RAINBOW TROUT FISHERY AND SPAWNING STOCK IN THE UPPER KLAMATH RIVER WILD TROUT AREA, COPCO, CALIFORNIA

by

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A Thesis
Presented to
The Faculty of Humboldt State University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

December, 1984

ABSTRACT

The rainbow trout fishery in the Upper Klamath River Wild Trout Area was examined in 1981 and 1982. In the spring of 1982, 281 mature rainbow trout were trapped at the mouth of Shovel Creek, the only known spawning tributary to the area. Males were 78 percent age two and females were 89 percent age three. Less than 10 percent of the upstream migrants had scale checks indicating prior spawning and less than 10 percent were recaptured as spent downstream migrants. Spawning success could have been limited by a lack of suitable spawning gravel, dewatering of redds from irrigation diversions, and fine sediments in the redds (13 percent of redd volume less than 0.85 millimeters in diameter) possibly from logging and cattle grazing in the area. The 1982 spawning produced a year class estimated to contribute a maximum of 32,903 fish to the Upper Klamath River. Most emigrated at age 0, and the few older fish rearing in Shovel Creek had slower growth than spawners or creeled fish. Rainbow trout creeled in the Upper Klamath River Wild Trout Area were primarily age one and two, with yearlings entering the fishery in late July. Creeled fish were significantly larger than spawners at back-calculated ages one ($p < 0.05$) and two ($p < 0.01$). Catch averaged 0.5 rainbow trout per hour; average fork length was 240 millimeters. Juvenile

steelhead stocked in Copco Reservoir (31,000 to 100,312 yearly in 1978 to 1980) possibly contributed to the Upper Klamath River Wild Trout Area creel and/or the Shovel Creek spawning run.

ACKNOWLEDGEMENTS

David Rogers of the California Department of Fish and Game provided invaluable field assistance and guidance in this project. I am especially grateful for his construction and installation of weir and traps. The California Department of Fish and Game also provided equipment and financial support for the field work. The United States Fish and Wildlife Service supplied additional equipment and office space.

I am grateful to the members of my committee for their time. Dr. Thomas Hassler provided encouragement and ideas throughout my research. Dr. Terry Roelofs gave supportive interest in the results of the research, and Dr. George Allen contributed helpful editorial comments.

Deserving of special thanks is Dr. David Hankin for his advice in analyzing the data. Patrick Collins and Nancy Diamond provided computer programs and assisted in their use.

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INTRODUCTION

California offers a wide variety of fishing experiences, including Wild Trout Areas where the emphasis is on maintaining wild stocks of fish in natural areas (Gerstung, 1975). Wild Trout areas require careful management to prevent reduction of the stocks from overharvest and habitat degredation.

In 1978, the California Department of Fish and Game began preparing a management plan for a designated Wild Trout Area on the Upper Klamath River. In 1980, the Department decided that to plan effectively, it required more detailed knowledge about fish populations and habitat conditions in the area. Past management had relied primarily on five limited creel censuses conducted on the Klamath River from 1974 to 1978 (Rogers, 1978). Shovel Creek was the only known spawning tributary to the Klamath River between John Boyle Dam and Copco Dam. Knowledge about the spawning run in this tributary was limited to data from an egg taking station that was operated from 1889 to 1912 and 1929 to 1934 (Calif. Dept. of Natural Resour., 1941; Calif. State Board of Fish Comm., 1892,1894), 1951 and 1952 opening day creel censuses on Shovel Creek (Coots, 1952), and spot electroshocking in 1976 and 1978 (Rogers, 1978). Insufficient spawning gravel was assumed to be a limiting factor in Shovel Creek, but this had not been substantiated (D. Rogers, California Department of Fish and Game, Yreka, California 96097).

Reported here are the results of a study, conducted from June to December 1981 and April to November 1982 on the Upper Klamath River Wild Trout Area and the associated spawning stream (Shovel Creek). Objectives of this study were to collect data on the life history characteristics of trout in Shovel Creek and examine factors limiting spawning in the creek. Of special importance was the relationship of the current spawning run in Shovel Creek to the Klamath River wild trout fishery, and the potential for improving Shovel Creek as a spawning area.

Specific objectives of the study were formulated to be:

1. Determine the number, size, age, and sex of the spawning trout population in Shovel Creek.
2. Compare age and growth of the spawning population to that of fish creeled in the Wild Trout Area.
3. Determine the dispersal of trout from the Shovel Creek spawning population and contribution to the Wild Trout fishery.
4. Determine the quantity and quality of spawning habitat in Shovel Creek.

STUDY AREA

The Upper Klamath River Wild Trout Area, located 49 kilometers north-east of Yreka, California, extends from the Oregon Border to Copco Reservoir, California (Figure 1). John Boyle Dam, 40 kilometers above the border, influences the water level in the Wild Trout Area.

Shovel Creek enters the Klamath River approximately 4.8 kilometers below the Oregon border at 814 meters elevation (Mount Diablo base and meridian, R3W, T47N, Section 27), and originates on the east slope of Willow Creek mountain (2388 meters elevation) in the central part of R3W, T46N, MD&M. The stream is 20.3 kilometers long (21.3 kilometers intermittant) and drains 142 square kilometers of the Casade Range which is composed of igneous rock. About twenty percent of Shovel Creek is controlled by the U.S. Forest Service, and there are numerous timber clearcuts in the headwater areas (Upper Klamath River file, Calif. Dept. of Fish and Game, Yreka, California 96097).

Stream discharge is primarily from precipitation and snow-melt. Winter and spring flooding is common, with flows probably reaching three to five cubic meters per second. Several perrenial springs agument the flow, but irrigation diversions in the lower two kilometers

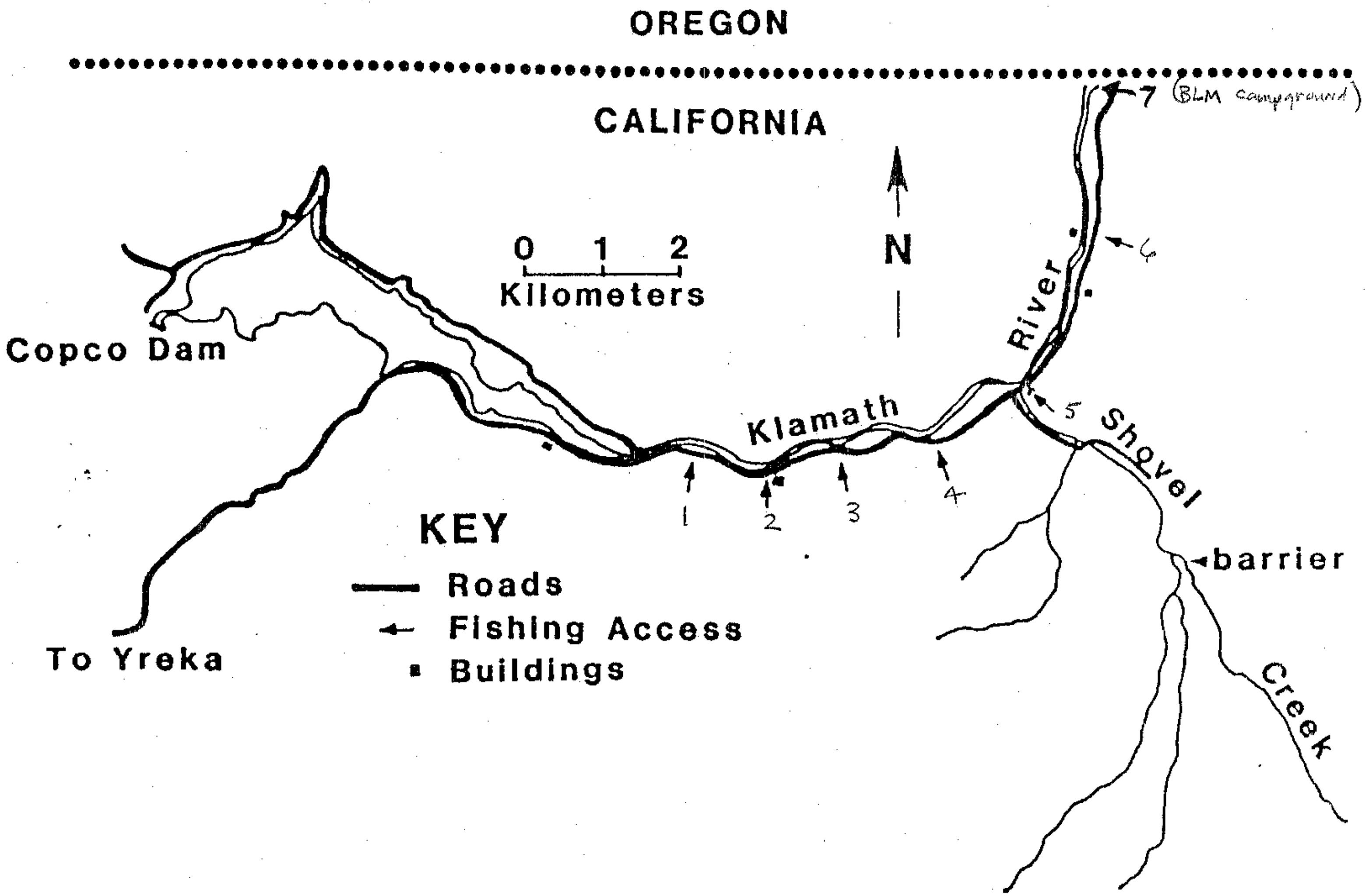

Figure 1. Upper Klamath River Wild Trout Area.

can reduce the flow at the mouth to 0.05 cubic meters per second in summer (Upper Klamath River file, Calif. Dept. of Fish and Game, Yreka, California 96097).

Study of Shovel Creek was confined to 3.2 kilometers of the stream, from the mouth upstream to a barrier falls. Most work was on the lower 2.4 kilometers, because of its accessibility to vehicles. From the falls downstream 1.6 kilometers, the stream drops 89 meters and from there to the mouth another 48 meters. The area typically has wet winters and dry summers. Average yearly rainfall at Copco Dam is 41.38 centimeters (Calif. Dept. of Water Resources, 1963). The air temperature ranges from -15 to 35°C (Rogers, 1978). According to Rogers (1978), vegetation includes "yellow pine" (*Pinus* sp), "black oak" (*Quercus kelloggii*), "alder" (*Alnus* sp), "willow" (*Salix* sp), and chaparral. The lower sections of the study area are surrounded primarily by pasture.

The study area is leased by the Pacific Power and Light Company to a rancher, whose cattle graze freely in the pasture and have access to the stream.

MATERIALS AND METHODS

Field Procedures

Spawners

In April 1982, a weir with up and down stream traps was placed across Shovel Creek, 60 meters above the mouth (Figure 2). Mesh in the weir captured all migrating fish greater than 30 millimeters in fork length. Traps were checked at least once per day from April until July. The trout were counted, sexed, measured (fork length), weighed, and examined for state of sexual maturity. Scale samples were taken from every available class (10 millimeter fork length increments) to a maximum of ten trout in each class. Scales were removed from the left side of the fish, below the dorsal fin and close to the lateral line (Chugunova, 1963). All upstream migrating trout were marked by removing the adipose fin. All downstream adult migrants trapped were examined for presence or absence of the adipose fin. Most of the healthy spent-fish recovered in the downstream trap were tagged with California Department of Fish and Game five-dollar-reward "trailer tags", described by Nicola and Cordone (1969). Trapping efficiency was checked in late April by electroshocking sections of the stream above the trap to determine the

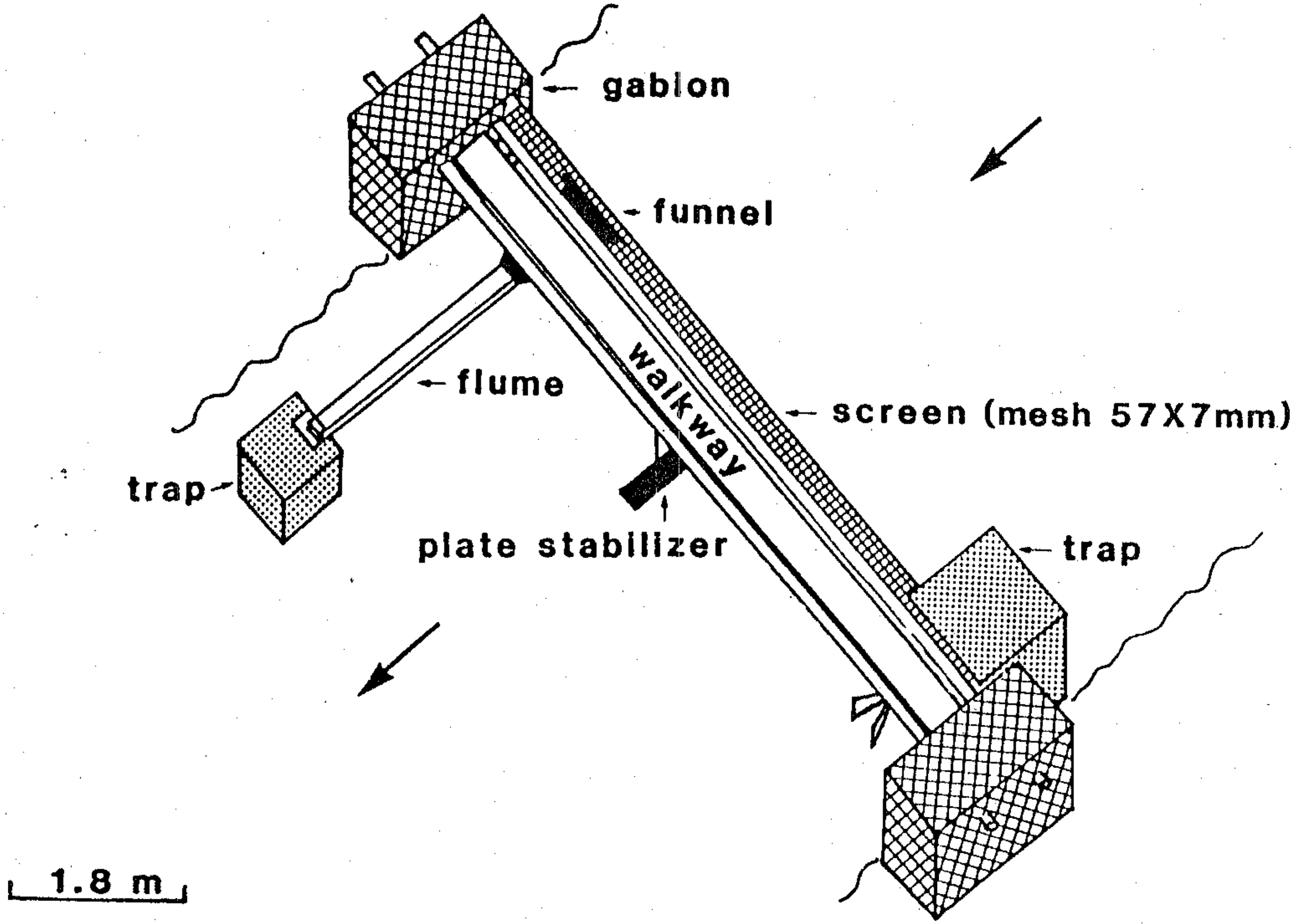

Figure 2. Weir on Shovel Creek with Upstream and Downstream Traps.

ratio of marked to unmarked adult trout. In late July, sections of stream were electroshocked to determine the number of adult fish not migrating from the stream. In July, scales were taken from electoshocked fish over 70 millimeters in fork length.

Habitat and Redd Map

In August 1981, I outlined a map of the lower 2.4 kilometers of Shovel Creek. I started at the mouth and placed numbered rebar stakes on alternate banks, about 60 meters apart. I measured distance and compass direction from the last stake and to the opposite bank, using a measuring tape and transit with compass. From these measurements, a diagram of the stream was made. Based on the developed map, I divided the stream into four 610 meter sections, numbered sequentially from the stream mouth.

During high water in the winter of 1982, the lower sections of the stream changed substantially and stakes washed out. These sections were remapped in April 1982.

From April to June 1982, I surveyed the lower 2.4 kilometers of the stream for redds, marking their locations on the map. Redd size and the depth and velocity (0.12 meter from the bottom) of the water immediately upstream of the redd was recorded. I measured depth and velocity of the water with a pygmy current meter (W.L.E. Gurely, Teledyne Co., Troy, New York).

Habitat Quality

Temperature, water quality, and water flows were measured at the weir from April to November 1982. The first two weeks, water temperature was measured with a pocket thermometer, one to two times per day, after which temperature data was available from a recording thermograph. Water quality was tested one to four times per month. The Portable Ecology Combination Kit (Model AL-36DT, Hach Chemical Co., Ames, Iowa) was used to determine pH, dissolved oxygen, alkalinity, and hardness. Phosphates were measured with an Orthophosphate Test Kit (Model PO-19, Hach Chemical Co., Ames, Iowa). Flows were measured one to four times per month on a transect just upstream of the weir, using a current meter (Price AA, Teledyne Co., Troy, New York). Flows were also measured at the head of the diversions in mid June, using a pygmy meter.

Spawning gravel quality was evaluated from McNeil gravel samples in five of the frequently used spawning areas (McNeil and Ahnell, 1964). Surface gravel size was visually estimated. All areas of stream large enough to accommodate at least one average sized redd, and containing gravel in the visually determined size range (6.35-76.2 millimeters) were measured and marked on the map.

Rearing habitat was evaluated in late September by analyzing one stream segment in each of the four stream sections. These segments were 15 to 46 meters in length. They were selected for accessibility and for having the water depth, water velocity, and stream bottom substrate generally observed in the section they represented. Each segment was subdivided into shorter segments, based on habitat similarity. In each subdivision, substrate composition and pool:riffle ratio (surface area of pools/surface area of riffles) was estimated, and water depth and velocity were measured at 15 to 30 points across a central transect.

Immature Fish

Outmigrating age-0 fish were trapped beginning late July 1982. The weir was covered with plastic sheeting, and two downstream fry traps were inserted. When the traps could not be serviced, they were removed and fish passed through the weir. Trapped fish were counted and measured, and scales were taken from all fish over 70 millimeters in fork length. Weights and scales were taken on random days from all fish trapped.

Instantaneous estimates of fry populations were made using the Seber and Le Cren (1967) two-pass-method of population estimation by electroshocking. Two Shovel

Creek stream segments were shocked in July, and the four representative segments selected for habitat analysis were shocked in September. Scales were taken from all electroshocked trout over 70 millimeters in fork length.

Creel Census

A creel census of fishermen in the Upper Klamath River Wild Trout Area was conducted in 1981 and 1982. Up to four weekend days and four weekdays per month were selected by stratified random sample for creel censusing. In 1982, holiday weekends were also sampled. On creel census days, fishermen were requested to stop upon exiting the area. Fishermen catches were counted and measured. Some trout weights and scale samples were taken. The fishermen's county of residence, stream section fished, hours fished, methods used, and fish returned to the stream were recorded.

Scale Analysis

Scales were soaked in soapy water for one to two days, rinsed and observed with a dissecting scope. The six best scales from each fish were mounted between two microscope slides. Scales were examined with a Realist Vantage I microform reader at 58X magnification. On each slide, one scale was selected for average size, symmetry, and readability. Measurements were made along the anterior median radius of the projected scale

(Bagenal and Tesch, 1978). Scales from a maximum of ten randomly selected fish in each 10 millimeter fork length increment were used in body-scale regressions. Scales were examined twice, two days apart. The second examination was made without knowledge of the first reading. If the two readings did not agree, an opinion was obtained from another reader. If no agreement could be reached, the fish was not aged.

Mean width between circuli was determined by dividing the scale radius distance between annuli or between focus and annulus, by the number of the circuli in that segment.

Data Analysis

Humboldt State University Program Package GROWTH, developed by Collins (1977) was used to compute length frequencies, length-weight:

$$\text{log weight} = \text{log } a + b(\text{log length}), \qquad (1)$$

where log a was the intercept and b the regression coefficient of the linear regression of log length on log weight, Fulton's (1911) Condition Factor:

$$\text{weight} = 100{,}000/\text{length}^3, \qquad (2)$$

body-scale regression:

$$\text{fork length} = a+b(\text{scale radius}), \qquad (3)$$

where a was the intercept and b the regression coefficient of the linear regression of scale radius on fork length, and back calculations. Back calculations were performed using the Y-intercept of the body-scale regression (a) in the Frazer (1916) and Lee (1920) modification formula

$$L_i = a+((L-a)/S)(S_i) \qquad (4)$$

where L_i was the back-calculated fork length at age i, S_i was the scale radius at age i, L was fork length at capture, and S was scale radius at capture.

Statistical comparisons were made using methods of Sokal and Rohlf (1969). Less than or equal to five percent probability of type one error was considered significant. Linear-regression line comparisons were made with F-tests. Comparisions between mean circuli width and back calculated lengths were made with t-tests. Comparisons of back calculated lengths between mature migrants, 1981 creeled fish, and 1982 creeled fish were conducted using a pooled mean square within groups. Sex ratios were compared using G-tests.

Age compositions were determined with an interactive computer program which fit preliminary values from the aged subsamples to length frequency histograms (MacDonald and Pitcher, 1979). Chi-square tests were used to ascertain goodness of fit.

Several techniques were used to obtain estimates of population numbers. Minimum population of migrating mature and immature fish was the number of fish actually trapped. The number of mature migrants was also estimated using the standard Peterson population estimate, with Chapman's (1951) modification:

$$n = \frac{\text{(marked fish+1)(recaptured fish-1)}}{\text{(recaptured marked fish+1)}} \qquad (5)$$

Size of the juvenile population in the electroshocked stream segments was estimated using the Seber and LeCren (1967) two catch equation:

$$n = \frac{2\text{(first catch)}}{\text{(first catch-second catch)}} \qquad (6)$$

Each segment estimate was then multiplied by the ratio of stream segment length to the length of the section it represented, to estimate section population. Section populations were summed to determine total stream population. Ninety-five percent confidence intervals were calculated for each section population estimate. Maximum stream population was considered to be the sum of the upper limits of the 95 percent confidence intervals. The maximum number of age-0 fish which emigrated was estimated by adding the maximum stream population, which had the potential to migrate, to an estimate of the maximum number of fish that emigrated before the stream estimate was made. Migration before electroshocking was calculated by multiplying the largest number of fish trapped in one day by the number of days that trapping was not possible, starting on the day that the first fry was noted, and adding this amount to the fish actually trapped during that period.

Rearing habitat (water depth, water velocity, and substrate composition) was summarized for each electroshocked stream segment by averaging values found for each segment, weighted by segment size. Segment areas and volumes (based on average depth) were summed to obtain electroshocked stream section area and volume.

Statistical Package for the Social Sciences, (SPSS; Nie et al., 1975) was used to computer tabulate creel census data. Estimates of catch and hours were calculated from the stratified random samples according to Scheaffer et al. (1979).

RESULTS

Mature Fish

Time of Migration

Adult trout migrating upstream were taken within hours of installation of the fish trap on March 31, 1982. No further migration was recorded until April 9, when two fish were captured. On April 10, a portion of the weir washed out and the upstream trap was inoperative until April 19. The trap operated continuously for the remainder of the study. The subsequent run had two peaks, occurring in late April and mid-May (Figure 3). The run ended on June 15.

Adult out-migrants were first taken on April 6, 1982, immediately after installation of the downstream trap. No other adults were trapped until April 28. The trap was inoperative from April 9 to April 21. Most downstream migration occurred from mid-May until June 10, and out-migration ceased on June 15 (Figure 4).

Size of Migration

A total of 226 67 293 upstream migrants were trapped and adipose fin clipped. Of the 67 outmigrating fish trapped, 12 were adipose marked. These data indicated a

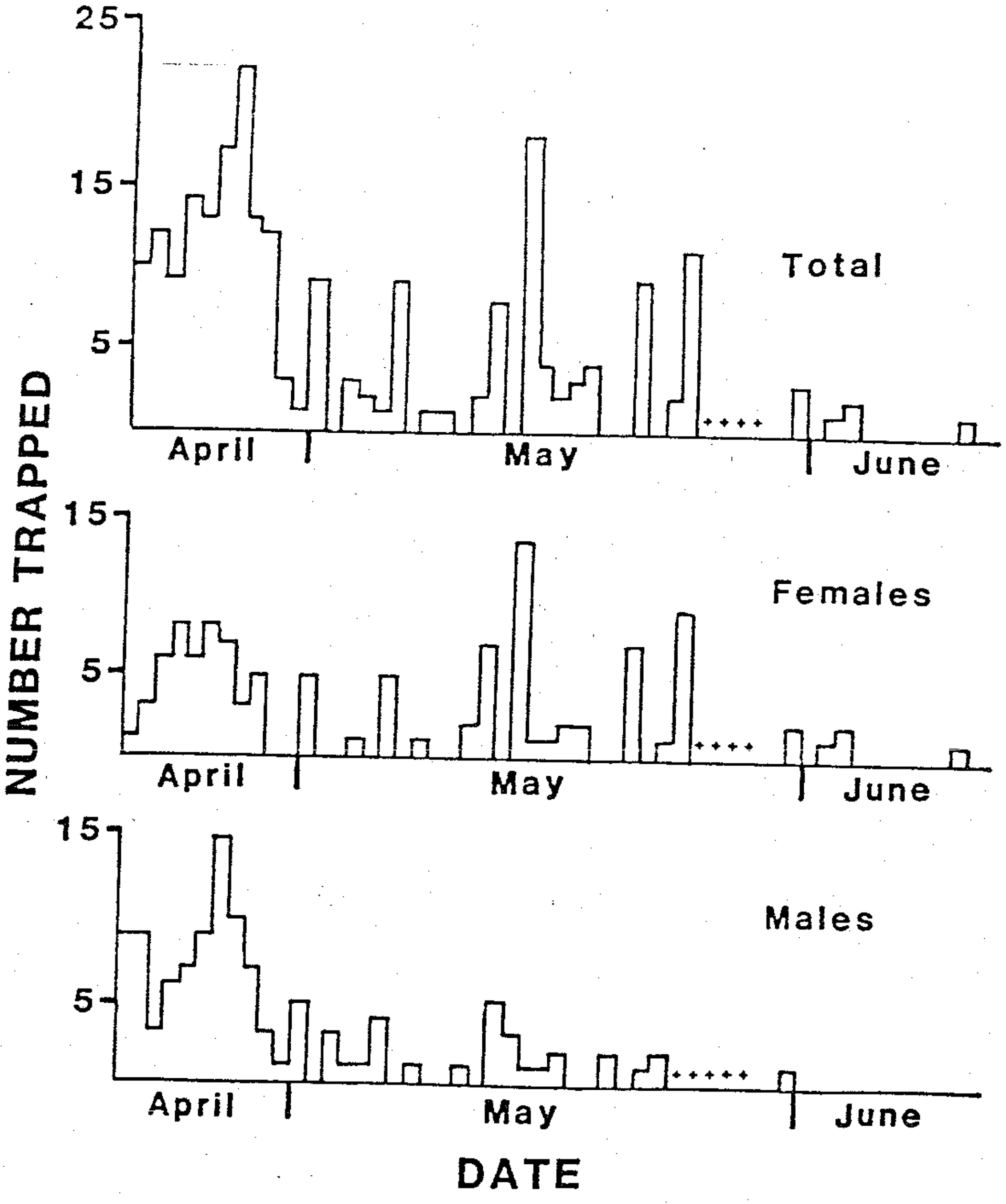

Figure 3. Migration of Spawning Rainbow Trout from Klamath River into Shovel Creek, April 20 to June 10, 1982. (+ indicates trap not sealed)

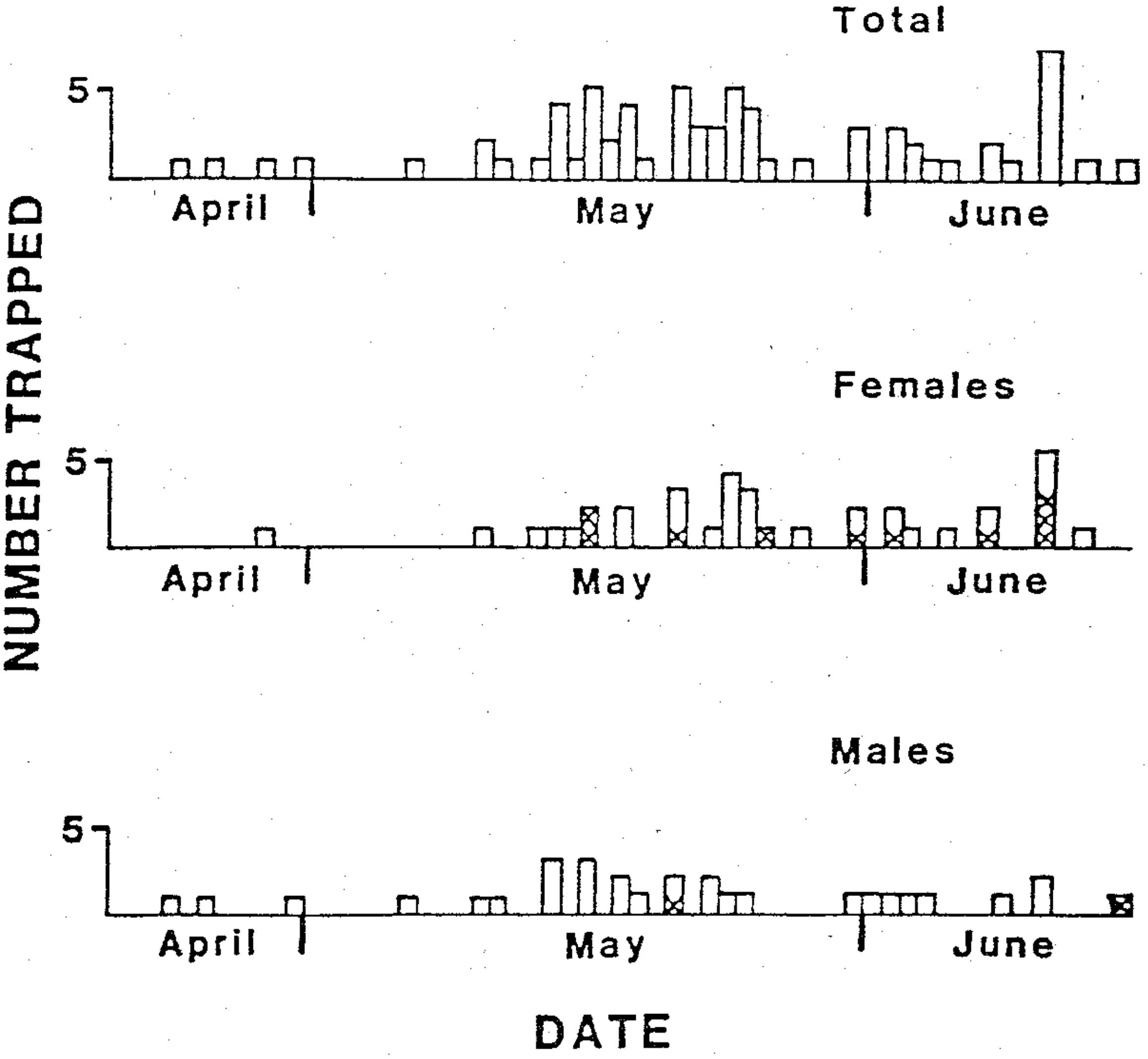

Figure 4. Downstream Migration of Spent Rainbow Trout from Shovel Creek into the Klamath River, April 22 to June 15, 1982. (X indicates an adipose clip)

minimum population estimate of 281 fish (marked fish plus unmarked outmigrants). The standard Peterson population estimate, with Chapman's (1951) modification, was 1187 fish.

Electrofishing population estimation in April was not possible because of high flows, but nine unmarked ripe fish were recovered in 160 meters in Section 1 on April 22 by electrofishing. On April 29, electrofishing Section 4 recovered no ripe fish. Electroshocking in Section 2 and 4 in late July captured unmarked fish up to 194 millimeters in fork length, all apparently immature fish.

Sex Differences

Males tended to migrate up Shovel Creek earlier than females. In April, the male to female ratio was 1.75:1, while in May it was 0.59:1. However, overall sex ratios did not differ significantly from an expected 1:1 ratio. The upstream male to female ratio was 1.05:1 and the downstream ratio was 0.69:1. Nine percent of the marked females and two percent of the marked males were recovered in the downstream trap. Ripe males were brightly colored, often with parr marks, while females had a silvery appearance.

Back Calculated Lengths

The body-scale regression-line equation for all migrating fish, mature and immature, was L=38.11 +

2.92(S)(r=0.97). Back calculated growth for mature fish is in Table 1. Fork length at age was similar for males and females, except at age four, when males were significantly ($p<0.01$) larger than females (Tables 2 and 3).

Length at Age at Capture

The average length at capture was substantially larger than back calculated growth for each age group indicating that some fish had not yet formed an annulus that year (Table 4). Adjusted lengths at capture for the age groups were derived by adding a year in age to each fish with greater than average annual scale growth beyond the last annulus. Average projected scale growth for females was 33 millimeters in year one and two, and 20 millimeters in year three. Average scale growth for males was 27 millimeters in year one and 35 millimeters in years two and three. The age of 24 of the 145 fish was changed, and the resulting adjusted lengths for the age groups at capture were close to backcalculated lengths except at age one (Table 4).

Circuli Spacing

Although circuli spacing for migrants was not measured, it was noted during scale analysis that the distance between circuli increased slightly after the first year of growth. There was no other change in spacing noticed, either between fish or between years.

Table 1. Back Calculated Mean Fork Lengths at Age and Increments of Length for Rainbow Trout in the Shovel Creek, California Spawning Run, 1982.

Group	Number	Annulus			
		1	2	3	4
Age					
1	31	109.5			
2	64	101.9	189.0		
3	38	96.5	192.4	291.5	
4	12	101.7	205.4	299.5	357.6
Lengths					
Average Length		102.1	191.9	293.4	357.6
Standard deviation		18.4	34.7	44.9	41.9
Number		145	114	50	12
Growth increments					
Absolute		102.1	89.8	101.6	64.1
Relative		100.0	87.9	52.9	21.9

Table 2. Back Calculated Mean Fork Lengths at Age and Increments of Length for Male Rainbow Trout in the Shovel Creek, California Spawning Run, 1982.

Group	Number	Annulus			
		1	2	3	4
Age					
1	25	106.0			
2	38	104.0	182.5		
3	6	104.9	206.0	304.4	
4	2	96.1	172.6	313.1	388.8
Lengths					
Average length		104.6	185.2	306.6	388.8
Standard deviation		18.4	32.2	60.6	66.6
Number		71	46	8	2
Growth increments					
Absolute		102.1	89.8	101.6	64.1
Relative		100.0	87.9	52.9	21.9

Table 3. Back Calculated Mean Fork Lengths at Age and Increments of Length for Rainbow Trout Females in the Shovel Creek, California Spawning Run, 1982.

Group	Number	Annulus			
		1	2	3	4
Age					
1	6	124.4			
2	26	98.8	198.5		
3	32	94.9	189.8	289.1	
4	10	102.8	211.9	296.7	351.3
Lengths					
Average length		99.7	196.4	290.9	351.3
Standard deviation		18.7	35.9	41.7	37.3
Number		74	68	42	10
Growth increments					
Absolute		99.7	96.7	94.5	60.4
Relative		100.0	96.9	48.1	20.8

Table 4. Mean Fork Lengths at Capture for Each Age Group of Rainbow Trout in the Shovel Creek Spawning Run, 1982.

	Age Group				
	1	2	3	4	5
Mean	190.5	232.0	336.1	381.6	
Standard deviation	24.3	58.4	54.3	46.9	
Number	31	64	38	12	
Adjusted Mean	182.3	202.5	305.6	368.3	447.0
Standard deviation	30.7	37.2	40.5	49.4	41.0
Number	9	68	39	26	2

Repeat Spawning

Spawning checks were noted on four males (five percent) and seven females (nine percent).

Length-Frequency and Age Composition

Fork lengths of fish trapped ranged from 140 5.5" millimeters to 22.4" 570 millimeters, averaging 268 10.6" millimeters (standard deviation = 83). Males were smaller than females, averaging 8.9 226 millimeters in fork length (standard deviation = 76), compared to an average of 305 millimeters (standard deviation = 63) for females (Figure 5).

In fitting the aged subsample to the length frequency histogram, back calculated lengths and lengths at age at capture (adjusted and unadjusted) were tried as preliminary values. The best fit (Chi-square = 33.3, df = 31) was obtained from the adjusted lengths at age at capture, with the mean length at age one held fixed. The resulting age class composition was 37 percent age two, 53 percent age three, seven percent age four, and three percent age five (Table 5). Males were 78 percent age two and females were 89 percent age three (Table 5).

Length and Weight

The length-weight relationship for upstream migrants was $W=0.000005(L^{3.133})$; for downstream migrants

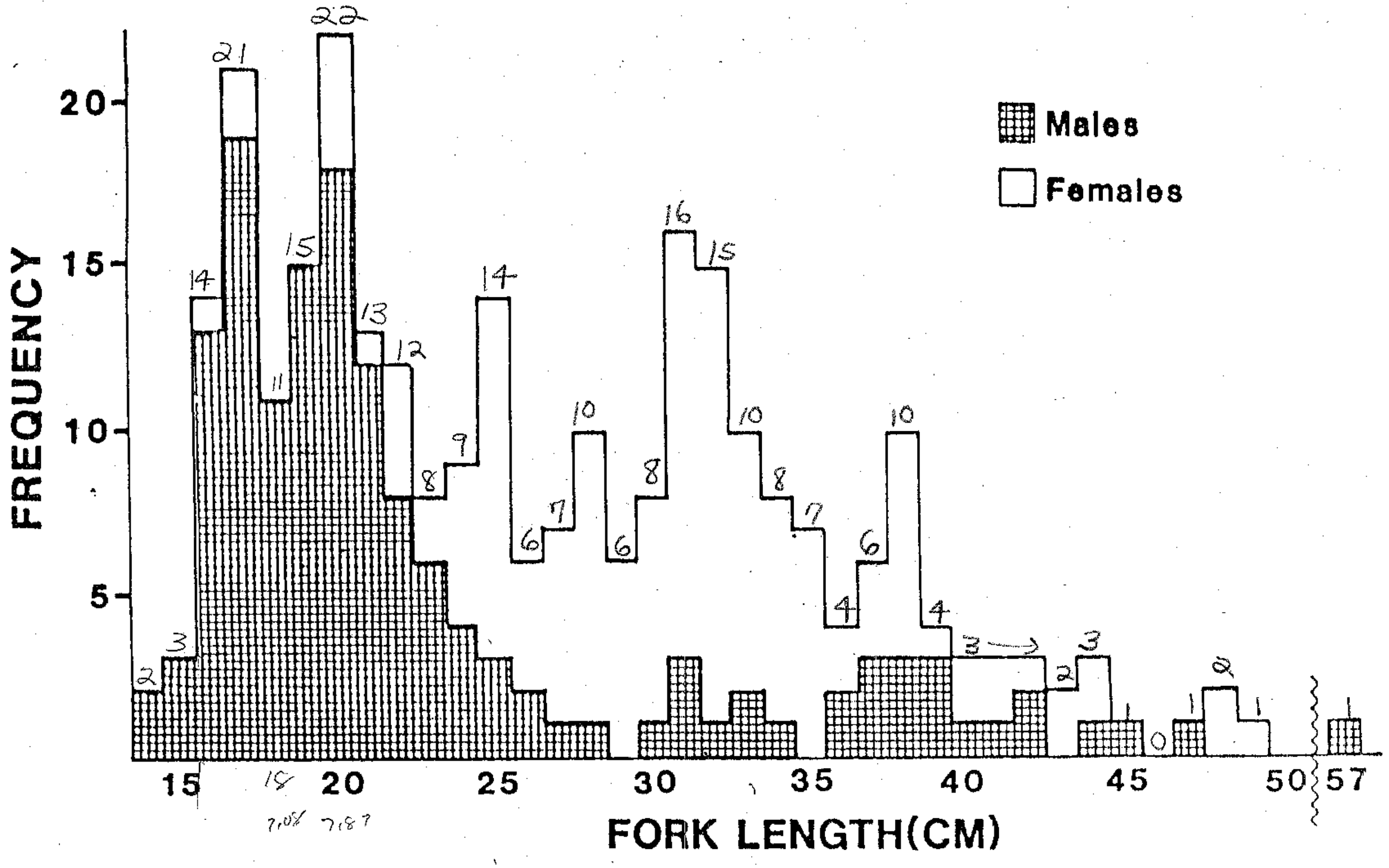

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Figure 5. Length Distribution of Mature Rainbow Trout Trapped in Shovel Creek, 1982.

Table 5: Fit of Adjusted Lengths at Capture to Length Frequency Histograms of Mature Migrants into Shovel Creek, California, 1982.

Statistic	Age 2	Age 3	Age 4	Age 5	Chi-square (df)
Males					25.2
					(30)
Proportion	0.781	0.063	0.144	0.012	
(S.E.)	(0.04)	(0.06)	(0.06)	(0.02)	
Mean (mm)	196.4	302.8	371.4	444.8	
(S.D.)	25.9	59.5	49.4	41.0	
Females					37.9
					(30)
Proportion	0.021	0.885	0.040	0.054	
(S.E.)	(0.02)	(0.09)	(0.11)	(0.04)	
Mean (mm)	186.6	305.6	371.4	444.8	
(S.D.)	30.3	51.5	59.5	49.4	
Total					33.3
					(31)
Proportion	0.373	0.531	0.065	0.030	
(S.E.)	(0.15)	(0.06)	(0.06)	(0.02)	
Mean (mm)	186.6	302.8	371.4	444.7	
(S.D.)	28.7	59.5	49.4	41.0	

it was W=.000007($L^{3.057}$). The mean condition factor was 1.21736 upstream (standard deviation = 0.32754), and 1.02144 downstream (standard deviation = 0.18223).

Immature Fish

Time of Migration

Age-0 fish out-migration apparently peaked in late summer (Figure 6). Age one and older fish migrated downstream earlier, with 93 percent trapped from April to June.

Number of Out-migrants

The minimum population estimate for outmigrating age 0 fish was the 2,750 actually trapped. The estimate of the maximum number of outmigrating age 0 fish was 32,903 fish, obtained by adding the September 16 upper limit electroshocking estimate of the stream population (20,123) to the maximum estimate of the number of fish that had migrated out before September 16 (12,780). The prior migration estimate was derived using June 10 as the day when the first fry was noted and 180 fish as the maximum trapped in one day. The number emmigrating to the Klamath River was reduced by migration into the irrigation ditches. Those fish were observed stranded and dying when the ditches were closed in October.

The number of age one and older immature fish trapped from April to November was 104. The study area

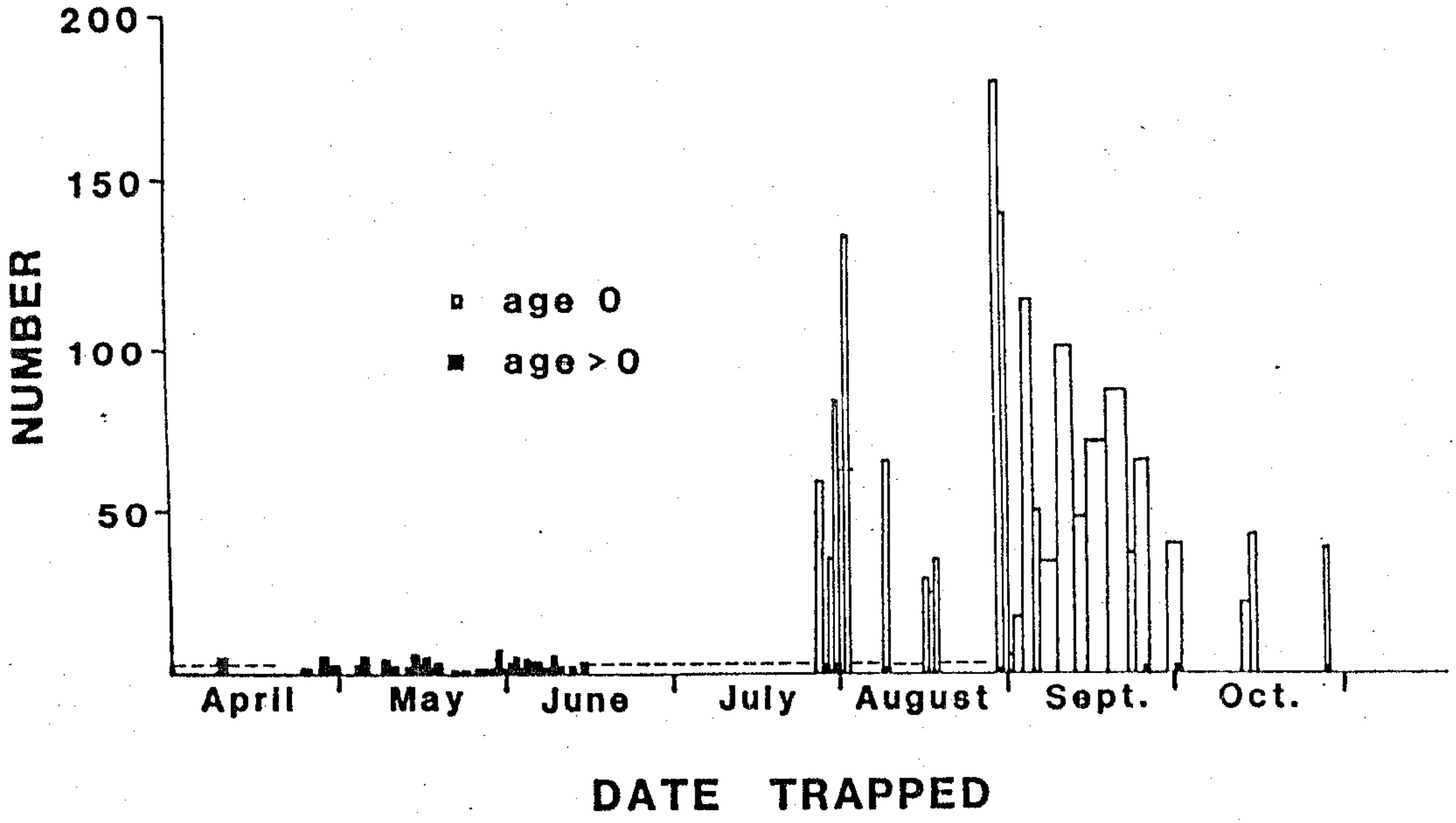

Figure 6. Downstream Migration of Immature Rainbow Trout from Shovel Creek into the Klamath River, 1982. (--- indicates trap not operational)

stream population of older fish estimated July 28 by the Seber and LeCren (1967) two pass method, was 174 fish.

Back Calculated Lengths

Tables 6 and 7 show back calculation results for trout sampled by trap and electrofishing. There was no significant difference in body-scale regression lines between the samples. The migrant fish (mature and immature) y-intercept was used to back calculate lengths for both groups because it was based upon the widest size range of fish. There was no significant difference in growth between the two groups. However, both had slower growth than the mature migrants and creeled fish (Figure 7).

Length-Frequency and Age Composition

Fry emergence from gravel occurred for at least three weeks. Yolk sac fry were still found in the gravel on June 26. Fork length at emergence was approximately 20 millimeters. Average length of age-0 outmigrants increased about 10 millimeters per month from July to November (Figure 8).

The majority of fish, both electroshocked (97 percent) and trapped (96 percent), were age-0. The older fish captured by electroshocking were 61 percent age one, 36 percent age two, and three percent age three. The older fish trapped from April until July were 75 percent age one and 25 percent age two

Table 6. Back Calculated Mean Fork Lengths at Age and Increments of Length for Immature Rainbow Trout Electroshocked in Shovel Creek, California, July and September, 1982.

Group	Number	Annulus		
		1	2	3
Age				
1	17	85.6		
2	10	75.1	117.3	
3	1	87.9	121.0	180.7
Lengths				
Average		81.9	117.7	180.7
Standard deviation		12.0	10.2	
Number		28	11	1
Growth increments				
Absolute		81.9	35.7	63.1
Relative		100.0	43.6	53.6

Table 7. Back Calculated Mean Fork Lengths at Age and Increments of Length for Immature Rainbow Trout Trapped Emigrating from Shovel Creek, California, 1982.

Group	Number	Annulus	
		1	2
Age			
1	24	76.7	
2	4	81.6	124.7
Lengths			
Average		77.4	124.7
Standard deviation		21.3	18.4
Number		28	4
Growth increments			
Absolute		77.4	47.3
Relative		100.0	61.0

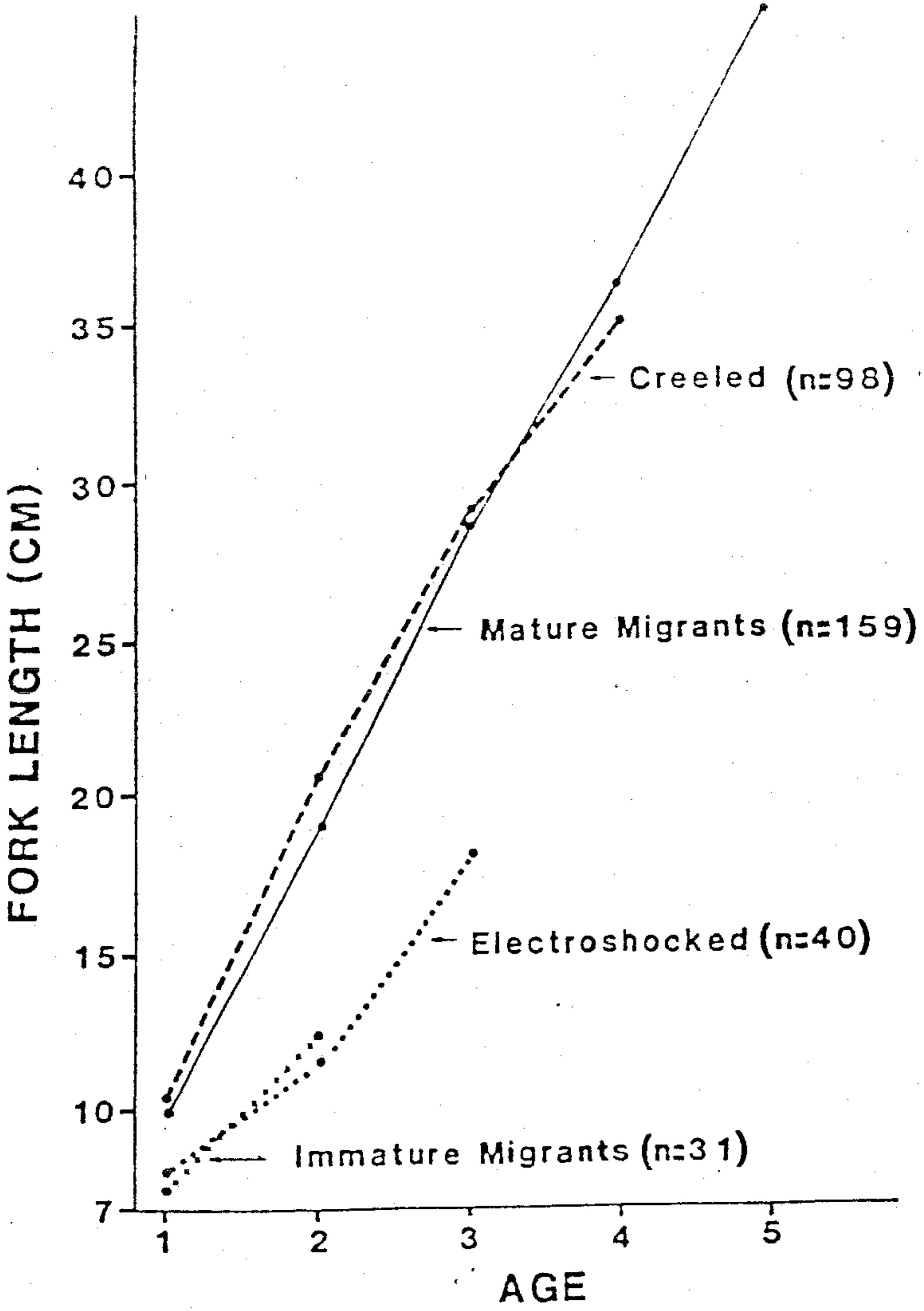

Figure 7. Growth in Length of Shovel Creek Migrants and Creeled Fish, Based on Mean Back-Calculated Lengths at Annulus Formation.

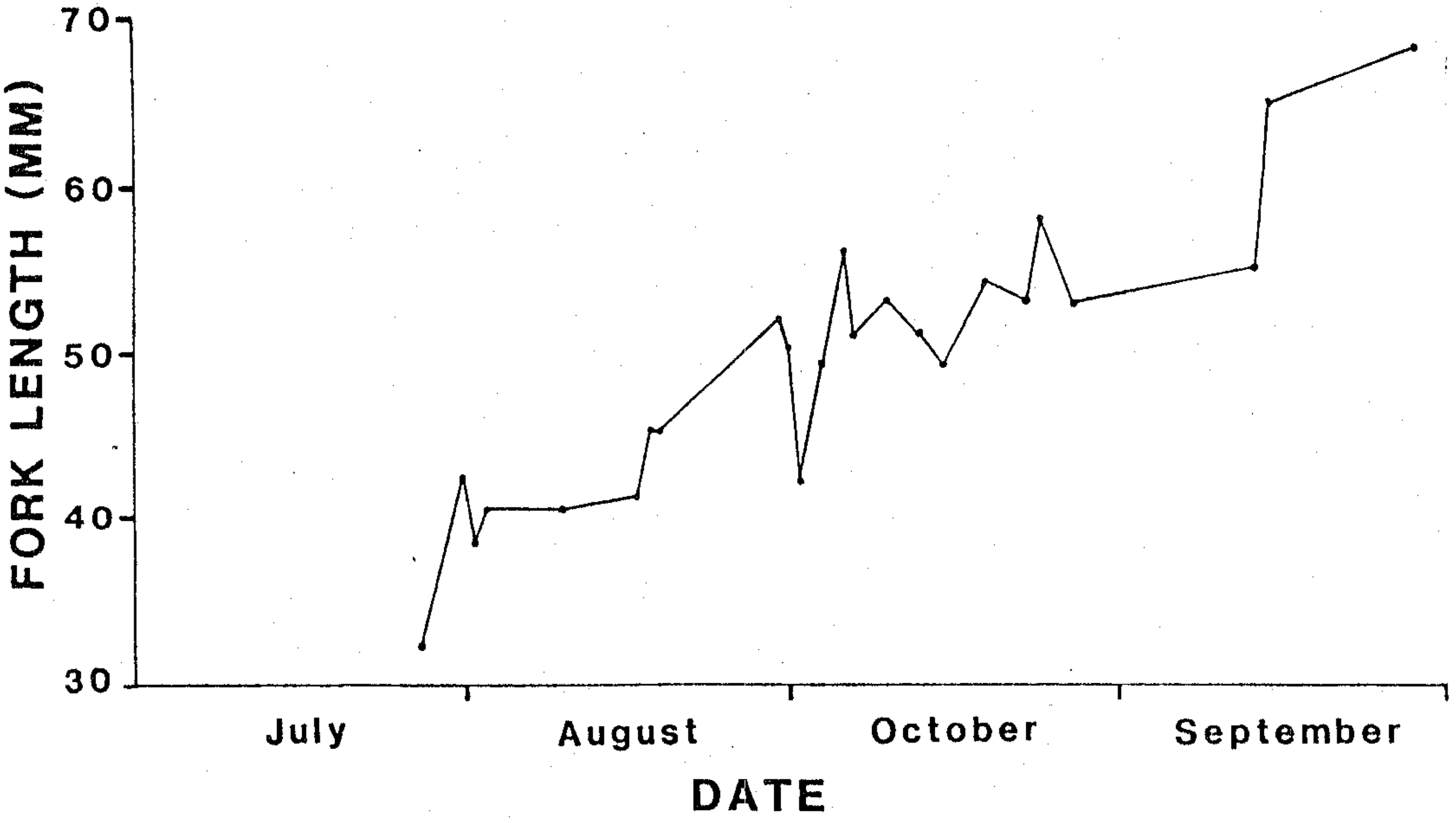

Figure 8. Average Fork Length of Age-0 Emigrants Trapped Near the Mouth of Shovel Creek, California, 1982.

(Chi-square = 17.0, df = 10). The older fish age composition was determined by fitting back calculated lengths to the length frequency histogram (Figure 9), with age two held constant.

Condition Factor

The average condition factor for immature fish migrating from April to June was 1.007 (standard deviation = 0.333). In late summer, between September and October, it averaged 1.025 (standard deviation = 0.332, n = 151).

Comparison by Stream Section

The number of age-0 fish in the electroshocked segments, and their average fork length, tended to decrease with distance from the stream mouth (Table 8). Age one and older fish were present only in Section 2 and 4, and Section 3 had the lowest total biomass of all immatures (Table 8).

Creeled Fish

Back Calculation

Because there was no significant difference in the body-scale regression lines over comparable fish length for creeled fish and mature migrants, the migrant (mature and immature) y-intercept, which was based on a wider length range, was used to back calculate lengths of the creeled fish. There was no significant

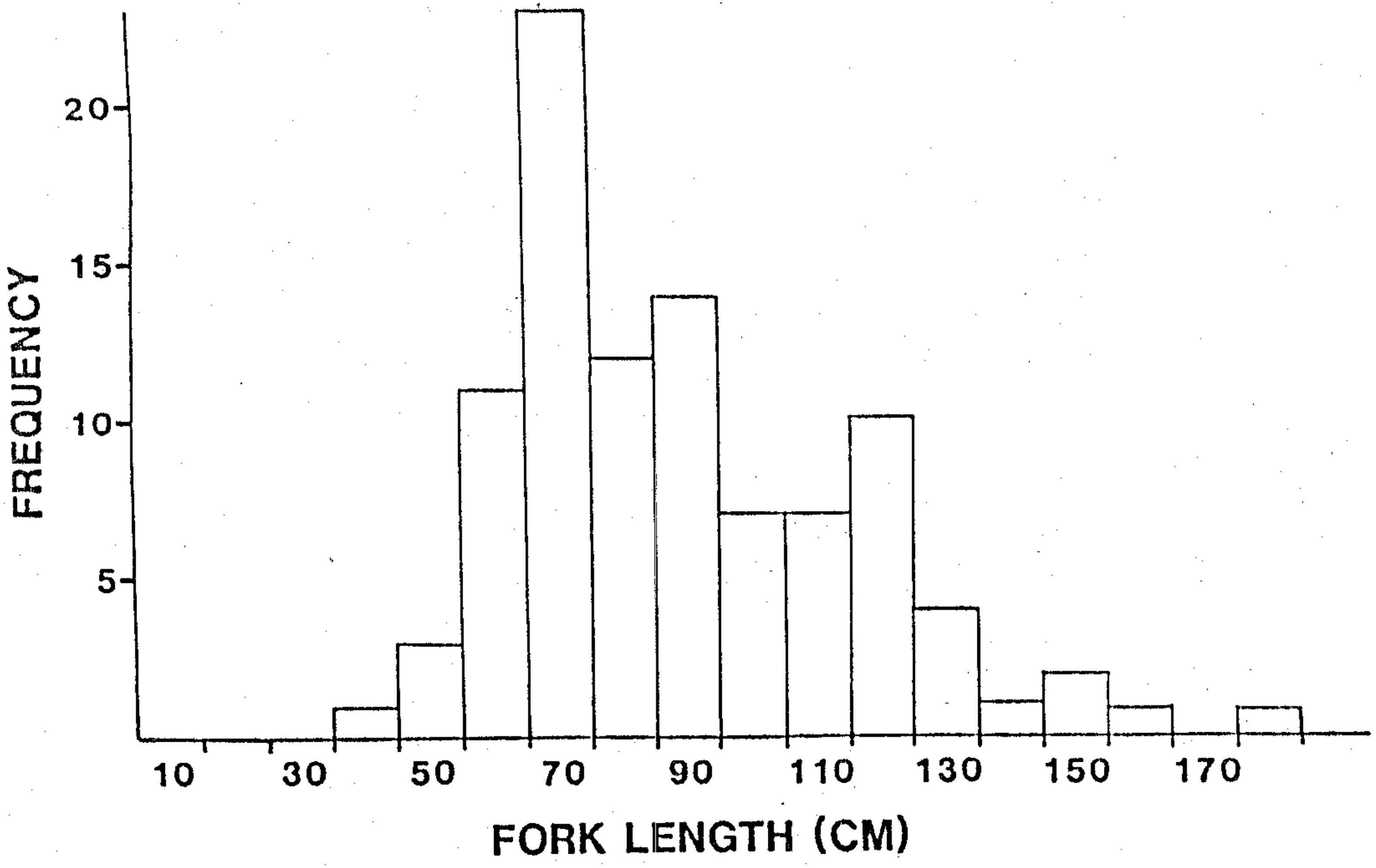

Figure 9. Length Frequency of Immature Rainbow Trout Trapped Out-Migrating from Shovel Creek, California, April to July, 1982.

Table 8. Electroshocked Rainbow Trout in Representative Sections of Shovel Creek, California, September, 1982. Mean numbers, fork lengths(mm), and biomass(g) (95 percent confidence intervals in parentheses).

	Section			
	1	2	3	4
Age-0				
Number/m^2	1.5 (1.2-1.7)	1.6 (1.1-2.0)	0.6 (0.5-0.6)	0.4 (0.3-0.5)
Number/m^3	12.8 (10.6-14.8)	5.1 (3.7-6.5)	4.2 (3.7-4.7)	1.7 (1.3-2.1)
Fork Length	58 (36-80)	52 (28-76)	50 (24-76)	48 (22-74)
Total				
Biomass/m^2	4.0 (3.6-4.4)	9.4 (7.8-11.0)	1.6 (1.5-1.7)	5.9 (5.7-6.0)
Biomass/m^3	34.9 (31.5-38.3)	30.9 (25.8-36.0)	12.6 --	23.0 --

difference between 1981 and 1982 creeled fish in back calculated growth, so years were combined (Tables 9 and 10). There was also no significant difference in first year growth of the 1981 and 1982 yearlings. The creeled fish were, however, significantly larger than the mature migrants at age one ($p<0.05$) and age two ($p<0.01$).

Circuli Spacing

Yearlings had similar first year circuli spacing in 1981 (1.7 per millimeter) and 1982 (1.8 per millimeter). All the 1982 yearlings had evenly spaced circuli with wider spacing in the second growing season. Twenty-five percent of the 1981 yearlings had uneven spacing, with no widening of spacing after the first annuli.

Length-Frequency and Age Class Composition

Fish caught in 1981 and 1982 were of the same average size: 9.4 236 millimeters (standard deviation = 47.3) and 9.5 242 millmeters (standard deviation = 47.0) respectively. The fork length distribution of the combined catches had a mode of 210-220 millimeters, and a mean of 239 millimeters (standard deviation = 47.2). Length-frequency distribution of the catch changed as the fishing seasons progressed, with the mode at increasingly smaller fork length with time (Figure 10).

The April and May length-frequency histogram, fitted to back calculated lengths, indicated an age

Table 9. Back Calculated Mean Fork Lengths at Age and Increments of Length of Rainbow Trout Creeled in Klamath River Wild Trout Area, California, 1981 and 1982 combined.

Group	Number	Annulus			
		1	2	3	4
Age					
1	38	109.0			
2	41	106.8	207.8 8.1"		
3	14	100.6	214.3	287.1 (11.3")	
4	5	116.6	201.7	272.2	350.8 (13.8")
Lengths					
Average		107.6	208.8	283.1	350.8
Standard deviation		17.4	37.0	34.9	18.5
Number		98	60	19	5
Growth increments					
Absolute		107.6	101.2	74.3	67.7
Relative		100.0	94.1	35.6	23.9

950.3

Table 10. Mean Fork Lengths at Capture for Each Age Group of Rainbow Trout Creeled in Klamath River Wild Trout Area, California, 1981 and 1982 combined.

	Age Group			
	1	2	3	4
Mean	203.8	266.0	323.9	353.6
Standard deviation	22.1	43.3	33.8	22.8
Number	38	41	14	5
Range Minimum	166.0	171.0	260.0	331.0
Range Maximum	263.0	335.0	390.0	385.0

age	No.	%	Length
1	38	38.7	8.0
2	41	41.8	10.5
3	14	14.3	12.8
4	5	5.1	13.9
	98	99.9	

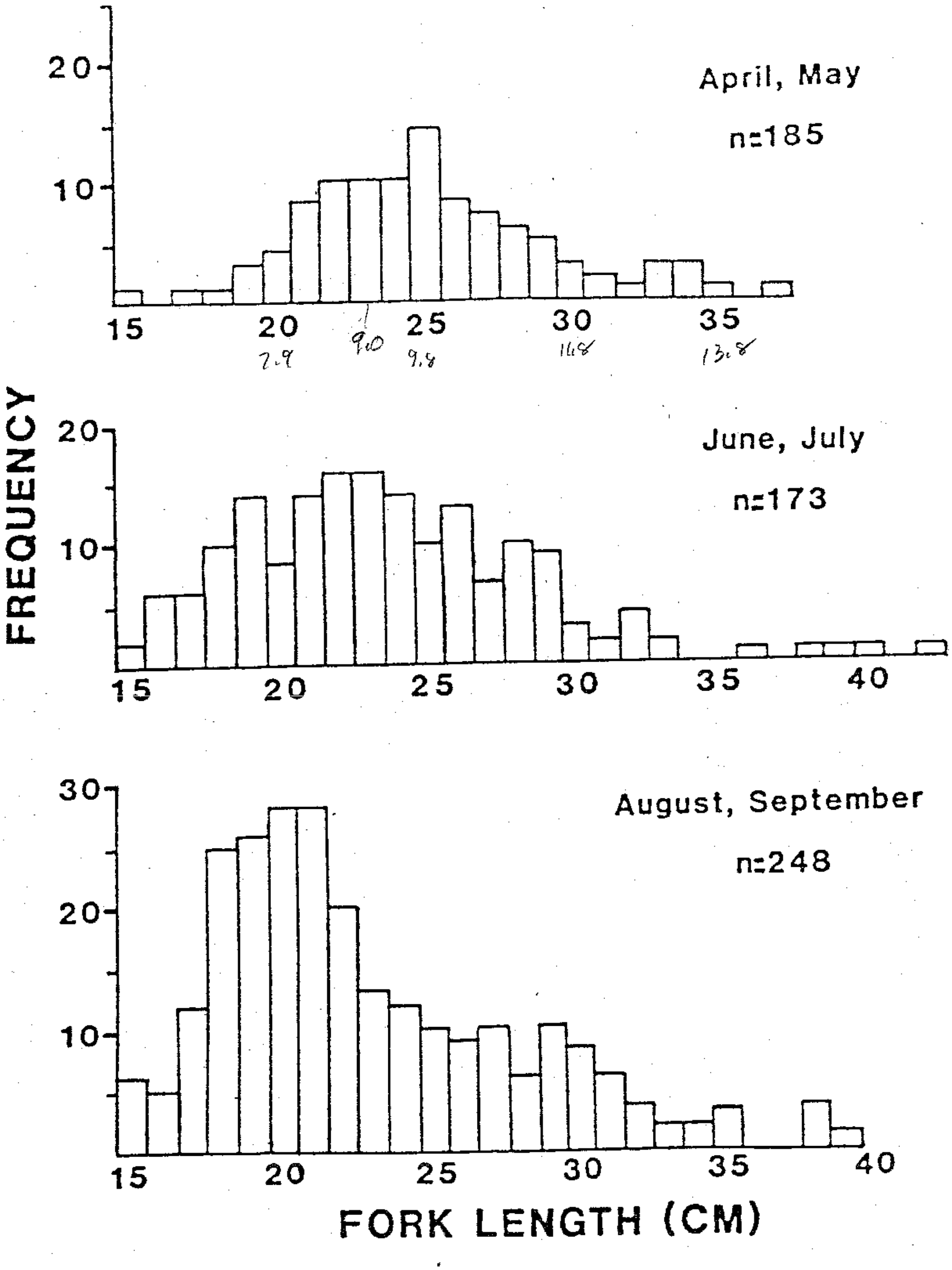

Figure 10. Length-Frequencies of Rainbow Trout Creeled During the 1981 and 1982 Seasons.

class composition of 72 percent age two, 27 percent age three, and one percent age four (Table 11). The August and September length-frequency histogram, fitted to length at age at capture, indicated the creel was then 66 percent age one, 32 percent age two, and two percent age three (Table 11).

Estimated Catch

The total estimated catch of trout in the Wild Trout Area from April to November, 1981 was 1,942 rainbow trout, with a 95 percent confidence interval of 1,158 to 2,726 fish. The catch from April to October was estimated at 1,918 (1,136-2,700) fish. The 1982 April to October estimate was 1,322 (880-1,764) fish. Total fisherman hours in 1981 were 4,176 (3,194-5,158), April to October 1981 4,025 (3,047-5,003) hours. The 1982 April to October angler effort estimate was 3,010 (2,544-3,476) hours. Estimated catch per hour was 0.47 in 1981 and 0.44 in 1982. Catch per hour ~~changed~~ appeared to change, however, as the fishing season progressed (Table 12). High water flow in April and July 1982 discouraged fishing and resulted in low catch per hour.

Fishing pressure on Shovel Creek itself was difficult to assess. The only fishermen to report actually fishing Shovel Creek were a game warden and his friend. They fished six hours on May 29, 1982, and caught two males and two females averaging 277

Table 11. Fit of Back Calculated Mean Fork Lengths to the April-May Histogram, and Length at Capture to the August-September Histogram for Rainbow Trout Creeled in the Wild Trout Area.

Statistic	Age 2	Age 3	Age 4	Chi-Square (df)
April-May				10.2 (20)
Proportion (S.E.)	0.716 (0.06)	0.273 (0.07)	0.011 (0.02)	
Mean (mm) (S.D.)	9.0" 228.3 26.8	11.3 288.0 34.9	13.8" 350.8 27.4	
August-September				13.6 (22)
Proportion (S.E.)	0.659 (0.04)	0.321 (0.04)	0.020 (0.01)	
Mean (mm) (S.D.)	193.3 23.0	270.2 34.8	369.8 19.4	

Table 12. Rainbow Trout Creel Census Data from Upper Klamath River Wild Trout Area, 1981-1982.

Year	Month	Days	Estimated Catch	Estimated Hours	Actual Catch/Hr	Estimated Catch/Hr
1981	April	1	133	226	0.59	0.59
	May	5	491	1084	0.43	0.45
	June	4	195	696	0.31	0.28
	July	6	267	706	0.33	0.38
	August	7	636	812	0.76	0.78
	Sept.	7	197	399	0.44	0.49
	Oct.	4	23	74	0.32	0.31
	Nov.	1	0	80	0	0
		35			.45	.47
1982	April	3	2	63	0.04	0.03
	May	8	271	887	0.39	0.31
	June	7	540	1348	0.39	0.40
	July	4	13	139	0.09	0.09
	August	4	248	354	0.67	0.70
	Sept.	2	248	223	0.73	1.11
		28				

millimeters in fork length. Groups of fishermen periodically sub-lease the land at the mouth of Shovel Creek to camp and fish, but it was not possible to determine their impact on the fishery because few would participate in the creel census.

Thirty spent spawners were tagged with five dollar reward tags and released. Three tags were returned by fishermen in 1982. A female was captured upstream of the Wild Trout Area, 51 days after it was tagged. Another female was creeled near the farthest upstream fishing access, 18 days after tagging. A male was caught after 14 days at the upstream edge of Copco Reservoir, below the Wild Trout Area.

Predation and Competition

Other Fish Species

Klamath smallscale suckers (_Catastomous rimiculus_) began moving upstream on April 23 in 1982. Thirty-nine were trapped going upstream and six moving downstream. Many, however, resisted entering the upstream trap. These fish spawned between the stream mouth and the weir. Upon emergence, sucker fry immediately emmigrated to the Klamath River.

The downstream trap also caught four immature brown trout (_Salmo trutta_), two marbled sculpins (_Cottus klamathensis_ Gilbert), and a lamprey (_Entosphenus_ sp). Lamprey scars were noted on several rainbow trout.

During electroshocking, two sculpins were found in Section 4, and four brown trout (76 to 156 millimeters in fork length) were shocked in the pools of Section 2 and 4.

Birds and Raccoons

Fish eating birds seen in the study area were osprey (*Pandion haliaetus*), common merganser (*Mergus merganser*), and dippers (*Cinclus mexicans*). An osprey was observed taking three adult trout. A raccoon (*Procyon lotar*) was seen eating immature fish captured in irrigation water.

Habitat

Water Quality

Water temperature was inversely related to stream flow and ranged from a low of 2.2°C on April 6 to 20°C July 30 (Figure 11). Diurnal temperature change was 1.7-6.7°C, with high temperatures occurring at 1500 and low temperatures at 0700 hours. Average daily temperatures did not drop below 4°C except from March 30 to April 7.

Dissolved oxygen reached a low of 78 percent of saturation on June 14 (9.1 milligrams per liter) and a high of 99 percent on September 23 (11.56 milligrams per liter). The pH was 7.5 to 8.0. Hardness and alkalinity

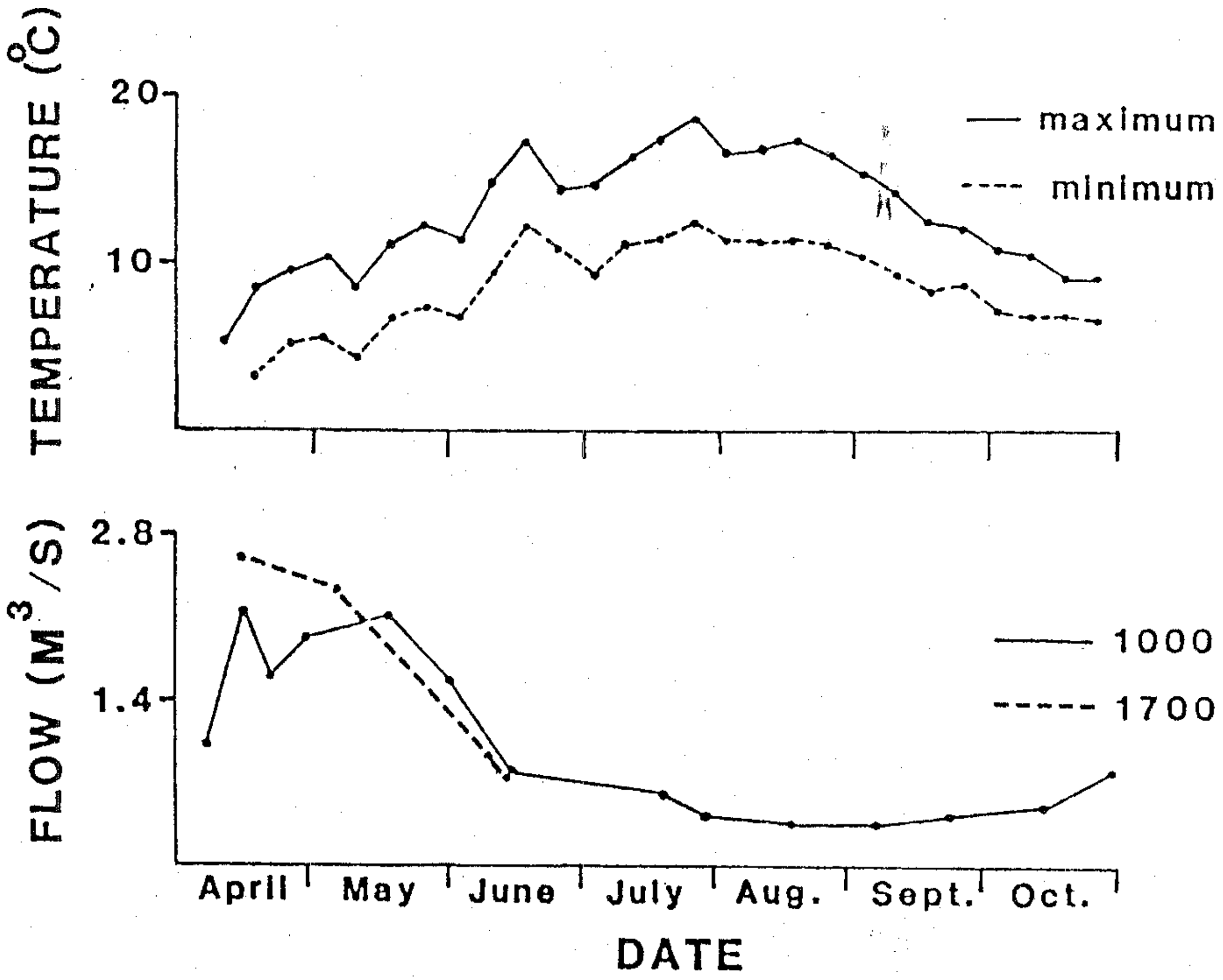

Figure 11. Water Temperature and Flows Taken above the Weir in Shovel Creek, California, April to November, 1982.

were roughly equivalent, with a range of 30 to 75 milligrams of $CaCo_3$ per liter. Orthophosphate concentration was one to six milligrams per liter except for the period April 12 to April 26, when it averaged 20 milligrams per liter.

Turbidity was 10 JTU's in April, but dropped to two JTU's in June. On May 24, turbidity was extremely high and the water was filled with bark. At this time, a caterpillar tractor was alledgedly being used in the stream to open irrigation ditches and drag out cut trees.

Water Flow

Flows upstream of the weir ranged from 2.59 to 0.32 cubic meters per second (Figure 11). From early April until mid May, snow-melt rapidly increased the flow in late afternoon. In late May the flow dropped, partially a result of two irrigation ditches being opened May 24, and a third on June 9, diverting a total of 0.26 cubic meters per second. The ditches were partially closed during the third week in October.

Water Depth and Velocity

Water depth measured over 79 redds during the spawning period, averaged $\overset{9''}{0.23}$ meters (standard deviation = 0.07). Water velocity measured $\overset{1.5 ft.}{0.458}$ meters per second (standard deviation = 0.12). When flow was reduced at the beginning of June, depths and velocities

2.3
2.3.
2.3

over the redds were greatly reduced, with redds totally exposed in at least three of the preferred spawning areas.

Depths and velocities, measured in the electrofishing sections in September, had ranges of 0.015 to 0.671 meters and 0.006 to 1.098 meters per second, respectively (Table 13).

Map and Redd Placement

Redds occurred primarily on the edges of the stream, and were closely spaced in heavily used areas (Figure 12-15). Superimposition of redds was noted in two areas. The total number of redds sighted was 79. The average redd was 0.3 square meters (standard deviation = 0.2), 24" 0.6 meters long and 20" 0.5 meters wide. Estimated size of gravel on the redd surface was .25" 6.35 to 3" 76.2 millimeters in diameter, with most less than 38.1 millimeters. The eight McNeil gravel samples taken from the redds had an average of 13 percent fines (less than 3 0.85 millimeters)(Figure 16). Section 1 (six samples) averaged 14 percent fines, Section 2 (one sample) 11 percent; and Section 3 (one sample) eight percent.

An estimate of the total available spawning gravel in the stream up to the falls barrier was 117 square meters. Suitable gravel located in and adjacent to redds was 53.7 square meters. In the lower 2.4

3.3 sq ft.

480 sq. in.

.6 meters
60. Centm
600 mm

2 X

Table 13. Mean Water Depths and Velocities and Pool:Riffle Ratios in Representative Segments of Shovel Creek, California in September, 1982 (Ranges in Parentheses).

Parameter	Section			
	1	2	3	4
Depth(m)	0.116 (0.02-0.27)	0.3 (0.02-0.67)	0.128 (0.02-0.34)	0.250 (0.03-0.50)
Velocity(m/s)	0.372 (0.02-1.10)	0.247 (0.02-1.03)	0.470 (0.03-1.09)	0.265 (0.02-0.65)
Width(m)	8.7 (8.5-9.0)	3.6 (3.3-4.3)	7.3 (6.1-7.9)	6.9 (6.7-7.2)
Pool:Riffle Ratio	0:1	0.1:1	0:1	0:1

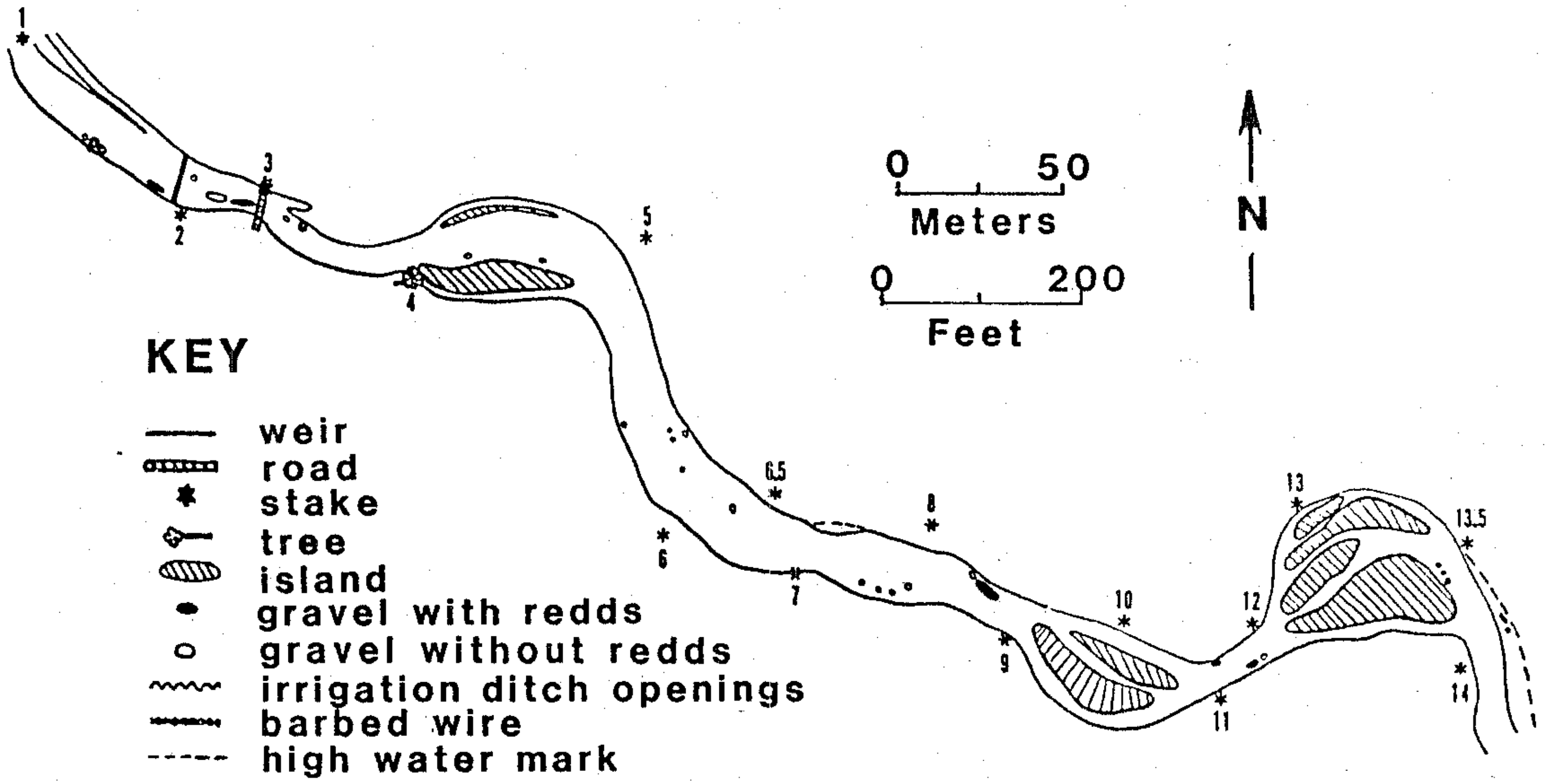

Figure 12. Section 1 of the Shovel Creek, California Study Area.

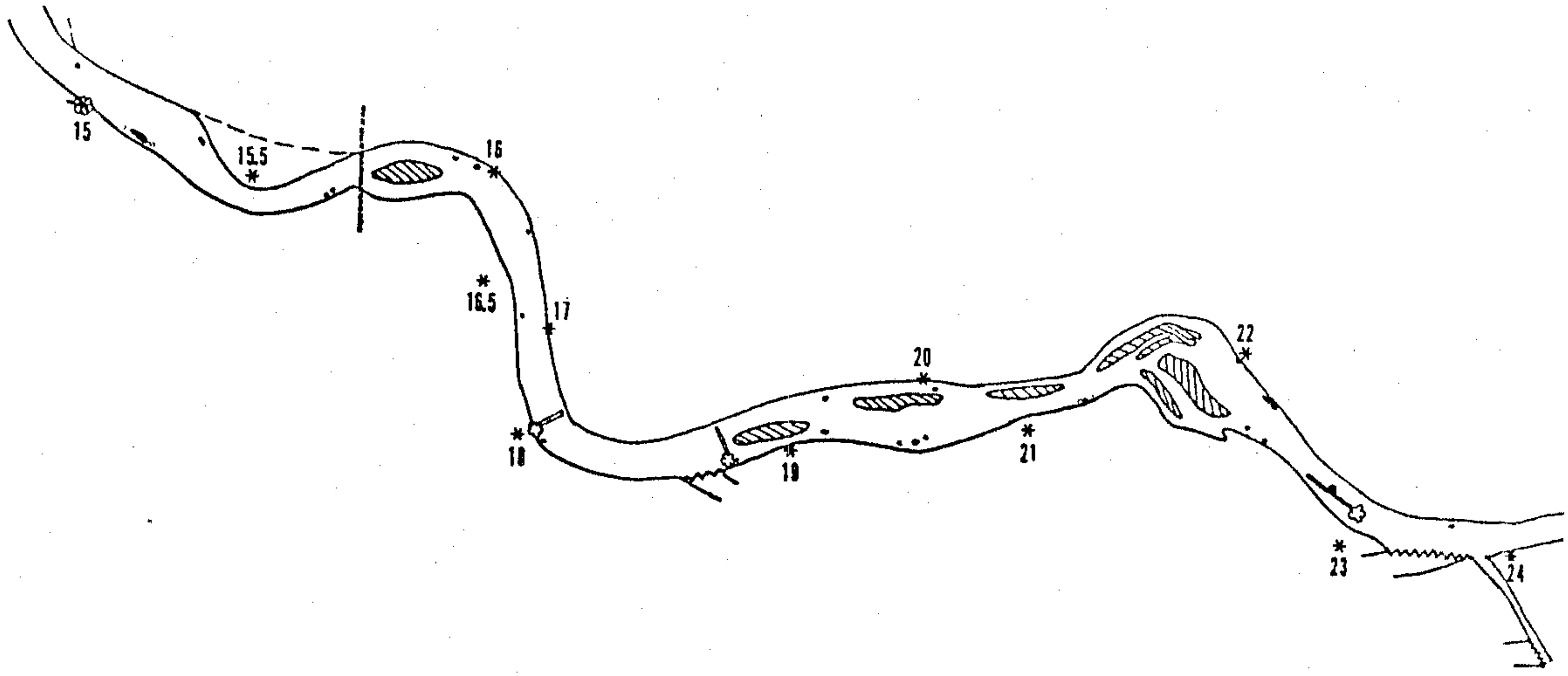

Figure 13. Section 2 of the Shovel Creek, California Study Area.

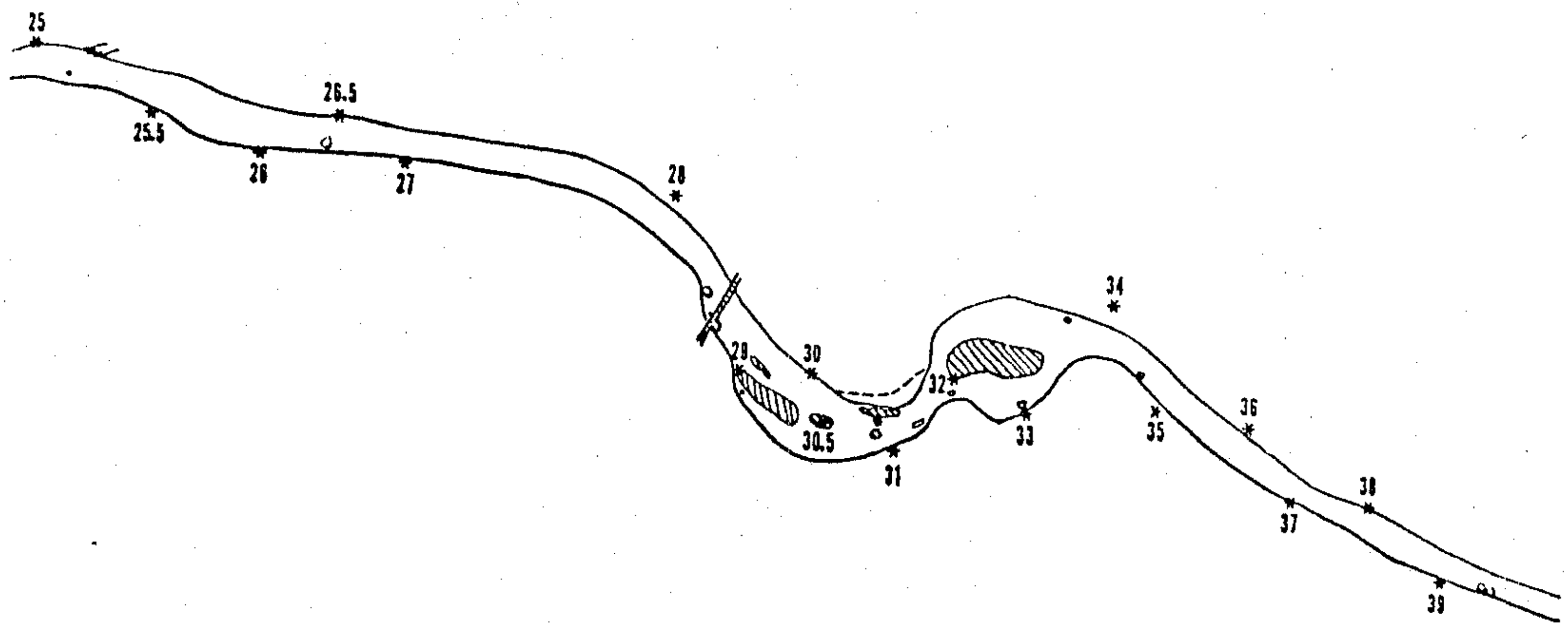

Figure 14. Section 3 of the Shovel Creek, California Study Area.

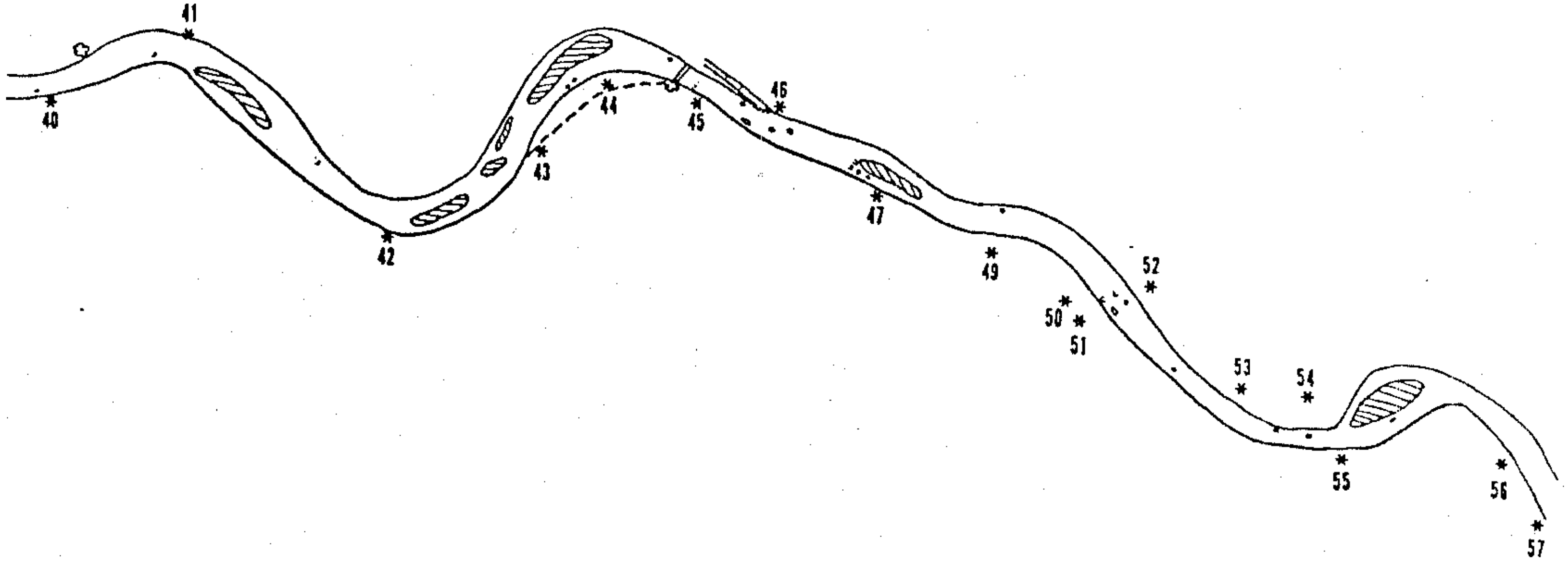

Figure 15. Section 4 of the Shovel Creek, California Study Area.

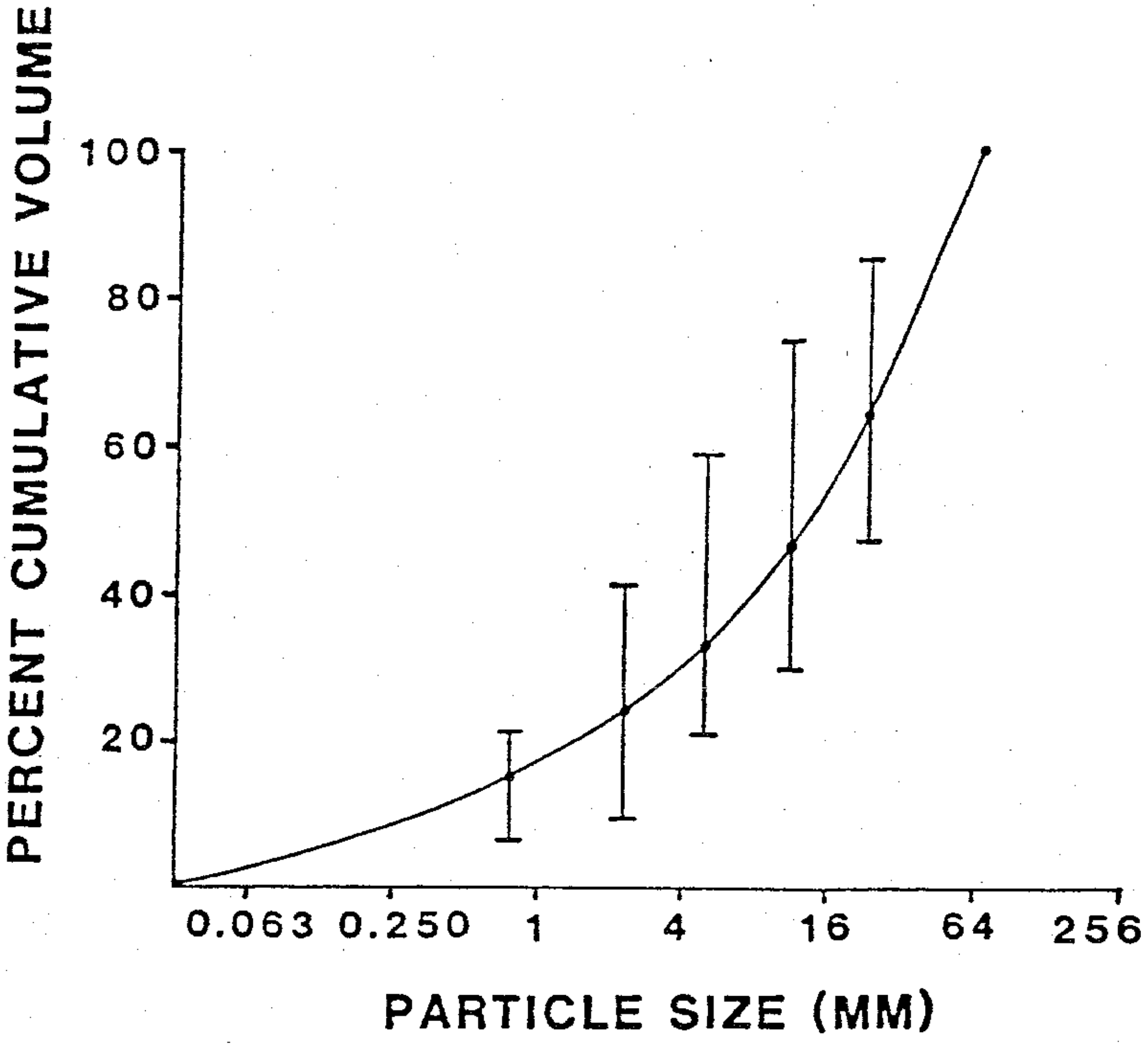

Figure 16. Average Spawning Gravel Composition in McNeil Samples, Shovel Creek, California, 1982. (ranges in brackets)

kilometers of the stream, Section 1 contained the greatest amount of gravel and the greatest number of redds, and Section 2 had the highest percent of utilization (Figure 17).

Cover

The amount of stream cover (streambank vegetation, overhanging banks, and large rocks) increased in the stream with distance from the mouth. Streambank vegetation changed from closely cropped grass, with occassional trees and blackberry bushes, in the Section 1, to dense alder growth in Section 4. The lower sections had unstable streambanks, and the 1982 winter flows widened and braided the stream. The upper section streambanks were overhanging and stable, with few changes from the winter flow. Rocks over 30 centimeters in diameter increased from 10 percent of the total in the Section 1 to 48 percent in Section 4.

Barriers

The waterfall barrier, approximately 3.2 kilometers upstream from the mouth was 1.7 meters high, above a 0.3 meter deep pool. The waterfall had a sharp turn in it, and part of the flow at the top was diverted by a log and rock. Above the barrier, the stream gradient increased sharply.

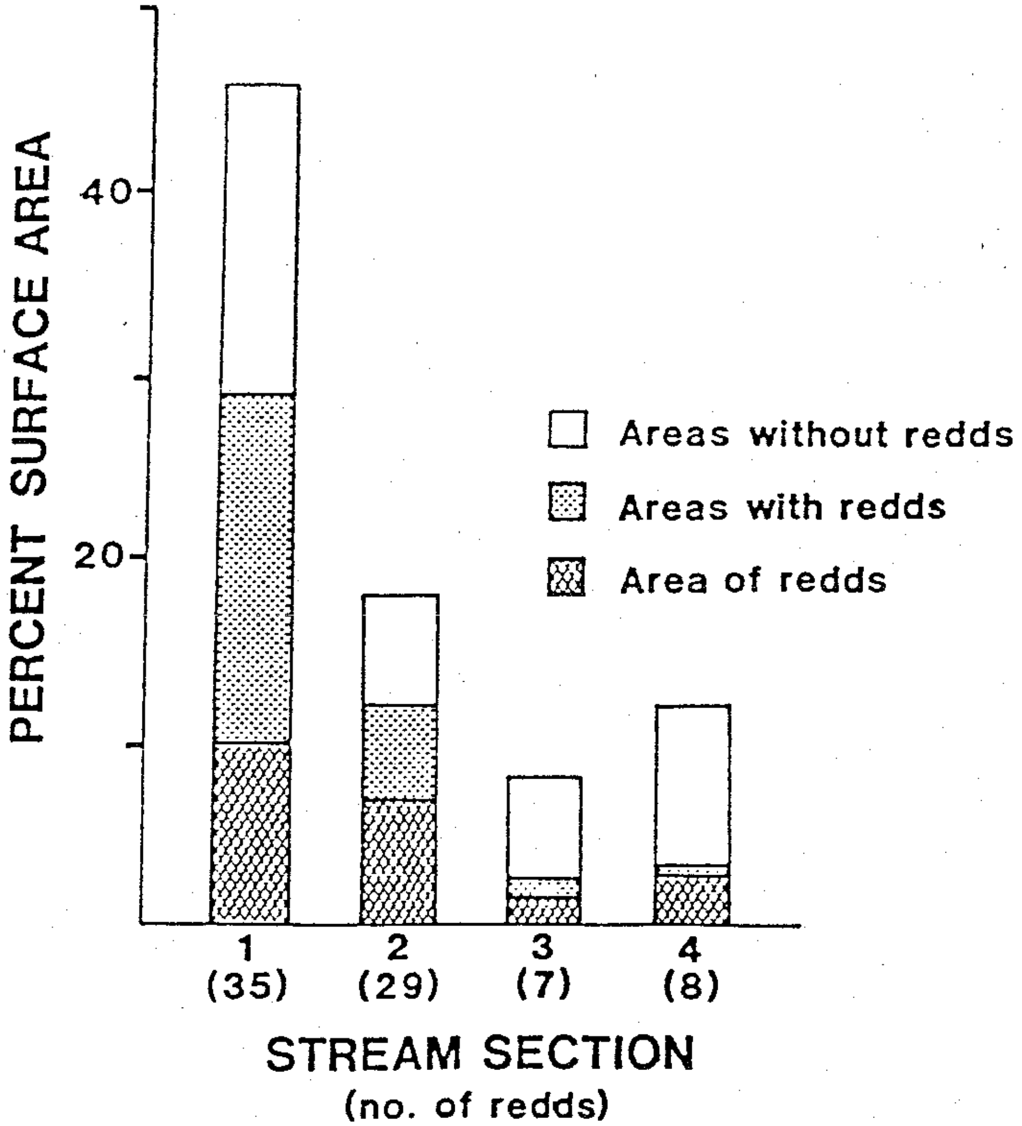

Figure 17. Surface Area and Utilization of Suitable Spawning Gravel by Stream Section in Shovel Creek, California, 1982.

DISCUSSION

Life History

Although trapping was not initiated until after the start of upstream migration, weather conditions in 1982 may have delayed the run. Rainbow trout in California normally spawn from February to June (Moyle, 1976). According to available records, the spawning run into Shovel Creek begins when the water temperature reaches 4.4°C, in the second to third week in February, with the majority of the run from March 15 to April 15 (Upper Klamath River file, California Department of Fish and Game, Yreka, Ca. 96097). Below normal temperatures could have caused a later than normal run in 1982. Air Temperatures at Yreka, 64 kilometers south-west of the study area, were 1.3°C below normal in March, and 2.7°C below normal in April (National Climatic Center, 1982). When the average water temperature in Shovel Creek dropped below 4°C from April 1-9, migration did in fact stop. Above normal rainfall and snowpack could also have delayed the run. Rainfall at Hilt, California, 32 kilometers west of the study area, was 9 centimeters above normal in February (National Climatic Center, 1982). In addition, a large amount of snow-melt in April prevented the normal evening flow reduction in the

Klamath River below John Boyle Dam and caused flows in Shovel Creek high enough to wash out the trap. These factors could have caused water velocities above 1.22 meters per second, the maximum for spawning migration (Thompson, 1972).

If a late spawning run did occur, then the majority of the run may have been trapped. This was supported by the small number of redds observed, although it was also possible that the high flows or superimposition destroyed earlier redds. If the minimum spawning population estimate of 281 fish was close to correct, the run had been seriously depleted over the years. At the egg taking station on Shovel Creek 1,100 fish were trapped in 1892, and 1,776 in 1893 (Calif.State Board Fish Comm., 1892, 1894). The opening day creel censuses conducted on Shovel Creek in 1951 and 1952, indicated catches for the day of 480 and 653 fish, respectively (Coots, 1952), with most of the fish spent spawners.

The Peterson estimate of 1,187 fish was nearer to past population sizes, but the estimate was based on a small sample size of recaptured fish. In addition, the population was not closed to migration, violating one of the assumptions of the method (Bagenal and Tesch, 1978). Unfortunately, the number of fish that entered and left Shovel Creek before the trap was put in and during the time it was washed out could not be estimated. Also, the survival rates of spawning fish may have been adversely affected by marking and handling the fish, which would result in an overestimate of the population. Hartman, et al. (1962) found that adipose clipping spawners reduced their survival rate from 30-50 percent to 15 percent. An accurate estimate of the spawning run would require that a weir with a solid foundation be in the stream and trapping fish by February. It would also be advisable to estimate marking mortality, and to obtain more than one year of data in order to determine variability resulting from environmental and year class differences.

The five percent downstream trapping recovery of marked spawners was less even than the 15 percent survival rate determined by Hartman et al. (1962). However, stratifying the fish by sex and age, the present study and Hartman et al.'s (1962) study had similar recovery rates for fish over 255 millimeters, 10-11 percent for females and three to five percent for males. Recovery rates for fish of both sexes under 255 millimeters, were much lower in Shovel Creek (one to four percent) than in Hartman et al.'s (1962) study (24-38 percent). This could indicate that the smaller fish in Shovel Creek were better able to circumvent the trap and/or overwinter in available pools, although none was captured by electroshocking. Fish frequently resisted going in the trap, and one distinctively marked fish repeatedly returned to the pool above the weir, but never entered the trap. The fish which did return had a condition factor within the range for healthy fish (Carlander, 1969), and a spawning weight loss of 16 percent, based on comparison of pre and post spawning condition factors, which was less than found by Mottley (1937) (16.7-25.2 percent) and Rayner (1949) (33.3-50 percent).

However, other factors indicate that the true survival rates were low, even for fish that were not handled. In spite of the relatively good condition factor of the returning fish, they were often battered and close to death, independent of prior handling. Eight of the fish, only one of which was adipose clipped, were in fact found dead in the trap or on the weir. The lack of repeat spawning, with spawning checks on only nine percent of the females and five percent of the males, also indicate great spawning mortality.

The age of the Shovel Creek fish at maturity was similar to rainbow trout in other studies. Most rainbow trout mature in their second or third year (Moyle, 1976). Males normally mature earlier, from nine months to two years, while females can mature from 22 months to six years (Carlander, 1969).

Minimum size at maturity, 140 millimeters for males and 163 millimeters for females, was smaller than in the studies reviewed by Carlander (1969), where the smallest mature male listed was 170 millimeters and the smallest female was 239 millimeters. Moyle (1976), however, stated that rainbow trout can spawn as small as 130 millimeters.

The length-frequency distribution of mature migrants was consistent with prior information on the Shovel Creek run. Electrofishing conducted from 1976 to 1978 indicated that mature fish ranged from 152 millimeters to 635 millimeters, with the majority from 178 millimeters to 229 millimeters (Rogers, 1978). The slight bimodality of size at age in the length-frequency histogram of mature migrants was possibly a result of two runs of fish. The egg taking station on Shovel Creek reported in 1892 an early run of large silvery fish, and a later run of short, colorful fish (Calif.State Board of Fish Comm., 1892). Two runs of fish have also been noticed at Spencer Creek, a similar spawning tributary located above John Boyle Dam (J. Fortune, Oregon Department of Fish and Wildlife, Klamath Falls, Oregon 97601). Although there was no distinct separation of the modes by time of migration in this study, trapping the entire migration for several years would be required to accurately assess the possibility of separate runs.

The migrating fish body-scale regression line and back calculated growth was close to values found for other rainbow trout populations. The 38 millimeter

Fraser modification used in this study was comparable to the 25-38 millimeter range found in studies reviewed by Carlander (1969). Back calculated growth for mature migrants was slightly greater than averages from other studies of river populations (Table 14). The Klamath River could support rapid growth because it is rich in nutrients and had ideal water temperatures for trout growth 53.6 – 64.4 °F (12-18^{o}C for six months of the year) (Rogers, 1978). The 1978 scale analysis for the Upper Klamath River Wild Trout Area (Snider and Linden, 1981) in Table 14 was based on a -4 millimeter Fraser modification, from the body-scale regression of a population in the South Fork of the Kings River, California (J. Deinstat, California Department of Fish and Game, Sacramento, California 95818). When the data were re-analyzed using the present study's 38.11 millimeter modification, the adjusted results were similar to the present study (Table 14). The larger first year growth from the 1978 scales could be the result of a different interpretation of the first annulus.

The back calculated first year growth of Shovel Creek immatures (77 millimeters) was consistent with both the average size of the age-0 outmigrants near the end of the growing season (69 millimeters), and the length-frequency distribution of the spring yearling emigrants (mode 70 to 80 millimeters). However, this growth was slow both in comparison to growth rates in

Table 14. Comparison of Back Calculated Mean Fork Lengths at Age of Rainbow Trout in Various Studies.

Study	Annulus			
	1	2	3	4
Present Study Summarized				
Spawners	107	192	293	358
Immatures (trapped)	77	125		
(electroshocked)	82	118	181	
Creeled Fish	108	209	283	351
Other Studies				
Upper Klamath River				
Wild Trout Area Creel 1978				
(Snider and Linden,1981)	92	192	284	-----
(Re-analyzed)	(117)	(204)	(288)	
Averaged California Streams				
(Snider and Linden,1981)	98	194	265	282
range	76-144	140-255	192-329	214-403
Small California Streams				
(Moyle, 1976)				
range	110-170	140-210	200-230	-----
Averaged Streams				
(Carlander, 1969)	87	171	246	308

the other studies previously mentioned and to growth rates determined in this study for mature migrants and creeled fish.

The difference in growth rates between the immature fish and the mature and creeled fish indicated that fish reared in Shovel Creek for one year or more did not significantly contribute to either future spawning or the creel. Based on the electroshocking and trapping data, it was apparent that there were too few of them to have an impact. Although these older fish would have higher initial survival rates than the fish that emigrate as fry, their slower growth could cause them to enter the creel later (Kwain, 1981) and mature later, thus increasing the time that they are susceptible to natural mortality.

The maximum estimated number of age-0 emigrants from Shovel Creek (32,903) was also small compared to the number of immature fish that are periodically stocked in Copco Reservoir (31,000-100,312 per year in 1978-1980; Iron Gate Hatchery stocking records, Copco, California 96097). This was especially true because the stocked fish were primarily yearlings, with higher expected survival rates than age-0 fish. The maximum estimate of age-0 emigrants was approximately derived, variation within the stream sections was not considered in the stream estimate, and selection of the stream segments may have been biased by using accessibility as one of the criteria, but it was close to that expected if the 138 females spawned. Based on an average fecundity of 2,210 eggs for three year old spring spawners (Leitritz, 1959), with a survival rate to downstream emigration of four to eleven percent (Bjornn, 1966), the size of emigration would be 12,475 to 34,307.

This study was not conclusive in determining the contribution to the creel resulting from the Shovel Creek age-0 emigrants. It was expected that if the creeled fish were primarily stocked fish, their first year growth rate would be greater than that of the spawning fish, assuming that the stocked fish do not spawn. Hatchery fish ordinarily have greater growth, with wider, more even spaces between circuli, than do wild trout (Bali, 1959; Koo, 1955). The creeled fish did have significantly greater first and second year growth than the spawners. However, a comparison of the growth of the 1981 creeled yearlings, (31,000 yearlings were stocked) to the yearlings caught in 1982, when none were stocked, showed no significant difference in either first year growth or circuli spacing. In fact, some of the 1981 fish had more uneven spacing than the 1982 fish. Fisherman selection of larger fish could have created a bias, resulting in both the greater growth of the creeled fish compared to the spawners, and the similarity in size of the yearlings caught. In addition, only fish with slower than normal hatchery growth were stocked, and they may have actually had growth similar to, or more uneven, than wild fish.

Tagging the spent spawners did show that they were subject to capture, but two of the three caught had migrated outside of the wild trout area. A further study is needed to mark the stocked fish in order to successfully determine their contribution to the creel relative to the wild fish.

The average size of the creeled fish in 1981 and 1982 was 236 and 242 millimeters respectively, and the average catch per hour was 0.44 and 0.47; similar to averages from creel censuses in recent years. However, the averages were lower than the 259 millimeters average size and 1.14 fish per hour catch in 1974, before the area was open to public access (Rogers, 1978). Analysis of the creeled trout indicated that the majority were captured at age one and two. According to the length frequency histograms and change in monthly catch per unit effort, one year olds enter the creel in late July or August. This capture of young fish resulted in small average size of creeled fish, and limited the number of spawners, because the fish were often captured before reaching maturity. Those fish that do spawn have a subsequent rate of capture of ten percent in the first year, according to the tag returns. This was high considering that some fish may have died after release. Hartman et al. (1962) found that spawners given an adipose clip and subsequently tagged have a survival rate of only two percent. If natural mortality from spawning could be reduced, additional creel restrictions could increase the size of fish caught, as well as increase the number of first time and repeat spawners.

Other predators and competitors were not seen in sufficient numbers to warrant control.

Habitat

The spawning habitat water depths and velocities preferred by fish in Shovel Creek were similar to those reported by other authors (Table 15). Average redd size and size range of surface gravel fit the California Department of Fish and Game's criteria for resident trout spawning areas (Hooper, 1973).

Insufficient spawning gravel was found to be a limiting factor in Shovel Creek. A conservative estimate of the amount of spawning habitat needed by each spawning pair is four times the size of an average redd (Burner, 1951). Using that criteria, even if the total number of females spawning in Shovel Creek was only the 138 actually seen, they would require a total of 166 square meters of spawning gravel. Shovel Creek contained only 117 square meters of potential spawning gravel, and only 54 square meters was under water depth and velocity known to be suitable for spawning. When adequate spawning habitat is not available, spawners may

Table 15. Water Depth and Velocity Used by Rainbow Trout for Spawning.

Source	Average Depth (m) (range)	Average Velocity(m/s) (range)
Present Study (1982) Shovel Creek, California	0.23 (0.09-0.37)	0.458 (0.21-0.70)
Hooper (1973) Literature Review	---- (0.21-0.33)	0.61 (0.43-0.82)
Smith(1973) Deschutes River, Oregon	0.342 (0.183-)	0.698 (0.488-0.909)
Waters(1976) California trout streams	---- (0.09-0.90)	---- (0.21-0.91)
Bovee(1978) Probability of Use Curves	0.21 (0.09-0.98	0.60 (0.1-0.98)

superimpose their redds on each other, causing egg and alvein mortalities (Orcutt, et al., 1968). Superimposition was noted in Shovel Creek, and it could explain the low number of redds seen (79) in comparison to the number of females. In addition, when the spawning grounds become crowded, increased fighting may cause injured fish and high mortality rates (Hartman, et al., 1962). This could explain the battered state and low recovery rate of the Shovel Creek spent spawners. Adding spawning gravel or barriers to trap gravel could increase both production and spawning survival.

The amount of fine sediments in Shovel Creek spawning material (13 percent less than 0.85 millimeters in diameter and 33 percent less than 4.75 millimeters) was greater than recommended for productive spawning. McNeil and Ahnell (1964) determined that productive spawning habitat had less than or equal to five percent fines less than 0.833 millimeters in diameter. Reiser and Bjornn (1979) recommended less than 25 percent fines under 6.4 millimeters in diameter for successful salmonid incubation. Fine sediments in redds reduce the permeability of the gravel, limiting the flow of water between gravel bed and stream (McNeil and Ahnell, 1964). Fine sediments can also result in entrapment or premature emergence of alveins (Witzel and MacCrimmon, 1981). In addition, the mean size of the gravel composition in the Shovel Creek recovered in the McNeil sampler was smaller than found in other studies (Orcutt, et al., 1968; Platts, et al., 1979). When the mean grain size was small, sediments readily filled voids (Platts, et al., 1983) and permeability and pore size was reduced (Lotspeich and Everest, 1981).

Although evaluating the effects of human use of the Shovel Creek habitat was not a specific objective of this study, it became apparent during the study that environmental degredation because of irrigation diversion, livestock grazing, and logging could also be limiting the Shovel Creek run.

Use of Shovel Creek for irrigation had adverse effects. The irrigation diversions lowered the streamflow from late May until October, which affected spawning migration, incubation, and rearing. Opening the ditches coincided with cessation of migration, and could have reduced the flow in the riffles below the 0.12-0.18 cubic meters per second needed for migration (Thompson, 1979). Shallower water also provides less cover, exposing the fish to predation and disturbance (Reiser and Bjornn, 1979). The decrease in flow was also harmful in that several redds were dewatered, and eggs and alveins in the exposed redds had little chance of survival. Even in the watered redds, there may not have been sufficient water flow over them to deliver oxygen to and flush metabolic wastes from the eggs and alveins (Reiser and Bjornn, 1979). In addition, the reduction in flow was associated with a decrease in water turbidity at the mouth, which may indicate settling of fine sediments, adding to the downstream increase in redd sedimentation.

Water removal may also have decreased the rearing capacity of the stream, particularly for age one and older fish. Older fish require deep water and pools (Allen, 1969). Based on general observation and the segments analyzed, the dewatered lower sections of Shovel Creek are primarily shallow riffles. The diversions could therefore be responsible for the small number of age one and older fish rearing in Shovel Creek, because emigration can occur when suitable habitat is not available. The effect of the diversions on age-0 fish rearing habitat was not clear. Average depth and velocity in all the segments analyzed were within the range preferred by age-0 fish in the studies reviewed by Reiser and Bjornn (1979) and Schmidt, et al. (1979). The downstream increase in density and average size of the young fish in the electroshocked sections could reflect the downstream increase in the number of redds, greater crowding from the reduced water flow, and/or downstream migration from the upper sections. The increase in size could result from earlier spawning in the lower areas or migration of only the larger fish from the upper areas. Further investigations would be valuable in assessing the situation. Instream flow analysis at varying flows could provide minimum flow recommendations for rearing, incubation, and migration. It is apparent from this study, however, that eliminating, or at least reducing or delaying water diversion, could benefit trout habitat.

A final problem caused by the irrigation diversions is that age-0 fish migrated into the ditches and were subsequently stranded. Screening the ditches would prevent this fish loss.

Another detrimental land use of the habitat by humans was associated with livestock grazing. Grazing can reduce the vegetative cover, and cause degraded streambanks and widening of the stream which was observed in the heavily grazed lower sections. Grazing related effects reduce fish cover and increase sedimentation from erosion (Platts and Martin, 1980). The added sediment could have increased the level of fine sediments in the redds, as well as decreased the rearing capacity of Shovel Creek. Sedimentation can reduce the summer rearing and winter holding areas in a stream (Reiser and Bjornn, 1979). Raleigh and Duff (1980) state that stream siltation was, in fact, the major cause of loss of winter cover for juvenile fish. Inadequate overwintering habitat may be limiting rearing in Shovel Creek, as indicated by the small number of yearlings in the stream in the spring, in comparison to the estimated number of age-0 fish in the fall. Fencing off the lower heavily-grazed sections of the stream from livestock could benefit both incubation and rearing of the trout.

Timber harvest in the study area was also apparently damaging to the trout population. The concurrent opening of irrigation ditches and dragging out of felled trees with a caterpillar tractor was done without the proper permits from the California Department of Forestry and the California Department of Fish and Game, and added sediment and organic debris to the stream. This could have discouraged migration. Cordone and Kelly (1961) found that migrating fish avoided excessively turbid areas, and a ripe fish was found in the downstream trap when Shovel Creek became turbid. In addition, the logging debris could have caused the June decrease in dissolved oxygen saturation to 75 percent, below the 80 percent needed to sustain swimming capacity (Reiser and Bjornn, 1979). Decomposition of logging debris (Hall and Lantz, 1969) and metabolism of micro-organisms feeding on the debris (Ponce, 1974) can reduce the amount of dissolved oxygen in a stream. Logging was also detrimental in that several skid roads were formed across the stream when the logs were removed, which could add to future sedimentation from erosion. Logging in the watershed, both in the study area and in the headwaters, could also increase runoff, adding to the naturally high spring flows (Platts and Martin, 1980). In the future, logging should be done with approved methods, designed to not increase erosion and runoff.

Human-related adverse impacts on the habitat should be closely monitored in the future to insure continuence of a wild stock of spawning fish, thereby preserving the Upper Klamath River as a California Wild Trout Area.

RECOMMENDATIONS

The following management recommendations for the Upper Klamath River Wild Trout Area are based on the results of this study:

1. Improve the habitat in Shovel Creek by adding spawning gravel, fencing the creek off from cattle, and delaying water diversions until after the end of June.
2. Screen irrigations diversion outlets to prevent loss of juvenile fish.
3. After habitat improvements have increased the available spawning area in Shovel Creek, restrict the creel further to allow females to mature before capture and prevent the taking of ripe spawners at the mouth of Shovel Creek.
4. Determine the contribution of stocked fish to the creel, and consider eliminating stocking in order to perserve the area for wild stocks.

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