravels are scarce above Cachagua Creek, but abundant below there, and the cobble below Cachagua Creek is lightly embedded with sand that probably originates from land development and roads in the Cachagua Creek watershed. A silt release early in the 1982 water year (October 1981) caused temporary, but significant, damage to the spawning and rearing habitat below Los Padres Dam.

Quality and Quantity of Rearing Habitat

We measured the quality and quantity of the rearing habitat in three representative sections of the Carmel River between San Clemente Reservoir and Los Padres Dam and calculated Rearing Indexes for each. The habitat quality ratings were lower than those above Los Padres, but because the stream is so much wider the RIs were higher than on the upper Carmel (Table IV-6). Between Syndicate Camp and Cachagua Creek, rearing habitat in 80 percent of the stream was constrained by a high degree of cobble embeddedness in sand. This, and reduced depth and velocity, lowered the juvenile rearing quality and the Rearing Indexes in those sections.

Fish Population

We measured the fish population in three reaches below Los Padres Dam by electrofishing during late July 1982. We used the same methods to capture and enumerate populations here as we did above Los Padres Dam. Besides large numbers of juvenile steelhead we captured only five adult and two young-of-the-year brown trout.

Table IV-6. Quantity and quality of juvenile steelhead rearing habitat in three sections of Carmel River between San Clemente Reservoir and Los Padres Dam. Summer 1982.

					Young-of-Year Steelhead			Yearling & Older Steelhead		
REACH	Length Measured (ft)	Flow (cfs)	Total Habitat Area (ft^2)	Mean Width (ft)	Suitable Habitat Area (ft^2) % of Total	Mean Quality of Suitable Habitat (0-8)	Rearing Index	Suitable Habitat Area (ft^2) % of Total	Mean Quality of Suitable Habitat (0-8)	Rearing Index
Above Confluence w/ Pine Creek	1173	16.7	30482	26.6	30482 (100)	4.4	114.5	28256 (93)	4.2	101.9
	1116	10.3	29946	26.2	29013 (97)	4.2	109.9	24591 (82)	3.8	82.6
Mean	1145									
Above Syndicate Camp	1466	16.7	48741	350	48317 (99)	2.8	90.6	41669 (85)	2.2	63.8
	1318	10.3	45906	330	40039 (87)	2.9	86.5	28769 (63)	2.1	44.9
Mean	1392									
Below Confluence w/Cachagua Creek	2604	16.7	74668	28.7	72479 (97)	4.8	133.1	65192 87	4.8	119.5
	2600	10.3	69885	26.9	68414 (98)		126.2	55702 (80)		96.3
Mean	2602									
					Means at	16.7	112.7			95.1
					Means at	10.3	107.5			74.6

The population of juvenile steelhead averaged 0.74 age 0+ and 0.03 yearling and older fish per linear foot (Table IV-7). By multiplying these averages times the reach length (28,512 feet) between San Clemente Reservoir and Los Padres Dam, we estimate that 21,100 age 0+ and 600 yearling steelhead were reared in this reach through the end of July. Our 1982 estimate was similar to Snider's (1983) estimate for 1973 (18,500), but significantly smaller than Snider's estimate for 1974 (33,000).

Young-of-the-year in this reach were growing very rapidly. By the end of July their mean fork length equaled 71 mm, almost as large as the 0+ age steelhead above Los Padres in October. This was despite a population density 2-3 times higher than that above Los Padres. Higher steelhead growth rate and population densities below Los Padres may be due to the absence of a large resident trout population, good rearing habitat, and good growing temperatures throughout most of this year. A count of steelhead in July and again in January indicates that almost all of the young-of-the-year moved downstream after less than one year's residence in the reach between the dams, and well ahead of the normal smolt migration time (Figure IV-9).

We believe the habitat between San Clemente Reservoir and Los Padres Dam was underseeded with young-of-the-year steelhead in 1982 because steelhead population density was relatively low, individual fish had high growth rates, the Rearing Index was relatively high, and the reach reared greater numbers of juveniles in 1973 when habitat conditions were similar to 1982.

Rearing Capacity

To estimate the capacity of this reach to rear young-of-the-year steelhead we converted our measures of RI (Table IV-6) into the number of fish per foot of stream using the relationship in Figure IV-8, and multiplied the average (1.76) by the reach length (28,512 feet). Based upon this analysis, the habitat in the 5.4-mile reach between San Clemente Reservoir and Los Padres Dam could have reared about 50,000 steelhead, or twice as many age 0+ steelhead as it did in 1982.

The Rearing Index and predicted steelhead density is primarily a function of streamflow and substrate conditions. Especially streamflow will be different each year. In 1982, late summer and fall streamflow below Los Padres Dam declined from 16.7 cfs on July 27, 1982 to 10.3 cfs on August 13, 1982. This decline is closer to the situation we would expect in dryer-than-average years, when the summer flows would probably be about 10 cfs. Based upon those flow measurements and our assessment that they were lower than average, our estimate that 50,000 young-of-the-year could be reared in the reach between San Clemente Reservoir and Los Padres Dam is probably low.

Juvenile Rearing in Tributaries Between San Clemente and Los Padres Dams

Three tributaries, Cachagua, Pine, and San Clemente creeks, rear significant numbers of juvenile steelhead. Snider (1983) estimated the juveniles in these creeks represent 5%, 30%, and 10% of the total population above San Clemente Dam. We measured juvenile rearing habitat in Cachagua and

Table IV-7. Population density of steelhead in the middle Carmel River between San Clemente Dam and Los Padres Dam.

SECTION	Number of Passes	Number Fish Collected	Length of Section in feet	Area of Section in ft^2	0+ age n/ft	0+ age lbs/ac	1+ age n/ft	1+ age lbs/ac	all ages n/ft	all ages lbs/ac
First section above concrete weir above Cachagua Creek	3	184	251.5	7998	0.72	9.09	0.02	2.85	0.75	11.94
Second section above concrete weir above Cachagua Creek	5	124	166	4084	0.73	10.60	0.01	0.54	0.75	11.14
Third section above concrete weir below Cachagua Creek	3	177	214	4943	0.77	14.35	0.06	10.51	0.83	24.86
TOTAL		485			0.74	11.35	0.03	4.63	0.78	15.98

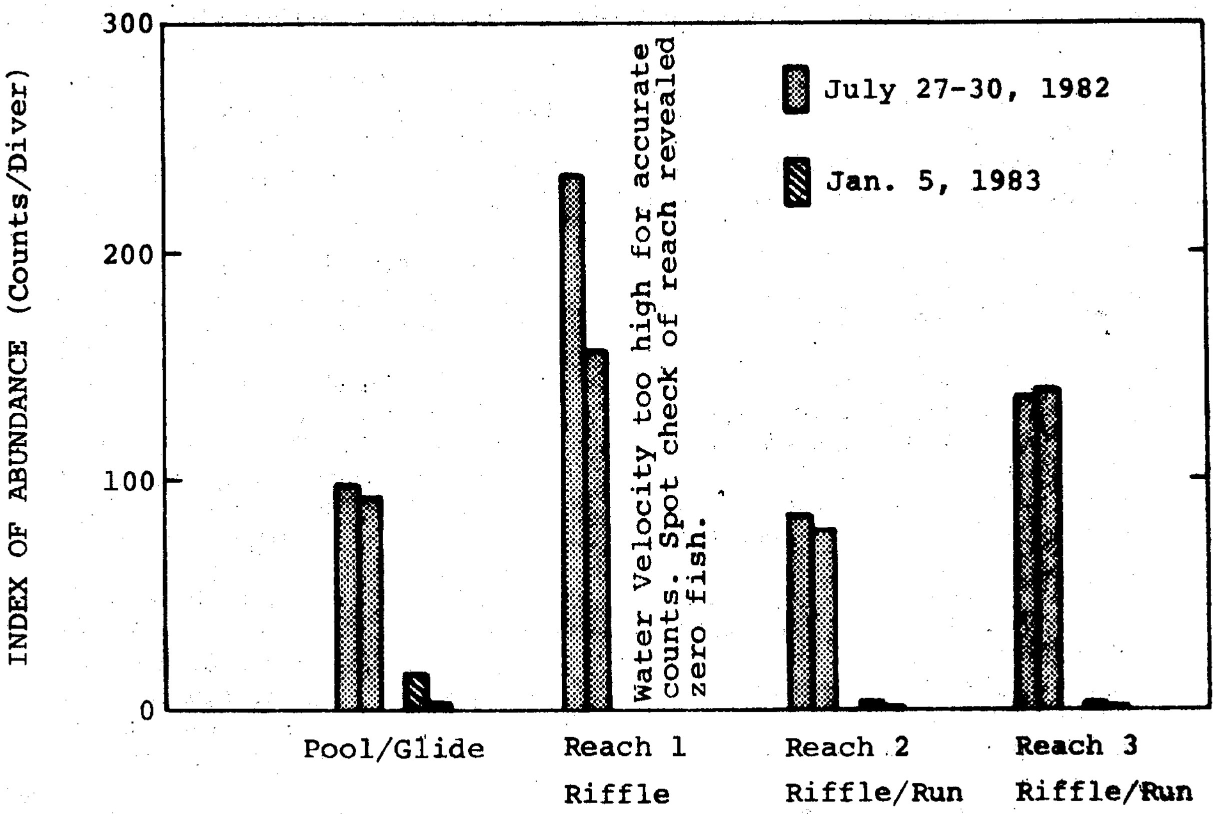


Figure IV-9. Counts of juvenile steelhead in four reaches of the Carmel River between San Clemente Reservoir and Los Padres Dam on July 27, 1982 and January 5, 1983. Two divers swam up the middle of the stream, each diver counted steelhead to the left or right of center exclusively. Due to double counting, numbers in reaches 1, 2, and 3 can only be used as an index of abundance. Sum of individual counts in pool/glide closely approximate actual abundance.

San Clemente creeks but we were unable to gather population data on either stream.

Chachagua Creek

Although Cachagua Creek drains a large watershed (44 sq mi), unit runoff is low compared to the rest of the Carmel River watershed. Measurements by MPWMD show runoff from Cachagua Creek is only 3.6 percent of the Carmel River at Robles del Rio. Summer flows are correspondingly low also, with 0.3 cfs flowing at Monterey County Bridge #528 in mid-August. Below Monterey County Bridge #528, streamflow is discontinuous and the stream completely dries up at the Nason Road Bridge.

The canyon and riparian corridor are relatively open; but there are patches of alder, oak, and sycamore that shade the stream, particularly, immediately below and above Tassajara Road where the canyon is narrow.

We surveyed rearing habitat in three reaches of Cachagua Creek and at two flows. At summer's end juvenile rearing habitat was poor (Table IV-8), and the quality was higher upstream than downstream. This trend probably occurs because streamflow decreases as the stream approaches Prince's Camp and a private road construction project increased the embeddedness of the cobble below Monterey County Road Bridge #529 during July and August 1982.

By calibrating Rearing Indexes in Table IV-8 with the RI vs population density relationship in Lagunitas and Zayante Creeks (Figure IV-8), we estimated that Cachagua Creek could have reared 4458 age 0+ steelhead during 1982 if the habitat had been fully seeded. This is close to the population numbers Snider estimated in 1974, and probably a reasonable assessment of the stream's ability to rear young-of-the-year steelhead.

San Clemente Creek

San Clemente Creek flows through a steep, narrow, and well shaded canyon. Its relatively small watershed contributes 12 percent of the Carmel River streamflow at San Clemente Dam. Summer flows are regulated by releases from a private reservoir 1.6 miles above San Clemente Reservoir and set at 1 cfs, or the natural flow, whichever is less. During 1982, streamflows declined to 0.6 cfs at MPWMD gage above San Clemente Reservoir.

It is our understanding that steelhead utilize all of San Clemente Creek and its tributaries, except Black Rock Creek, where a waterfall blocks adult migration. We were unable to obtain permission to conduct a stream survey above Black Rock Creek. Consequently, all our habitat measurements were in the reach below there.

We surveyed steelhead habitat in four sections (Figure IV-7) totaling 5300 feet at flows ranging from 0.6-3.9 cfs (Table IV-9). The amount of suitable young-of-the-year habitat decreased from 74,000 sqft at 2.7 cfs to 47,000 at 0.6 cfs but the average quality declined only slightly from 3.4 to 2.9. Because of this, the Rearing Indices declined in

Table IV-8. Quantity and quality of juvenile steelhead rearing habitat in three reaches of Cachagua Creek below proposed damsite. Jul-Aug 1982

REACH		Length Measured (ft)	Flow (cfs)	Total Habitat Area (ft²)	Mean Width (ft)	Young-of-Year Steelhead: Suitable Habitat Area (ft²) & % of Total	Young-of-Year Steelhead: Mean Quality of Suitable Habitat (0-8)	Young-of-Year Steelhead: Rearing Index	Yearling & Older SH: Suitable Habitat Area (ft²) & % of Total	Yearling & Older SH: Mean Quality of Suitable Habitat (0-8)	Yearling & Older SH: Rearing Index
Bridge behind Cachagua store up-stream to sandstone cliff, left bank.		1466	2.6[1]	17596	120	17310 (98)	3.1	36.3	14791 (84)	2.2	22.4
		1324	0-0.4	12130	9.2	9129 (75)	1.6	11.1	2493 (21)	0.4	3.9
Mean Length:		1395									
Starting at County Road Bridge #528 upstream for:		1850	2.6	23171	12.5	21601 (93)	4.1	47.5	15553 (67)	2.8	23.6
		1718	0.4[2]	19850	11.6	7131 (36)	1.9	8.0	2557 (13)	0.7	1.1
Mean Length:		1784									
Starting at County Road Bridge #529 upstream for:		2495	2.6	31475	12.6	30863 (98)	2.4	29.7	27195 (86)	2.1	22.4
		2347	0.4	19433	8.3	15726 (81)	2.7	17.8	6061 (31)	1.8	4.7
Mean Length:		2421									
At 2.6 cfs	Totals	5811		72242		69774			57539		
	Means				12.4		3.2	37.8		2.4	22.8
At 0.4 cfs	Totals	5389		51413		31986			11111		
	Means	5600			9.7		2.1	12.3		1.0	3.2

[1] Flow measured at Nason Road Bridge (MPWMD gaging station).

[2] Flow measured at County Road Bridge [3]528, flow at Nason Bridge, zero.

Table IV-9. Quantity and quality of juvenile steelhead rearing habitat in four reaches of San Clemente Creek below proposed damsite. July-August 1982.

					Young-of-Year Steelhead			Yearling & Older SH		
REACH	Length Measured (ft)	Flow (cfs)	Total Habitat Area (ft^2)	Mean Width (ft)	Suitable Habitat Area (ft^2) & % of Total	Mean Quality of Suitable Habitat (0-8)	Rearing Index	Suitable Habitat Area (ft^2) & % of Total	Mean Quality of Suitable Habitat (0-8)	Rearing Index
Pool at MPWMD streamgage	1025	3.9	15427	15.1	15283 (99)	2.2	33.3	15123 (98)	2.5	36.9
upstream for:	1024	1.0	11671	11.4	10629 (91)	2.8	29.4	6757 (58)	2.4	15.9
	1053	0.6	12512	11.9	9929 (79)	3.1	29.2	6642 (53)	2.7	17.1
Mean Length:	1034									
From point 1600 ft below to 200 ft	1818	2.7	26294	14.5	25991 (99)	3.7	53.3	24859 (95)	3.2	43.9
above tributary on left bank.	1854	0.9	20960	11.3	19332 (92)	3.1	32.7	11209 (53)	2.4	14.5
	1788	0.6	22460	12.6	17243 (77)	2.6	25.2	9631 (43)	2.2	11.6
Mean Length:	1820									
From point 200 ft above left bank	1444	2.7	17728	12.3	16678 (94)	3.9	450	13259 (75)	4.0	36.4
tributary to near San Clemente Creek	1363	1.0	14658	10.8	14548 (99)	2.9	31.3	7928 (54)	2.3	13.4
trail crossing.	1522	0.6	17284	11.4	10989 (64)	2.9	21.2	8264 (48)	2.3	12.3
Mean Length:	1443									
From point 1/4 mile below to point 200	1114	2.7	16197	14.5	16142 (100)	3.6	52.5	11456 (71)	3.3	34.2
ft below tributary on right bank.	1074	0.9	13756	12.8	13185 (96)	2.6	32.2	5440 (40)	2.0	100
	970	0.6	12650	130	8506 (67)	2.9	25.4	5423 (43)	1.6	8.9
	1053									
At 2.7-3.9 cfs										
Totals:	5401		75646		74094			64697		
Means :				14.1		3.4	460		3.3	37.9
At 0.9-1.0 cfs										
Totals:	5315		61045		57694			31334		
Means :				11.6		2.9	31.4		2.3	13.5
At 0.6 cfs										
Totals:	5174		64906		46667			29970		
Means :				12.2		2.9	25.3		2.2	12.5
MEAN LENGTH ALL REACHES	5297									

direct proportion to changes in flow between 2.7 and 0.6. At summer's end, the average Rearing Indices were 25.3 and 12.5 for age 0+ and yearling steelhead.

Based upon our Rearing Index measurements and Figure IV-8, we estimate that San Clemente Creek could have supported about 14,356 young-of-the-year steelhead in 1982. This estimate is similar to the 11,731 Snider (1983) found in 1973, but about twice the number, 6,821, he measured in 1974. The difference between numbers in 1973 and 1974 is best explained by the threefold decline in returning adults in 1974 compared to 1973 (Table IV-4).

Juvenile Rearing in the Lower Carmel River Below San Clemente Dam to the Narrows

Large numbers of adult steelhead successfully spawn in the 11-mile reach of the Carmel River between San Clemente Dam and Schulte Road. In winter and early spring water quality and substrate conditions in this reach are usually adequate to insure reasonably good hatches and fry emergence so that, unlike the reaches above Los Padres Reservoir, this reach begins most springs well seeded with young steelhead.

Between San Clemente Dam and the USGS gage a small summer flow, leakage from the dam, has remained in most years but most of the fish have died as the summer flows declined and finally ceased altogether. Only in wet years was there a small summer flow for a short reach below San Clemente Dam and significant survival of young fish. Increasing summer flows below San Clemente dam to provide rearing habitat is a major goal of the MPWMD Watershed Management Plan and recent agreements between the California-American Water Company and the Department of Fish and Game.

River Configuration--In the reach from San Clemente Dam downstream to Powell's Hole, the configuration of the Carmel River is controlled by bedrock outcrops. Below Powell's Hole the river's course is probably controlled by the interaction of alluvial deposits with peak flows that periodically rearrange, scour, and deposit bedload along the course of the stream. Kondolf (1982) has identified several channel changes that have occurred following high flows in the period from 1979-1981 and has associated these changes with increased bank erosion caused by groundwater pumping and succeeding high flows. Although there are several bedrock outcrops in this reach, the degree to which they influence the river's course is unknown.

Substrate Condition--In the reach from San Clemente Dam downstream to Tularcitos Creek, substrate material is predominantly large cobble and boulders. Gravel is more abundant below Tularcitos Creek. Unfortunately, large amounts of fine sediment also are contributed by Tularcitos Creek. Since our 1982 field assessment, large deposits of this fine sediment have reduced the steelhead rearing habitat there but efforts are underway to correct the problem. Boulder and cobble concentrations gradually diminish with distance below Rosie's Bridge (Esquiline Road) and gravels predominate in the reach between the Narrows and Robinson Canyon. Below Robinson Canyon sand concentrations increase and then dominate the substrate material below Schulte Road.

Summer Streamflow Below San Clemente Dam--Operating San Clemente Dam as a diversion dam and increasing the groundwater pumped from both aquifers below San Clemente Dam has reduced streamflows throughout the summer months. This limits rearing habitat below San Clemente Dam every year. Streamflow drops precipitously when flashboards are installed at San Clemente Dam and has often declined to zero or near zero in August or September. Since the 1976-1977 drought, summer flows at Robles del Rio have remained above zero because 1978, 1980, and 1982 were very wet years and Cal-American Water Company pumped less water from the upper aquifer. Recent agreement between the water company and the California Department of Fish and Game and reduced pumping from the upper aquifer may improve this situation.

Existing Water Temperature

The degree to which the water surface is shaded determines how water temperature changes along coastal stream. Except for the first 3.0 miles, where the stream is well shaded, the Carmel River below San Clemente Dam flows through a wide canyon with only scattered patches of riparian forest. The degree of shading ranges from 45 percent immediately below San Clemente Dam to 3 percent in Garland Park (Figure IV-10). Because the degree of shading is so low in the reach between Schulte Road and Rosie's Bridge, and measurements collected by the USGS showed temperatures ranging from 70° to 82° F, we thought that temperature in the Carmel River would be too high for steelhead.

During late spring and early summer we, and MPWMD staff, daily read maximum-minimum thermometers submerged at various points along the river to define the problem.

Water temperatures leaving San Clemente Reservoir rose from May through August, reaching the mid- and, sometimes, high 70°s in August--but dropped each night to the mid- or low 60°s (Table IV-10). Even in riffles, surface water temperatures were often 5 degrees to 14 degrees warmer than water under cobble where fish were residing during the day.

As we expected, the warm water and relatively low flows (11.8 cfs in July, and 1.85 cfs in August) coming from San Clemente Reservoir lost heat in the well-shaded canyon above Tularcitos Creek. Maximum daily water temperatures then increased as the stream flowed through the relatively unshaded reach down to Robinson Canyon. The minimum daily temperatures which occurred in the night were surprisingly low. Below the canyon the daily maximums were lower, primarily because air temperatures are lower as the stream approaches the ocean and there is more fog.

In 1982, water temperatures were suitable for rearing steelhead throughout the lower Carmel River because of the combination of reduced air temperatures and fog in the lower reaches and cold water upwelling from the streambed. Additional information on water temperature is found in Appendix D.

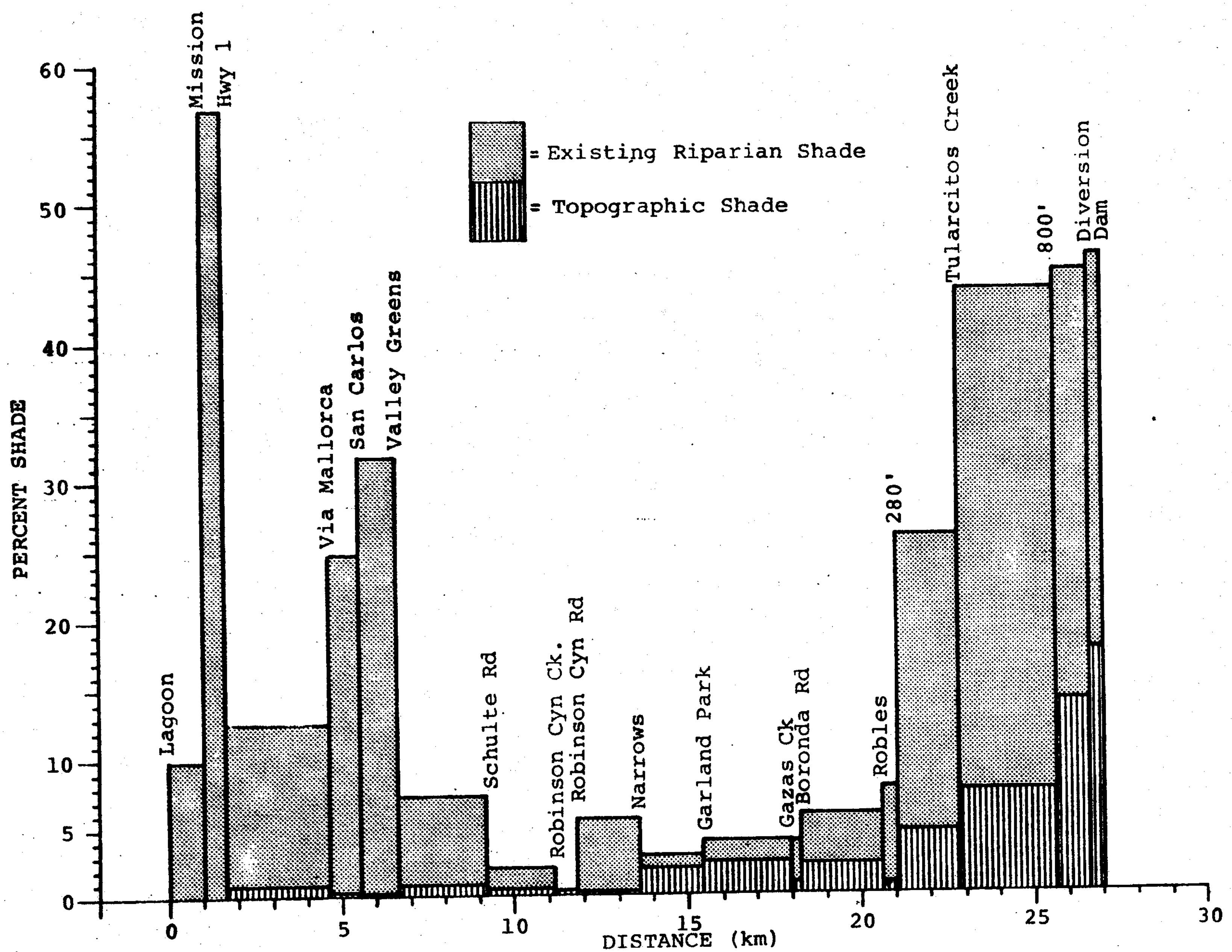


Figure IV-10. Topographic, existing riparian shade at summer equinox on the Carmel River, 1982. Based on SOLSHAD calculation. Appendix D.

Table IV-10. Means of daily maximum-minimum water temperatures in Carmel River, 1982. Degrees F.

LOCATION	Km from Dam	MAY Max	MAY Min	JUNE Max	JUNE Min	JULY Max	JULY Min	AUGUST Max	AUGUST Min
San Clemente Diversion	0.54	63.2	56.6	68.2	63.5	72.7	65.1	76.1	65.0
Below Tularcitos Creek	4.41					66.4	57.3	66.5	57.1
Robles del Rio	6.70							74.2	62.6
Old Boronda Road	9.27	68.4	56.4	73.5	61.0	74.2	60.0		
Don Juan	12.11			72.0	61.2	74.4	60.5	77.7	60.6
Robinson Canyon	16.43	70.0	54.5	73.9	60.5	76.7	61.6	77.1	61.4
San Carlos	24.37	66.5	58.0	71.2	61.7	74.7	62.7	72.5	60.2
Via Mallorca	25.25	70.1	53.3	72.5	60.9	74.5	62.7	7.3	61.1
Highway 1	28.14								

Quality and Quantity of Habitat

We selected five sections to represent the stream between San Clemente Dam and the Narrows. In each section, we measured the quantity and quality of rearing habitat and calculated rearing indices at four flows as streamflow at Robles del Rio declined from 53 cfs in the late spring and early summer of 1982 (Table IV-11). We did not measure juvenile rearing habitat in the 9.5-mile reach of the Lower Carmel below the Narrows where, because of the sandy substrate, habitat is generally much poorer than above.

In all sections both habitat quality and quantity declined by nearly one-half as flows dropped from 46-53 cfs to 5.6-8.5 cfs. Because the Rearing Index is a function of both, the Rearing Indexes declined by 2/3 - 3/4. The relationship between the Rearing Index and streamflow is somewhat different in each section (Figure IV-11).

Fish Population

Before it dried up in the summer, the lower Carmel River contained a small population of sculpins, a few brown trout, larger populations of hitch and stickleback, and abundant young-of-the-year steelhead. Lampreys enter from Carmel Bay to spawn in the spring. Our electroshocker failed at the beginning of our attempt to measure the steelhead juvenile population in this reach and, in the time required for repairs the streamflow had ceased and large losses of fish had occurred. To estimate the population we used counts made during diving surveys on June 13, 1982, when the streamflow had fallen to 56 cfs and was clear.

Two biologists (Li and Dettman) swam upstream and tallied juvenile steelhead with hand counters in 65 sections of the stream (Table IV-12). A recorder walked upstream, 100-150' behind the divers, recording the number of fish tallied, the length and width of each short reach, and the stream width that was censused. They classified fish estimated as being less than 3 inches long as young-of-the-year steelhead and larger fish as yearlings. They censused a total of 1.4 miles or 14 percent of the juvenile steelhead habitat between the Narrows and San Clemente Dam. Using population density estimates from Table IV-12, and our assessment that 9.7 miles of the Lower Carmel between the Narrows and San Clemente Dam was juvenile steelhead habitat, we calculated the total population of age 0+ steelhead at 138,874.

Most of these fish were subsequently eaten by birds or died as the stream dried up later in the year.

Rearing Capacity at Various Streamflows

We estimated the capacity of the Carmel River below San Clemente Dam to the Narrows to rear juveniles at various streamflows (Table IV-13) by:

(1) Choosing a range of flow releases (5-40) expected with either the "active mitigation" or the 27,000 acre-feet new San Clemente Alternative.

Table IV-11. Quantity and quality of juvenile rearing habitat in five reaches of the Carmel River between the Narrows and San Clemente Dam.

REACH	Length measured	Streamflow at USGS gage (cfs)	Total surface area (ft²)	Mean width (ft)	YOUNG-OF-THE-YEAR STEELHEAD: Habitat area (ft²) and percent of total	YOUNG-OF-THE-YEAR STEELHEAD: Habitat/1 adjusted for mean length of each reach (ft²)	YOUNG-OF-THE-YEAR STEELHEAD: Mean quality of suitable habitat (0-8)	YOUNG-OF-THE-YEAR STEELHEAD: Rearing Index	YEARLING & OLDER STEELHEAD: Habitat area (ft²) and percent of total	YEARLING & OLDER STEELHEAD: Habitat/1 adjusted for mean length of each reach (ft²)	YEARLING & OLDER STEELHEAD: Mean quality of suitable habitat (0-8)	YEARLING & OLDER STEELHEAD: Rearing Index	Observer/2
From MPWMD stream gage upstream to Eucalyptus Grove on left bank.	4,606	46	208,524	45.3 (49.2)*	201,664 (97)	151,489	4.1	181.4	129,992 (62)	97,649	3.8	107.6	DD
	3,245	40	165,018	50.9	140,400 (85)	149,702	3.7	159.1	77,533 (47)	82,670	3.5	83.4	DD
	3,299	18	168,185	51.0	160,235 (95)	168,055	3.4	168.4	118,256 (70)	124,027	2.7	99.7	SL
	3,589	8.5	131,487	36.6	117,026 (89)	112,820	2.0	64.6	57,988 (44)	55,904	1.3	21.5	GS
MEAN LENGTH	3,460												
From Bedrock Pool above Garland Park to Gazas Creek.	4,361	46	207,041	47.5	201,119 (97)	190,097	6.4	297.1	175,375 (85)	165,764	4.2	167.5	SL
	4,456	40	204,799	46.0	194,871 (95)	180,264	5.5	242.4	159,869 (78)	147,886	4.2	152.0	SL
	3,859	16	157,801	40.9	156,426 (99)	167,087	3.8	153.1	114,527 (73)	122,332	2.5	73.6	SL
	3,812	5.6	139,059	36.5	130,656 (94)	141,281	2.3	78.0	95,931 (69)	103,732	1.7	42.0	SL
MEAN LENGTH	4,122												
From Boronda Road Bridge to Paso Hondo critical riffle.	3,058	49	144,576	47.3	144.156 (100)	137,603	5.8	275.0	126,977 (88)	121,205	3.7	153.0	DD
	2,844	38	145,038	51.0	138,310 (95)	141,957	5.3	259.3	117,325 (81)	120,419	3.7	151.0	SL
	3,011	19	150,107	49.9	110,181 (73)	106,814	3.6	130.8	25,694 (17)	24,860	2.8	23.6	DD
	2,763	6.6	90,247	32.7	85,214 (94)	90,025	2.1	71.6	64,179 (71)	67,803	1.3	32.3	SL
MEAN LENGTH	2,919												
From Rosie's Bridge to Camp Stephani	3,664	53	148,057	40.4	148,057 (100)	142,763	5.1	207.5	142,539 (96)	137,443	4.8	186.7	DD
	3,512	38	135,645	38.6	130,937 (97)	131,720	4.6	171.8	104,460 (77)	105,085	4.1	120.6	DD
	3,476	18	122,105	35.1	109,895 (90)	111,697	3.2	110.7	57,558 (47)	58,502	2.8	46.7	DD
	3,478	8.5	112,378	32.3	91,304 (81)	92,748	2.8	73.6	51,837 (46)	52.657	2.3	34.0	DD
MEAN LENGTH	3,533												

Table IV-11 (continued). Quantity and quality of juvenile rearing habitat in five reaches of the Carmel River between the Narrows and San Clemente Dam.

					YOUNG-OF-THE-YEAR STEELHEAD				YEARLING & OLDER STEELHEAD				
REACH	Length measured	Streamflow at USGS gage (cfs)	Total surface area (ft^2)	Mean width (ft)	Habitat area (ft^2) and percent of total	Habitat/1 adjusted for mean length of each reach (ft^2)	Mean quality of suitable habitat (0–8)	Rearing Index	Habitat area (ft^2) and percent of total	Habitat/1 adjusted for mean length of each reach (ft^2)	Mean Quality of suitable habitat (0–8)	Rearing Index	Observer/2
From Russell's Bridge to Cal-American Water Co. Filter Plant.	3,153	53	115,061	36.5	109,042 (95)	97,214	5.2	178.2	102,565 (89)	91,440	4.7	153.8	SL
	2,214	38	65,376	29.5	65,376 (100)	83,004	5.9	174.1	65,126 (100)	82,687	5.3	155.7	GS
	2,942	18.5	86,251	29.3	57,059 (66)	54,518	3.5	67.8	41,196 (48)	39,362	2.5	35.3	GS
	2,933	5.6	67,004	22.8	66,154 (99)	63,402	2.5	55.8	58,335 (87)	55,909	0.8	15.9	GS
MEAN LENGTH	2,811												
At 46-53 cfs TOTAL	18,842					719,166				613,501			
MEAN							5.3	227.8			4.2	153.9	
At 38-40 cfs TOTAL	16,271					686,647				538,747			
MEAN							5.0	201.3			4.2	132.5	
At 16-19 cfs TOTAL	16,587					608,171				369,083			
MEAN							3.5	126.2			2.7	55.8	
At 5.6-8.5 cfs TOTAL	16,575					436,874				336,005			
MEAN							2.3	68.7			1.5	29.1	

/1 Habitat at each flow corrected by multiplying ratio $\frac{\text{habitat X}}{\text{reach length surveyed}}$

/2 Observers: DD David Dettman; SL Stacy Li; GS Gary Stern.

* Length of reach surveyed at 40, 18, and 8.5 cfs was slightly less than that surveyed at 46 cfs. Width in parentheses is of that portion of the reach surveyed at 40, 18, and 8.5 cfs.

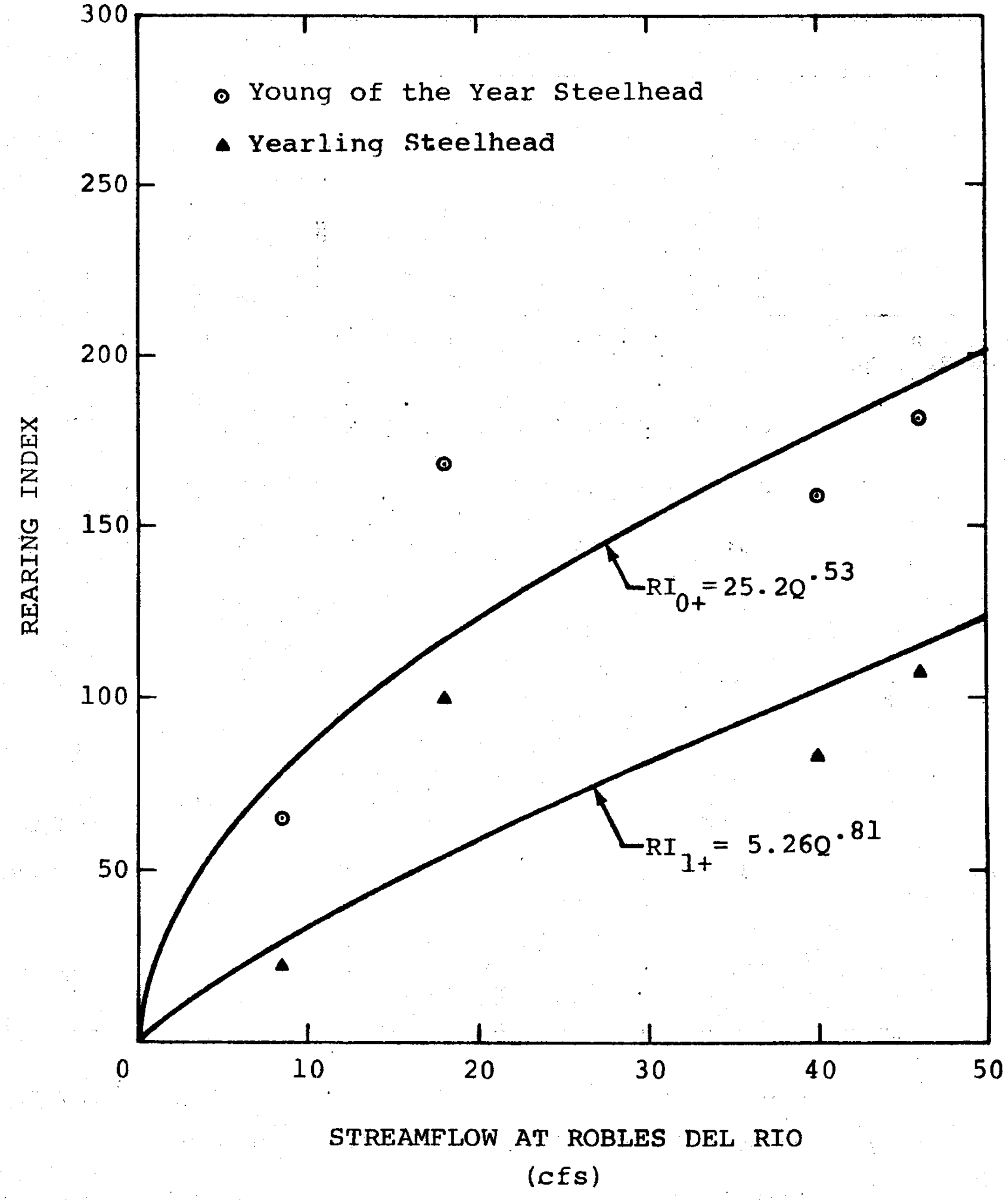


Figure IV-11a. Relationship between juvenile steelhead rearing indexes and streamflow in the Carmel River between the Narrows and the Eucalyptus grove below Garland Park.

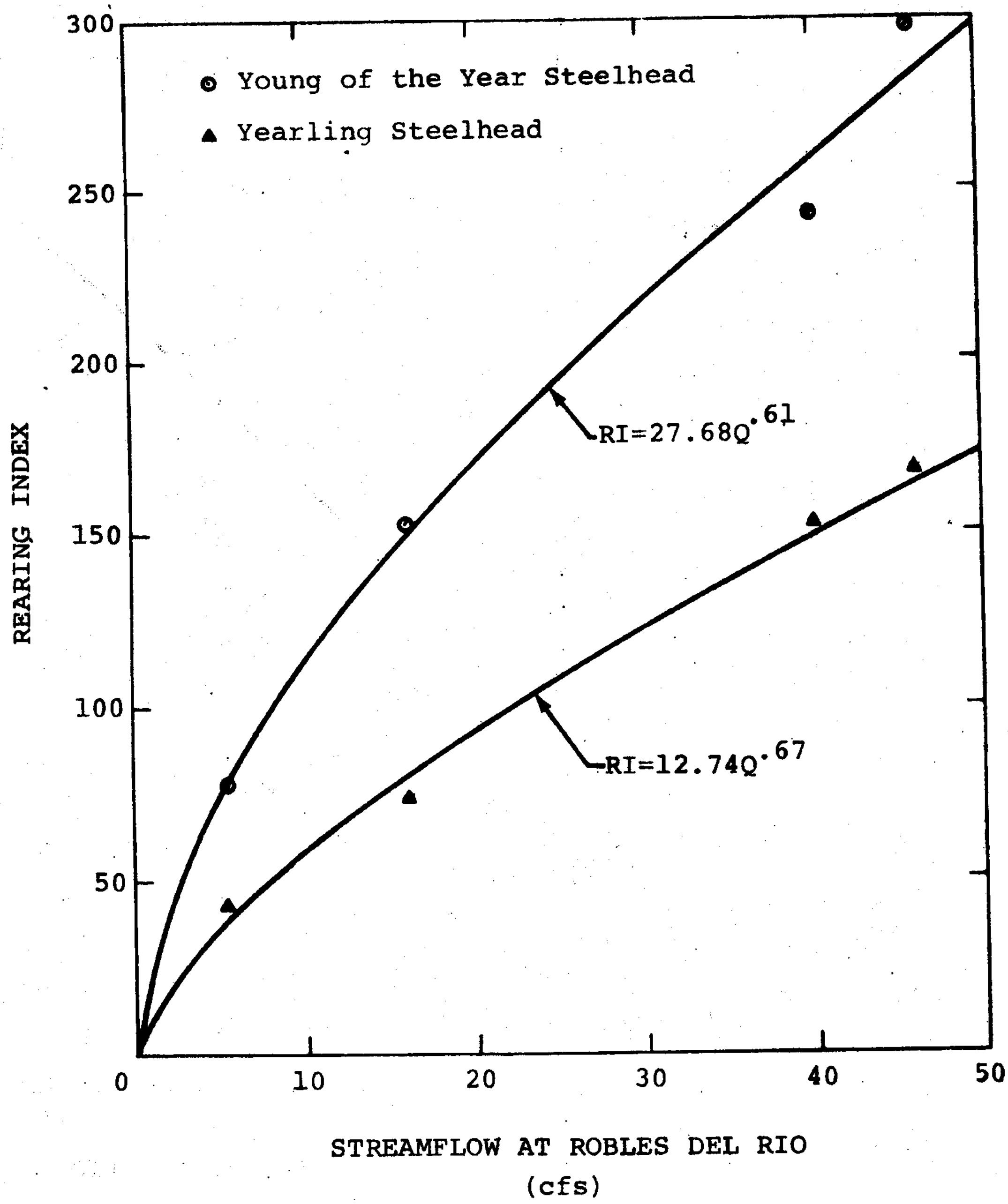


Figure IV-11b. Relationship between juvenile steelhead rearing indexes and streamflow into Carmel River between Bedrock Pools above Garland Park and Gazas Creek.

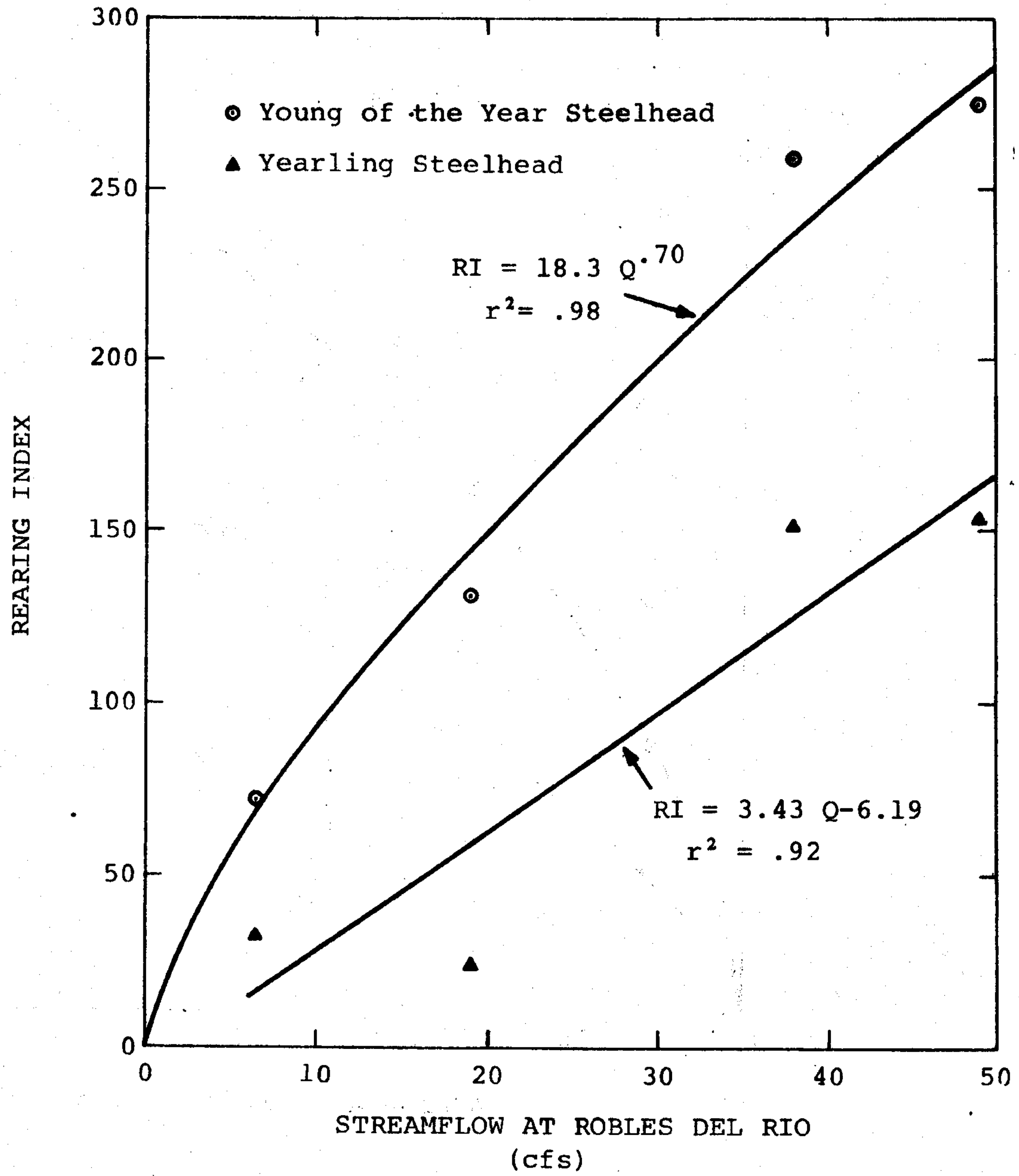


Figure IV-11c. Relationship between juvenile steelhead rearing indexes and streamflow in the Carmel River between Boronda Road Bridge and the Paso Hondo critical riffle.

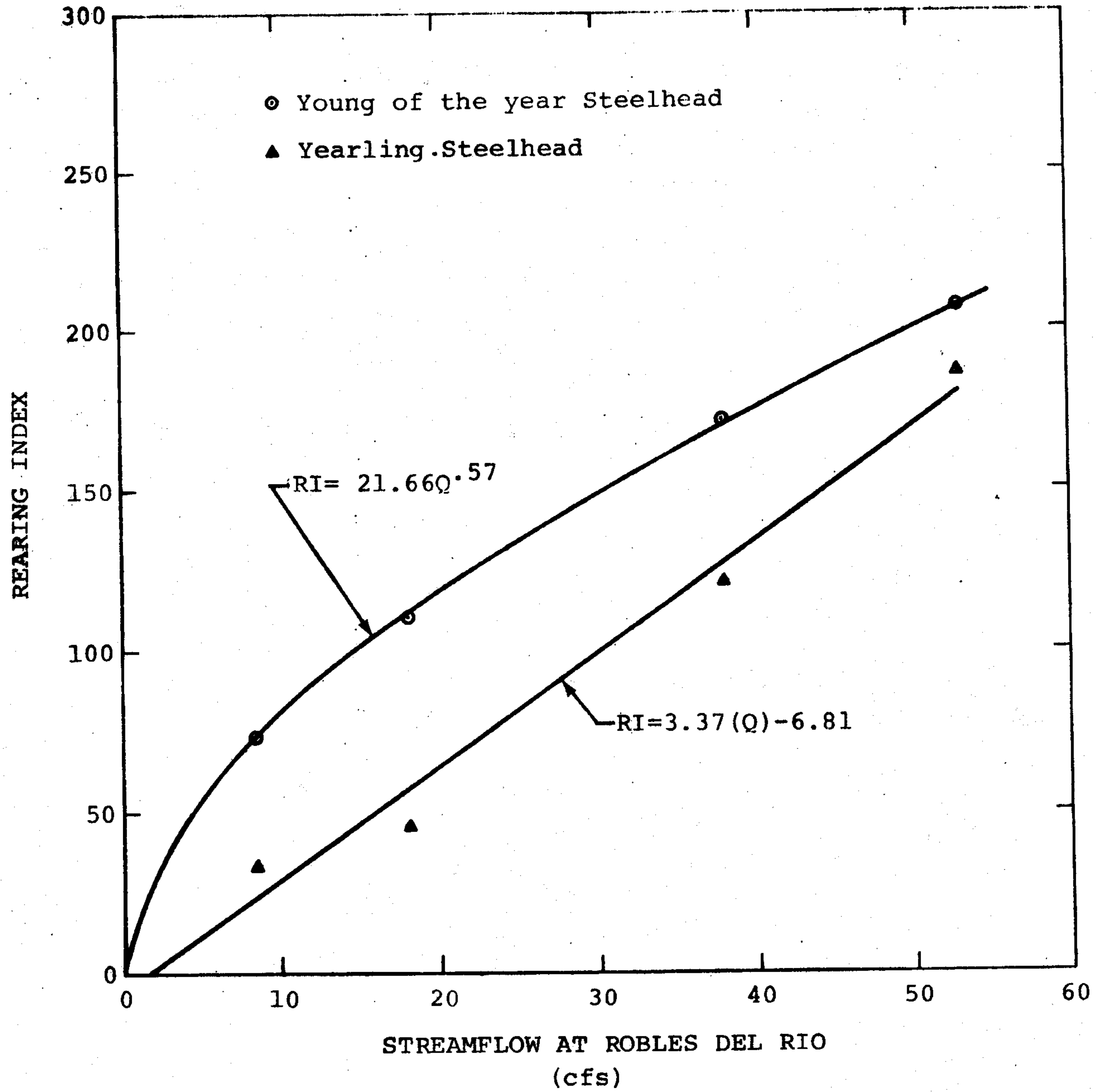


Figure IV-11d. Relationship between juvenile steelhead rearing indexes and streamflow in the Carmel River between Rosie's Bridge (Esquiline Road) and Camp Stephani.

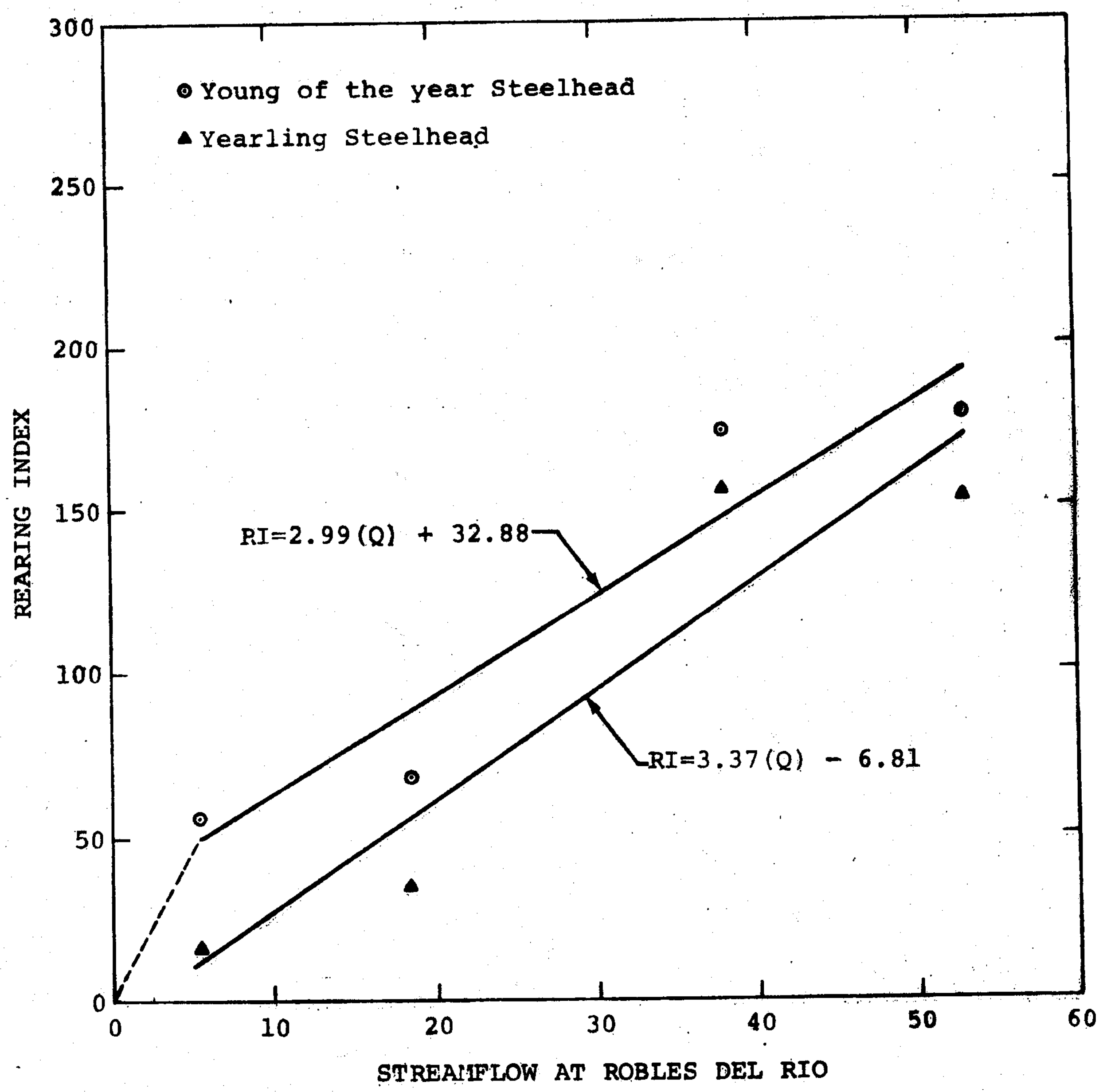


Figure IV-11e. Relationship between juvenile steelhead rearing indexes and streamflow in the Carmel River between Russell's Bridge and California-American Water Company's filter plant.

Table IV-12. Population of age 0+ steelhead in 65 sections of the Carmel River June 13, 1982 between the Narrows and San Clemente Dam.

LOCATION - CHARACTER		Reach Length(ft)	Reach Area(ft^2)	Number of age 0+ steelhead in reach	Population Density no/ft	Population Density no/ft^2
Garland Park above foot bridge						
	Rn	130	4,810	50	.38	.0104
	R	84	2,604	42	.50	.0161
	Rn	53	3,445	180	3.40	.0522
	G	85	4,590	578	6.80	.1259
	R	130	2,600	187	1.44	.0719
	G	130	4,680	162	1.25	.0346
	Rn	125	3,750	401	3.21	.1069
	Rn	145	5,510	64	.44	.0116
	Rn	75	2,475	294	3.92	.1188
	R	140	3,780	353	2.52	.0934
	G	105	13,125	3,262	31.07	.2485
	P	75	5,250	248	3.31	.0472
	Rn	146	9,490	366	2.51	.0386
	R	75	3,600	148	1.97	.0411
	G	160	16,000	313	1.96	.0196
		90	5,400	0	.00	0
	P	120	7,800	335	2.79	.0429
	G-P	140	9,100	397	2.84	.0436
	Rn	100	4,600	399	3.99	.0867
	Rn	120	5,520	284	2.37	.0514
	Rn	64	1,984	113	1.77	.0570
	R	150	6,000	395	2.63	.0658
	P	85	3,400	214	2.52	.0629
	TOTALS	2,527	129,513	8,785		
	Means:				3.63	.063
	95% confidence limits				±2.66	±.023
Below Rosie's Bridge (Esquiline Road)						
	P	70	3,360	317	4.54	.0943
	R	100	5,000	368	3.68	.0736
	R	145	6,670	440	3.03	.0660
	R	100	4,500	326	3.26	.0724
	R	70	3,220	209	2.99	.0649
	R	40	1,800	122	3.05	.0678
	Rn	70	3,500	310	4.43	.0886
	Rn	140	7,000	206	1.47	.0294
	G	150	8,700	473	3.15	.0544
		175	8,750	406	2.32	.0464
	P	115	5,290	381	3.31	.0720
	Rn	80	3,200	235	2.94	.0734
	Rn	160	7,200	455	2.84	.0632
	R	130	4,160	274	2.11	.0659

Table IV-12 (continued). Population of age 0+ steelhead in 65 sections of the Carmel River June 13, 1982 between the Narrows and San Clemente Dam.

LOCATION - CHARACTER		Reach Length(ft)	Reach Area(ft^2)	Number of age 0+ steelhead in reach	Population Density no/ft	Population Density no/ft^2
Below Rosie's Bridge (Esquiline Road) (continued)						
Rn		70	3,500	450	6.43	.1286
P		155	5,890	564	3.64	.0958
G		100	2,700	145	1.45	.0537
Rn		95	2,375	122	1.28	.0514
R		90	1,800	141	1.57	.0783
G		100	7,000	143	1.43	.0204
P		90	3,150	79	.88	.0251
P		90	3,150	120	1.33	.0381
Rn		230	6,900	462	2.01	.0671
G-P		180	3,960	337	1.87	.0851
P		90	2,520	137	1.52	.0544
P		125	4,375	255	2.04	.0583
	TOTALS	2,960	119,670	7,477		
	Means:				2.63	.065
	95% confidence limits				±.51	±.026
Above Camp Stephani						
P		90	4,680	260	2.89	.0556
Rn		60	2,880	130	2.17	.0451
Rn		125	5,125	207	1.66	.0404
G		65	2,470	122	1.88	.0494
P		150	5,400	263	1.75	.0487
Rn		125	5,000	435	3.48	.0870
R		95	3,325	217	2.28	.0659
G		165	5,445	141	.85	.0259
P		160	5,600	209	1.31	.0373
P		210	6,300	227	1.08	.0360
Rn		80	2,480	141	1.76	.0569
R		55	1,100	197	3.58	.1791
R		25	500	17	.68	.0340
R		90	2,340	83	.92	.0355
P		220	9,900	146	.66	.0147
Rn		65	2,145	84	1.29	.0392
	TOTALS	1,780	64,490	2,879		
	Means:				1.77	±.053
	95% confidence limits				+.49	±.02
OVERALL	TOTALS	7,267	313,673			
	Means:				2.78	.061
	95% confidence limits				±.94	±.010

Table IV-13. Estimated capacity of the Carmel River to rear age 0+ steelhead through their first summer between the Narrows and San Clemente Dam at various streamflows.

REACH	Length (ft)	Equation used to predict steelhead/ft of stream at various streamflows measured at Robles del Rio/1	Estimated capacity of each reach to rear young-of-the-year steelhead at various streamflows as measured at Robles del Rio and in 1982.					
			5 cfs	10 cfs	20 cfs	30 cfs/3	40 cfs/3	1982 flows/2
Narrows to Bedrock Pools above Garland Park	15,874	Density = $.35Q^{.53} + 0.25$	17,006	22,784	31,151	37,668	43,219	4,000
Bedrock Pools above Garland Park to Gazas Ck confluence	4,000	Density = $.39Q^{.61} + .25$	5,164	6,355	10,700	13,421	15,804	6,000
Gazas Ck confluence to Rosie's Bridge (Esquiline Road)	9,309	Density = $.26Q^{.57} + .25$	8,385	11,320	15,677	19,148	22,145	0
Rosie's Bridge (Esquiline Road) to Russell's Bridge	7,008	Density = $.30Q^{.57} + .25$	7,014	9,563	13,348	16,363	18,966	4,873
Russell's Bridge to San Clemente Dam	14,962	Density = $.04Q + .71$	13,615	16,608	22,593	28,577	34,562	10,211
Totals from Narrows to San Clemente Dam	51,153		51,184	66,640	93,469	115,177	134,696	25,084

/1 Equations may overestimate density at flows < 5 cfs.

/2 Based upon assessment that streamflow declined to: 2 cfs at Robles del Rio; 1 cfs above Tularcitos Creek; and that approximately 10,000 fish survived low water conditions between the Narrows and Gazas Creek.

/3 Reader cautioned that equation used to predict density has not been calibrated at Rearing Indexes in Carmel River when flows are above 20 cfs.

(2) At each flow calculating the Rearing Index in each reach between the Narrows and San Clemente Dam on the basis of the relationships shown in Figure IV-11.

(3) Transforming the Rearing Index of each reach into an estimate of the number of juvenile steelhead per linear foot—on the basis of the relationship between Rearing Index and density found in Lagunitas and Zayante Creeks (Figure IV-8).

(4) Calculating populations in each reach by multiplying population density per foot times reach length.

(5) Summing the calculated populations in the reaches between the Narrows and San Clemente Dam (Table IV-12).

In this way we estimate the Carmel River could support a young-of-the-year population ranging from 45,000 if summer and fall flows were 5 cfs, to 135,000 if they were 40 cfs (Figure IV-12). These estimates are based on 1982 streambed conditions—changes in erosion rates, sediment transport, and the amount of sand in the streambed would modify the potential population supported by flows ranging from 5-40 cfs. In a later section we have used the relationship to evaluate the effects of various water supply alternatives on juvenile steelhead populations.

Comparison of Our Juvenile Rearing Habitat Assessment with that of the US Fish and Wildlife Service 1979

In the spring of 1979, the US Fish and Wildlife Service utilized the IFG4 plus HABTAT Model to estimate "weighted usable habitat" for both yearling and young-of-the-year steelhead in the Carmel River in the vicinity of Garland Park and three-quarters of a mile below San Clemente Dam. Their results indicate an increase in these habitats as flows rose from 32 cfs (the lowest flow they measured) up to 50 cfs at the San Clemente site, and to 100 cfs at Garland Park. After that, increasing flows caused a decline in the habitat for juvenile steelhead. The flows were measured at Highway 1.

We did not measure young-of-the-year or juvenile habitat above 40 cfs because summer flows above that level are not being proposed by any project. Because of this, and because the USF&WS "weighted usable habitat" can not be compared to our Rearing Indices or to our estimates of the stream's capacity to rear young fish at various flows, our findings are not comparable.

Effect of Streamflow on Growth

While the curve in Figure IV-12 depicts the number of steelhead that can be reared with various streamflows, it does not address an equally important aspect of a steelhead's juvenile life, that is, growth. Because most steelhead in the Carmel River reach the smolt stage and enter the ocean within one year, the probability of their ocean survival and return as adults is directly influenced by their growth during this first year. As an index of how steelhead growth might be influenced by streamflow we estimated total

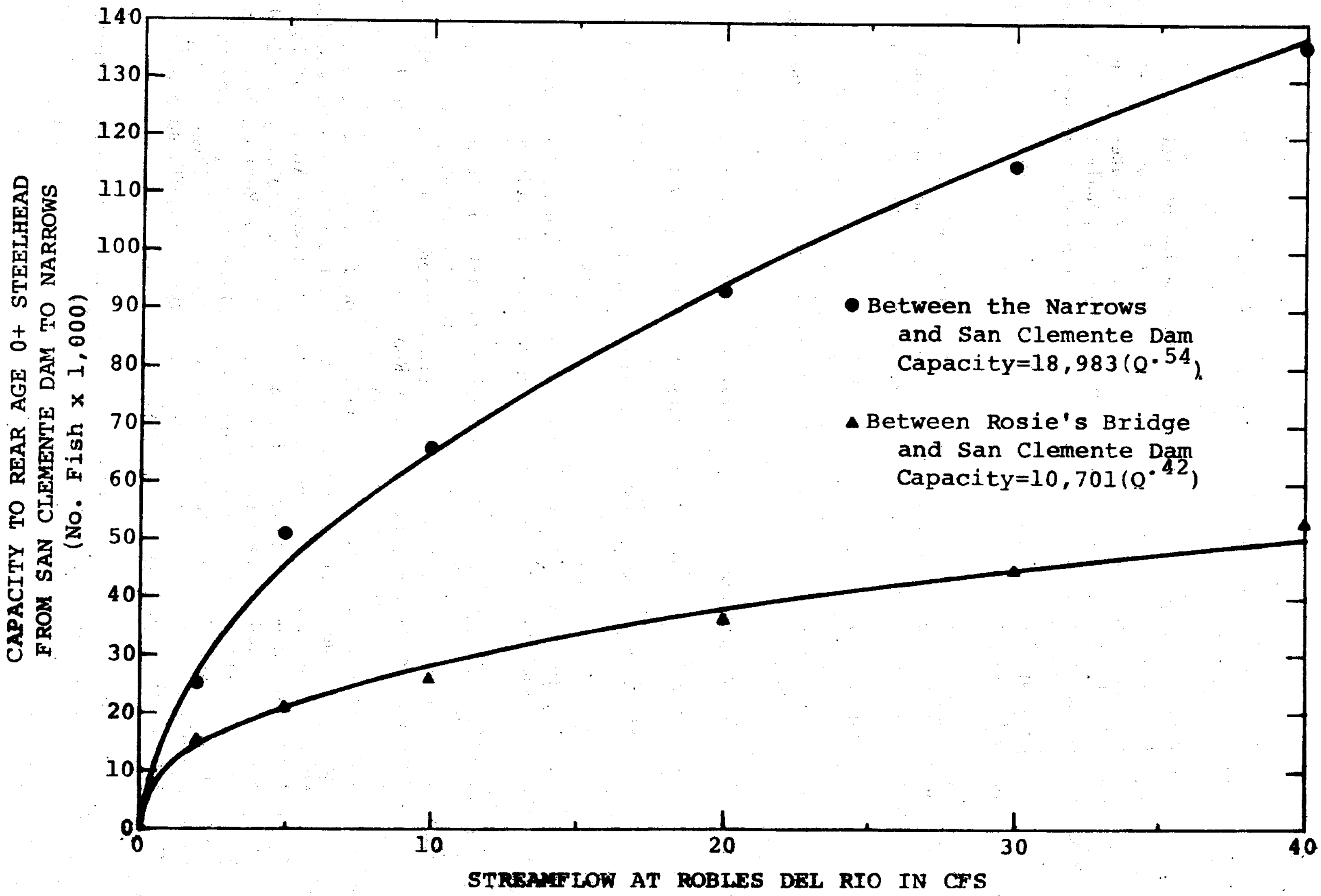


Figure IV-12. Relationships between capacity to rear age 0+ steelhead in the Carmel River between the Narrows and San Clemente Dam and Rosie's Bridge and San Clemente Dam, and streamflow at Robles del Rio.

"production" in terms of net gain in the weight of the steelhead population during various streamflows.

Production is defined as the total elaboration of fish biomass during any time interval, including what is formed by individuals that do not survive to the end of the time period (Chapman 1971). Estimates are usually expressed by weight and require several measurements of population size and mean weight during the time period for which production estimates are needed.

We estimated young-of-the-year population size on three dates, on April 15, June 13, and September 30, 1982.

April 15, 1982 We first began noting large numbers of steelhead fry during the third week of April 1982. We estimated the total population size above the Narrows on April 15, 1982 at 681,000 by the equation:

Population size = N (P) F (E) where:

N = Total number of steelhead nests observed during 1982 spawning season (219)

P = Proportion nests that were above the Narrows (0.83)

F = Fecundity estimate, number eggs per female (7500)

E = Fraction of eggs that successfully emerge as fry (assumed to be 0.5)

June 13, 1982 We estimated the 0+ age steelhead at 139,000 by diving in 65 sections of the stream as previously described.

September 30, 1982 Streamflows declined from 15 cfs at Robles del Rio in mid-July, to 2 cfs by August 5, and averaged about 2 cfs throughout August and September. The stream dried up in most of the reach between the Narrows and Esquiline Road but water remained in two short reaches, below Gazas Creek and Garland Park, where juvenile steelhead were concentrated into 12 pools. The fish were too crowded for us to count them well but we estimated that about 10,000 age 0+ steelhead survived in these pools. In the 2.4 mile reach between Rosie's Bridge (Esquiline Road) and San Clemente Dam many juveniles probably survived the low water period. Based upon curves relating the Rearing Index to streamflow (Figure IV-11) and steelhead population density to Rearing Index (Figure IV-8), we estimate that 15,000 age 0+ steelhead were reared above Rosie's Bridge. We estimate the total age 0+ steelhead population was about 25,000 on September 30, 1982.

We constructed Figure IV-13 and used regression analysis to develop a curve relating population size and time.

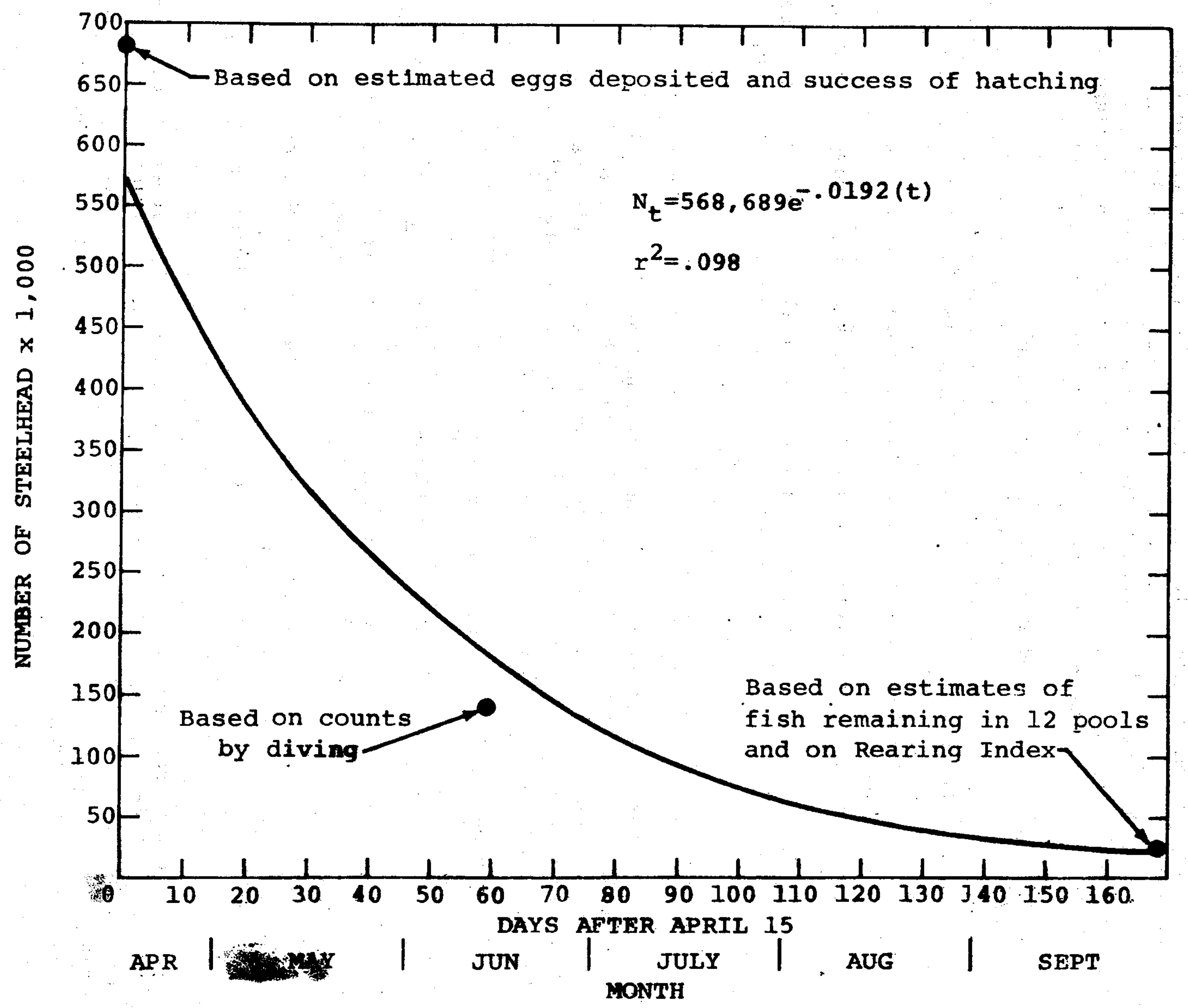


Figure IV-13. Estimated decline in number of age 0+ steelhead in the reach of Carmel River between the Narrows and San Clemente Dam during spring and summer 1982.

Growth Estimate for Age 0+ Steelhead

We estimated growth for age 0+ steelhead during the period from April 15 to August 29, 1982. Based upon measurements in Waddell Creek (Shapovalov and Taft 1954) we assumed that steelhead weighed 0.18 grams when they emerged from the gravel. On three subsequent dates, June 18, August 3, and August 29 we estimated the mean weight of age 0+ steelhead by:

(1) collecting a sample of juvenile steelhead,
(2) constructing length frequency graphs for each sample.
(3) estimating ages of length classes on these graphs from an analysis of fish scales that were sampled on June 18, August 3, and August 29, 1982,
(4) using this information to calculate the mean weight of age 0+ steelhead.
(5) plotting the mean weight of age 0+ steelhead on the sampling dates, and,
(6) calculating a regression equation (Figure IV-14) that best describes the relationship between mean weight and time beginning at 0 days on April 15, 1982.

Estimate of Production During the Period April 15-August 15, 1982

We used the numerical procedure outlined by Chapman (1971) to estimate production from April 15-September 30, 1982. Based upon the curves in Figures IV-13 and IV-14, we estimated mean weight and numbers at 2-week intervals from April 15 to August 15, 1982 (Table IV-14), and calculated production during each time interval by the equation:

$P = G\bar{B}$ where, P = Production in kg

G = Instantaneous growth rate, $= \ln \bar{w}_E - \ln \bar{w}_B$ where,

$\bar{w}_E$ = mean individual weight at the end of the time period,

$\bar{B}$ = Mean stock biomass during the 2-week period.

$\bar{w}_B$ = mean individual weight at the beginning of the time period.

Using the results of Table IV-14, we estimate the lower Carmel River between the Narrows and San Clemente Dam produced a total of 2100 kg (2.3 tons) of 0+ age steelhead during the period from April 15-August 15, 1982. By summer's end, approximately 1800 kg or 86 percent were lost, many consumed by predators on the stream.

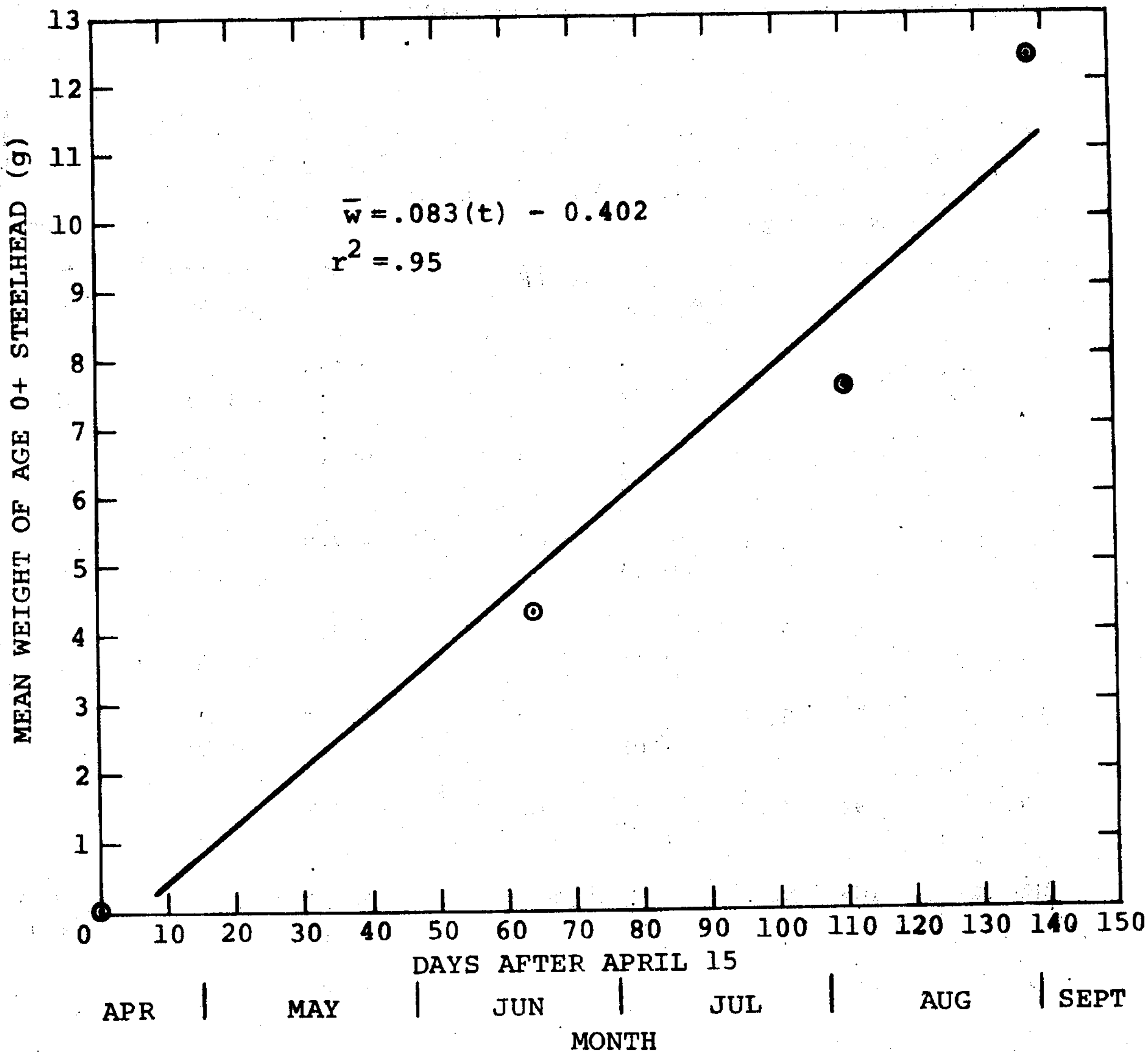


Figure IV-14. Growth of age 0+ steelhead in Carmel River below San Clemente Dam during spring and summer, 1982.

Table IV-14. Production estimate for age 0+ steelhead in the Carmel River between the Narrows and San Clemente Dam during late spring and summer 1982.

MON	DA	Days from Begin. of Estimate	Mean Weight	Instan-taneous Growth	Population Number	Population Biomass (kg)	Mean Biomass (kg)	Production	Mean Stream-flow at Robles del Rio (cfs)
APR	15	0	0.18		568,689	102.4			
				1.54			226.85	349.4	
MAY	1	16	0.84		418,272	351.4			
				0.91			503.35	458.1	156.0
MAY	16	31	2.09		313,605	655.4			
				0.52			731.35	380.3	95.0
JUN	1	47	3.50		230,657	807.3			
				0.30			813.50	244.1	66.3
JUN	16	62	4.74		172,938	819.7			
				0.23			798.20	183.6	36.1
JUL	1	77	5.99		129,662	776.7			
				0.19			739.80	140.6	14.3
JUL	16	92	7.23		97,215	702.9			
				0.17			657.50	111.8	9.5
AUG	1	108	8.56		71,503	612.1			
				0.13			571.65	74.3	2.1
AUG	15	122	9.72		54,649	531.2			
				0.14			485.25	67.9	1.7
SEP	1	139	11.14		39,430	439.3			
				0.10			405.00	40.5	1.8
SEP	15	153	12.30		30,136	370.7			
				0.10			338.30	33.8	2.8
SEP	30	168	13.54		22,595	305.9			
		TOTAL						2084	
		MEAN				539.6			

In the previous pages of this Chapter, we have described the amount and quality of juvenile steelhead rearing habitat in the different reaches of the Carmel River and its tributaries above San Clemente Reservoir. We have also estimated the number of young steelhead that can be reared there under conditions that existed in 1982, if the river is fully seeded with fry. These estimates are summarized in Table IV-15. Summer streamflows in most of the basin were higher in 1982 than normal, and for that reason the habitat was probably of somewhat better quality than in a normal year. We estimated that 230,000 juveniles could have been produced in 1984 in the 31.8 miles of stream above the San Clemente Reservoir.

While large numbers of steelhead spawn below the San Clemente Dam, the actual production of juveniles is low because survival depends upon streamflows continuing throughout the entire summer, fall, and following winter. A recent agreement between the Department of Fish and Game and the California-American Water Company has begun to provide a small permanent flow for a few miles below San Clemente Dam. We have seen no estimates of the number of steelhead that could be reared in this flow but expect that it is less than the 51,000 we estimated could be reared if a permanent 5 cfs reached the Narrows.

Table IV-15. Juvenile steelhead habitat in 1982 and estimates of potential juvenile steelhead populations in the Carmel River Basin upstream of San Clemente Reservoir with 1982 habitat conditions.

STREAM	Juvenile Steelhead Habitat (lin ft)	Average Stream Width (feet)	Young-of the-Year Rearing Index	Population Density[1] No per ft		Composition of Population by Number		
				Age 0+	Age ≥1+	Age 0+	Age ≥1+	TOTALS
UPSTREAM OF LOS PADRES RESERVOIR								
Mainstem Carmel River	36960	21.8	106.2	1.74	0.26	63927	9561	73488
Miller Fork	30096	12.0	54.8	1.02	0.15	30623	4532	35155
Danish Creek	8976	12.3	57.0	1.05	0.16	9407	1392	10799
Subtotals	76032 (14.4 Mi)					103957	15485	119442
BETWEEN LOS PADRES AND SAN CLEMENTE DAMS								
Mainstem Carmel River	28512	28.7	110.1	1.79	0.07	51076	1959	53035
Cachagua Creek	10560	9.7	12.3	0.42	0.00	4458	46	4504
San Clemente Creek	23760	11.9	25.3	0.60	0.02	14356	418	14774
Pine Creek	29040	6.0	na	1.21	0.09	35138	3163	38301
Subtotals	91872 (17.4 mi)					105028	5586	110614
Basin Total	167904 (31.8 mi)					208985	21071	230056

1 Population density estimates for young-of-the-year steelhead are based on the relationship in Figure IV-8 and rearing indexes of the Carmel River upstream of San Clemente Reservoir, except in Pine Creek where the density is based on the number of young-of-the-year in the stream in 1973. Population density of yearling steelhead based on percent age composition of the juvenile steelhead populations surveyed by CF&G in 1973 and 1974, and D. W. Kelley & Associates in 1982.

CHAPTER V. DOWNSTREAM MIGRATION OF JUVENILE STEELHEAD

Timing of Downstream Migration

In California coastal streams, the main seaward migration of steelhead smolts generally occurs during the late winter and spring. We believe that the higher January-March flows required in the Carmel River for adult migration will be sufficient for those juveniles that emigrate early, but that the April-June migrants will need special minimum flows of their own.

We examined the downstream migration of steelhead in the lower Carmel River during May and June 1982 by periodically counting the numbers of juvenile fish in eight pools between Carmel Lagoon and Esquiline Road (Figure V-1) and comparing the changes in those numbers as the season progressed. Flows were too high to permit such counts in April.

All counts were made by two divers who each made two passes through a pool and used the mean of the four counts as an estimate of the population. Fish were recorded as "smolts" or "nonsmolts". Smolts were easily recognized by their blacktipped tail fins, lack of parr marks, and a silvery appearance. They are undergoing changes to prepare them for ocean life. Nonsmolts seined from the lagoon at this time were slightly smaller (Figure V-2).

The mean number of steelhead smolts steadily declined in the pools during May and early June, while the nonsmolts generally increased (Figure V-3a). The number of nonsmolts increased more in the four pools above the Narrows than in the pool below (Figure V-3b). During these changes streamflows were steadily declining from almost 300 to 50 cfs and water temperatures were increasing steadily from 15^{o} to 19^{o} C (Figure V-3c).

We periodically sampled for juvenile steelhead in the Carmel Lagoon with a 100' x 8' x 5/8" mesh bag seine. The lagoon was usually turbid in the spring, making it very difficult to observe the fish by diving. Until late May, we usually, but not always, were able to capture relatively large numbers of juvenile steelhead in the lagoon and a high percentage of them were smolts (Table V-1).

The fish were returned to the lagoon after our counting and measuring. During the work 400 were marked by removal of a few scales. We recaptured only three: one had been in the lagoon 13 days, one 11 days, and one was captured twice and had been in the lagoon 17 days at its second capture. From this data, and the fact that mean length did not increase (Figure V-4) during this period of rapid individual growth, we formed an opinion that most smolts spent only a short time in the lagoon before going to sea.

Almost all of the steelhead captured in the lagoon <u>prior</u> to June were yearlings, progeny of the steelhead that spawned in the winter and spring of 1981. Young-of-the-year, progeny of the 1982 spawning, moved into the lagoon during June and July.

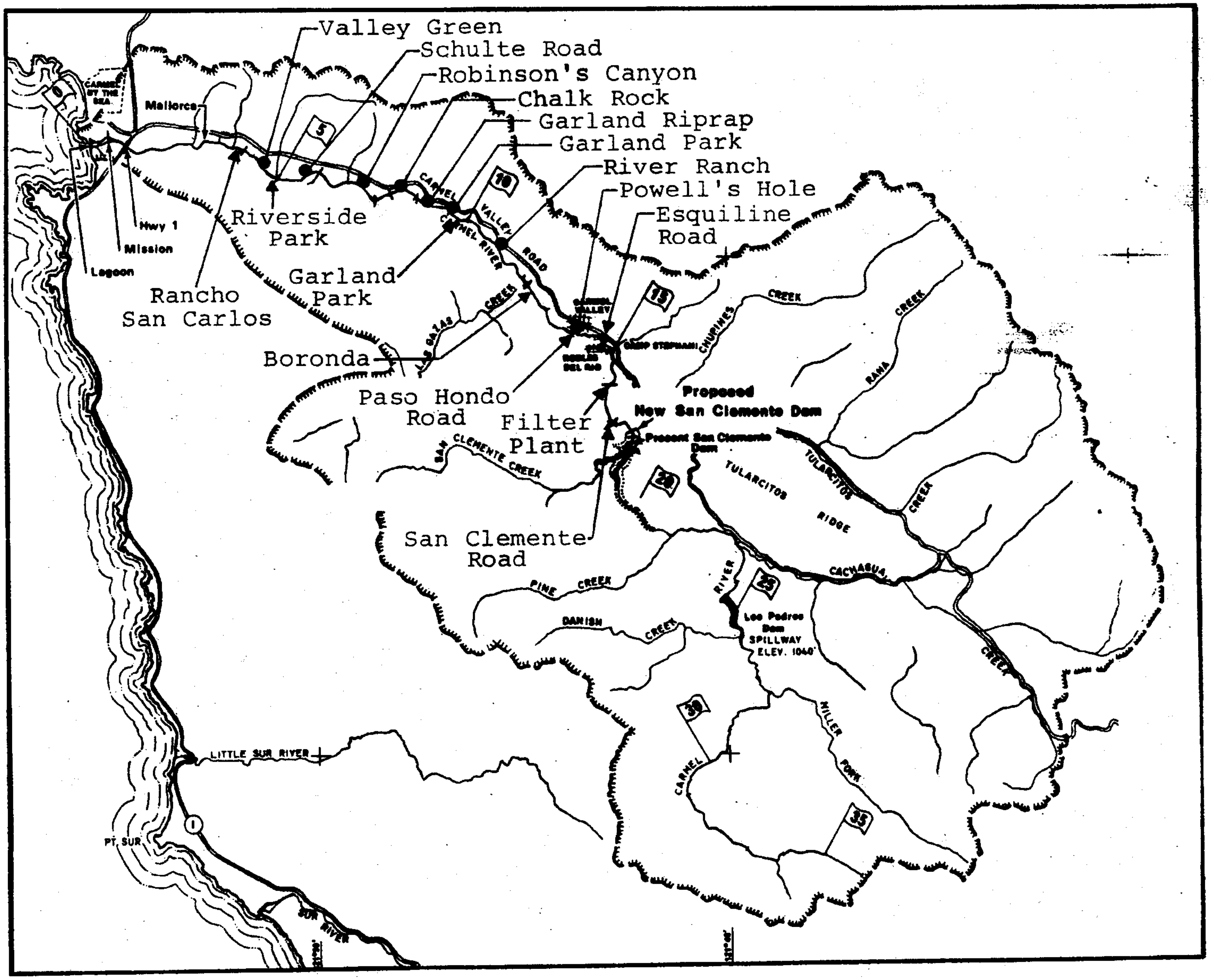


Figure V-1. Location of pools (●) in Carmel River where downstream migrating juvenile steelhead were counted from April 26 to June 10, 1982, and of riffles (▲) where benthic invertebrates were sampled as one assessment of steelhead food distribution.

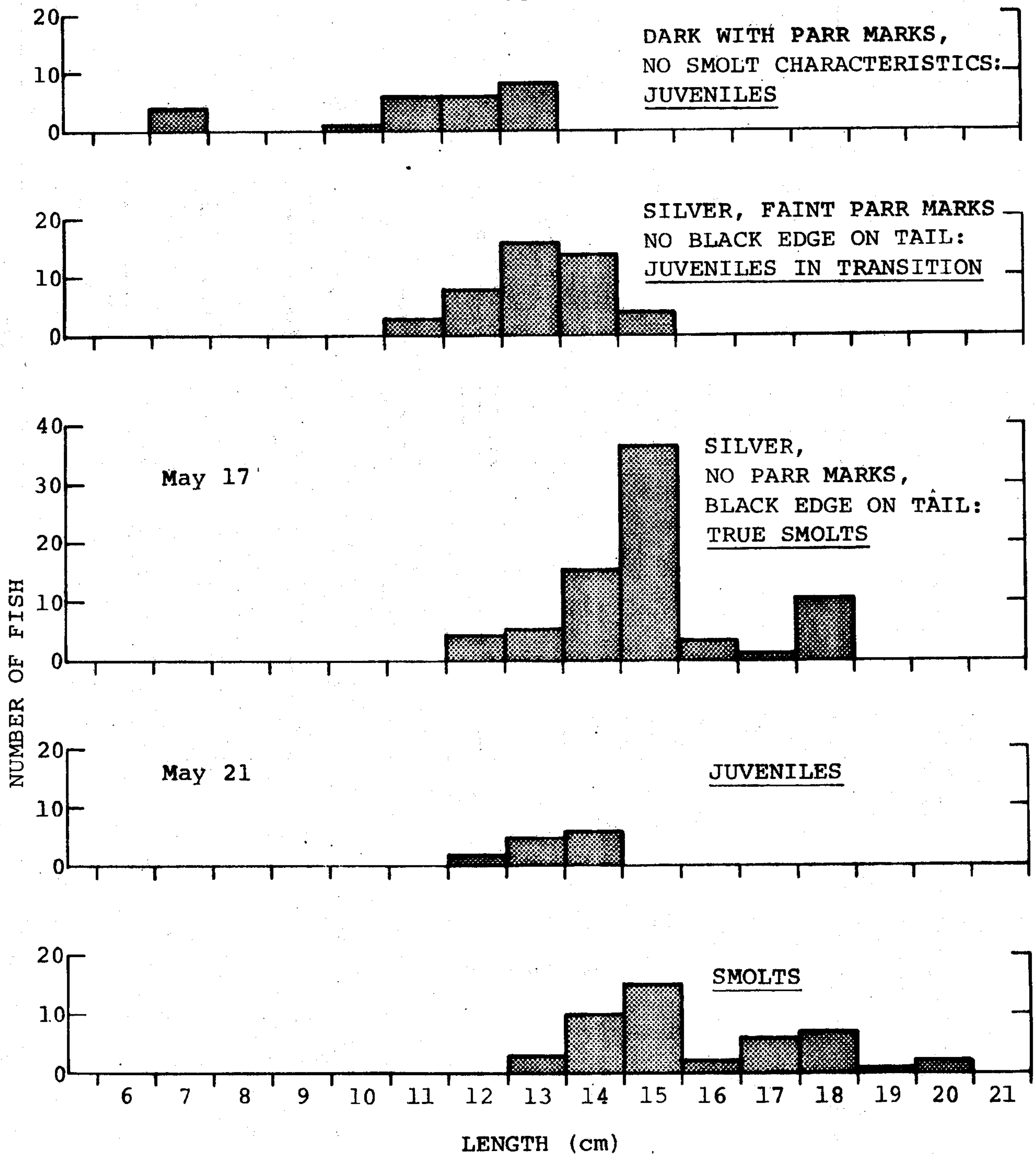


Figure V-3. (A) Mean number of smolts and other juveniles observed in eight pools in Carmel River; (B) Mean number of nonsmolts in four pools above and below the Narrows; (C) Streamflow in Carmel River at Carmel plus mean maximum-minimum water temperatures taken at Robinson Canyon Bridge during April, May, and June 1982.

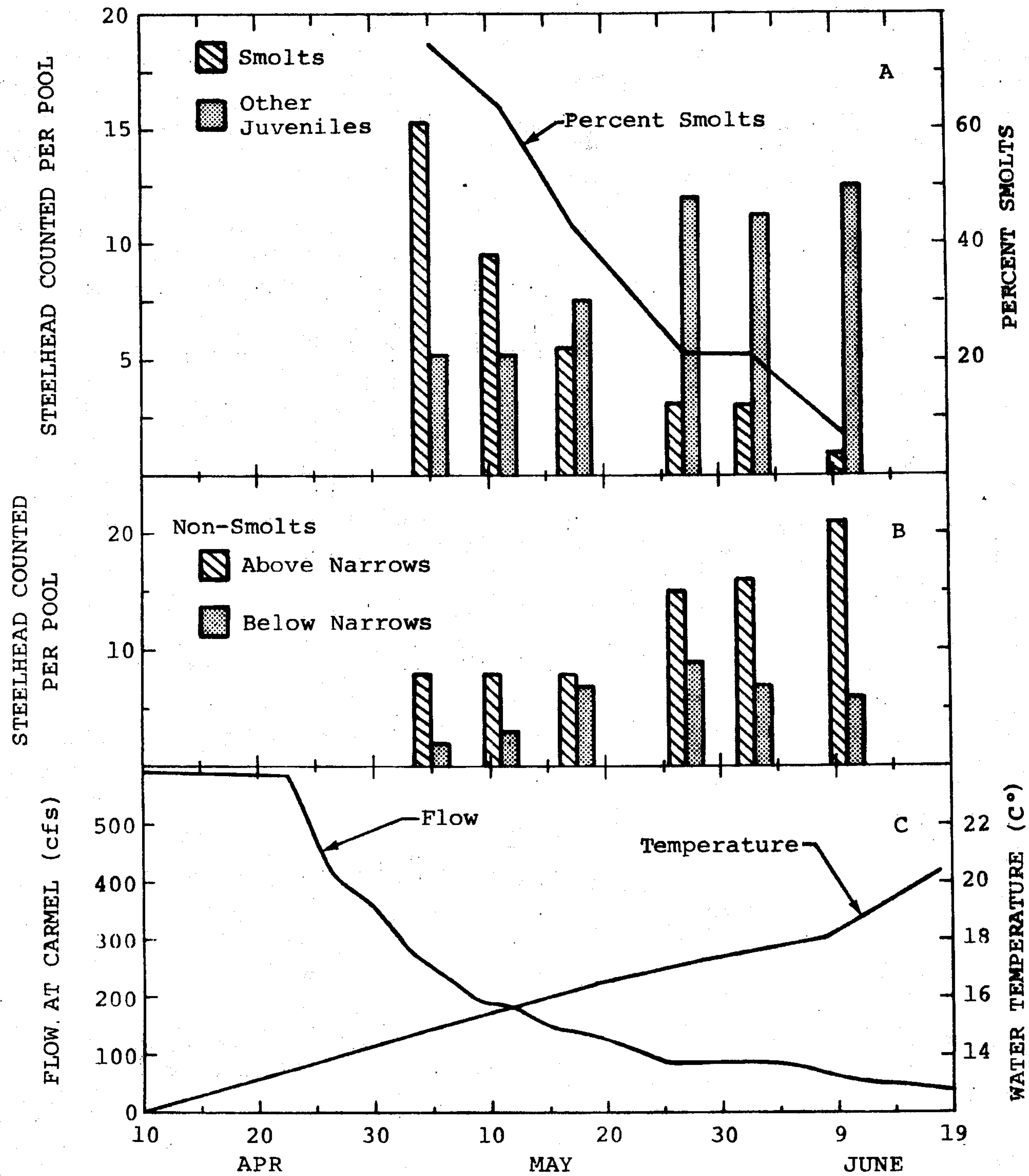


Figure V-2. Fork lengths of juvenile steelhead with and without smolt characteristics seined from the Carmel Lagoon, 1982. Smolts were only slightly larger.

Table V-1. Catch (number per haul) of 100' x 8' x 3/8" mesh seine in Carmel Lagoon 1982.

DATE	Number of Hauls	Young of Year	Total	YEARLINGS: Without Smolt Characteristics	YEARLINGS: With Smolt Characteristics	% Smolts
Apr 26	1	0	97	0	97	100
May 4	2	0	6	0	6	100
May 10	2	0	1	0	0.5	100
May 17	1	0	144	25	119	83
May 21	1	0	60	0	60	100
May 26	2	1	0	0	0	0
Jun 2	1	0	10	4	6	60
Jul 7	1	26	0	0	0	0
Jul 21*	1	36	0	0	0	0
Aug 31	1	1500	45**	45**	0	0
Oct 17	2	0	0	0	0	0

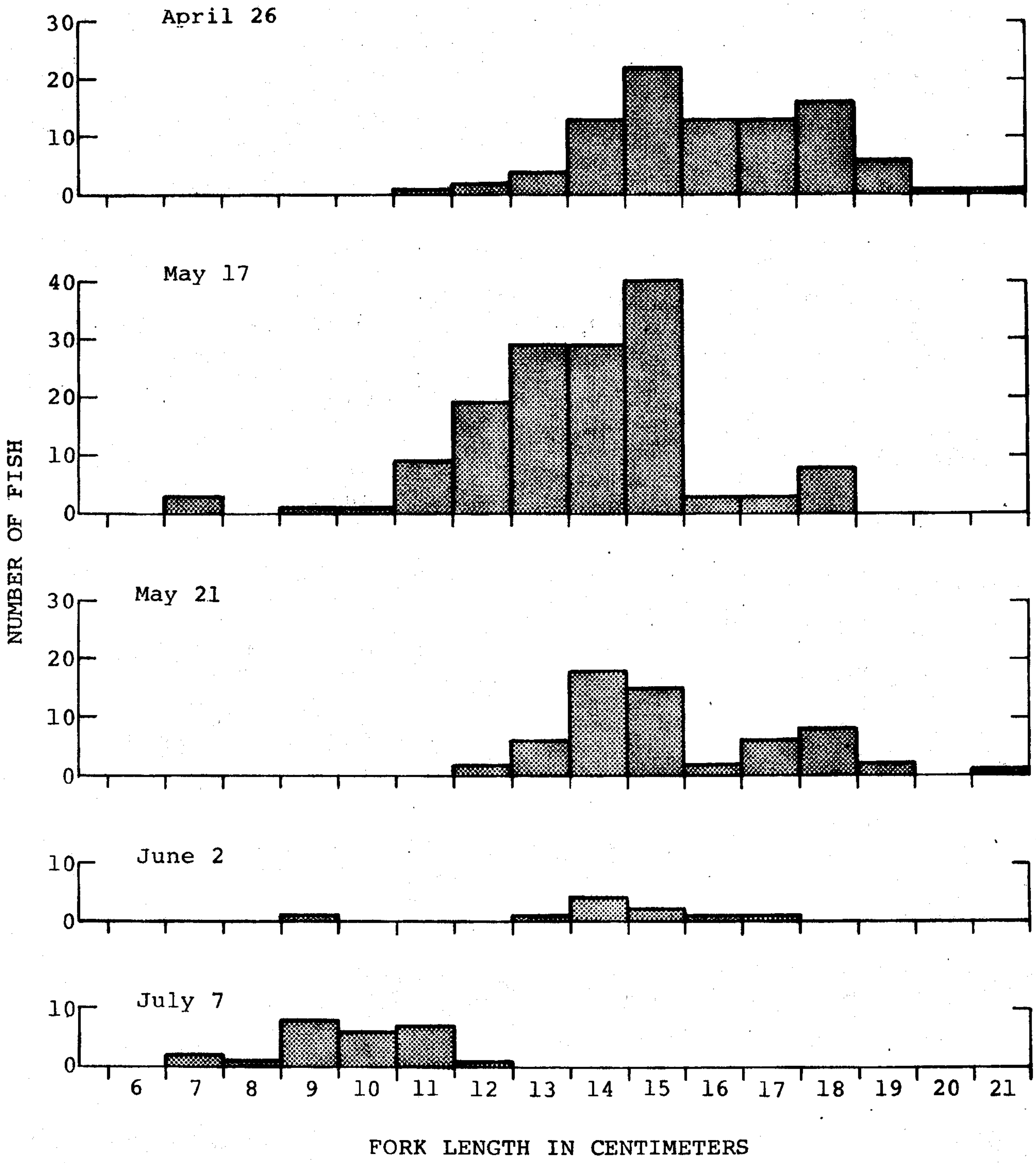


Figure V-4. Fork lengths of juvenile steelhead seined in the Carmel Lagoon April 26-July 27, 1982. The lack of any increase in size suggests fish were not staying long in the lagoon.

From these changes in seine catch in the lagoon and counts in pools upstream we concluded that, probably, during May the smolts were migrating from the Carmel River below San Clemente to the ocean at about the same rate as nonsmolts were moving down into the lower Carmel River below San Clemente Reservoir.

Some desmoltification (transformation of a smolt back to a nonsmolt) due to the warming water temperature probably also occurred.

Downstream Passage of Juveniles Through Los Padres Reservoir

Juvenile steelhead reared above Los Padres Reservoir must be able to move downsteam through that reservoir and San Clemente Reservoir to the ocean.

Los Padres Reservoir was built in 1949 and is located upstream some 24 miles from Carmel Bay. When full, the reservoir covers 67 acres and holds 2000 acre-feet of water. The small size insures a high rate of water exchange in most years. We have no measure of the flow entering Los Padres, but can make some estimates based on the flows measured at the USGS gage at Robles del Rio. In 1962, the median flow year of the 1958 to 1982 period, the annual flow at Robles del Rio was 42,000 acre-feet. A conservative estimate is that 75 percent of the flow or 31,500 acre-feet at Robles del Rio, passes through Los Padres. We estimate that the median annual exchange rate is 31,500/2000 or 15.8 times and that the annual exchange rate ranged from 0 in 1977 to 59.3 in 1969.

Although Los Padres Reservoir becomes too warm in its surface layers and has poor dissolved oxygen conditions in its colder, deeper water in summer and fall, water temperatures and dissolved oxygen concentrations are adequate for steelhead smolts to migrate through it in the spring (Table V-2).

In 1982 the reservoir did not have a large population of fish that would prey on juvenile steelhead. In May we set two multimesh 100' gillnets in Los Padres overnight, and fished them again for 4 hours during the day. We caught only five yearling trout or steelhead that ranged in total length from 119-137 mm and four 2 and 3-year-old trout or steelhead that ranged in size from 245-255 mm. These fish had been feeding primarily on midge larvae originating in the reservoir bottom and on insects from the surrounding land. Food items from the inflowing river provided a minor portion of their diet (Appendix C). The lake was not stratified, so that food from the entire lake including the bottom was available to the fish.

On September 1, two gillnets were again fished overnight. Four yearling trout (98-118 mm long) and one 2-year-old trout (184 mm long) were the only fish caught. Examination of their stomach contents showed that most of their food was phantom midge larvae and cladocerans (Appendix C). Bottom dwelling invertebrates were no longer available to fish because of the low oxygen levels in the deeper water.

Los Padres Reservoir was drained in the fall of 1981 so that the fish population we found in the spring of 1983 was atypical. A larger

Table V-2. Temperature and dissolved oxygen reading at selected depths in Los Padres and San Clemente reservoirs on April 21-23 and August 31/September 1, 1982.

LOS PADRES

April 23, 1982			September 1, 1982		
Depth (ft)	Temperature (C)	Dissolved Oxygen (ppm)	Depth (m)	Temperature (C)	Dissolved Oxygen (ppm)
0	14.2	8.8	0	22.5	8.5
10	13.6	8.8	1	22.0	
20	12.0	8.6	2	22.0	
30	11.8	8.8	3	22.0	
40	10.7	8.8	4-6	21.5	
50	10.0	8.4	7-9	21.0	6
60	10.0	7.6	10-11	20.5	4.2
70	9.9	7.6	12-13	20.0	
			14	19.7	
			15	19.5	2

SAN CLEMENTE

April 21, 1982				Aug.31,'82 1800		Sept.1, '82 0900	
Depth (ft)	Temperature (C)	Dissolved Oxygen (ppm)	Depth (m)	Temp. (C)	D.O. (ppm)	Temp. (C)	D.O. (ppm)
0	14.5	9.2	0	22.0	8.5	20.5	7.5
10	14.5	8.8	8	20.5	8.0	20.5	7.0
20	14.0	9.0	10	20.5	8.0	20.5	6.5
30	13.5	8.8	13	20.2	3.3	20.2	5.5
40	13.0	8.6	15	19.0	1.1	19.7	1.3

resident population of various species would be normal.

Most downstream migrating steelhead pass over the spillway. The spillway at Los Padres Dam is very rough and the fish probably suffer abrasion at low flows. Abrasion has been shown to cause delayed mortality in salmonids. Until 1983, at low flows, juvenile steelhead were dropped on the rocks below the end of the spillway. We understand that those rocks have been removed and that the Department of Fish and Game has suggested that the spillway be smoothed and reconstructed so that low flows pass down a narrow channel that drops into the pool.

Downstream Passage of Juveniles Through San Clemente Reservoir

San Clemente Reservoir was built in 1921 and is located 18.5 miles upstream of Carmel Bay. The reservoir has filled with sediment over time so that it has a storage capacity now of approximately 1200 acre-feet and covers 37 acres when full.

The rate of water exchange in existing San Clemente Reservoir is much higher than that of Los Padres. Assuming that 90 percent of the flow at Robles del Rio passes through San Clemente, then 37,800/1200 or 31.5 would be the number of times that the volume of San Clemente Reservoir was completely exchanged in the median year, 1962. The annual extremes of exchange would be from no exchange in 1977 to 112.5 times in 1969.

Water temperatures and dissolved oxygen concentrations were suitable for smolts to migrate through San Clemente on April 21, 1982 (Table V-2). In dry, warm years temperatures in San Clemente may be high enough to discourage continued downstream migration during late May (Figure V-5). We fished two 100' gillnets overnight and again for 2 hours the next day. We caught ten steelhead ranging in total length from 103 to 128 mm, one steelhead 230 mm, one hitch 235 mm, and approximately 25 crayfish. Stomachs of the 11 steelhead contained primarily midge larvae eaten as drift from the river (Appendix C). The lake was not thermally stratified and food in the entire lake was available to foraging fish.

We measured temperature and dissolved oxygen concentrations and sampled fish again on August 31 and September 1, 1982. The temperatures then were marginal for a good steelhead environment (Table V-2). Two gillnets were set overnight and 20 trout and 69 green sunfish were caught. Based on scale readings of trout, 15 were young-of-the-year fish ranging in size from 86-89 mm, 3 were yearling from 85-100 mm, and 2 were 2-year-olds at lengths of 110 and 123 mm. The trout were feeding on midge and phantom midge larvae (Appendix C).

Usually downstream migrating juvenile steelhead can pass over the San Clemente spillway and free fall into the pool below or go down the fish ladder. However, the spring installation of the spillway flash boards on the dam cuts off the only route of migration for smolts through the dam, except for the fish ladder, until water begins to spill over the gates again. With the boards in, and the water spilling over them, the fish must free fall

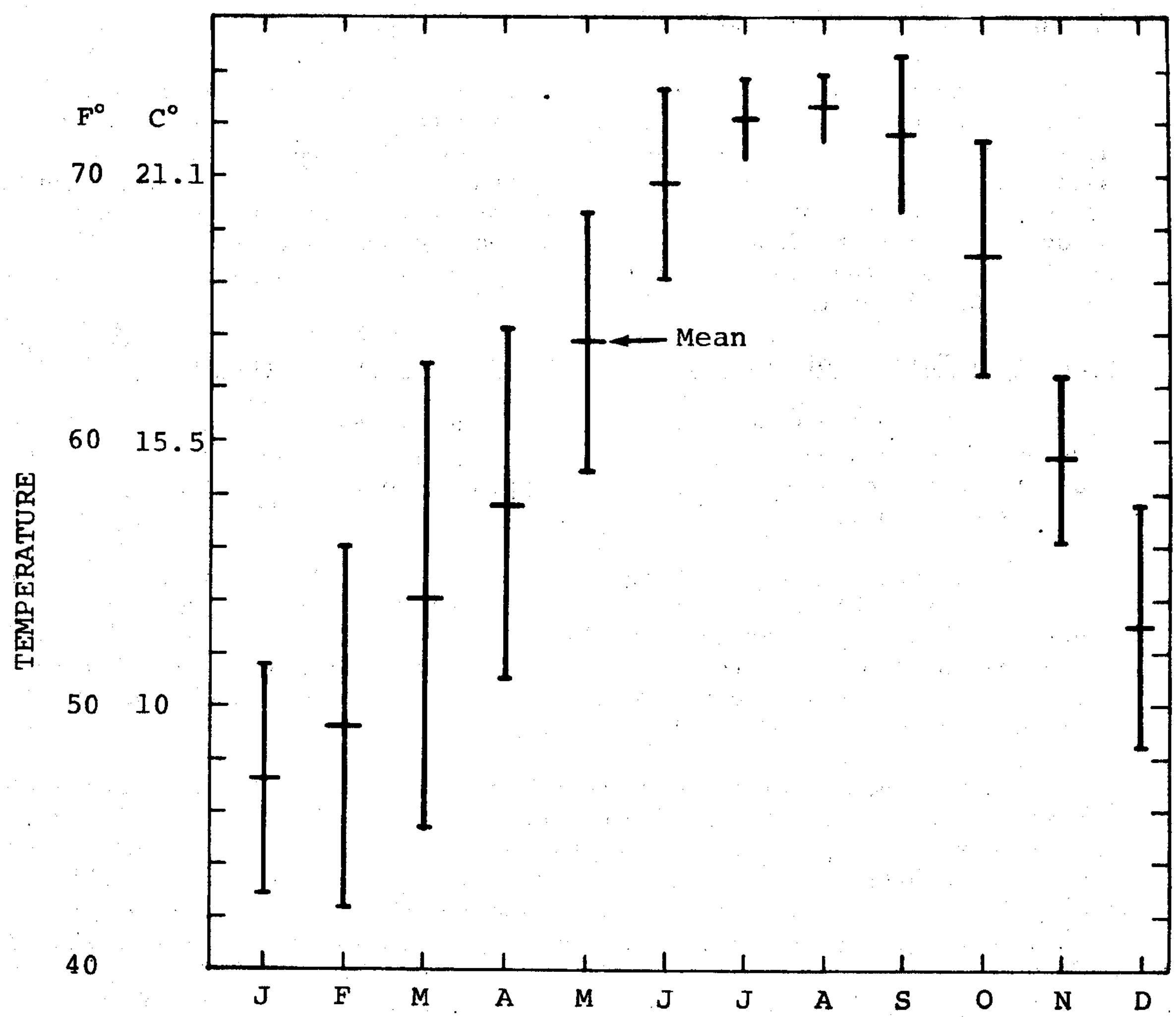


Figure V-5. Maximum mean monthly surface temperatures of San Clemente Reservoir from 1967 to 1981. Both the mean temperature and 95% confidence intervals are shown. In some years, San Clemente Reservoir temperatures may reach levels high enough to discourage downstream movement of smolts. (Data from California-American Water Company) approximately 12 feet onto a concrete apron. Then, they must flop and free fall again into the pool at the base of the dam. Some scheme should be devised whereby spill is maintained over the dam or through the fish ladder at all times from April through June and the fish do not strike the concrete apron when falling over the boards.

Historical Flows and Downstream Migration

We have found a significant relationship between the number of adult steelhead counted annually at the San Clemente fish ladder from 1962 through 1973 and the total April-May flow 2 years earlier. There was a steady increase in the number of steelhead counted as spring flows 2 years earlier rose to about 15,000 acre-feet for those 2 months (Figure V-6). Additional flows above this level did not appear to result in an increase in the size of the adult run. Scales from 32 adult fish were examined, and 69 percent had been at sea for 2 years before returning. We concluded that the larger April-May flows provide better conditions for the survival of downstream migrating smolts.

In years like 1966, 1968, and 1972, spring flows were so low and ceased so early that mortality of emigrants at the two dams, and from bird predation, etc., in the lower Carmel River and Lagoon can be assumed to have been high (Figure V-7). This was reflected in the low 1968, 1970, and 1974 adult counts in the San Clemente fish ladder. The adult count in 1972 was very low in spite of high spring flows in 1970, but that was probably due to the low 1972 winter flows (Figure II-4) which were inadequate to attract steelhead adults in or even allow passage over the riffles for more than a few days during the entire migration season. The modest run of 1964 was also probably reduced by low winter flows. Spring flows that averaged only 28.5 cfs during April-May of 1964 produced an average level San Clemente count in 1966, and a flow of 27.6 cfs in April-May of 1971 did so in the winter of 1973. The 4 years of largest counts of adults in the ladder were 2 years after the high April-May flows of 1963, 1965, 1967, and 1973. Based upon this evidence, we concluded that April-May flows are very important to the survival of downstream migrating juveniles.

Food for Downstream Migrants

Food is a very important requirement for young steelhead smolts. We have observed them actively feeding on aquatic and terrestrial insects that were drifting into pools where fish were concentrated. As spring water temperatures rise, their increasing metabolism requires increasing amounts of food to grow or just to survive. Growth is important because larger smolts have a better chance of surviving their first months of ocean life and returning as adults.

To increase our understanding of how juvenile steelhead food production and availability are related to substrate conditions and riparian vegetation, Wayne C. Fields, Jr., of Hydrozoology, made a series of studies on the Carmel River below San Clemente Reservoir in 1982 (Appendix C). In each of seven locations distributed over the lower Carmel River from San Clemente

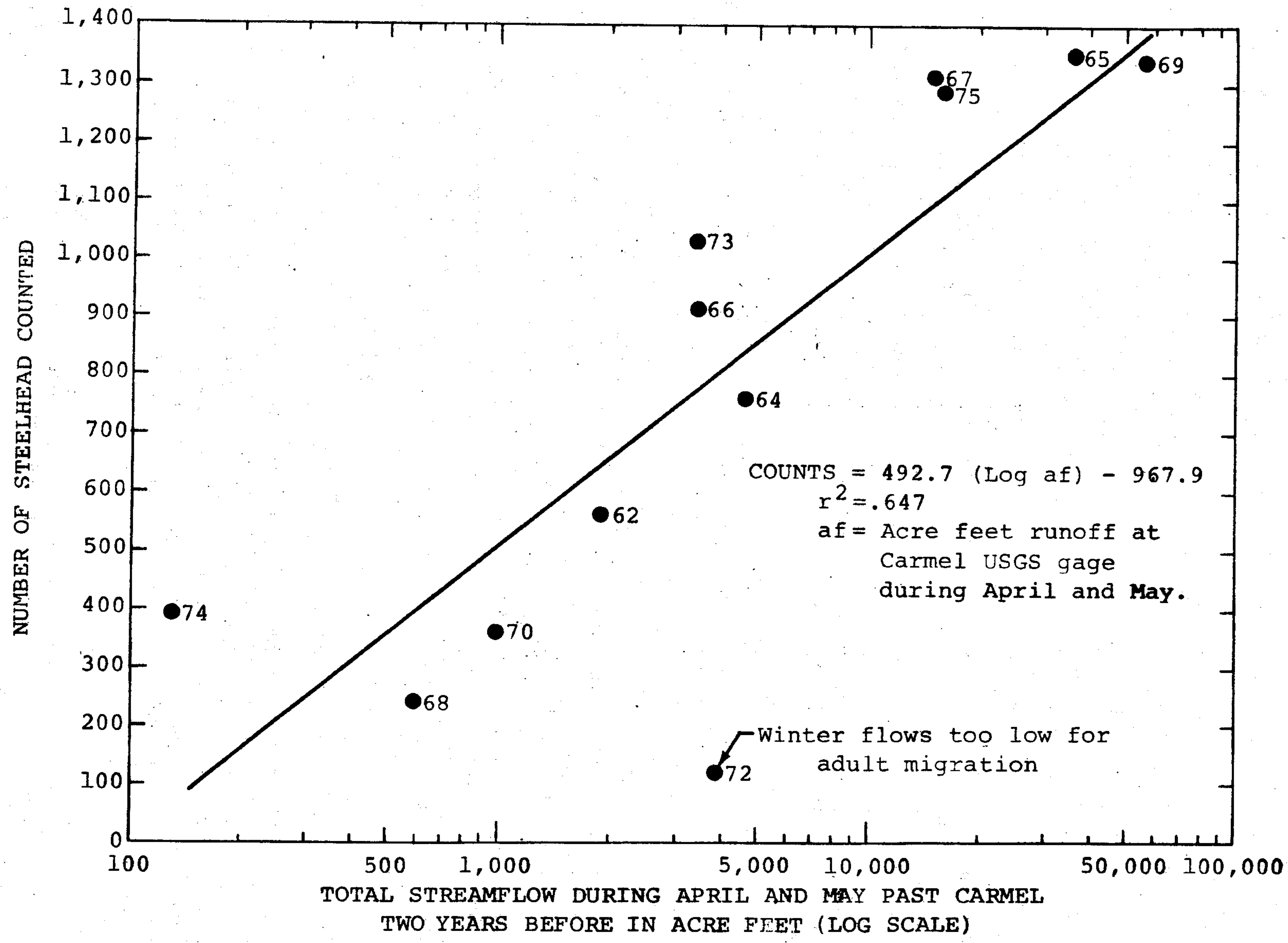


Figure V-6. Relationship between total adult steelhead counted at San Clemente fish ladder each year from 1962 to 1975, and the total acre-feet of flow past Carmel gage two years earlier in April and May during the period of downstream migration of smolts. Numbers adjacent to points indicate year of fish counts.

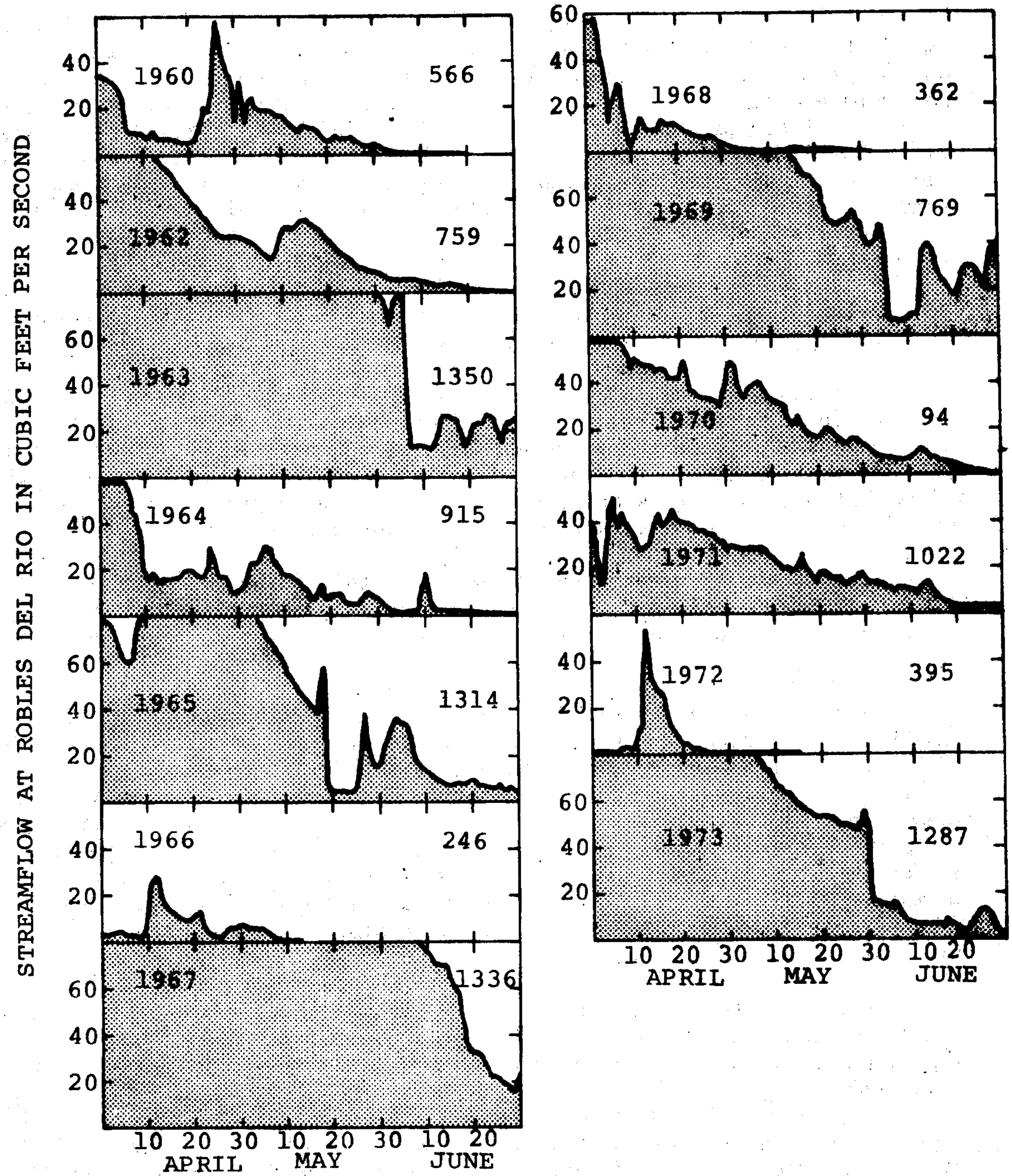


Figure V-7. Mean daily flows in April, May, and June from 1960 to 1973 in the Carmel River at Robles del Rio. Numbers top right of each graph are counts of adults in San Clemente fish ladder, two years later.

Dam to the lagoon, he collected the invertebrates living on 3 sqft of the stream bottom during mid-March and again during late May. In March, he found many more and larger organisms and many more species where the Carmel River bottom consisted primarily of cobble and gravel (Figure V-8). In the sandy Rancho San Carlos Reach, and the Riverside Reach where the bottom was sand and gravel, the fauna was very sparse and composed of a few small species. Fields attributed this scarcity to the movement of small gravel and sand during the high flows in March.

By May, the gravel at Riverside Park had stabilized because of lower flows. Except in the sandy reach at San Carlos Road where the streambed was still moving, the fauna had increased over what it was in March.

Fields then examined the stomachs of steelhead smolts collected from three different reaches of the Carmel River below San Clemente Dam. He selected three reaches to represent broad differences in substrate conditions. The fish were caught by angling on May 5-8, 1982 in Garland Park, a reach with cobble bottom; just below Schulte Road, a reach with gravel bottom; and, at Valley Greens Golf Course, a reach of sand bottom.

There appeared to be fewer smolts in this lower sandy reach. It took Fields and Li 2 hours to catch 19 fish by angling in the cobble reach, 4 hours to catch 20 over the gravel reach, and 8 hours to catch 14 over the sandy reach.

The fish were actively feeding throughout the angling period. By examining their stomachs, Fields found that their food was primarily invertebrates floating on the surface or suspended in the water column and drifting downstream. He identified the invertebrates to species and separated them into three categories: (1) those that are prone to let go their hold on or in the bottom and drift downstream with the current; (2) those that are not prone to intentionally drift but sometimes do when the substrate is moving; (3) terrestrial insects, or the adult forms of aquatic insects that have emerged from the stream to start their adult phase and have fallen back into the river for one reason or another.

He found that both the drifting aquatics and the terrestrials were of great importance as food (Table V-3). The nondrifting benthos were of slightly more importance in the sandy reachs where those animals were easily dislodged.

Because smolts were eating primarily drifting organisms and there was more benthos in cobble/gravel than in sandy reaches, Fields hypothesized that the availability of the aquatic invertebrates to the feeding smolts is related to substrate conditions. By fishing with a net specially designed to sample the drifting organisms, he estimated the total number of aquatic organisms that were drifting downstream over a 24-hour period between May 5-8. He found that 3-4 times as many aquatic invertebrates were drifting over the cobble and gravel bottom reaches than were drifting over the sand bottom reach (Figure V-9).

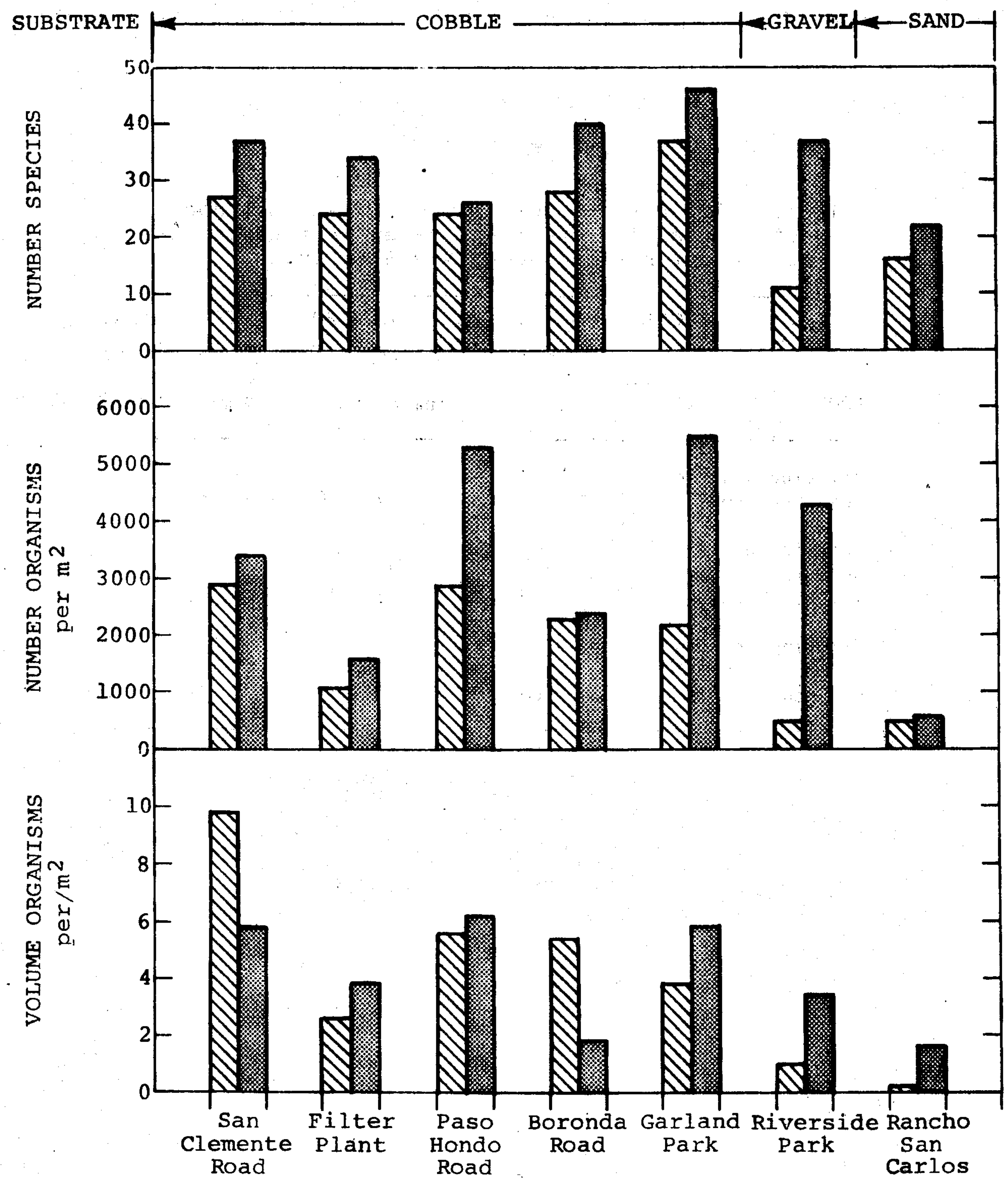


Figure V-8. Number of species, number of organisms, and volume of organisms at various sampling sites in Carmel River below San Clemente Dam in mid-March [hatched] and late May [stippled], 1982 (Appendix C).

Table V-3. Percent composition of stomach contents of 53 yearling steelhead taken in reaches with different bottom types, May 6-8, 1982.

	COBBLE (N=19) Garland Park		GRAVEL (N=20) Schulte Road		SAND (N=14) Valley Greens	
FOOD		Vol.	Number	Vol.	Number	Vol.
drifting aquatic invertebrates	59	36	94	70	69	17
nondrifting aquatic invertebrates	2	5	3	18	13	33
drifting terrestrial insects or emerged aquatics	39	60	3	12	19	50

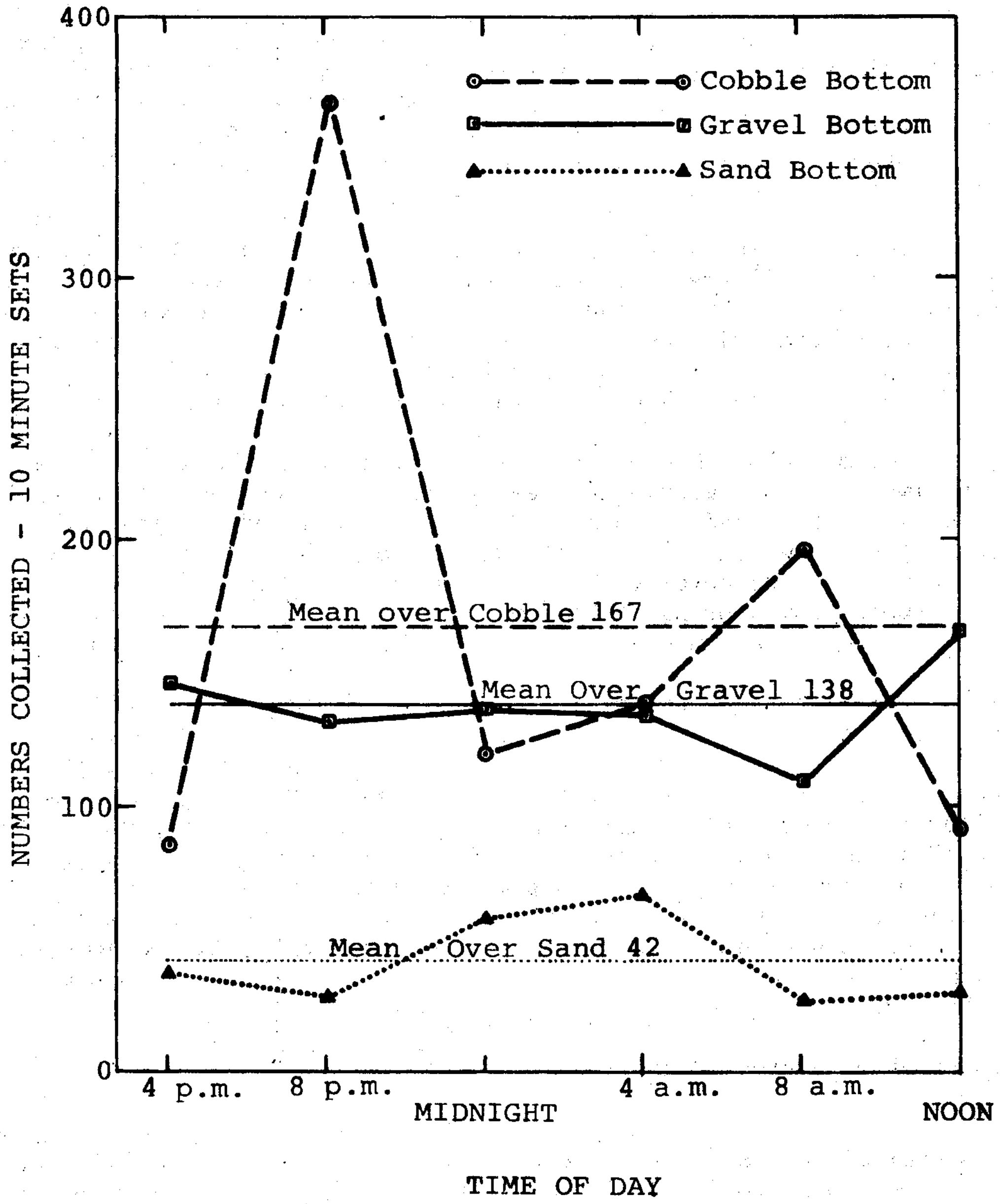


Figure V-9. Stream drift of aquatic invertebrates from three different substrates in the Carmel River, May 5-8, 1982.

Fields' final investigation was to follow up his finding that terrestrial insects were important smolt food by investigating what factors affected their availability to fish. He hypothesized that most terrestrial insects either fall into the stream from riparian trees or shrubs, or are in someway associated with riparian trees or shrubs. Such vegetation has been greatly reduced along the Carmel River.

To test this, Fields measured the drift of terrestial insects at the lower end of ten 100-meter reaches, half of which enjoyed a dense stand of riparian trees and shrubs, and half of which were nearly bare of them. He found that reaches with dense stands of riparian vegetation contributed over 20 times as many organisms to the drift as did the reaches that were bare of trees or shrubs. Table V-4 lists the six for which there are comparable data.

Based upon this evidence we conclude that the amount of smolt food and ultimately smolt growth is greatly influenced not only by streamflow, but also by streambed conditions and, where the streambed is sand, by riparian vegetation from which terrestrial insects fall into the stream. We do not have enough data to develop quantitative relationships between smolt food and either smolt growth or survival, but Figure V-10 illustrates our concept of how streamflows influence growth and survival through food production.

Summer flows or, at least, near surface water is needed by riparian vegetation which is in turn needed to prevent erosion. If erosion is not controlled, more of the streambed becomes sandy and fewer aquatic invertebrates are produced for food--the fish must depend more upon terrestrial insects that fall from the riparian trees. The function of spring streamflow is to provide good production of aquatic invertebrates in the reaches of cobble and gravel, to provide surface area under or near the riparian vegetation to receive the terrestrial insects that fall in, to distribute both kinds of food in the stream as drift, and to provide physical habitat so the smolts and juveniles that are not yet smolts can feed and grow on their way downstream.

Summary of Downstream Migration

Because streamflows were so high this year, we did not find when the downstream migration of juvenile steelhead began. As flows declined from 300 cfs in late April to 50 cfs in early June, the pools in the Carmel River from San Clemente Dam downstream to the lagoon continued to support large populations of yearling steelhead. As the temperatures warmed during May, the number of these fish that were true smolts (with the characteristic black tipped tail fins and silver bodies, indicating they were preparing to enter salt water) decreased and the numbers of yearlings of about the same size increased. Some of the smolts probably reverted to nonsmolts and stopped their downstream migration as the water warmed. The larger increase in nonsmolts in the upper pools suggested to us that large numbers of yearlings continued to come down over San Clemente Dam until early June. Our evidence also suggests that the smolts do not stay long in the Carmel Lagoon. By early June we were unable to seine any yearlings there but some young-of-the-year had moved down to occupy that water.

Table V-4. Effect of riparian shrubs and trees on number and volume of terrestrial insects available as food for downstream migrating smolts (Fields 1983 Appendix C).

LOCATION	DATE	FLOW	% of shoreline covered with shrubs and trees	Terrestrial organisms in 30 minute drift sample	
				Number	Volume in ml
Carmel Valley Ranch	5/29/82	78 cfs	none	10	trace
1/4 mi east Hwy. 1	5/29/82	78 cfs	60%	89	0.10
East Schulte Road	6/17/82	45 cfs	none	9	trace
Valley Greens Golf C.	6/17/82	45 cfs	100%	382	0.79
East Schulte Road	6/17/82	45 cfs	none	19	0.02
Valley Greens Golf C.	6/17/82	45 cfs	100%	403	0.72
Average					
			none	13	trace
			87%	291	0.54

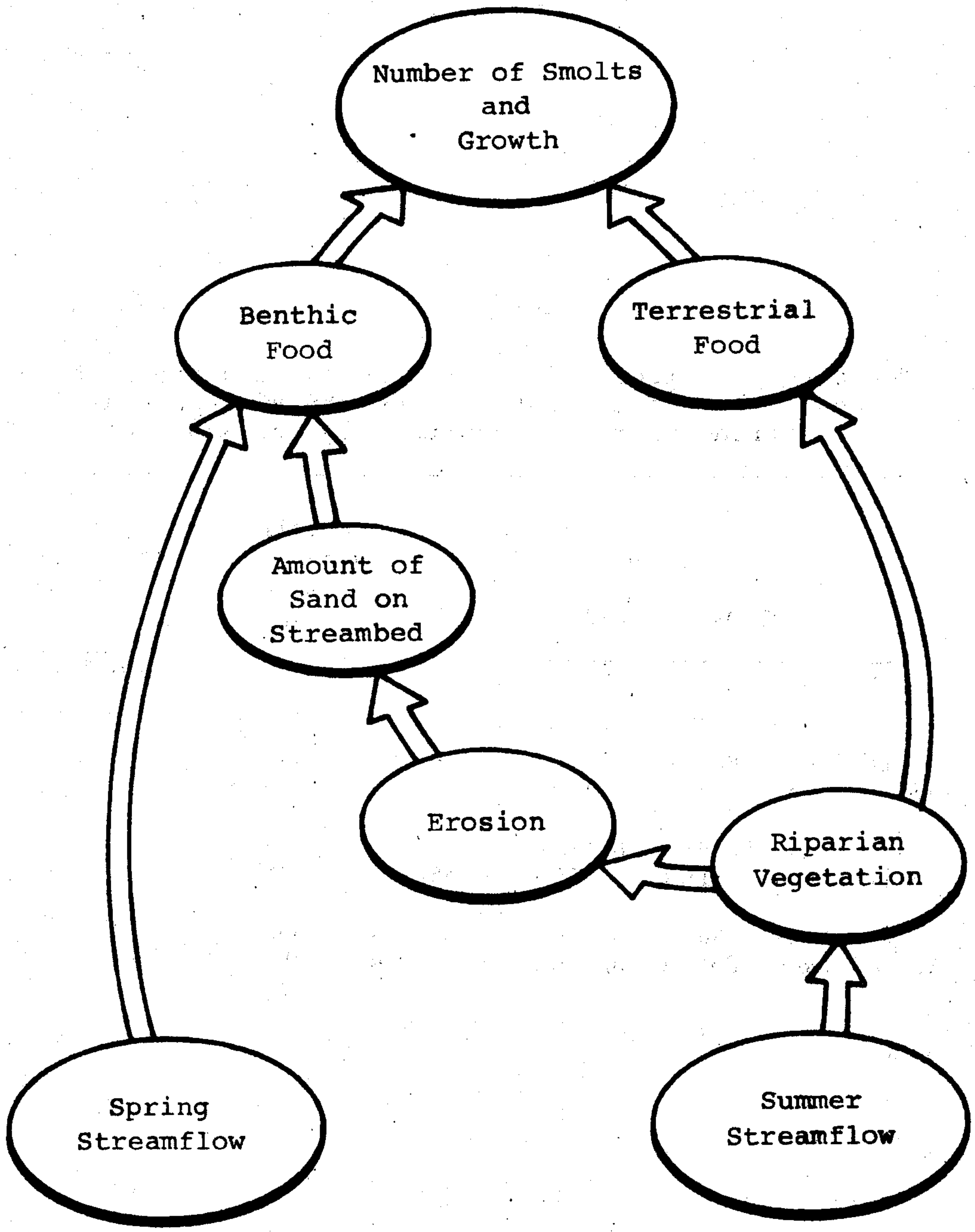


Figure V-10. Relationship between smolt growth and numbers, and streamflow, vegetation, erosion, sand, and food in the Carmel River below San Clemente.

Comparison of the numbers of adult steelhead counted in the San Clemente ladder for 12 years with the spring streamflows 2 years later provides good evidence that the April and May flows were extremely important for the juveniles, 70 percent of which migrated downstream 2 years before they were counted in the ladder. Up to a total April through May flow of about 15,000 acre-feet, larger spring flows produced larger adult runs of steelhead 2 years later.

In years when spring flows become low or zero before the end of May, the reason for low survival is obvious. In less extreme cases, the lower flows probably increased the mortality of emigrating juveniles when passing over Los Padres and San Clemente Dams, bird predation in the lower river, and the chance of desmolting because of warm temperatures before they reach the ocean.

A large and continuous supply of invertebrates drifting in the stream is important as food for the downstream migrants. W. C. Fields found that substrate conditions and riparian vegetation were both extremely important to the production and availability of food. He found that in reaches where the substrate was cobble drifting aquatic invertebrates were abundantly available as food, but that in the sandy reaches an abundant food supply depended upon terrestrial insects that fall into the stream from riparian vegetation.

The work done on downstream migrants suggests that a combination of maintaining reasonably high streamflows during April and May, increasing the amount of the Carmel River which is covered with gravel or cobble instead of sand, and increasing the extent of the riparian vegetation would be a powerful combination toward raising the survival and growth rates of the downstream migrating smolts and increasing the steelhead run.

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