RELATIONSHIPS BETWEEN STREAMFLOW, REARING HABITAT, SUBSTRATE CONDITIONS, AND JUVENILE STEELHEAD POPULATIONS IN LAGUNITAS CREEK, MARIN COUNTY, 1979

A REPORT PREPARED FOR

THE MARIN MUNICIPAL WATER DISTRICT

by

D. W. Kelley and D. H. Dettman

February 1980

D. W. KELLEY, *Aquatic Biologist*
323 FORUM BUILDING
1107 - 9TH STREET
SACRAMENTO, CALIF. 95814
PHONE (916) 443-3781

March 3, 1980

Mr. J. Dietrich Stroeh
General Manager
Marin Municipal Water District
220 Nellen Avenue
Corte Madera, CA 94925

Dear Diet;

Here is our final report on the work MMWD requested us to do on Lagunitas Creek during the summer and fall of 1979. You set us to three tasks.

The first, was to update the relationship we developed in 1978 between the volume of streamflow and the amount of rearing habitat for juvenile salmonids. The new relationship is illustrated in Figure 2 on page 4 of this report.

Our second task was to check the validity of our rearing habitat assessments in terms of actual fish populations. In late summer and fall we measured the juvenile steelhead populations in 11 riffles and 10 glides, and found them to be highly correlated with our "rearing indexes" for those sections of stream. Those relationships are illustrated in Figures 4 and 5 on pages 10 and 11 of this report. There were few salmon in 1979, so we could not assess the validity of our rearing indices for salmon.

Our third task, which the Board requested on November 20, was to measure the effect of sand deposition on fish in Lagunitas Creek. We assessed this by measuring the degree to which cobble was embedded in sand in each of the reaches where we also measured the steelhead population Figure 6 on page 18 illustrates what we found - a strong inverse relationship between the degree to which cobble is embedded in sand and the numbers of steelhead per square meter of stream.

The report is also a good description of the quality of rearing habitat existing in 1978-79 and the maximum potential production of steelhead in that habitat. It is a baseline with which you can compare habitat and steelhead production after the Kent Dam is raised.

LABORATORY: 1530 MOUNTAIN VIEW LANE NEWCASTLE, CALIFORNIA 95658 - TELEPHONE (916) 663-2535

We have not investigated the flows needed for upstream migration, spawning, egg incubation, or downstream migration of salmon and steelhead. Because salmon and steelhead populations continue to reflect the recent drought and because construction activities may interfere with the normal behavior of salmon and steelhead, I believe such studies cannot be efficiently made for the next couple of years.

Sincerely,

Don

Don W. Kelley

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INTRODUCTION AND SUMMARY

During the spring, summer, and fall of 1979, we assessed the salmon and steelhead rearing habitat and fish populations in Lagunitas Creek, Marin County (Figure 1). Our purpose was to help evaluate the streamflow releases being proposed to enhance rearing habitat in connection with the raising of Kent Dam. The information gained augments data gathered during 1978 in connection with the Environmental Impact Report on the project.

As in 1978, we measured changes in the quantity and quality of the rearing habitat as streamflow declined during the spring, and on the basis of these measurements developed a series of "rearing indexes" for different flows. In mid-June when streamflows in much of Lagunitas Creek had declined to about 2 cfs, the Marin Municipal Water District began to release 2.5 cfs from Kent Reservoir. This release simulated post-project conditions as they are presently planned.

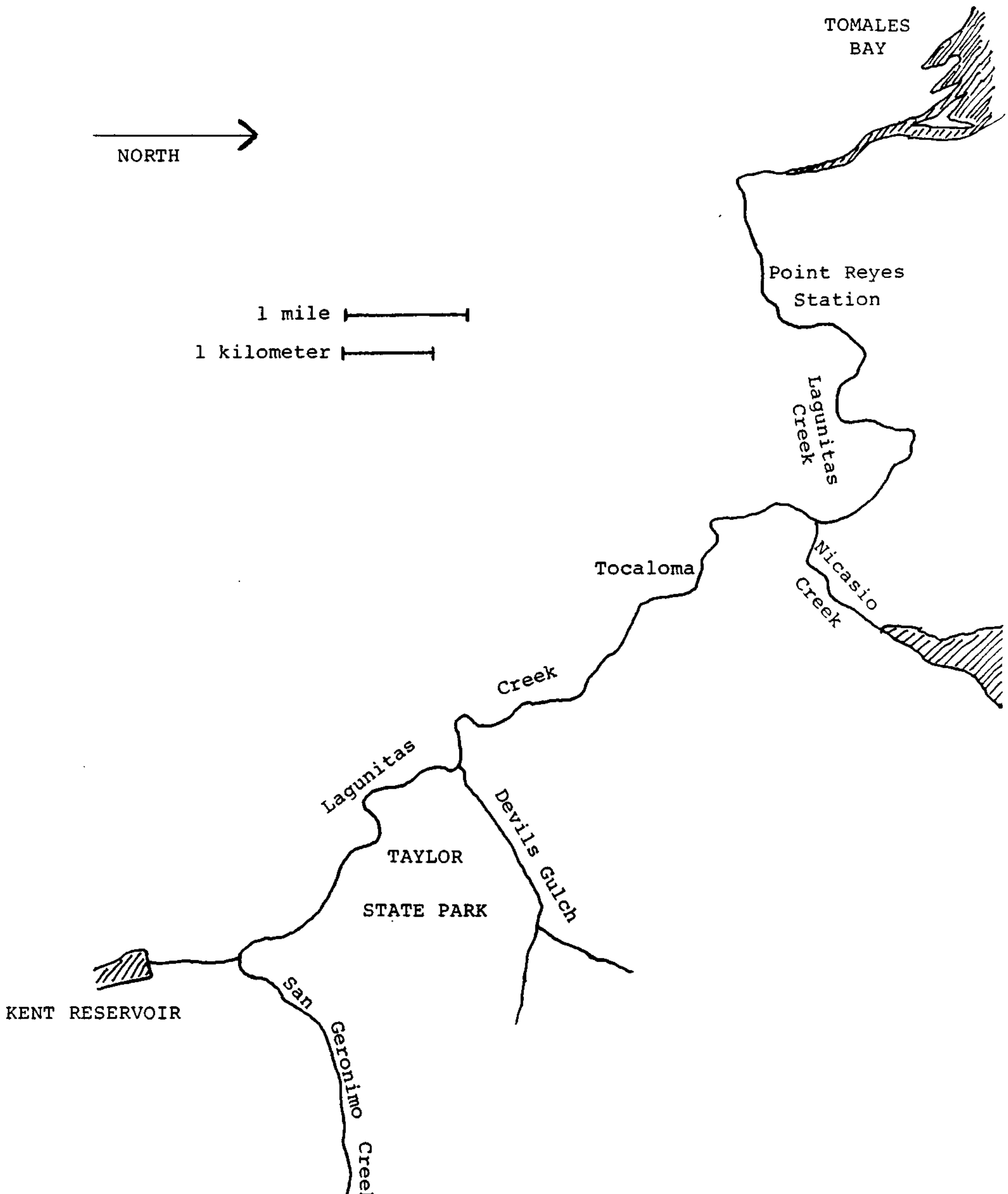
In the late summer and fall, we estimated the juvenile steelhead populations by electrofishing and found that our rearing indexes were valid measures of habitat, and that both the "rearing indexes" and steelhead populations were extremely sensitive to the degree to which streambed cobble was embedded in sand.

Using the mathematical relationships we developed between the volume of streamflow, rearing indexes, and juvenile steelhead populations, we estimated that, if substrate conditions in Lagunitas Creek remained the same as they are now, and if the other factors which affect steelhead production do not change, releasing 3 cfs from the Kent Reservoir will about triple steelhead production in Lagunitas Creek from San Geronimo to its junction with Nicasio Creek. The poor 1978 salmon run made it impossible to obtain quantitative information on salmon, but we believe the changes are likely to affect them similarly.

THE RELATIONSHIP BETWEEN STREAMFLOW AND REARING HABITAT

Biologists of the California Department of Fish and Game believe that the present almost annual decline of summer flow to below 0.5 cfs is the principal factor affecting the size of both salmon and steelhead runs in Lagunitas Creek. As the flows decline, the young fish that have been produced by spawning in the previous fall and winter must live in a smaller stream where their habitat quality is greatly

Figure 1. Lagunitas Creek flows from Kent Reservoir 19.2 kilom.erers (11.5 miles) to the south end of Tomales Bay.



diminished because of reduced depth and current velocities. They are subject to crowding and unusual amounts of predation. Under such conditions, even if large numbers of eggs have been deposited and fry produced, there is room and habitat for only a few to survive during the 5 to 6 months until fall or winter rains increase streamflows.

Although we have not measured spawning habitat or the conditions affecting egg incubation in Lagunitas Creek, we believe the Department of Fish and Game (DFG) assessment is correct. Full seeding of all the available rearing habitat would require only a few hundred spawning salmon and steelhead. There appears to be more than adequate spawning gravel for that number and its condition appears to be such that we would not expect egg survival rates to be unusually low.

In 1978, we began measuring the quantity and quality of the juvenile rearing habitat in two reaches of Lagunitas Creek chosen to represent that portion of the stream that would be affected by the proposed releases of water from Kent Reservoir. From data gathered as streamflows declined in the spring of 1978, we developed two curves illustrating the relationship between streamflow and the quality and quantity of rearing habitat as expressed in a series of "rearing indexes." These curves were presented to Marin Municipal Water District in October 1978 (Kelley and Reineck) From April 13 through June 27, 1979, we made a similar set of measurements in the same reaches.

The two reaches, "State Park" and "Tocaloma," are different in gradient, channel shape, and substrate composition, and these differences result in differences in the amount and quality of juvenile rearing habitat produced by any given volume of flow. The quantity and quality of the rearing habitat in the flatter and sandier Tocaloma reach are significantly less, and the rate of increase in that habitat as flows increase is also less (Figure 2).

The 1978 measurements made at 4.6 cfs in the State Park reach have been discarded as being aberrant, either because the drought had caused an unusual condition in the reach measured, or because there were errors in the field assessments which we have been unable to discover. Those measurements caused the curve developed in 1978 to suggest that rearing habitat in the State Park reach did not increase much as flows increased above 3 cfs. Our 1979 measurement convinced us that this is not true, and on October 5, 1979, we notified both the Marin Municipal Water District and the Department of Fish and Game of the new relationships.

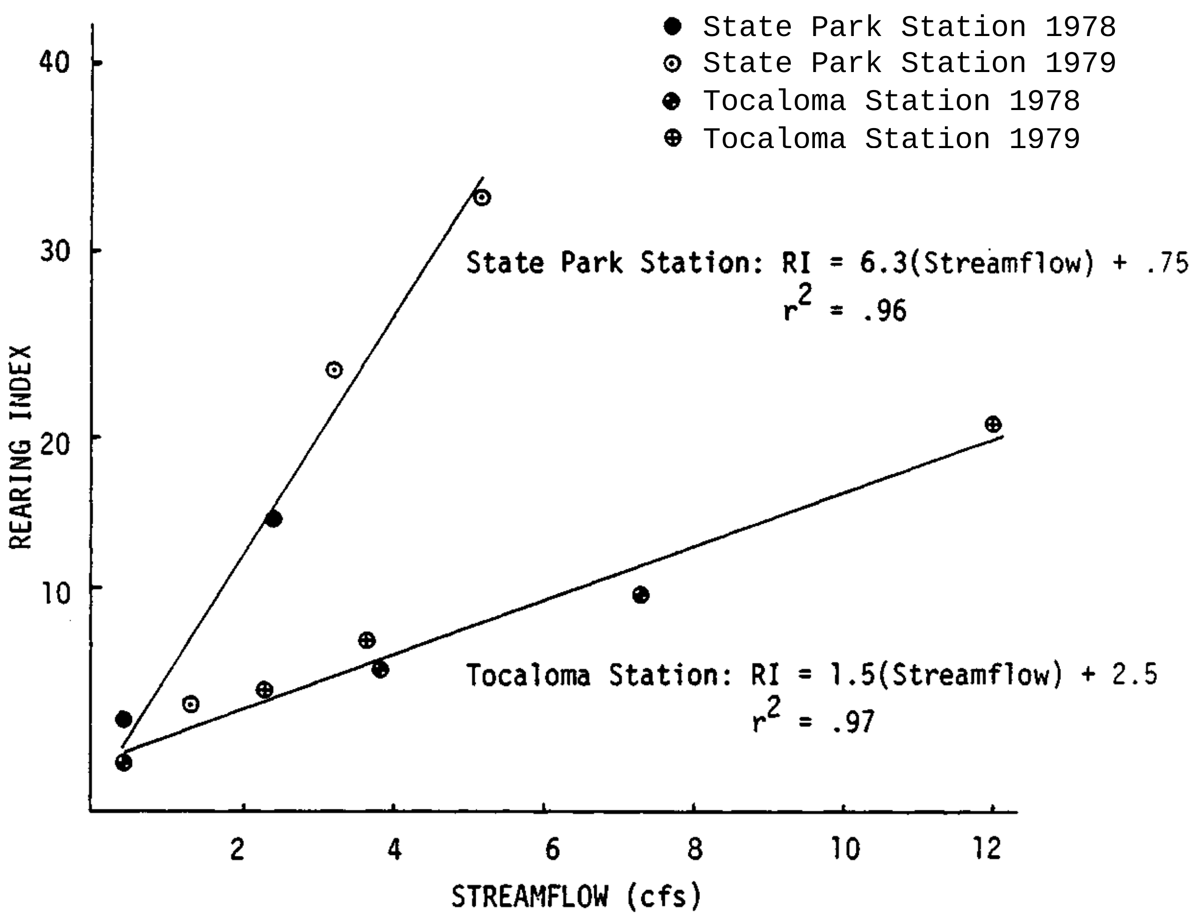


Figure 2. The influence of streamflow on juvenile salmonid rearing habitat in Lagunitas Creek - 1978 and 1979

In the Tocaloma reach, the relationships between streamflow and rearing habitat did not change between 1978 and 1979.

Two years of measurements provided evidence that, if substrate and channel conditions remain as they were in 1978 and 1979, increasing the streamflows in the almost 6-kilometer reach of Lagunitas Creek from San Geronimo Creek downstream to Jewell from 0.5 cfs to 3 cfs will increase the rearing index there by a factor of about 5--from 3.9 to 19.6. In the flatter reach from Jewell to the Tocaloma Bridge, and in a part of the remaining 3.2 km downstream to the junction of Nicasio Creek, an increase in flow from 0.5 to 3 cfs will about double the rearing index, changing it from 3.3 to 7.0.

It is important to recognize that, even though the rearing index in the lower, flatter Tocaloma reach is less than one-third as great as that in the State Park reach, there are patches of excellent habitat there. They will respond to increases in flow as rapidly as the good habitat in the upstream area.

THE RELATIONSHIP BETWEEN REARING INDEXES AND STEELHEAD POPULATIONS

The rearing indexes described in this report are averages that include thousands of measurements on many riffles, pools, and glides. Wading up the stream, we measured the area of each glide, riffle, and pool that we believed would be used by juvenile salmon or steelhead, and rated its quality as poor, fair, good, or excellent. Those ratings were graded 1, 2, 4, or 8, multiplied by the area so graded, the products totaled, and the total divided by the length of the stream reach being assessed. The measurements in 1979 were done in meters and the 1978 data was converted from feet for comparison in this report. Notes on factors limiting the quality of the rearing habitat were made as each pool, riffle, and glide was assessed.

Electrofishing at both the Tocaloma and State Park stations on June 11, 1979, had resulted in our estimating the steelhead populations in those reaches at about 1.3 and 1.8 juvenile steelhead per meter of stream. About one-third of these were yearling steelhead produced by spawning in early 1978. We were able to find only two juvenile silver salmon. On the basis of low numbers and the higher than usual proportion of yearling steelhead, we concluded that Lagunitas Creek had not been fully seeded by spawning steelhead and hardly seeded at all by salmon during their fall and winter 1978-79 spawning season. Most coastal streams had poor salmon and steelhead runs that fall and winter, probably reflecting poor survival during the first year of the drought.

Since the chances of relating the rearing indexes to the populations of juvenile salmonids in Lagunitas Creek depended upon reasonably complete seeding of the stream by spawning fish, and since that apparently had not happened, we requested supplemental stocking from the Department of Fish and Game. On July 3, they distributed approximately 30,000 young-of-the-year, 5-7-cm-long steelhead from their Mad River Hatchery in Lagunitas Creek from the Kent spillway to the Tocaloma Bridge. These fish, combined with the naturally produced juvenile steelhead, were enough to saturate the spring rearing habitat so that as flows dropped, survival in different parts of the stream would be related to the quantity and quality of the rearing habitat there. Following the normal spring decline in streamflow to about 1.5 cfs in the State Park, and a week before the fish were planted, Marin Municipal Water District began releasing 2.5 cfs from Kent Dam into Lagunitas Creek. This release created better than normal conditions for survival--conditions similar to those being proposed with the Kent Project.

The Department of Fish and Game generously offered to stock juvenile salmon as well as steelhead. We declined that offer because the available salmon were significantly larger than wild fish would have been and we thought them unlikely to behave like salmon naturally produced in Lagunitas Creek.

It was with these conditions — full seeding of the stream with steelhead and no seeding with salmon--that we began a series of measurements to assess the value of a 2.5 cfs release.

From August 29 through October 12, we measured the fish populations and rearing indexes in 11 riffles, 10 glides, and 4 pools selected to represent a wide range of habitat quality in Lagunitas Creek. These small reaches averaged 19 meters long. Each was isolated by stretching one-quarter-inch mesh seines across the stream to prevent any fish from moving in or out of the section during our work there. We then made a series of passes from the lower to the upper end of the section with a Mark VII Smith-Root electro-fisher, emitting 300 volts of pulsed direct current. On each pass we attempted to capture as many fish as possible. The catch of each pass was measured and the fish were kept out of the section until a pass resulted in very few or no fish being caught. The diminishing numbers of fish caught in the series of passes was used to estimate the population by the method of Ricker (1975) (Table 1). Almost all of the steelhead caught were young-of-the year. Their mean length was 6.6 cm (Figure 3).

From San Geronimo Creek downstream we found a high positive correlation between the population density of juvenile steelhead in both glides and riffles of Lagunitas Creek and our rearing indexes (Figures 4 and 5). Doubling the rearing index appears to about double the fish population. We used linear and exponential regression analysis to test for the significance of relationships and we developed formulas to compute fish population from the rearing indexes.

In pools we found very few young steelhead—too few to expect a relationship between their population density and our rearing index.

Six of the 25 reaches assessed were in the 1-kilometer section of Lagunitas Creek from its junction with San Geronimo Creek upstream to Kent Dam. Steelhead populations there were much lower than in habitat of similar quality downstream. The steelhead population declined from 6.5 per meter stocked in that reach on June 28 to 1.6 per meter when we electrofished on September 24. Rearing habitat was physically very good but we concluded that some environmental factor not considered in our rearing indexes had reduced the population. Very low flow here before the 2.5 cfs release was started in mid-June may have prevented adequate food development (aquatic insects) and/or the colder water temperatures of the release may have caused some of the fish to leave or not survive. We concluded that the data from this reach were not comparable with that from Lagunitas Creek below San Geronimo Creek and we did not use it in the correlation analysis.

ESTIMATION OF TOTAL STEELHEAD POPULATIONS

We have in the above section described the numerical relationships developed from 1978 and 1979 field data between:

a. the volume of streamflow and the quantity and quality of juvenile salmonid rearing habitat--a term we call the "rearing index"--for two representative reaches of Lagunitas Creek (Figure 2); and

b. the rearing indexes and late summer and fall juvenile steelhead populations in 11 riffles and 10 glides of the same stream (Figures 4 and 5).

Table 1. Number of steelhead caught, population estimates, and density in Lagunitas Creek late summer and fall 1979.

Date	Habit.Type Location	STEELHEAD CATCH 1st	2nd	3rd	4th	5th	6th	Popul. Estimate	Station Length	Station Area	Linear Density	Area Density
SHAFTER TO TOCALOMA												
28 Aug (1)	Glide Taylor Pk.	3	4	2	1	0	_	12	12.9	63.9	.93	.19
28 Aug (2)	Glide Taylor Pk.	9	9	7	7	5	-	77	38.2	328.1	2.02	.23
29 Aug (3)	G/Rif. Cheda Ranch	82	33	16	-	-	-	141	21.2	160.0	6.65	.88
30 Aug (4)	Glide " "	26	16	11	-	-	-	72	23.9	156.0	3.01	.46
30 Aug (5)	Glide " "	17	3	2	3	5	4	34	24.4	234.2	1.39	.15
30 Aug (6)	G/Pool Tocaloma	19	8	8	3	-	-	42	16.6	92.6	2.53	.45
9 Oct (7)	Glide Bwt. Taylor Pk. & Shafter Br.	16	12	3	-	-	-	38	24.4	372.1	1.57	.10
11 Oct (8)	Glide Taylor Pk.	27	19	16	10	-	-	103	36.6	393.0	2.82	.26
										Means:	2.62	.34
29 Aug (9)	Riffle Taylor Pk.	12	15	4	4	5	1	47	17.0	126.1	2.76	.37
8 Oct (10)	Riffle " "	23	7	1	-	-	-	32	15.2	115.5	1.97	.28
8 Oct (11)	Riffle " "	24	9	3	-	-	-	38	16.5	112.5	2.30	.34
8 Oct (12)	Riffle " "	5	0	0	-	-	-	5	10.1	46.1	.49	.11
9 Oct (13)	Riffle Bwt.Taylor Pk. & Shafter Br.	11	2	0	-	-	-	13	12.4	51.1	1.05	.26
10 Oct (14)	Riffle Taylor Pk.	46	20	5	-	-	-	76	11.9	67.5	6.40	1.13
10 Oct (15)	Riffle Jewell	31	11	9	2	-	-	55	13.4	89.4	4.10	.62
11 Oct (16)	Riffle Taylor Pk.	31	16	9	5	-	-	66	14.9	100.8	4.40	.66
11 Oct (17)	Riffle " "	35	13	6	-	-	-	57	24.7	221.8	2.30	.26
										Means:	2.86	.45
28 Aug (18)	Pool Taylor Park	10	3	0	-	-	-	15	40	355	.38	.04
8 Oct (19)	Pool " "	14	4	2	-	-	-	20	21.7	118.4	.92	.17
										Means:	.65	.11
KENT RESERVOIR TO SHAFTER BRIDGE												
8 Oct (20)	Glide	3	4	2	2	0	-	15	7.9	44.1	1.90	.34
8 Oct (21)	Glide	7	1	2	3	1	0	14	14.3	99.7	0.98	.14
										Means:	1.44	.24
26 Sept(22)	Riffle Shafter Br. to Dam	9	8	3	2	1	-	26	14.6	80.1	1.78	.32
26 Sept(23)	Riffle "	11	11	4	-	-	-	40	16.8	127.4	2.38	.31
										Means:	2.08	.32
26 Sept(24)	Pool	Population Estimated w/ Snorklng Survey						15	18.6	140.2	0.81	.11
26 Sept (25)	Pool	10	6	1	-	-	-	19	11.2	98.2	1.70	.19
										Means:	1.26	.15

Numbers in parentheses refer to locations described in Appendix B

Figure 3. Length frequency of juvenile steelhead in Lagunitas Creek, Marin County, August-October 1979.

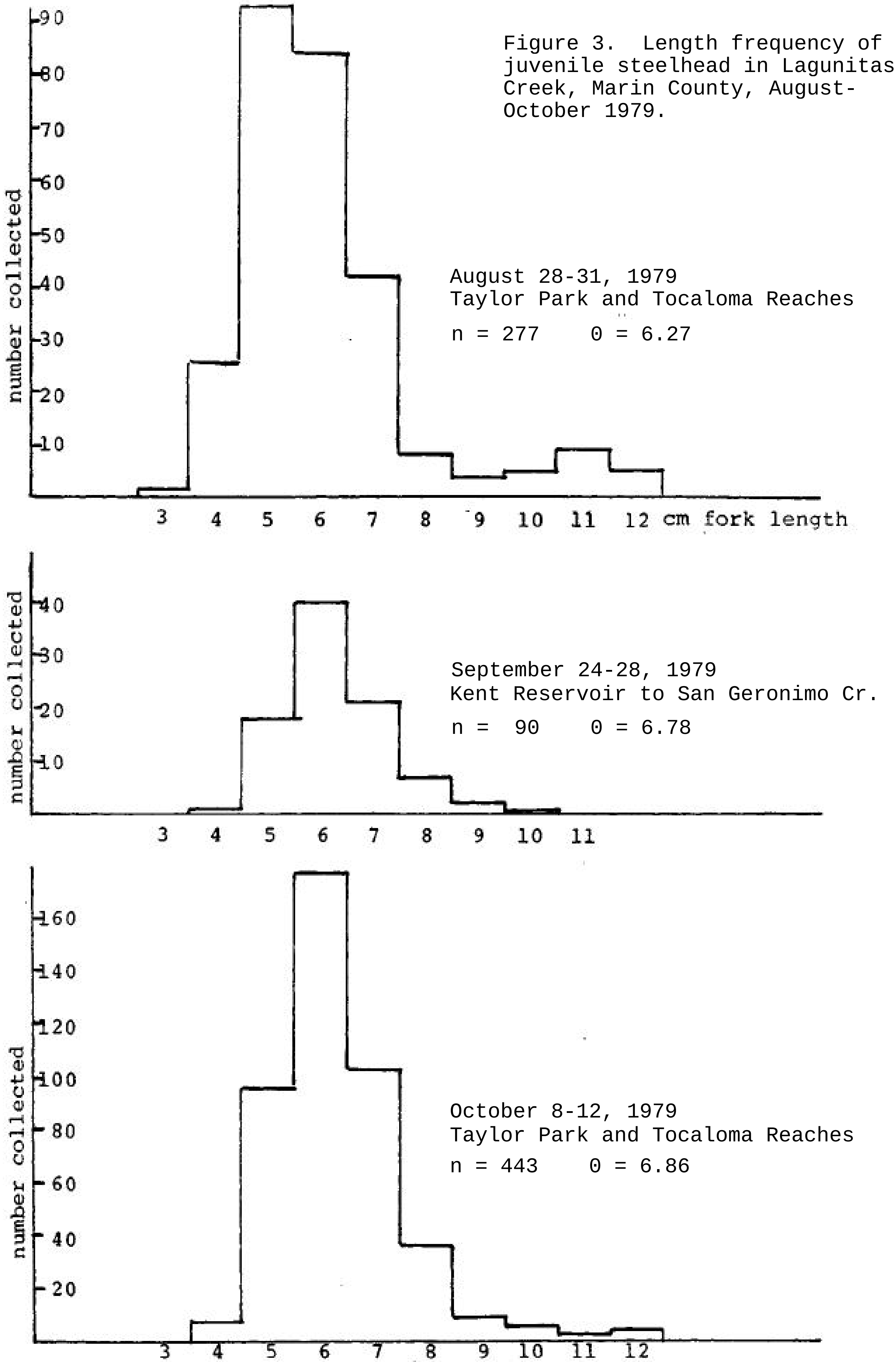
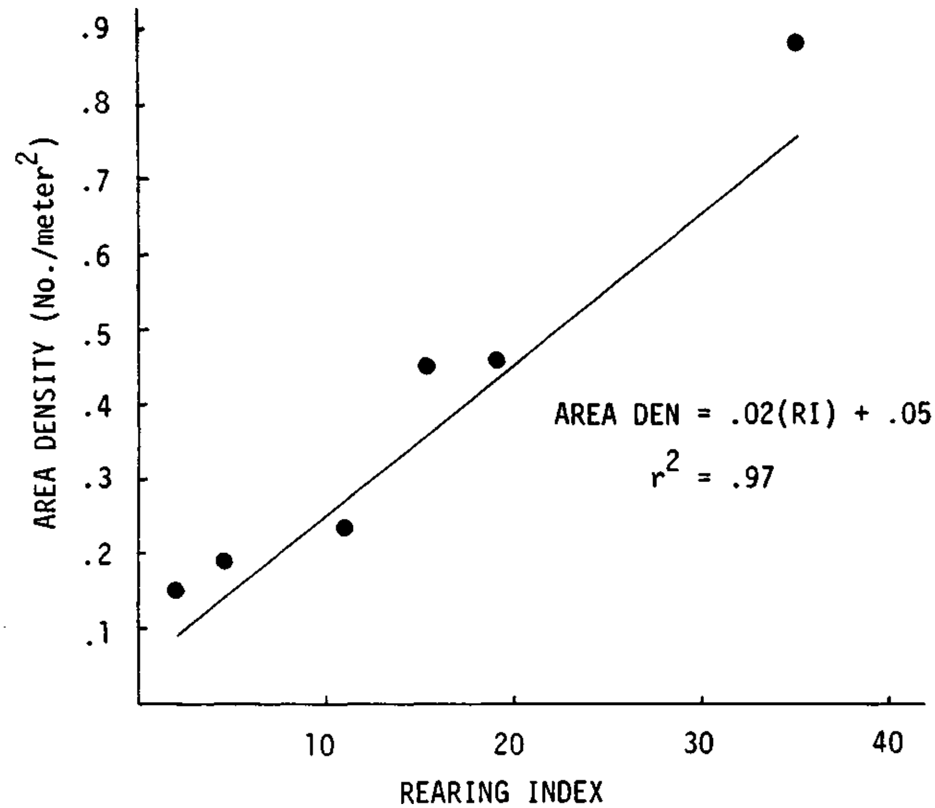


Figure 4. Relationship between indexes of rearing habitat and juvenile steelhead population density in <u>glides</u> of Lagunitas Creek. Data from August 27-31 survey by D. W. Kelley.



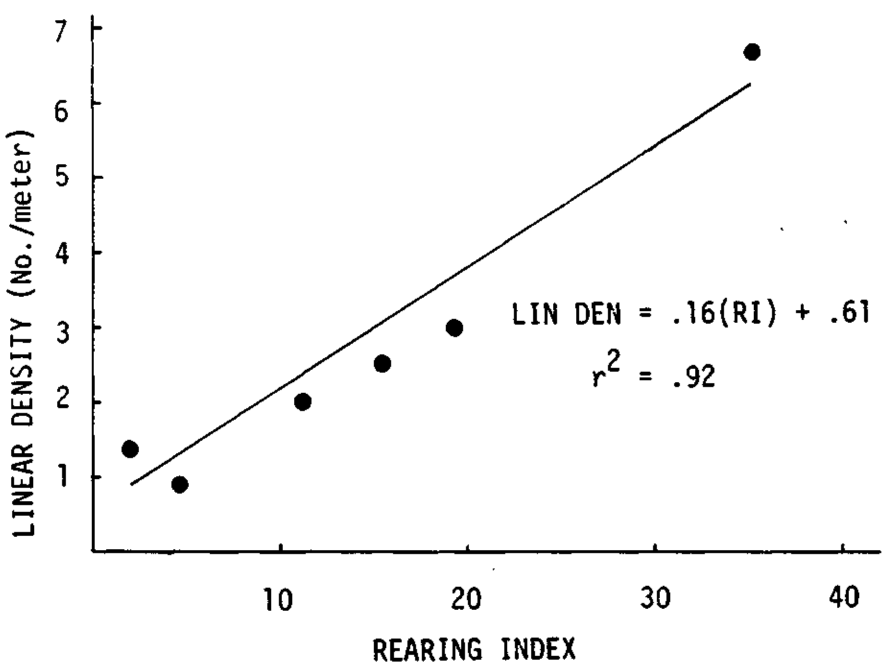
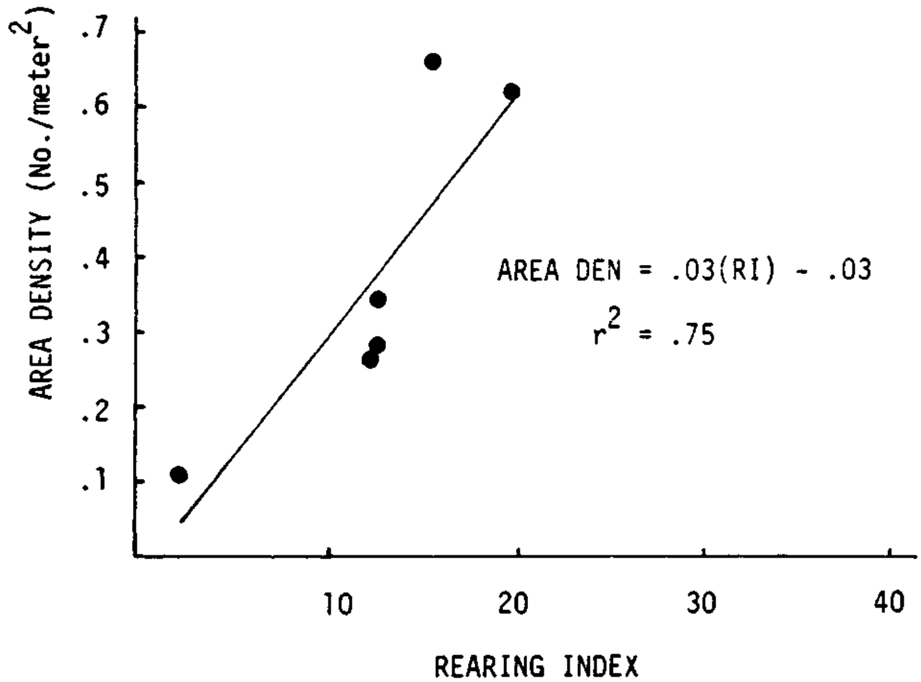
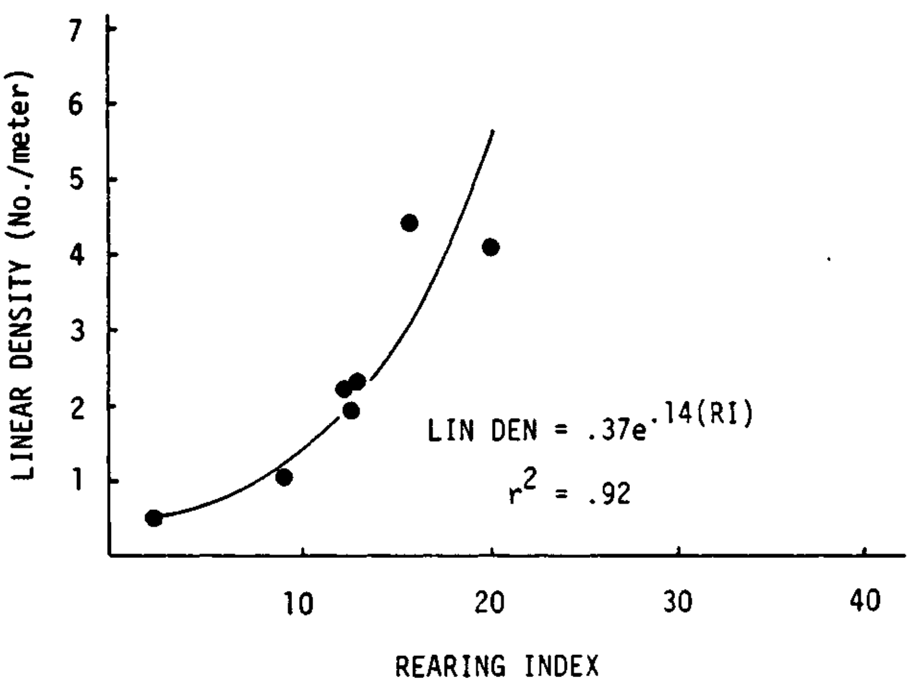


Figure 5. Relationship between indexes of rearing habitat and juvenile steelhead population density in riffles of Lagunitas Creek.





In this section we will use those relationships to estimate the potential steelhead production of Lagunitas Creek at various flows.

On the basis of the data presented, it is possible to express the density of juvenile steelhead as a function of streamflow. For example, with the equation relating rearing indexes (RI) to streamflow (Q) in the State Park (Figure 2):

$$RI = 6.3 (Q) + 0.75, \text{ and}$$

the equation relating linear density (LD) of steelhead in riffles to rearing indexes (Figure 5):

$$LD = 0.37e^{0.14(RI)}$$

we can yield by substitution:

$$LD = 0.37e^{0.14(6.3(Q) + 0.75)}$$

$$LD = 0.37e^{0.88(Q) + 0.11}$$

Using similar methods for riffles and glides in various reaches of the stream we developed Table 2.

Table 2. Linear density (LD) of juvenile steelhead trout expressed as a function of streamflow (Q) in riffles and glides of two reaches of Lagunitas Creek 1/

	Riffles	Glides
State Park Reach	$LD = 0.37e^{(0.88 \times Q + 0.11)}$	$LD = 1.11 Q + 0.73$
Tocaloma and Brushy Reaches	$LD = 0.37e^{(0.21 \times Q + 0.35)}$	$LD = 0.24 Q + 1.01$

1/ These relationships are valid only at flows between 0.5 and 5 cfs, and at channel and substrate conditions found during the summer and fall of 1979.

These functions relating volume of streamflow to juvenile steelhead populations can be then applied to different reaches of Lagunitas Creek to estimate populations at any streamflow up to 5 cfs through the Taylor Park, and 12 cfs through Tocaloma. We have calculated the population estimates for 0.5, which is about the present low summer and fall flow, and for flows of 1, 2, and 3 cfs that will be the post-project releases according to the October 1, 1979 DFG/MMWD agreement (Table 3).

For previously explained reasons we do not have data to estimate the production in the kilometer of Lagunitas Creek between San Geronimo Creek and the Kent Dam. Part of that section will be destroyed by enlargement of the dam itself. The 1.4-kilometer reach of Lagunitas Creek just below the Tocaloma Bridge is largely unshaded, subjected to severe bank erosion, sediment deposition, and channelization. Water temperatures are now sometimes too warm there for good steelhead production. The reach will improve somewhat with the released flow but we doubt if it will provide significant numbers of steelhead without rehabilitation of riparian vegetation.

We estimate that an increase of summer flows from about 0.5 cfs to 3 cfs would increase the juvenile steelhead population of the 11.7-kilometer San Geronimo-Nicasio reach from present levels of about 7,000 to 21,000 juvenile steelhead. Flows of 1 cfs would produce about 9,000 and flows of 2 cfs would produce an estimated 14,000 juvenile steelhead.

We can make no estimate of salmon production but the magnitude of change with changing streamflows is likely to be somewhat like that of steelhead.

The lower reach of Lagunitas Creek below Nicasio Creek is probably important rearing habitat for both steelhead and salmon. Because Marin Municipal Water District must release water from Nicasio Reservoir to satisfy a downstream diversion at the head of tidewater, the reach of lower Lagunitas Creek below Nicasio Creek now has a minimum summer flow usually between 2 and 4 cfs. The project will release that water from Kent instead of Nicasio Reservoir, and neither flows nor production of salmonids in this lower reach will be significantly changed during the summer.

According to the October 1, 1979 Agreement between the Department of Fish and Game and Marin Municipal Water District, whether a 1, 2, or 3 cfs release will be made will depend on the total volume of water in MMWD reservoirs on the previous May 1.

D. W. KELLEY & Associates aquatic biology

March 23, 1982

Mr. Richard Rogers
Assistant General Manager
Marin Municipal Water District
220 Nellen Avenue
Corte Madera, CA 94925

SUBJECT: Table 3 in our February 1980 report, "Relationships Between Streamflow, Rearing Habitat, Substrate Conditions, and Juvenile Steelhead Populations in Lagunitas Creek, Marin County, 1979".

Dear Dick;

Recently Bruce Agee, a staff member of the Instream Flow Group of the State Water Resources Control Board, pointed out some errors in Table 3 of the report we prepared for you in February 1980 on Lagunitas Creek. I enclose 25 copies of a corrected table, and would be grateful if you would distribute it to those who received copies of the report.

The corrections slightly increase the number of steelhead that we estimated could be reared at 3 cfs in Lagunitas Creek, but make no significant difference in any of the conclusions based on those estimates.

Sincerely,

DW Kelley

Don W. Kelley

cc: Ray Dunham
Bruce Agee
Jim Martin

enclosures

(Corrected)

Table 3. Estimated fall juvenile steelhead populations at various flows in Lagunitas Creek from San Geronimo Creek to Nicasio Creek. These estimates assume that substrate conditions and factors other than streamflow will not change from what they were during the summer of 1979 and that flows required during the fall, winter, and spring for fish migration, spawning, and egg incubation are adequate.

	San Geronimo Creek to Jewell		Jewell to Tocaloma		Tocaloma to Nicasio Creek			
					Meadow Reach	Brushing Reach		TOTAL
Length in meters	5,907		2,624		1,371	1,776		11,678
Percent riffles	23		14		This habitat is poor for steelhead-probably rears none at 0.5 cfs, few at 2.0 cfs.	11		
Meters of riffles	1,359		367			195		
Percent glides	42		67			23		
Meters of glides	2,481		1,758			408		
Percent pools	35		19			65		
Meters of pools	2,067		499			1,154		
ESTIMATED NUMBER OF STEELHEAD AT 0.5 CFS FLOW								
	Riffles	Glides	Riffles	Glides		Riffles	Glides	Total
Numbers/m	0.64	1.29	0.58	1.13		0.58	1.13	
Total	870	3,200	213	1,987		113	461	6,844
ESTIMATED NUMBER OF STEELHEAD AT 1 CFS FLOW								
Numbers/m	1.00	1.84	0.65	1.25		0.65	1.25	
Total	1,359	4,565	239	2,198		127	510	8,998
ESTIMATED NUMBER OF STEELHEAD AT 2 CFS FLOW								
Number/m	2.40	2.95	0.80	1.49		0.80	1.49	
Total	3,262	7,319	294	2,619		156	608	14,258
ESTIMATED NUMBER OF STEELHEAD AT 3 CFS FLOW								
Numbers/m	5.79	4. 06	0.99	1.73		0.99	1.73	
Total	7,869	10,073	363	3,041		193	706	22,245

(Original, slightly flawed) Table 3. Estimated fall juvenile steelhead populations at various flows in Lagunitas Creek from San Geronimo Creek to Nicasio Creek. Those estimates assume that substrate conditions and factors other than streamflow will not change from what they were during the spring of 1979 and that flows required during the fall, winter, and spring for fish migration, spawning, and egg incubation are adequate.

	San Geronimo Creek to Jewell	Jewell to Tocaloma	Tocaloma to Nicasio Creek: Meadow Reach	Tocaloma to Nicasio Creek: Brushing Reach	Total
Length in meters	5,907	2,624	1,371	1,776	11,678
Percent riffles	23	14		11	
Meters of riffles	1,359	367		195	
Percent glides	42	67		23	
Meters of glides	2,481	1,758		408	
Percent pools	35	19		65	
Meters of pools	2,067	499		1,154	

	San Geronimo Creek to Jewell: Riffles	San Geronimo Creek to Jewell: Glides	Jewell to Tocaloma: Riffles	Jewell to Tocaloma: Glide	Meadow Reach	Brushing Reach: Riffles	Brushing Reach: Glides	Total
ESTIMATED NUMBER OF STEELHEAD AT 0.5 CFS FLOW					This habitat is poor for steelhead - probably rears none at 0.5 cfs few at 2.0 cfs.			
Numbers/m	0.64	1.24	0.58	1.13		0.56	1.09	
Total	870	3,076	213	1,987		109	445	6,700
ESTIMATED NUMBER OF STEELHEAD AT 1 CFS FLOW								
Numbers/m	1.00	1.84	0.65	1.25		0.65	1.25	
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Number/m	2.40	0.80					0.80	
Total	3.262	7,319	294	2.619		156	608	14,258
ESTIMATED NUMBER OF STEELHEAD AT 3 CFS FLOW								
Numbers/m	5.79	3.75	0.99	1.73		0.80	1.49	
Total	7.869	9,304	363	3,041		156	609	21,342

District Reservoir Storage on Previous May 1	Release	Expected Frequency
More than 45,600 acre-feet	3 cfs	83%
21,500-45,600	2 cfs	13%
Less than 21,000 acre-feet	1 cfs	4%

The annual May 1 reservoir storage and the frequency of the 3, 2, and 1 cfs releases were part of the MMWD computer simulation of how the project would operate. These estimates assumed an annual MMWD water use of 16,000 acre-feet from Kent and 8,500 from Nicasio Reservoir. Using those estimates we can calculate that, if the channel size, shape, and substrate remains the same as it was in the late summer and fall of 1979, post-project fall population of juvenile steelhead will average about 20,000 fish.

This estimate is, of course, not the total production in the Lagunitas Creek drainage. Both San Geronimo Creek and Devil's Gulch are spawning and, to a lesser extent, rearing habitats. Since they will not be affected by the proposed project, we made only some reconnaissance-level observations there (Appendix A).

THE IMPORTANCE OF SUBSTRATE CONDITIONS

An important question is whether the channel and substrate will change as a result of the project. Whether a stream bottom is sandy or covered with boulder or cobble has a very large effect on that stream's ability to support salmonids of any kind. Many hundreds of investigations on this subject have been published in scientific literature, and it is beyond the scope of this report to review them. We mention only the review paper of Cordone and Kelley (1961) describing the large amount of evidence available 19 years ago that sediment was harmful, and the recent excellent work of the University of Idaho (Bjornn, et al., 1977) which provided some of the most useful recent data.

Bjornn and his colleagues tested how the accumulation of coarse sand around the cobble in streambeds affected the ability of the streams to support juvenile salmon and steelhead. During our extensive measurements of rearing habitat in various parts of Lagunitas Creek, we identified the large degree to which cobble and boulder were embedded in sand and the degree to which sand had filled the pools as important major factors limiting rearing habitat.

In 70 out of 130 assessments, we recorded "embeddedness" as the principal constraint to better juvenile rearing habitat. In late summer and fall we also measured the degree to which cobble was embedded in the reaches where we measured steelhead populations (Table 4) . The measurements of embeddedness were made by casting a 60-cm-diameter barrel hoop seven times into the stream, picking up each cobble larger than 45-mm-diameter, and measuring the percentage to which it had been embedded in the sand. Cobble below 45-mm size have been shown to be significantly less useful in providing cover so we did no measurements of their embeddedness.

These sections were chosen to represent a wide range of habitat types so that we could test the effect of embedded-ness on fish populations. Their exact locations were marked with survey monuments and are described in Appendix B of this report so that future embeddedness in them can be compared to 1979 conditions.

In both riffles and pools, we found a highly significant inverse relationship between the degree of embeddedness and the juvenile steelhead populations. The evidence is strong that relatively small increases in embeddedness are associated with large decreases in steelhead density (Figure 6) . This is especially true at the lower levels of embeddedness where an increase of 10 to 15 percent in mean embeddedness correlates with a steelhead reduction of over 50 percent. This sensitivity of habitat to sand deposition emphasizes the importance of maintaining adequate flushing flows and controlling land use practices that cause erosion in the watershed. A slight increase in sand deposition can easily negate the benefits of increased summer flows.

QUALIFICATIONS

As with all experimental work in natural systems, there are important qualifications to keep in mind when interpreting our results. The four most important follow:

1. A large portion of the steelhead in Lagunitas Creek this year were planted fish--small young-of-the-year from Mad River Hatchery. Survival of these, combined with the wild fish, may have been different than we would expect from a completely wild steelhead population from natural spawning of the Lagunitas Creek run.

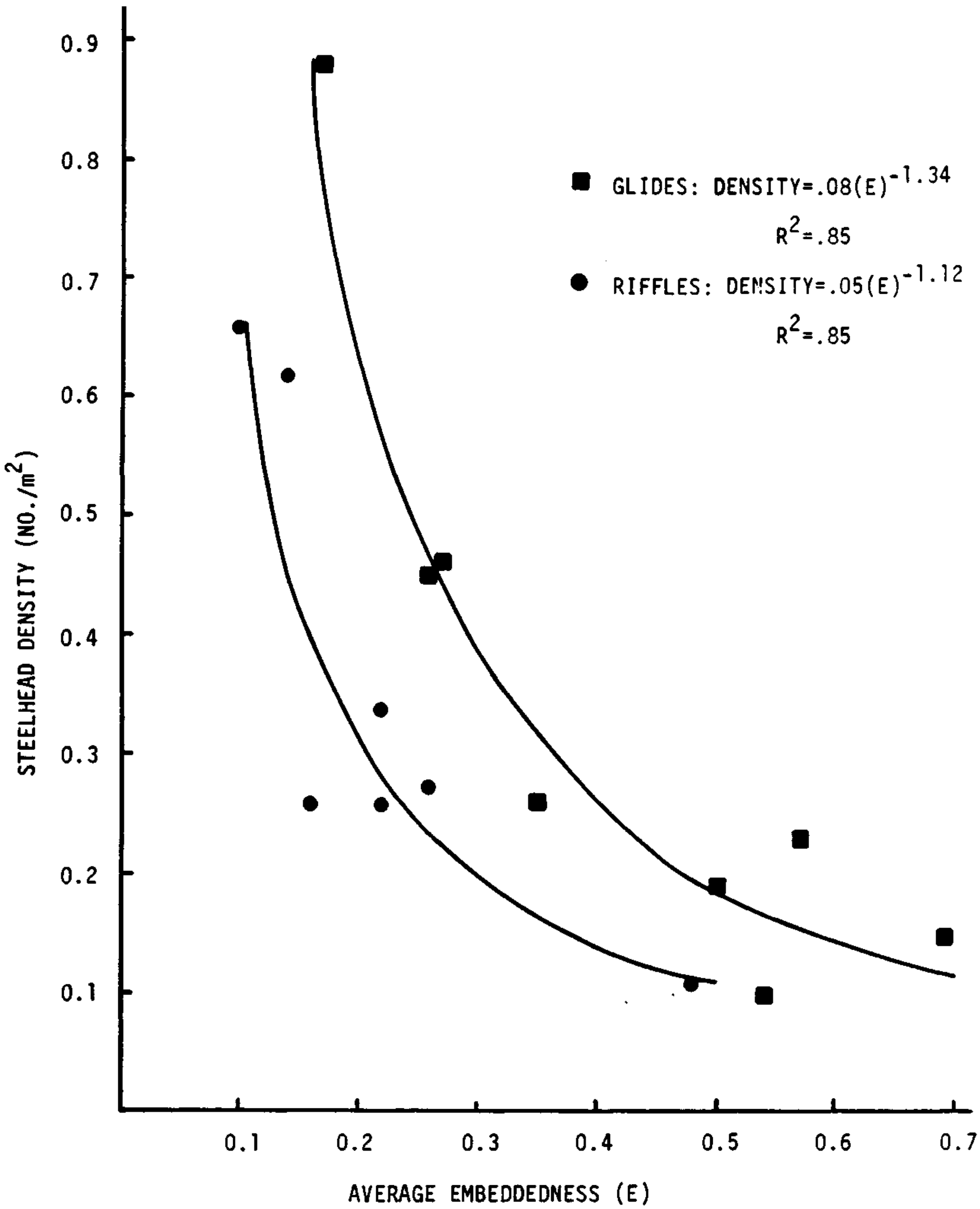
We thought that we could detect the difference between the planted fish and the wild stock, both by the way they looked and the way they behaved. The fish we thought were planted were less wary and may have been subject to higher predation by kingfishers

Table 4. Cobble embeddedness in Lagunitas Creek during summer and fall 1979. Embeddedness is defined as the percent to which the height of cobble is embedded in sand. Symbols: *, predominantly bedrock; s, predominantly sand.

	Mean Embeddedness of Individual Samples												Overall of Section			
Date Habitat Type	1	2	3	4	5	6	7	8	9	10	11	12	Mean	SD	n	±95 confidence limits
SHAFTER BR. TO TOCALOMA																
28 Aug (1) Glide	.44	.60	.43	.41	.43	.63	.67	.58	.58	.40			.50	.23	134	±.04
28 Aug (2) Glide	.67	.54	.68	.47	.74	.58	.48	.53	.57	.62	.40	.55	>.57	.23	117	+.04
29 Aug (3) Glide/riffle	.13	.08	.10	.19	.14	.18	.19	.19	.28	.14			.17	.20	258	+.02
30 Aug (4) Glide	.38	.23	.29	.23	.18	.24	.03	.24	.18	.41			.27	.25	219	+.04
" " (5) Glide	.49	.45	.52	.65	1.00	.54	.65	1.0	1.0				.69	.32	93	+.06
" " (6) Glide/Pool	.20	.32	.26	.26	.24	.26	.09	.37					.26	.25	174	+.04
9 Oct (7) Glide	S	.65	.53	0	.8	s	.60						.54	.30	9	±.25
11 Oct (8) Glide	.06	.48	.24	.23	.47	.50	.52						.35	.31	110	±.06
													0O.42			
29 Aug (9) Riffle	.34	.27	.26	.26	.17	.05	.27	.17	.22	.17	.14		.21	.22	112	+.04
8 Oct (10) Riffle	.24	.21	.27	.27	.22	.29	.28						.26	.22	221	±.02
8 Oct (11) Riffle	.17	.18	.21	.19	.20	.23	.27						.21	.22	185	±.04
9 Oct (12) Riffle	.90	.52	0	.45	.40	.57	.57						.48	.39	36	±.14
9 Oct (13) Riffle	.24	.17	.27	.20	.14	.21	.36						.22	.23	187	±.04
10 Oct (14) Riffle	.45	.26	.32	.30	.56	.32	.38						.39	.31	129	±.06
10 Oct (15) Riffle	.10	.16	.15	.14	.17	.16	.14						.14	.18	222	+.02
11 Oct (16) Riffle	.01	.11	.08	.11	.13	.17	.10						.10	.15	196	±.02
11 Oct (17) Riffle	.09	.12	.18	.15	.28	.28	.13						.16	.24	186	±.04
													0O.24			
8 Oct (18) Pool	S	S	.33	.82	.49	.73*	.56*						.58	.28	50	+.08
KENT RESERVOIR TO SHAFTER BR.																
26 Sept (20) Glide	.39	.39	.40	.45	.32	.56							.42	.31	146	±.05
26 Sept (21) Glide	.42	.31	.31	.20	.37	.28	.37						.33	.26	128	±.04
													0 .38			
26 Sept (22) Riffle	.35	.29	.35	.18	.33	.28	*						.28	.30	167	±.04
26 Sept (23) Riffle	.18	.12	.09	.11	.15	.01*	*	.22					.14	.17	178	±.03
													0 .21			
26 Sept (24) Pool	.21	.22	.32	.33	.35	.37	.38	.39	.39	.39			.39	.22	168	±.03
26 Sept (25) Pool	*	.71	*	.54	.60	.56	.48						.53	.28	74	±.06
													0 .46			

Numbers in parentheses refer to location in Appendix B.

Figure 6. Relationships between average degree to which cobble larger than 45-mm diameter is embedded in sand and steelhead density of Lagunitas Creek



and herons that are common along Lagunitas Creek. Survival can be roughly estimated by adding the 1.59 steelhead-per-lineal-meter density that we found on June 11, 1979, before the Mad River fish were stocked, to the 3.15 fish per meter that were stocked on July 3. The reduction from the total of 4.74 fish per meter to an average 2.53 that we measured from late August through early October is evidence that about half of the spring population survived the summer. This survival is high, but it might have been higher if all of the fish were wild stocks whose behavior had evolved to meet the various environmental conditions in Lagunitas Creek.

2. A second qualification to remember is that very few salmon were being reared in Lagunitas Creek this year. While the young silver salmon tend to spend more time in pools and less in riffles than do young steelhead, there are major overlaps in their habitat requirements and they do compete for the same food supply. The absence of salmon may have increased the survival rates of the young steelhead this summer. If they had been present, however, the combined steelhead and salmon populations would probably have been significantly greater than those of the steelhead alone.

3. We assume that the limited natural reproduction, combined with the stocking, fully seeded Lagunitas Creek this year, but we are not certain. Our data is evidence that it was seeded well enough to cause the young steelhead to occupy glides and riffles according to their quality, but starting out the summer with more fish might have resulted in a larger fall population of juveniles than we found this year -- and greater differences attributable to differences in the rearing indexes.

4. The most urgent qualification is that <u>our predictions are valid only if substrate conditions</u> and all other factors that affect salmonid production in Lagunitas creek <u>remain the same.</u> If the enlarged Kent Reservoir is operated to save power costs, as proposed under alternates A and B in the Environmental Impact Report, the frequency, magnitude, and duration of large flows in Lagunitas Creek above its junction with Nicasio Creek would be reduced by more than 50 percent in many years (Kelley, 1978). The effect of those reductions on substrate conditions and how to prevent them from worsening is the subject of current investigations agreed to by the Department of Fish and Game and the Marin Municipal Water District.

OTHER FACTORS AFFECTING SALMONID PRODUCTION

Our investigations on the salmon/steelhead of Lagunitas Creek have been limited to assessments of one phase of their life cycle, that of the juveniles rearing in the stream. They have been restricted to studying the effects of streamflow and substrate changes on the physical aspects of juvenile rearing habitat and of how physical conditions, expressed as "rearing indexes" and "embeddedness" are related to juvenile survival.

All stages in the life history, except that of the adults in the ocean, will be affected by the proposed flow changes (Figure 7).

One important factor that may change is water temperature. On September 5, 1979, the release of 2.4 cfs from Kent Reservoir reduced water temperatures in Lagunitas Creek down to Devil's Gulch (Figure 8). On October 11, the temperature of the release was much higher and caused water temperatures at least down to Devil's Gulch to be higher than they would otherwise have been. On November 5, the releases of larger flows of Nicasio Reservoir water were made just above Devil's Gulch and those releases raised the water temperature slightly.

We do not have enough information to define how the project will affect future water temperatures in Lagunitas Creek, but present the above as evidence that changes are likely to occur and they should be predicted and assessed in order to determine if a multilevel outlet structure is needed in the new dam.

The ultimate agreement between the Department of Fish and Game and the Marin Municipal Water District on operation of the raised Kent Reservoir will need to describe the flows, including whatever flushing flows are required, to maintain rearing habitat and also whatever flows and other conditions are necessary for upstream migration and spawning of adults, for egg incubation, and for the downstream migration of young into Tomales Bay.

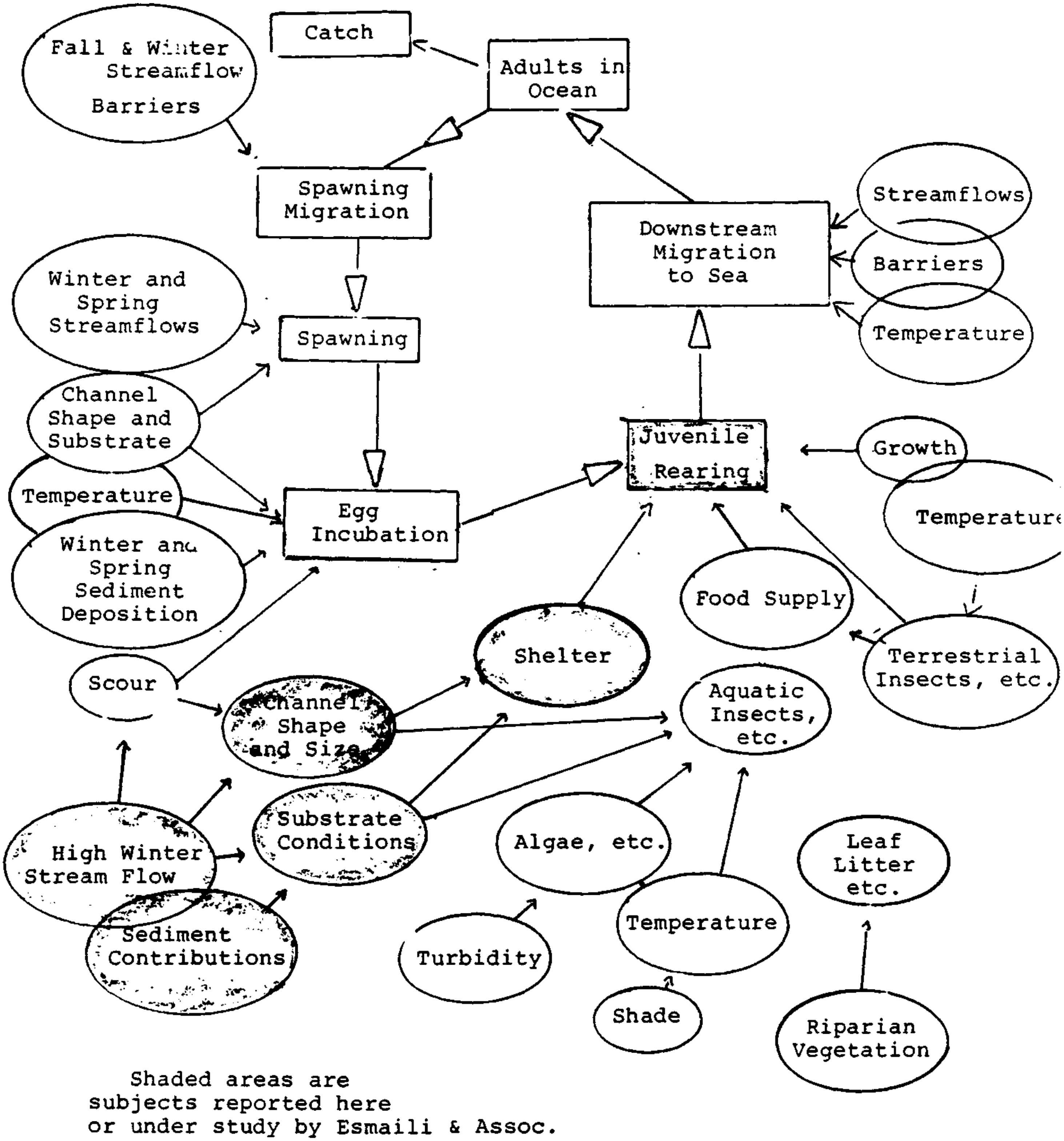
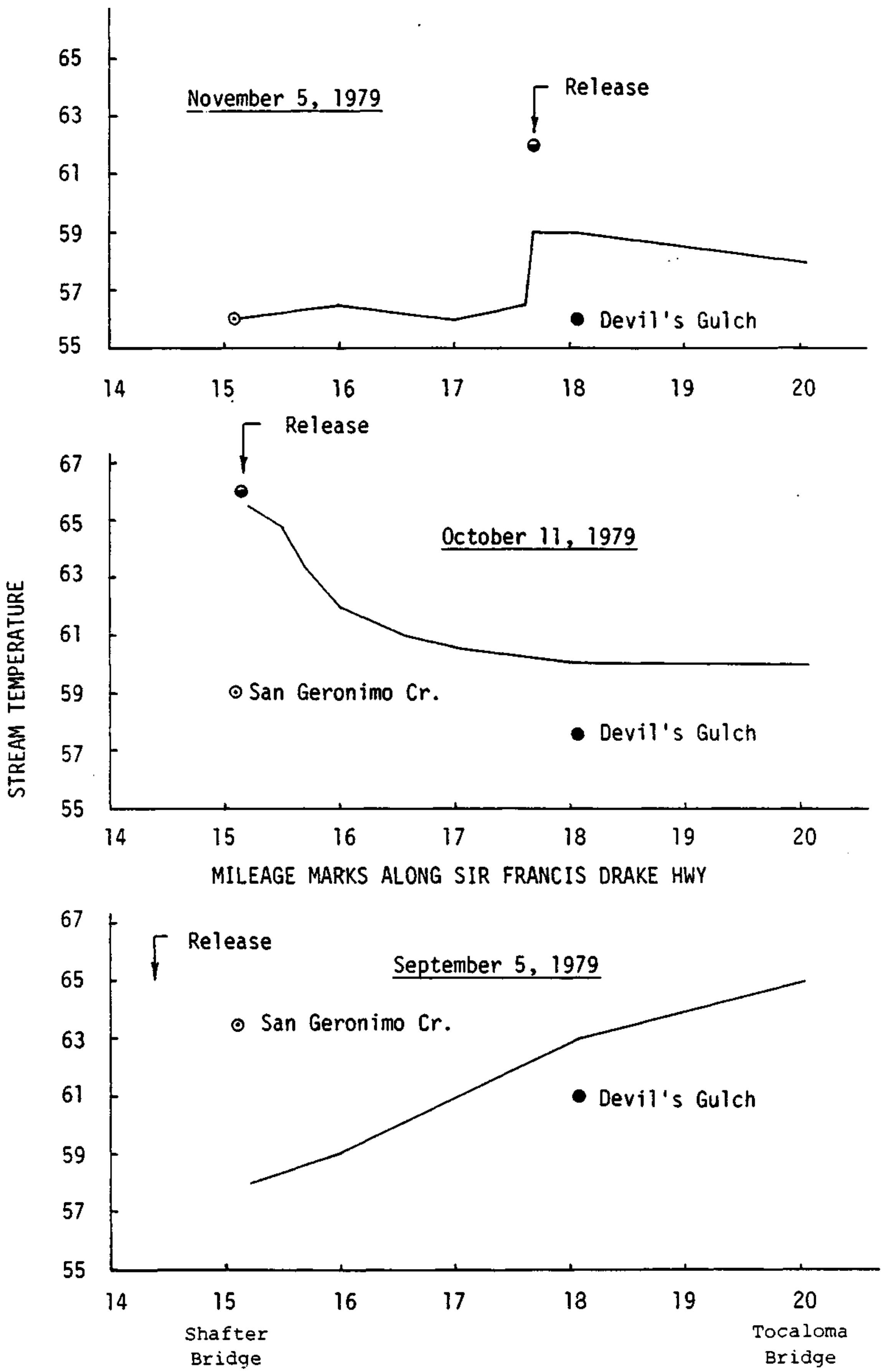


Figure 7. Factors Affecting Steelhead and Salmon Production in Lagunitas Creek, California.

Figure 3. The effect of streamflow releases from Kent Reservoir on the stream temperatures of Lagunitas Creek.



CITATIONS

Bjornn, T. C., M. A. Brusven, M. P. Molnau, J. H. Milligan, R. A. Klamt, C. Chacho, and C. Schaye. 1977. Transport of granitic sediment in streams and its effects on insects and fish. College of Forestry, Wildlife and Range Sciences, University of Idaho. Bulletin Number 17. September 1977. 43 pp.

Cordone, Almo J. and Don W. Kelley. 1961. The influences of inorganic sediment on the aquatic life of streams. California Fish & Game. Vol. 47, No. 2, April 1961.

Kelley, D. W. 1978. Investigations on Lagunitas Creek and Tomales Bay. Appendix 2 - Aquatic Biology and Focused Environmental Impact Report on Raising Kent Lake. 44 pp.

Kelley, Don W., and Rollin C. Reineck. 1978. Relationship between streamflow and salmonid rearing habitat in Walker and Lagunitas Creeks, Marin County. Prepared for the Marin Municipal Water District, October 4, 1978. 18 pp.

Ricker, W. E. 1975. Handbook of computation for biological statistics of fish populations. Fish. Res. Bd. Com. Bull. 119. 300 pp.

APPENDIX A

INITIAL RECONNAISSANCE SURVEY: SAN GERONIMO CREEK, DEVIL'S GULCH, AND LAGUNITAS CREEK

June 27-29, 1979

by David Dettman

The relationships between salmonid rearing habitat and streamflow are being studied on Lagunitas Creek, Marin County, California. Thirty thousand young-of-the year steelhead were stocked in Lagunitas Creek on July 3, 1979, in order to fully seed several sections of Lagunitas Creek with varying habitat qualities. In conjunction with this stocking the Marin Municipal Water District is releasing 3 cfs from Kent Reservoir. We propose to follow the survival and growth of juvenile steelhead in these fully seeded sections of Lagunitas Creek in order to assess the effect of enhanced summer flows upon smolt production and to establish a relationship between our rearing index (measure of quality and quantity of rearing habitat) and fish numbers and biomass. Thus far our investigations have been concentrated on the sections of Lagunitas Creek between Tocaloma Bridge and the confluence of San Geronimo Creek. However, in order to know the effectiveness of enhanced summer flows, we must estimate the numbers of young steelhead produced in other parts of the Lagunitas watershed that may be independent from the mainstream of Lagunitas Creek. In order to identify other important nursery areas we initiated a reconnaissance survey of two tributary streams (San Geronimo Creek and Devil's Gulch) and the lower part of Lagunitas Creek below Tocaloma Bridge. These areas are outlined in Figure 1. Our objectives were to characterize the total area of each stream in terms of pools, glides, and riffles; to estimate the rearing qualities of each pool, glide, and riffle; to note important barriers to upstream and downstream migration; and qualitatively note the relative importance of each stream as a nursery area for the 1979 year class of salmonids.

Devil's Gulch

Devil's Gulch flows for 2.4 miles before entering Lagunitas Creek in Samuel P. Taylor State Park. I surveyed a 3,847-foot reach from the road bridge on Sir Francis Drake Highway to Stairstep Falls (Figure 2).

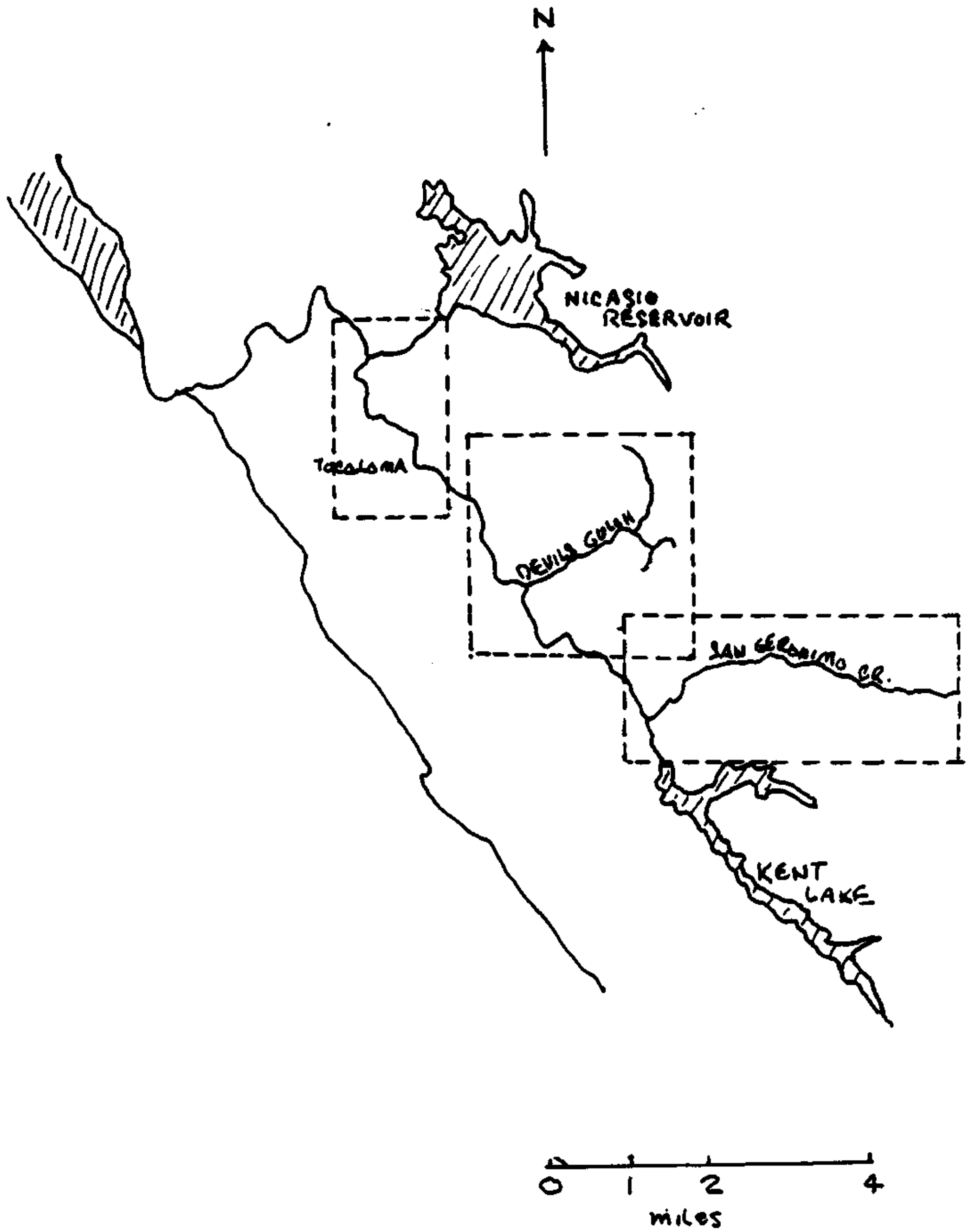


Figure 1. Areas outlined in dashed lines were surveyed from June 27-29, 1979.

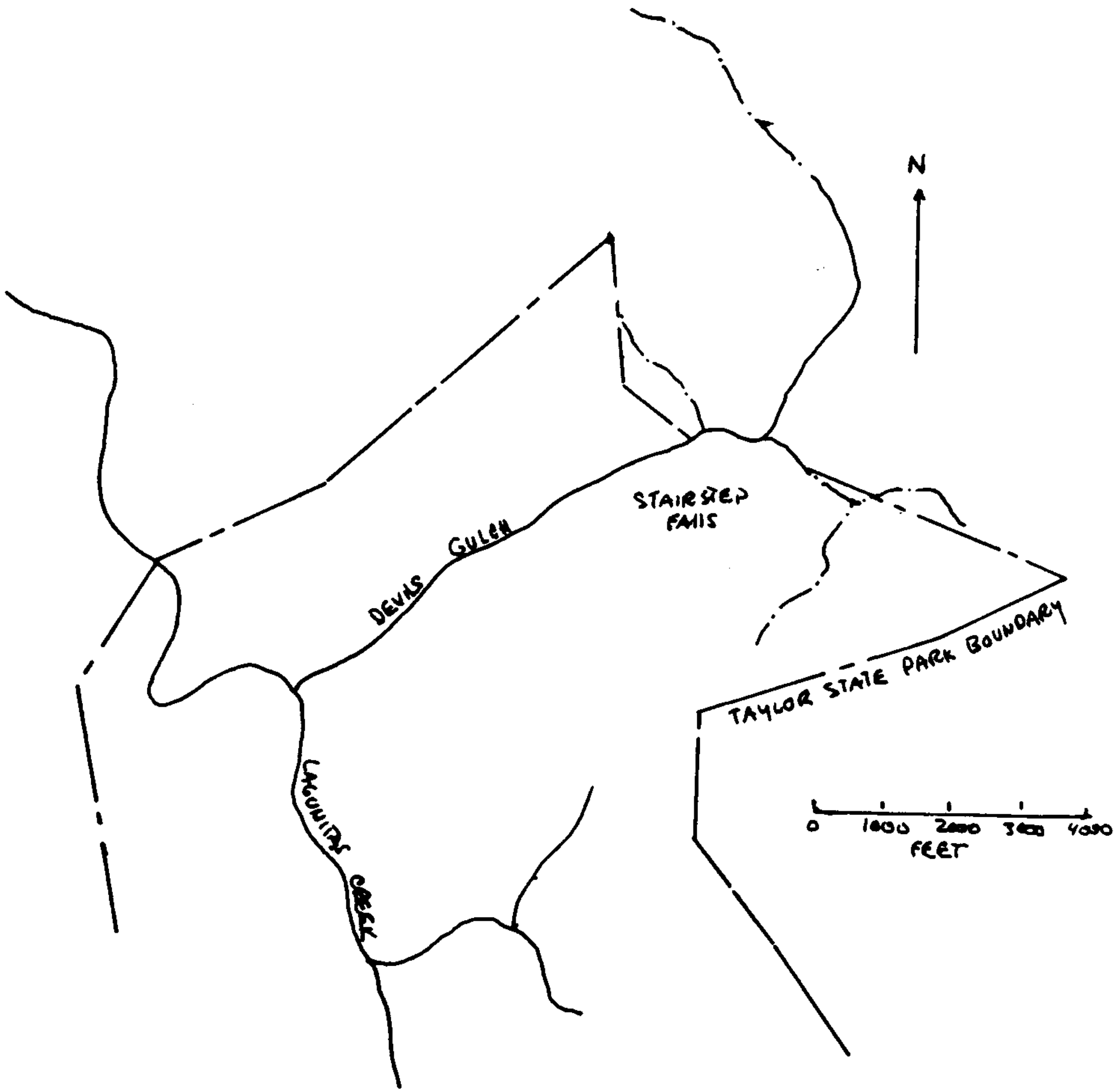


Figure 2. Map of Devil's Gulch showing the upstream extent of reconnaissance survey (Stairstep Falls) completed on June 27, 1979.

Devil's Gulch is a major spawning tributary of Lagunitas Creek. Young-of-the-year are very numerous throughout the stream and the density of fish in many pools approached one fish per linear foot. However, the major constraint here will be late summer flows and the capacity of the stream in most summers is very low. It is probable, as flows recede in late July and August, that most young-of-the year will move down into the mainstream of Lagunitas Creek. This is substantiated by the fact that yearlings were very sparse in comparison to young-of-the-year. In contrast, yearlings made up 35 percent of the steelhead population in our Tocaloma station on June 8, 1979.

The steep gradient, narrow canyon, relative clean substrate (low embeddedness), and well shaded water make for excellent potential rearing habitat. However, the rearing habitat quality averaged only poor to fair, with the major constraint being streamflow. Riffles accounted for a relatively large portion of the total area (Table 1). The substrate in riffles was exceptional, with gravel and cobble making up 27 and 39 percent of the substrate area. While habitat quality averaged only poor to fair, many individual riffles, pools, and glides were of good to excellent quality. The importance of Devil's Gulch should not be slighted by its low summer flows. It is an important nursery area through mid-Summer, as numerous fish grow to 50 mm before moving into Lagunitas Creek.

San Geronimo Creek

On June 28, 1979, Barry Kecht and I walked a 3-mile section of San Geronimo Creek from its confluence with Lagunitas Creek to the staircase fish ladder in the town of San Geronimo. I noted qualitative rearing conditions, major rearing constraints, major barriers, and landmarks in this section. In addition, I did a "detailed" survey of rearing habitat in two reaches: a 1,636-foot reach just upstream from Shafter, and a 2,679-foot reach upstream from the Lagunitas Road bridge in Lagunitas (Figure 3). The results of these two surveys are presented in Tables 2 and 3, and will be discussed separately.

San Geronimo Creek is an important spawning and nursery area. Rearing capacity throughout most of the stream is limited by waterflow during late summer. Substrate is generally in good condition, except for portions in the town of San Geronimo, from the old concrete dam (Forest Knolls) upstream to the lefthand channelized tributary, and from the Lagunitas School bridge to the fish ladder.

Table 1. Devil's Gulch, Lower Reach, Lagunitas Creek Watershed, Estimated Flow 0.2 cfs, June 27, 1979

Number of:	Glides	Pools	Riffles	Bedrock	Total
	35	21	37	4	
Total length (feet)	1,574	566	1,612	95	3,847
0 width	8.6	8.5	6.9	3.9	
Area (square feet)	15,083	5,173	11,393	417	32,066
% length of total	41	15	42	2	
% area of total	47	16	36	1	
0 % sand and silt	40.6	43.1	16.8	8.4	
0 % gravel	31.3	10.3	27.4	-	
0 % cobble	18.4	12.9	39.2	-	
0 % boulders	3.4	3.2	8.3	-	
0 % bedrock	6.1	30.5	8.6	91.6	
0 rearing quality	1.4	1.7	1.6	-	

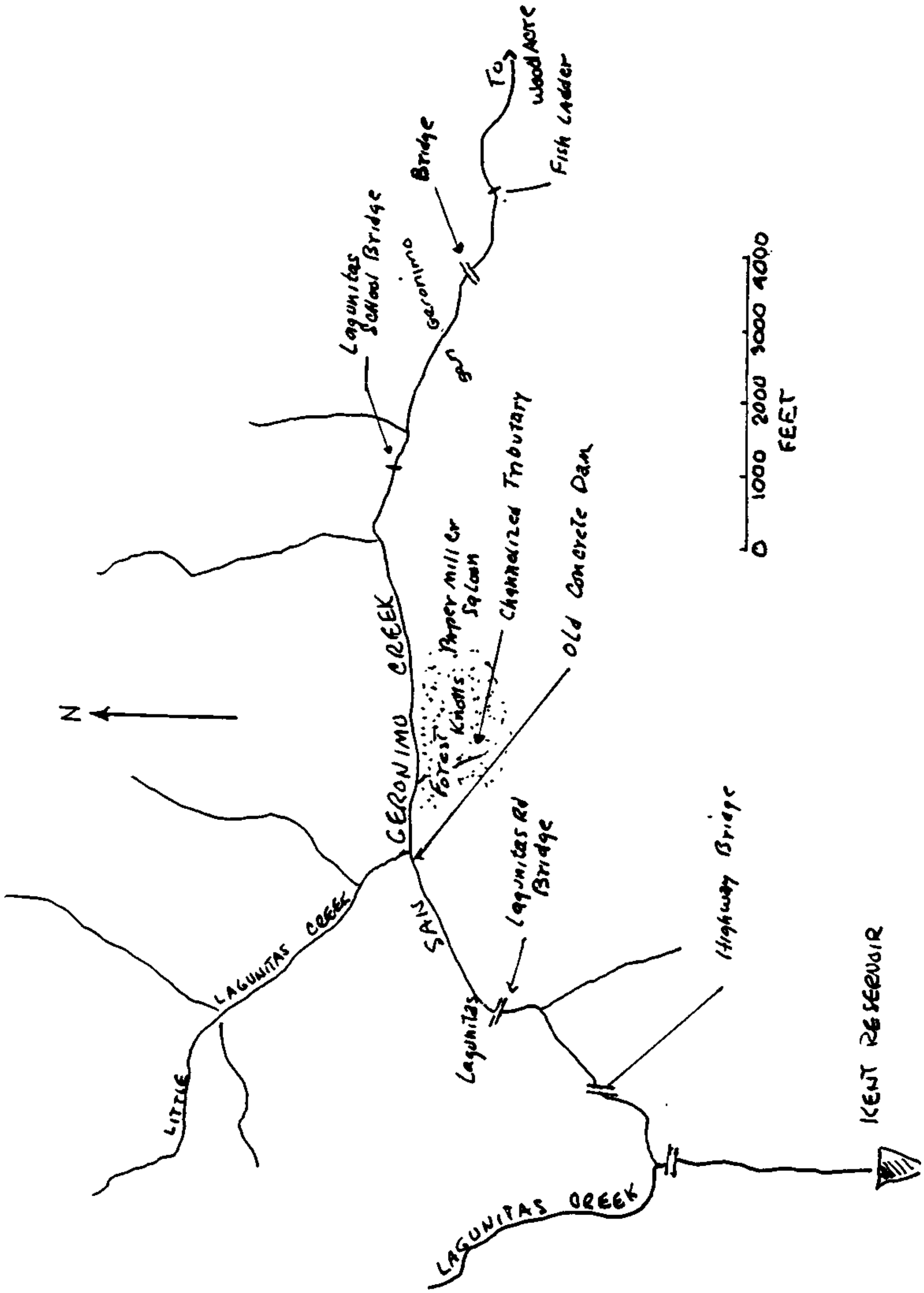


Figure 3. Detailed map of San Geronimo Creek showing major landmarks along stream.

Table 2. San Geronimo Creek, Shafter Reach, Estimated Flow 0.7 cfs, June 28, 1979

Number of:	Glides	Pools	Riffles	Bedrock	Total
	9	6	5	-	
Total length (feet)	605	734	297	-	1,636
0 width (feet)	14.1	17.1	7.8	-	
Area (square feet)	8,735	14,136	2,466		25,337
0 length of total	37	45	18	-	
% area of total	34	56	10		
0 % sand and silt	41.9	31.7	17.3		
0 % gravel	33.2	48.8	30.8		
0 % cobble	0.8	1.4	1.2		
0 % boulders	4.7	5.5	14.0		
0 % bedrock	19.4	12.5	36.7		
0 rearing quality	1.1	1.5	1.7		

Table 3. San Geronimo Creek, Lagunitas Reach, Estimated Flow 0.5 cfs, June 28, 1979

	Glides	Pools	Riffles	Bedrock	Total
Number of:	17	11	10	2	
Total length (feet)	1,072	999	530	78	2,679
0 width (feet)	14.8	16.7	12.2	6.1	
Area (square feet)	16,457	16,396	6,685	472	40,010
% length of total	40	37	20	3	
% area of total	41	41	17	1	
0 % sand and silt	39.7	44.2	12.2	-	
0 % gravel	36.4	16.7	34.1	-	
0 % cobble	10.3	7.3	43.8	tr	
0 % boulder	5.1	6.9	1.1	tr	
0 % bedrock	8.6	24.9	8.8	98	
0 rearing quality	1.2	3.1	1.5		

In riffles where cobble is abundant, it is well exposed with minor embeddedness. However, during late summer when streamflows are minimal even minor embeddedness may significantly reduce rearing habitat as only the upper two-thirds of the cobble is above water. Pools are deep with many receiving a habitat quality rating of good to excellent. Some pools appear reduced in size by sedimentation. Pools are the major habitat of salmon during late summer.

Both steelhead and silver salmon were found in San Geronimo Creek, at least up to Forest Knolls. One group of 30 salmon was distinguished by its schooling behavior in a one-half-foot-deep pool, 200 feet above Little Lagunitas Creek.

Shafter Reach: This reach extends from a major bedrock outcrop just above the confluence with Lagunitas Creek to the Lagunitas Road bridge in Lagunitas. Streamflow was approximately 0.7 cfs at the time of the survey. The substrate in this reach is controlled by numerous bedrock out-croppings. The percentage of cobble is very limited throughout glides, pools, and riffles (Table 2), and this is a major constraint to rearing quality. Riffles are typically narrow and short and are interspersed between long pools and glides. The pools are generally well shaded and deep, and probably account for most of the late summer rearing habitat. The effect of removing shade was noted in a 700-foot section where several homeowners removed most of the riparian vegetation along the creek and created three small rock impoundments. Before modifications, this was a gravel-bottomed glide and riffle section; now the substrate is covered with a dense mat of algae and the water velocity is nil except over the very short sections of each rock dam.

<u>Lagunitas Reach:</u> This reach extends from the Lagunitas Road bridge to an old concrete impoundment adjacent to a major righthand tributary. Streamflow was estimated to be 0.5 cfs. Lagunitas Reach is distinctly different from Shafter Reach in that bedrock is not as instrumental in controlling the substrate composition. Alluvial deposits are more pronounced, with cobble making up 43 percent of the substrate area in riffles. Rearing quality in riffles was slightly lower than Shafter Reach due to greater stream widths, shallower depths, and decreased streamflow. Pools in this reach were rated at fair to good and were distinctly better than pools in Shafter Reach, due to greater depths and more cover along the streambanks.

The remainder of San Geronimo Creek up to the fish ladder in San Geronimo can be characterized into four discrete reaches as follows:

1. From the old concrete dam upstream to the channelized lefthand tributary. This section is of low rearing quality except in pools. Most glides and riffles are exposed to sunlight and have high concentrations of algae. The cobble is about 0.7 embedded.

2. From the channelized tributary to Paper Mill Creek Saloon. This section has good shading, the cobble is well exposed, and all pools are 4 to 6 feet deep.

3. From Paper Mill Creek Saloon to Lagunitas School bridge. The rearing quality in this reach is similar to Lagunitas Reach. The most notable feature is the 8-9-foot deep pool at the upstream end that was formed below a 3-foot high concrete dam. The dam becomes passable at high flows as adults are able to use the exceptionally deep pool for sounding.

4. Lagunitas School bridge to fish ladder in San Geronimo. This section is highly embedded. Long, deep pools and glides have sand filled substrates. Riffles are inconsequential and very shallow. The banks are usually undercut in pools and glides and fish retreat to these areas when frightened. As streamflow recedes, these refuges will be retained and form the only good habitat.

Middle Lagunitas Creek

On June 29, 1979, I surveyed a 2-mile section of Lagunitas Creek from just above the Nicasio Creek confluence to the old bridge at Tocaloma junction (Figure 4). This section is divided into two discrete reaches: Brushy Reach and Meadow Reach. Streamflow was measured at 4.3 cfs during the survey.

Brushy Reach. This 5,862-foot-long reach extends from the .50 mile road marker on county road 221 to the beginning of a meadow environment adjacent to a large white barn on road 221. Much of the riparian vegetation is composed of blackberry vines, stinging nettle, and thistle. This made for hazardous walking, and at one point I was unable to survey a 700-foot section due to deep pools, steep banks, and briar patches. The canyon in this reach is very narrow and drops less than 40 feet per mile. Seventy-five percent of the habitat area is pools with excellent cover along the streambanks. A large portion of most pools is covered with sand and silt (Table 4). Riffle habitat was limited to only 6 percent of the habitat area and the substrate of most riffles was covered with gravel. Velocity over most riffles was too high and flow too laminar for young-of-the-year salmonids. However, the transition area from riffles to the next pool was

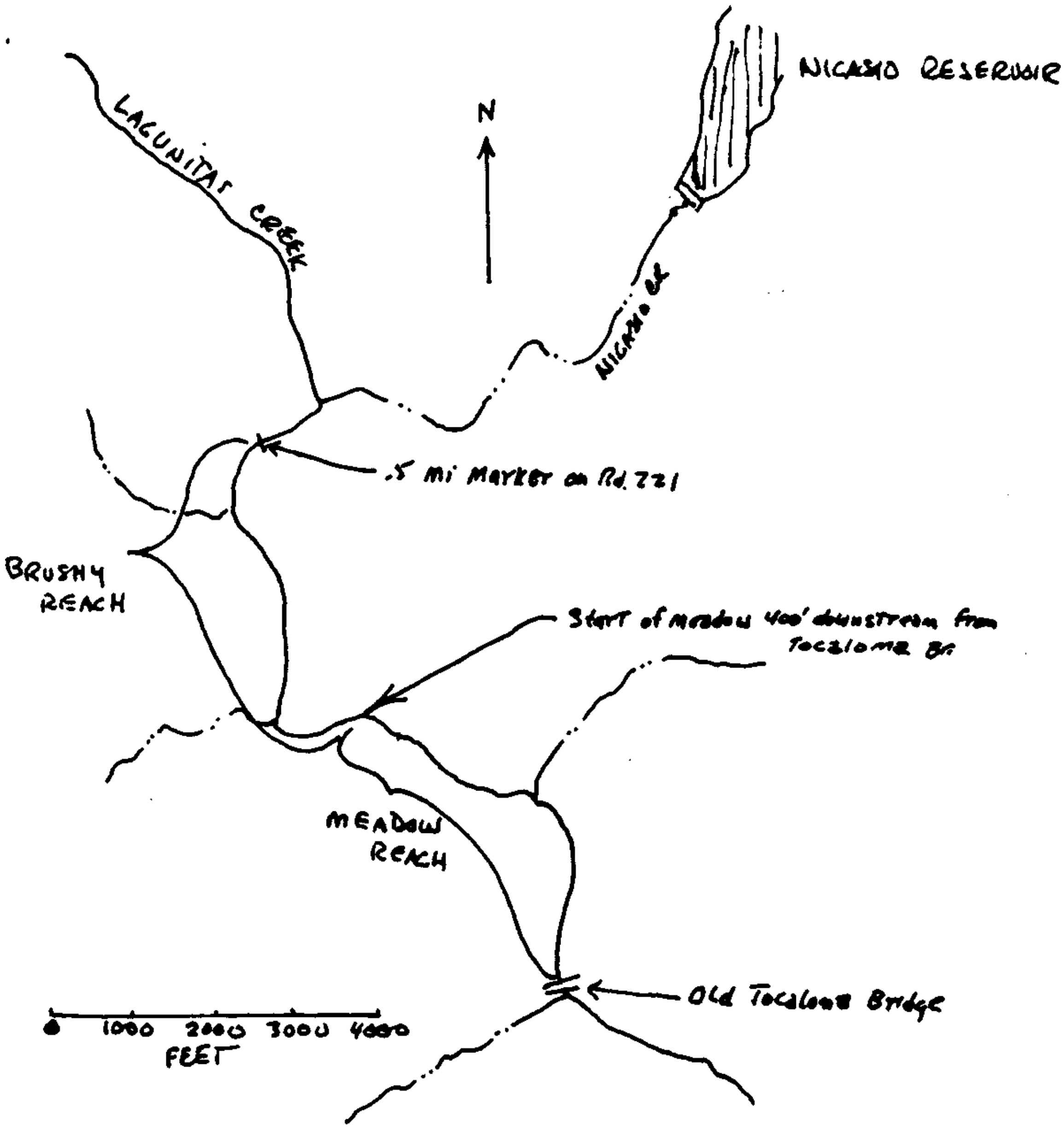


Figure 4. Map of lower Lagunitas Creek from Nicasio Creek confluence to old Tocaloma bridge.

Table 4. Lagunitas Creek, Brushy Reach, Measured Flow 4.3 cfs, June 29, 1979

	Glides	Pools	Riffles	Bedrock	Total
Number of:	32	25	19	-	
Total length (feet)	1,205	3,381	590	0	5,862
0 width (feet)	16.4	21.8	10.4		
Area (square feet)	20,743	82,457	6,245	0	109,445
% length of total	23	65	11		
% area of total	19	75	6		
0 % sand and silt	54.7	93.0	12.4		
0 % gravel	40.9	6.8	83.4		
0 % cobble	3.5	0.2	3.8		
0 % boulder	0.9	tr	0.4		
0 % bedrock	-	-	-		
0 rearing quality	1.9	1.9	1.8		
Number of spawning redds	17	1	0		18

usually of exceptional quality. These areas are responsible for the fair rating given to riffle environments (Table 4). Glide environments were rated fair due to a few exceptional glides with good-to-excellent rearing conditions. Although I have not seen this reach with nonaugmented flows, it seems logical that flow through riffles would be reduced to a trickle and the majority of rearing habitat would be confined to the edges of pools.

Glide environments were preferred for spawning activity, with 17 steelhead redds found in glides with predominantly gravel bottoms. The importance of this lower area for spawning activity should not be ignored, and the effects of decreased flushing magnitude and frequency should be mitigated with increased erosion control in the watershed.

Meadow Reach: This 4,573-foot reach extends from the downstream edge of the meadow along road 221 to the old bridge at Tocaloma junction (Figure 4). Lagunitas Creek flows through a relatively broad valley in this reach. The composition of the habitat is similar to Brushy Reach, with pools, glides, and riffles making up 73, 24, and 3 percent of the total area. The meadow environment is probably a modification of the native riparian vegetation created to provide grazing pasture. Dairy cows have grazed extensively along the streambanks and the erosion and crumbling of streambanks has filled pools and glides with excessive amounts of sand and limited the undercutting of banks. This process is reflected in the low average rearing habitat qualities of pools, glides, and riffles (Table 5). The stream is exposed to solar radiation for a great portion of the day and this has resulted in algal choked glides and riffles. In its present condition this section of Lagunitas Creek is providing very little rearing habitat for juvenile salmonids. However, 16 redds were deposited in this reach. Survival of eggs in these redds was probably limited by excessive sand and high temperatures. The situation in this reach is similar to the conditions on Walker Creek where bank erosion seriously limits rearing habitat. These conditions could be corrected with adequate fencing along the creek to limit access of dairy cows.

Table 5. Lagunitas Creek, Meadow Reach.

Lagunitas Creek Channelized Reach Estimated Flow =4.5 cfs June 29, 1979	Glides	Pools	Riffles	Bedrock Chute	Total	Average
Number of:	29	34	15	--		
Total Length (ft)	1500	2748	325	--	4573	
0 width (ft)	13.1	20.9	9.0	--		
Area (sq.ft)	20,971	64,783	2,801	--	88,555	
% length of total	33	60	7	--		
% area of total	24	73	3	--		
0 % sand and silt	66.3	95.0	22.5			
0 % gravel	30.4	4.6	68.3			
0 % cobble	3.1	0.3	9.2			
0 % boulder	tr.	tr.	tr.			
0 % bedrock	--	--	--			
0 Rearing Quality	0.76	0.74	1.12			
# Spawning redds	10	3	3			
Gradient:						

APPENDIX B

The Location of Reaches Where Juvenile Steelhead Populations and Cobble Embeddedness Were Measured in the Late Summer and Fall of 1979.

All 19 of the sections of Lagunitas Creek where steelhead populations (Table 1) and cobble embeddedness (Table 4) were measured during the late summer and early fall of 1979 (Figure B-l) were marked by driving a two-foot section of one-half inch diameter steel conduit into the ground at the stream edge, but above high water mark, at either the upper or lower end of the section. The top six inches of each marker was sprayed with International Orange paint, and the letters MMWD and a number listed in Column 2 Table B-l of this appendix was stamped along the top edge of each marker. Those sections can be examined in the future to determine how they have changed. The reaches were selected to represent a wide range in habitat quality and their average embeddedness, steelhead populations, or other characteristics would not necessarily represent the average of all Lagunitas Creek.

Future investigators wishing to find each section are advised to locate the closest highway marker on Sir Francis Drake Boulevard (Table B-l, Column 5), and then walk along the highway either up or downstream to position themselves at the actual highway mileage described in Column 6. The steel pipe, with the orange top, marking each section will be found near the streambank opposite that point. Column 7 describes whether the pipe marks the upstream or downstream end of the section, and whether it is found on the left or right bank looking downstream. Column 8 provides additional information to help locate the marker.

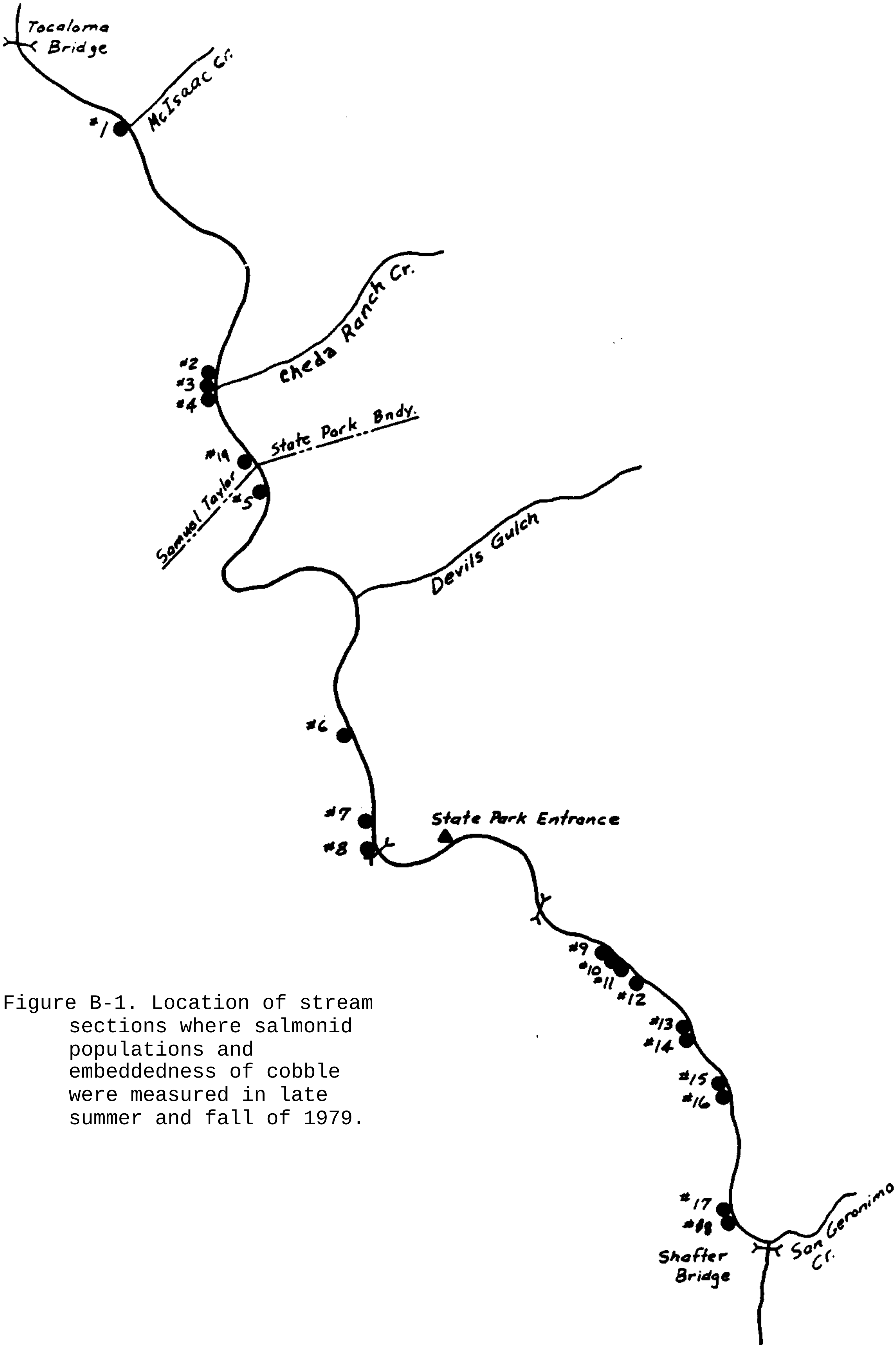


Figure B-1. Location of stream sections where salmonid populations and embeddedness of cobble were measured in late summer and fall of 1979.

Table B-l. Location of sections where steelhead populations and embeddedness of cobble were measured in late summer and fall of 1979, Lagunitas Creek, Marin County, California.

Station Number	Peg No.	Character	Approx. Location	Closest Hwy. Marker	Actual Hwy. Mileage	Monument/Station* Reference		Notes on Monument Location
						End	Bank	
1	10	Glide	Taylor Park	16.21	16.20	U	L	In base of 6' rdwd tree, 8' above channel
2	11	Glide	Taylor Park	16.21	16.19	D	L	3' above channel
3	2	G /R	Near Cheda Ranch Cr.	19.20	19.20	D	R	2' above channel
4	3	Glide	Near Cheda Ranch Cr	19.17	19.17	D	R	7' above channel adjacent to forked alder tree
5	4	Glide	Near Cheda Ranch Cr	19.17	19.15	D	R	At base of 3' alder downstream side of tree. next tree upstream with PG&E tree archer and steel cable
6	1	G /Pool	Tocaloma	20.13	20.14	D	R	Adjacent to alder downstream from small right hand tributary through McIsaac's property 15' above channel, at base of 3' rdwd stump
7	16	Glide	Taylor Park	15.61	15.57	U	L	
8	8	Glide	Taylor Pk. Campgrd	. 17.24	17.25	D	L	Below bridge in campground
9	12	Riffle	Taylor Park	16.09	16.14	U	L	30' above channel
10	15	Riffle	Taylor Park	15.61	15.63	U	L	10 above channel, 45' below hywy road shoulder
11	14	Riffle	Taylor Park	15.86	15.90	U	R	20' above channel, at base of 8' clumped rdwd
12	18	Riffle	Betwn Taylor Park sign & Shafter Bridge	15.32	15.35	D	L	15' above channel, at base of 5' rdwd tree
13	17	Riffle	Taylor Park	15.38	15.39	U	L	12' above channel, base of 1.5' crooked rdwd
14	19	Riffle	Jewell	18.90	18.91	U	R	12' above channel, base of 2' alder just downstream of road culvert
15	5	Riffle	Jewell	18.76	18.77	D	R	12' above channel in riprap
16	6	Riffle	Taylor Park	17.64	17.57	D	L	25' above channel, 15' from base of alder direct across stream from knob of bedrock & apple orch.
17	7	Riffle	Taylor Park	17.32	17.35	U	L	8' abv channel, below camp #2 in State Park
18	9	Pool	Taylor Park	16.21	16.21	U	L	15' abv channel, just upstream from bedrock knob
19	13	Pool	Taylor Park	15.86	15.88	D	R	20' abv channel

* End: U = upstream; D = downstream. Bank: L = left bank looking downstream; R = right bank looking downstream.