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State of California
The Resources Agency
DEPARTMENT OF FISH AND GAME

THE POTENTIAL FOR REHABILITATING SALMONID HABITAT IN CLEAR CREEK, SHASTA COUNTY

Memorandum Report

This report was prepared under the Department of Water Resources Work Authority 1600-4468

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FOREWORD

During the 1981 fiscal year, the Northern District of the Department of Water Resources (DWR) investigated Antelope, Mill, Deer, Churn and Clear creeks and the Scott River cursorily to determine the potential for improving fish, wildlife, recreation, and aesthetic qualities by increased instream flows and other actions; and to set priorities for more extensive future studies. As part of a contractual commitment to DWR, the Contract Services Section conducted studies on Clear Creek as part of this study to evaluate the potential for rehabiliting salmonid habitat.

State of California
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DEPARTMENT OF FISH AND GAME

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CHAPTER 1. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This report summarizes findings of two years of study evaluating the potential of Clear Creek to support a larger run of chinook salmon, *Oncorhynchus tshawytscha* and steelhead, *Salmo gairdneri*. Rehabilitation could be focused around habitat manipulation.

Conclusions

1. The average annual run of fall-run chinook salmon in Clear Creek has declined slightly.
2. The 1981 fall (October 25, 1981, to January 8, 1982) and late fall-run (January 9, 1982, to April 17, 1982) estimates were 3,133 and 875, respectively.
3. The 1982 fall-run (November 6, 1982, to January 18, 1983) estimate was 785. No late fall-run estimate was taken due to extremely high flows.
4. All spawning activity occurred downstream from McCormick-Saeltzer Dam (kilometre 10.4—mile 6.5). Most activity was concentrated between kilometre 4.8 and 9.5 (mile 3.0 and 5.9).
5. Analysis of substrates from six known salmon spawning riffles below McCormick-Saeltzer Dam and five potential salmon spawning riffles above the dam showed that most riffles were compacted with sand.
6. Results of a previous study showed a loss of 93 percent of the potential chinook spawning habitat above McCormick-Saeltzer Dam in the five years following the construction of Whiskeytown Dam.
7. The fish ladder at McCormick-Saeltzer Dam is inoperable. It prevents salmon and steelhead from reaching any existing or potential spawning habitat above the dam.

Recommendations

1. Rehabilitation measures should begin with appropriating optimum flows for fall- and late fall-run salmon spawning and rearing.
2. Habitat restoration methods below McCormick-Saeltzer Dam should include gravel cleaning and riffle reconstruction.
3. The fishway should be repaired and the reach of stream above McCormick-Saeltzer Dam should be developed for salmon spawning.
4. Artificial propagation methods should be used as enhancement measures once salmon habitat is restored.
5. A viable steelhead run does not exist in Clear Creek and to create one would require major habitat alteration efforts. Efforts should be focused on rehabilitating the existing salmon runs first.

CHAPTER 2. INTRODUCTION

Clear Creek is an important producer of fall-run chinook salmon in the upper Sacramento River system. The population trend from 1951 to 1982 shows a slight decline in fish returning to spawn in Clear Creek.

This decline may be largely due to factors which also affect other runs of salmon in the Sacramento River system. Pollution, commercial and illegal fishing, delays in adult migration and mortality of juveniles at the Red Bluff Diversion Dam, inadequate screening of diversions and loss of suitable spawning habitat could all be major contributing factors. This study, however, was designed to emphasize an in-basin restorative program as a means of increasing salmon production.

I examined the following elements that relate to chinook salmon populations and habitat in Clear Creek: (1) historic and current population levels of adult salmon; (2) timing and characteristics of juvenile outmigration; (3) spawning habitat; (4) fish ladder rehabilitation; (5) predator control; and (6) rearing ponds and spawning channels. In addition, I discuss the potential to develop steelhead in Clear Creek. Results of this study and data from previous studies could be used to develop recommendations for enhancement and rehabilitation measures, for monitoring programs and for future studies.

CHAPTER 3. DESCRIPTION OF STUDY AREA

Clear Creek, a tributary to the Sacramento River, enters from the west between Anderson and Redding (Figure 1). It drains an area of 616 km^2 (238 mi^2). There are two dams on Clear Creek--Whiskeytown, located 26 kilometres (16 miles) from the mouth, and McCormick-Saeltzer, located at kilometre 10.4 (mile 6.5). The flow from the upper Clear Creek watershed is controlled at Whiskeytown Dam, which is operated by the U. S. Bureau of Reclamation (USBR). Water is also imported from Trinity Reservoir on the Trinity River stored in Whiskeytown Lake. Water can then be released into Clear Creek or through the Spring Creek Conduit which empties into Keswick Lake. The present flow schedule from Whiskeytown into Clear Creek is 1.4 m^3/s (50 ft^3/s) for 10 months beginning in January and 2.83 m^3/s (100 ft^3/s) for the remainder of the year. McCormick-Saeltzer Dam diverts about .15 LM^3/s (5 ft^3/s) of water into the Townsend Flat water ditch for irrigation in an area north of Clear Creek and west of Highway 273.

There are two definable reaches of stream which are approximately divided by Clear Creek Road Bridge (killometre 13.6--mile 85) (Figure 1). Upstream, the creek flows through a narrow, rocky canyon with little riparian vegetation. This area is characterized by a series of pools, cascades, and small waterfalls. There is relatively little gravel deposition in this area.

Downstream, the creek flows through a gravelly plain lined with thick riparian vegetation. There is currently one company actively extracting gravel near the flood plain at kilometre 4.8 (mile 3.0). Historically, gold was placer mined throughout the creek; in more recent years gravel mining has become more prevalent. Mine tailings are still located adjacent to the flood

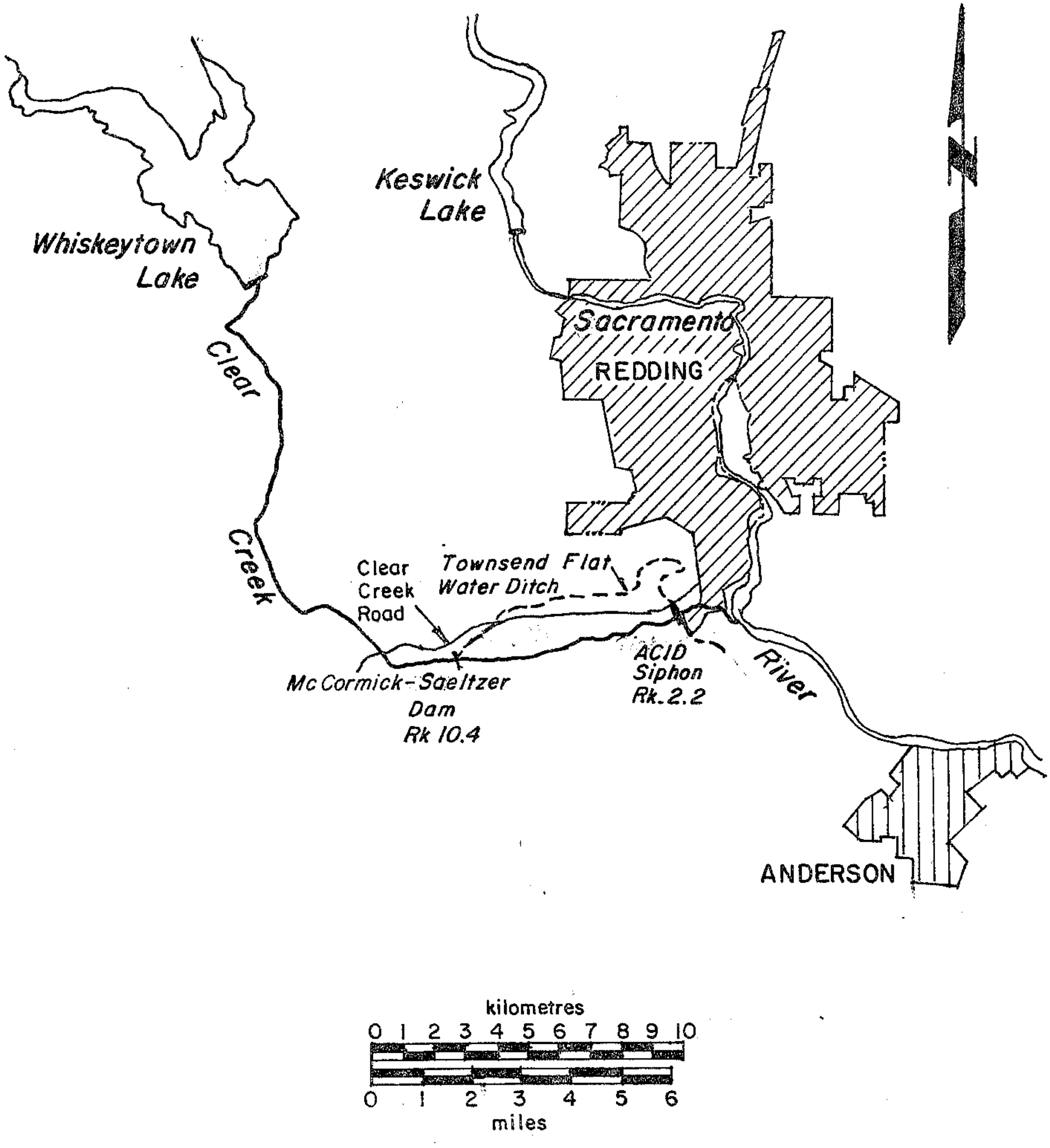


FIGURE 1. Clear Creek project area

plain. In addition to the present day gravel extraction along the creek, there is some small-scale suction-dredge gold mining in the stream between kilometre 4 and 13.5 (mile 2.5 and 8.4).

CHAPTER 4. ADULT CHINOOK SALMON ESCAPEMENT

Methods

Escapement estimates of fall-run chinook salmon for 1955 to 1980 were compiled from DFG salmon spawning stock reports (Reavis, 1981). Estimates for 1951 to 1953 were obtained from Warner (1956).

To estimate the current spawning escapement, we counted salmon carcasses in Clear Creek from the mouth to McCormick-Saeltzer Dam (kilometre 10.4--mile 6.0) (Figure 1). The area between Clear Creek Road Bridge and McCormick-Saeltzer Dam was surveyed twice during the 1981 and 1982 sample periods to verify that the dam was a barrier to upstream fish migration.

We counted salmon carcasses once each week from October 25, 1981, to April 29, 1982, and from November 6, 1982, to January 18, 1983. Each carcass was tagged by fastening a No. 3 hog ring to its mandible. Tick marks were notched into the hog rings with wire cutters to identify the appropriate week of tagging. The sex and fork length of each carcass were noted. The location of each carcass (to the nearest 0.1 kilometre--0.16 mile) was recorded, and each carcass was placed back in the water in the same area where it was tagged. Tagged carcasses that were recovered were cut open to note spawning success and then cut in half to avoid recounts.

Spawning escapement was estimated using the method of Schaefer (Ricker, 1975) and modified by Reavis (1981):

$$N = \Sigma \left(Rij \cdot \frac{Mi}{Ri} \cdot \frac{Cj}{Rj}\right) - \sum_{2}^{i} Mi$$

Where,

M_i = number of fish marked in the ith period of marking.

C_j = number of fish caught and examined in the jth period of recovery.

R_{ij} = number of fish marked in the ith marking period which are recaptured in the jth recovery period.

R_i = total recaptures of fish tagged in the ith period.

R_j = total recaptures during the jth period.

N = population estimate.

Results

Historical Chinook Salmon Runs

Estimates of historic salmon runs in Clear Creek fluctuate yearly (from a low of 330 in 1957 to a high of 10,000 in 1963, with a yearly average of about 2,200 fish - Figure 2, Table 1).

1981-82 Spawning Escapement

During 25 weekly counts beginning October 26, 1981, 704 salmon carcasses were tagged and released. The fish were divided into two groups--fall-run and late fall-run (Figure 3a). The fall-run continued through the week of Jaunary 8, 1982, when no carcass was recovered and few live fish were observed. A surge of live fish and carcasses was observed the following week, signifying the beginning of the late fall-run which continued through mid-April. For the purposes of population estimation, each run was treated separately.

Of 545 fall-run chinook salmon carcasses tagged, 110 were recovered, which translates to a population estimate of 3,133 fish (Table 2). Of the 545 carcasses recovered, 208 were males (62 percent), representing a sex ratio of 1.6 males per female.

Of the 159 late fall-run chinook salmon carcasses tagged, 35 were recovered, which translates to a population estimate of 875 fish (Table 3). Most salmon carcasses examined were females (62 percent), representing a sex ratio of 1.7 females per male. The combined sex ratio for both runs was 1.3 males per female.

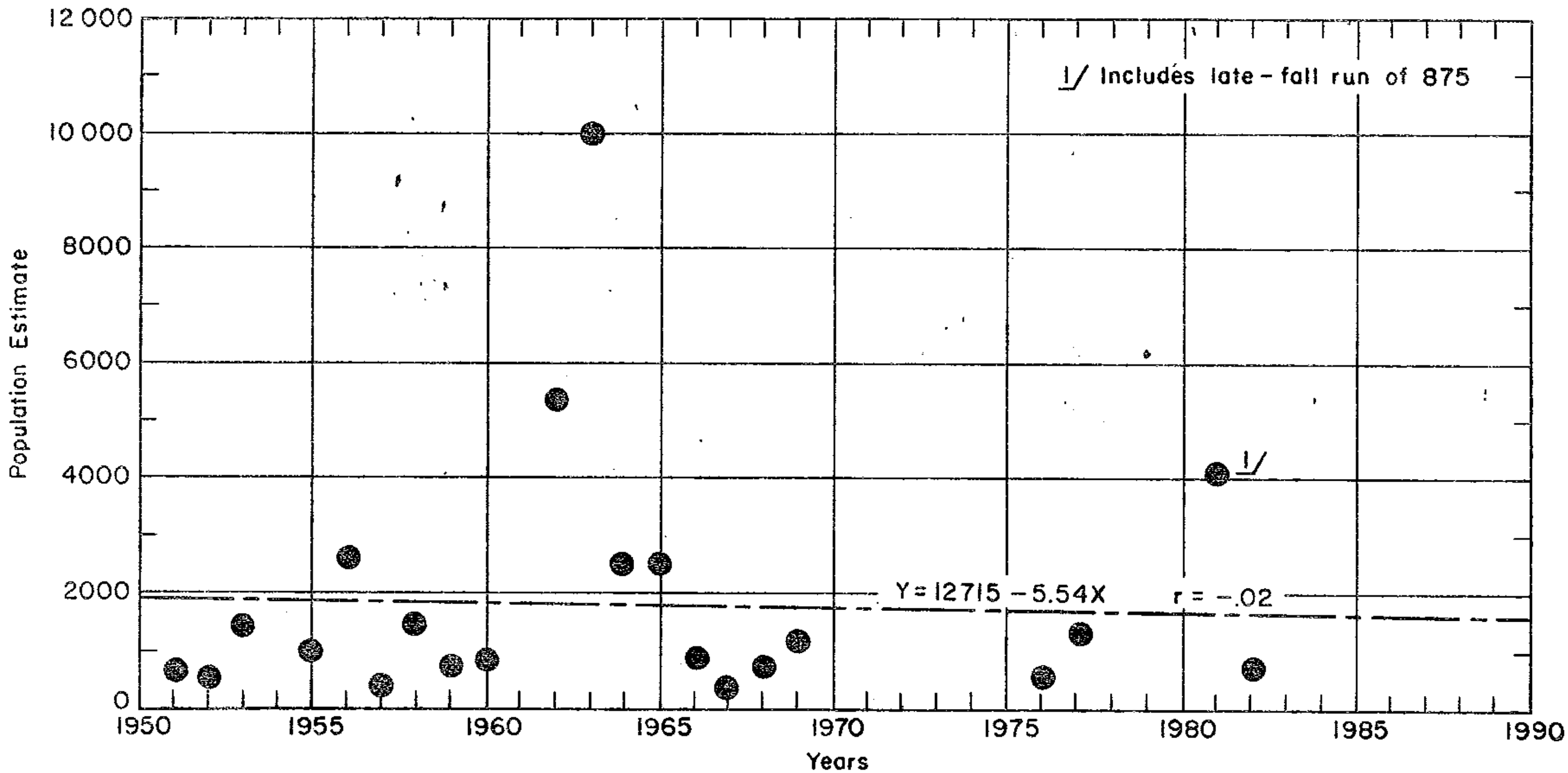


FIGURE 2. Historic levels of fall-run chinook salmon that spawn in Clear Creek, Shasta County.

TABLE 1

Fall-Run Chinook Salmon Spawning Stock Estimates for Clear Creek, from the Mouth to McCormick-Saeltzer Dam, 1956-1981

Year	Survey Trips	Actual Number of Carcasses Counted	Percent Recovery	Estimate
1951	Estimate is based on single aerial survey redd counts			700 1/
1952	Estimate is based on single aerial survey redd counts			550 1/
1953	Estimate is based on single aerial survey redd counts			1,580 1/
1954	No recorded information is available			
1955	-	-	-	1,003 2/
1956	4	530	20	2,650
1957	6	66	20	330
1958	6	313	20	1,600
1959	4	62	8	755
1960	6	116	13	900
1961	No survey	-	-	-
1962	2	1,071	20	5,400
1963	6	1,169	12	10,000
1964	3	718	29	2,500
1965	2	843	34	2,500
1966	5	230	26	900
1967	3	66	18	370
1968	5	280	35	800
1969	3	310	25	1,240
1970-75	No survey	-	-	-
1976	9	152	15	1,013
1977	5	165	12	1,362
1978	2	3	No estimate	
1979	2	75	No estimate	
1980	No survey			
1981	23	701	17	4,008 3/
1982	11	492	63	785

1/ Conducted by U.S. Fish and Wildlife Service (Warner, 1956).

2/ This figure represents an actual count of adult fish planted in Clear Creek that were trapped and trucked from the Keswick trap (Warner, 1956).

3/ Includes late fall-run estimate of 875.

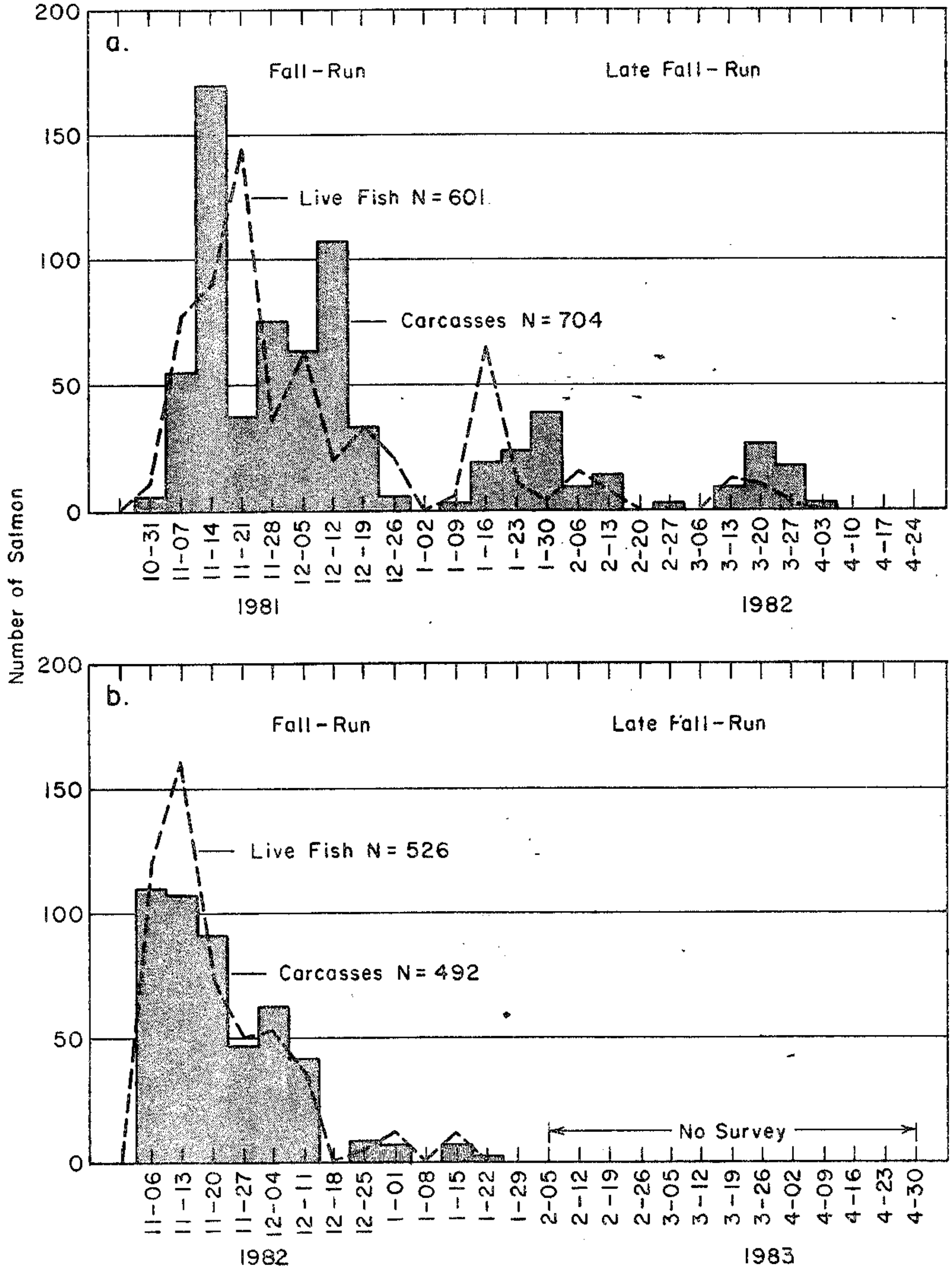


FIGURE 3. Weekly counts of chinook salmon carcasses and live fish in Clear Creek, Shasta County; a) October 1981 to April 1982 and b) October 1982 to January 1983.

TABLE 2

Population Estimates of Fall-Run (October 25, 1981 to January 8, 1982) Chinook Salmon Based on Carcass Tag and Recovery Data for Clear Creek from Mouth to McCormick-Saeltzer Dam Using Schaefer's Method

Recovery Period (j)	Tagging Period (i) Oct 31	Nov 7	Nov 14	Nov 21	Nov 28	Dec 5	Dec 12	Dec 19	Dec 26	Jan 2	Jan 8	Tags Recovered (Rj)	Total Fish Recovered (Cj)*	Population Estimate (N)
Oct 31	-											-	6	-
Nov 7	3											3	54	81
Nov 14	1	12										13	180	727
Nov 21			2									2	40	835
Nov 28			5	7								12	89	993
Dec 5			1	1	12							14	77	292
Dec 12				1	18	18						37	142	375
Dec 19					3	44	20					27	59	269
Dec 26												0	4	0
Jan 2									1			1	1	4
Jan 8								1				1	3	96
Tags Recovered (Ri)	4	12	8	9	33	22	20	1	1	0	0			3672+
Total Tagged (Mi)	6	51	167	38	77	63	105	32	4	0	2			

* Includes tagged fish recovered.

\+ Total tagged fish from second week on must be subtracted: 3672 - 539 = 3133

$$\text{Population Estimate (N)} = \Sigma \left(R_{ij} \cdot \frac{M_i}{R_i} \cdot \frac{C_j}{R_j}\right) - \sum_{2}^{i} M_i$$

TABLE 3

Population Estimates of Late-Fall Run (January 9 to April 17, 1982) Chinook Salmon Based on Carcass Tag and Recovery Date for Clear Creek from Mouth to McCormick-Saeltzer Dam Using Schaefer's Method

Recovery Period (j)	Tagging Period (j) Jan 9	Jan 16	Jan 23	Jan 30	Feb 6	Feb 13	Feb 20	Feb 27	Mar 6	Mar 13	Mar 20	Mar 27	Apr 3	Apr 10	Apr 17	Recovered (Rj)	Recovered (Cj)*	Estimate (N)
Jan 9																-	2	-
Jan 16	1															1	22	22
Jan 23		1														1	24	504
Jan 30			5													5	44	145
Feb 6			2	12												14	23	59
Feb 13	1			1	3											5	19	35
Feb 20																0	0	0
Feb 27																0	1	0
Mar 6																0	0	0
Mar 13																0	7	0
Mar 20										1						1	27	189
Mar 27											8					8	24	78
Apr 3																0	1	0
Apr 10																0	0	0
Apr 17																0	0	0
Tags Recovered (Ri)	2	1	7	13	3	0	0	0	0	1	8	0	0	0	0			1032+
Total Tagged (Mi)	2	21	23	39	9	14	0	1	0	7	26	16	1	0	0			

* Includes tagged fish recovered.
\+ Total tagged fish from second week on must be subtracted: 1032 - 157 = 875

$$\text{Population Estimate (N)} = \Sigma \left(Rij \cdot \frac{Mi}{Ri} \cdot \frac{Cj}{Rj}\right) - \sum_{2}^{i} Mi$$

1982-83 Spawning Escapement

During 12 weekly counts 492 carcasses were tagged and released (Figure 3b). Two hundred and eighteen of these were recovered which translates to a population estimate of 785 (Table 4). Sixty-four percent of recovered fish were males, representing a sex ratio of 1.8 males per female.

Because of record precipitation and uncontrolled spills from Whiskeytown Dam, a survey of the 1983 late fall-run could not be conducted.

TABLE 4

Population Estimates of Fall-Run (November 6, 1982 to January 18, 1983) Chinook Salmon Based on Carcass Tag and Recovery Data for Clear Creek from Mouth to McCormick-Saeltzer Dam Using Schaefer's Method

Recovery Period (j)	Tagging Period (i) Nov 6	Nov 13	Nov 20	Nov 27	Dec 4	Dec 11	Dec 18	Dec 25	Jan 1	Jan 11	Jan 18	Tags Recovered (Rj)	Total Fish Recovered (Cj)*	Population Estimate (N)
Nov 6												-	110	-
Nov 13	63											63	171	215
Nov 20	10	36										46	137	261
Nov 27	10	8	28									46	94	184
Dec 4	3	5	10	2								20	84	187
Dec 11	1	3	4	9	21							38	81	248
Dec 18												0	0	
Dec 25												0	9	
Jan 1					1							1	9	26
Jan 11									3			3	13	35
Jan 18										1		1	1	10
Tags Recovered (Ri)	87	52	42	11	22	0	0	0	3	1	0			1166+
Total Tagged (Mi)	110	108	91	48	64	43	0	9	8	10	1			

* Includes tagged fish recovered.

\+ Total tagged fish from second week on must be subtracted: 1166 - 382 = 785

$$\text{Population Estimate } (N) = \Sigma \left(R_{ij} \cdot \frac{M_i}{R_i} \cdot \frac{C_j}{R_j}\right) - \sum_{2}^{i} M_i$$

CHAPTER 5. CHINOOK SALMON SPAWNING HABITAT

Methods

The distribution of salmon spawning was determined by counting redds weekly during carcass tagging surveys. New redds were counted and displayed on a 7 1/2-minute topographic map which is accurate to the nearest 0.16 kilometre (0.1 mile).

The quality of the chinook salmon spawning gravels in Clear Creek was determined by analyzing the size composition of substrate samples from six spawning riffles below McCormick-Saeltzer Dam and five potential spawning riffles above the dam.

A cylinder 60-cm (24-in) long with a 45-cm (15-in) diameter with serrations at one end and handles attached to the other was rotated manually into the streambed. Gravel samples were removed to a depth of about 25 cm (10 in), which is the average depth of a chinook salmon redd (Puckett and Hinton, 1974).

The composition of gravel in each sample was determined by washing gravel through a series of sieves and separating it into six categories (Table 5). The material retained in each sieve displaced an equal volume of water which was collected in a bucket and weighed. The 0.04-cm to 0.4-cm (0.015- to 0.16-in) sized samples were drained for 15 to 20 minutes. Since this small material could not be dried conveniently, the equation $D = 1.95 + 0.6504\ W$ (D = dry weight and W = wet weight) was used to convert the weight of samples of wet material to the weight of dry material. Finally, each sample was checked to see if it met the criteria in Table 5. These criteria were developed from samples taken from chinook salmon redds from the Sacramento River and tributaries (Van Woert and Smith, MS) and are generally consistent

TABLE 5

Criteria for Identifying Suitable Spawning Gravel for Chinook Salmon 1/

Gravel Size Centimetres	Percent by Volume
15.2 - 30.5	30 or less
7.6 - 15.2	10 or more
2.5 - 7.6	50 or less
1.3 - 2.5	20 or less 2/
0.4 - 1.3	20 or less 2/
0.04 - 0.4	20 or less 2/

1/ Pollock (1969).

2/ The three smaller sizes in combination should not exceed 50 percent (Puckett and Histon, 1974).

with standards developed by numerous years of salmon-spawning channel research (Pollock, 1969).

Results

Redds were located throughout most of the lower creek. Virtually all of the available riffles were utilized (Figure 4). A majority of the spawning activity during the 1981-82 spawning season was concentrated between kilometre 4.8 and 9.5 (mile 3.0 and 5.9) (Figure 4a).

Virtually all substrate samples were laden with sand, and as a result, were extremely compacted. Only one of the six known spawning riffles met substrate criteria for suitable salmon spawning (Table 6). Only two of five potential spawning riffles met these criteria (Table 7).

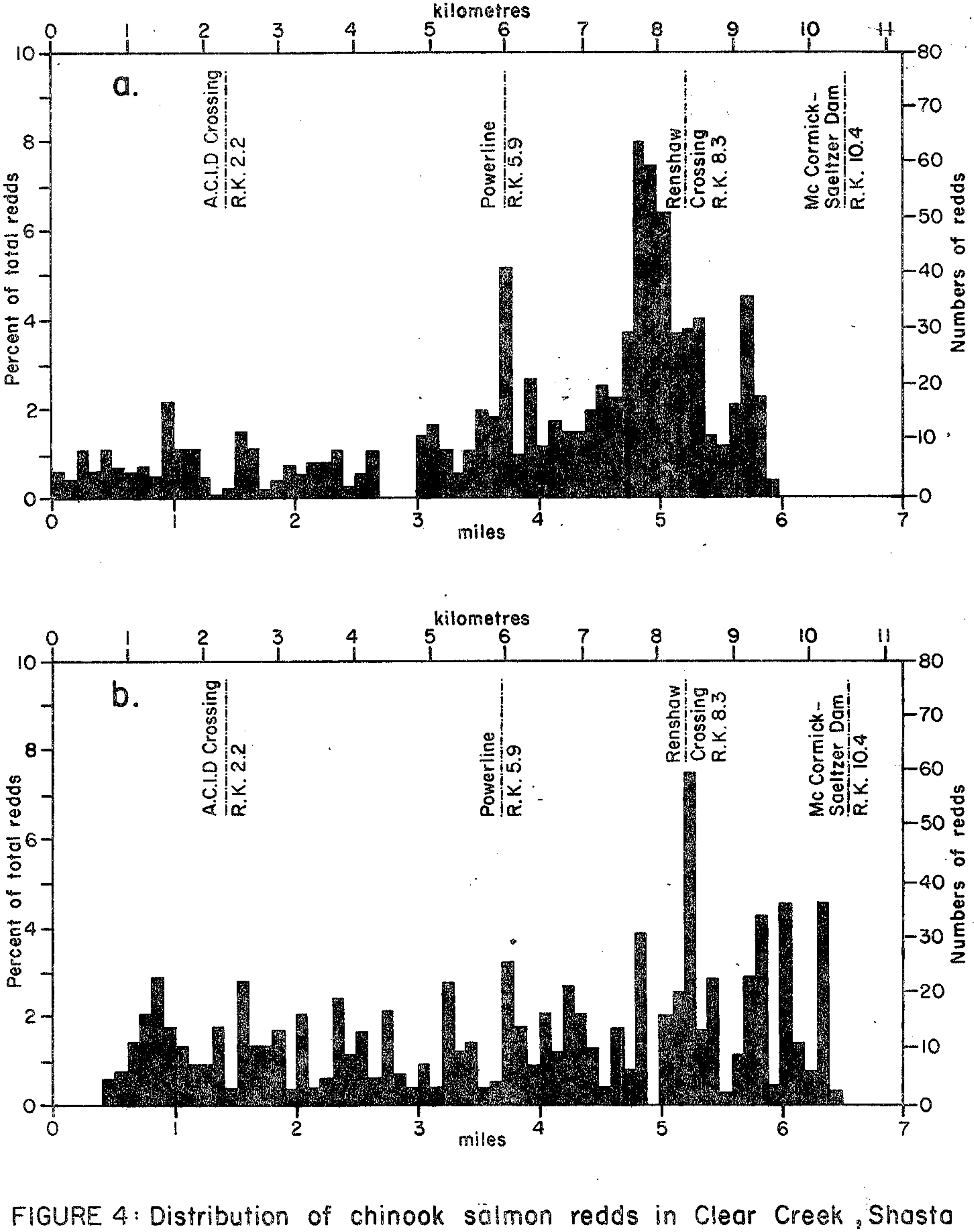


FIGURE 4: Distribution of chinook salmon redds in Clear Creek, Shasta County, a) October 1981 to May 1982 and b) November 1982 to January 1983.

TABLE 6

Percent Composition of Substrates for Six Spawning Riffles in Clear Creek, Below McCormick-Saeltzer Dam, 1982

River Kilo-metre	Centimetre Substrate Size						Potential Available Habitat (M^2)	Meets Substrate Criteria
	15.2-30.5	7.6-15.2	2.5-7.6	1.3-2.5	0.4-1.3	0.04-0.4		
8.21	0	13.0	22.5	13.8	12.3	38.4	470	No
8.34	0	20.5	22.1	11.9	12.0	33.4	700	No
8.37	0	32.6	20.9	9.7	14.7	22.8	115	Yes
8.53	0	15.5	22.2	8.7	10.1	43.5	580	No
8.58	0	9.3	26.5	13.2	8.2	42.8	465	No
8.61	11.5	21.3	13.7	9.4	11.5	32.5	700	No

TABLE 7

Percent Composition of Substrates for Five Potential Spawning Riffles in Clear Creek Between McCormick-Saeltzer Dam and Clear Creek Road Bridge, 1982

Above River Kilo-metre	McCormick-Saeltzer (potential spawning riffles) Centimetre Substrate Size						Potential Available Habitat (m^2)	Meets Substrate Criteria
	15.2-30.5	7.6-15.2	2.5-7.6	1.3-2.5	0.4-1.3	0.04-0.4		
10.59	0	31.9	19.1	9.3	10.3	29.4	280	Yes
10.78	0	12.9	24.8	12.6	11.2	42.5	250	No
10.86	10.4	16.8	18.8	9.2	9.8	35.0	105	No
10.94	7.2	4.9	19.7	9.1	10.1	28.5	370	Yes
12.25	8.2	17.7	13.7	7.9	13.7	38.8	350	No

Discussion

Our surveys indicated that all salmon spawned below McCormick-Saeltzer Dam. No salmon was seen upstream during surveys or by surveyors in previous studies. This is probably because the fishway at McCormick-Saeltzer Dam has not functioned properly since it was rebuilt in 1958.

Previous studies have been conducted on Clear Creek to assess salmon spawning habitat. Hinton (MS) determined composition of spawning riffles below McCormick-Saeltzer Dam (Table 8). Warner (1956) quantified the potential spawning habitat for the reach above McCormick-Saeltzer Dam prior to the construction of Whiskeytown Dam, while Coots (MS) repeated those efforts after construction.

Hinton's data show three of four riffles met criteria for salmon spawning. Our survey of six riffles within the same area shows that only one met the criteria. All of our samples were compacted with sand. Based on the data presented, it is clear that the quality of Clear Creek gravel has declined markedly since 1965.

Warner (1956) estimated that before Whiskeytown Dam, habitat above McCormick-Saeltzer Dam could probably support 6,000 salmon; however, Coots (MS) found that for this same area 93 percent of the potential spawning gravels were lost during the 5 years after completion of Whiskeytown Dam (Table 9).

We found little suitable spawning habitat in this reach. Gravel in the inaccessible riffles above McCormick-Saeltzer Dam were compacted with sand. With the exception of the area of concentrated spawning (kilometre 4.8 to 9.5), many redds were located in isolated "pockets" of gravel. Many riffles in these areas with suitable depths and velocities were mostly devoid of gravel with nothing remaining except exposed bedrock or compacted mud.

Spawning gravel in Clear Creek is of poor quality and would cause high mortaility of eggs and fry deposited there. The effects of fine inorganic

TABLE 8

Percent Composition of Substrates for Four Chinook Salmon Spawning Riffles in Clear Creek Below McCormick-Saeltzer Dam 1965[1/]

River Kilo-metre	Centimetre Substrate Size						Potential Available Habitat (m²)	Meets Substrate Criteria
	15.2-30.5	7.6-15.2	2.5-7.6	1.3-2.5	0.4-1.3	0.04-0.4		
5.92	0	20.0	26.7	17.3	19.4	16.6	450	No
5.94	6.9	17.6	29.3	13.4	16.8	16.0	2,440	Yes
5.95	0	34.0	31.6	8.6	11.4	14.4	625	Yes
5.97	5.0	22.0	27.4	10.9	16.2	18.5	630	Yes

1/ Hinton, unpublished DFG file data.

TABLE 9

Composition of Chinook Salmon Spawning Gravel in Clear Creek from Whiskeytown Dam to McCormick-Saeltzer Dam, 1971[1/]

Section by River Kilometre	Useable Spawning Area (m²) 1956 Survey	1970 Survey	Change from 1956 to 1970
18.6 - 17.0	8 361	725	-91%
17.0 - 16.0	8 046	372	-95%
16.0 - 9.0	3 633	334	-91%
9.0 - 7.0	12 226	819	-93%
TOTAL	32 266	2 249	-95% (average)

1/ Coots, unpublished DFG file data.

particulate matter is well documented (Allen, 1940; Cordone, 1956; Alderdice, et al, 1958; Alderdice and Pickett, 1958; Cordone and Kelley, 1960; Bjornn, et el, 1977). Fine sediments prevent intragravel water flow, which provide eggs and alevins with oxygen and removes metabolic wastes. In addition, compacted gravels prevent newly hatched alevins from emerging.

Data from previous reports and from our studies show that the amount of spawning habitat in Clear Creek is diminishing--probably because of the following factors:

<u>The construction of Whiskeytown and McCormick-Saeltzer dams</u>

Most gravel recruitment has been halted by Whiskeytown Dam. McCormick-Saeltzer Dam impedes gravel transport and limits flushing flows.

<u>Controlled flows</u>

Lack of sufficient peak flows decreases the ability of the stream to transport gravel. In addition, lowered flows have allowed riparian vegetation to encroach into the floodway. This inhibits lateral migration of the active stream channel, which reduces recruitment of gravel from streambanks. Lateral migration of the stream channel in Clear Creek is probably the only existing source of gravel recruitment (D. Parfitt, DWR Engineering-Geologist, pers. communication).

<u>Gravel extraction</u>

Gravel has been extracted from the flood plain in the lower 13 km (8 mi) at a rate of about 122 300 m^3 (160,000 yd^3) per year (Parfitt and Buer, 1980), although the rate of extraction may be much less now. Clear Creek usually contributes little gravel to the Sacramento River except on years with extremely high flows.

CHAPTER 6. FISH PASSAGE

Methods

The creek was inspected between Whiskeytown Dam and the mouth for impediments to upstream-migrating adult salmonids. We also reviewed plans for the original design of the fish ladder by California Division of Architecture. We inspected the ladder entrance, portal structure, velocity barrier, and stream channel configuration by diving.

Results and Discussion

Two series of natural falls which constitute potential fish barriers are located in Clear Creek; one at kilometre 16 (mile 9.9) and one at kilometre 19 (mile 12). Unless fish passage facilities are provided, these impediments represent the uppermost extent of fish migration and would limit fishery improvement measures.

There is a check dam (kilometre 2.2--mile 1.4) (Figure 5) in the reach below McCormick-Saeltzer Dam that protects the siphon of the Anderson-Cottonwood Irrigation District (ACID) Canal. It is a 1.2-m (4-ft) high, two-stage sheet piling dam. A spillway was cut into the dam to serve as a fish ladder after the streambed below had degraded. This dam does not hinder fish passage.

McCormick-Saeltzer Dam (kilometre 10.4--mile 6.5) was built in 1903. It is a barrier to fish migrating due to a damaged and inoperable fish ladder located on the south bank. This fishway was constructed during the summer of 1958. It replaced the original fish ladder which had never effectively provided fish passage. The existing fishway is a "pool and weir-type" fish ladder. It is approximately 113 m (370 ft) long and ascends 12.5 m (41 ft) (Figure 6).

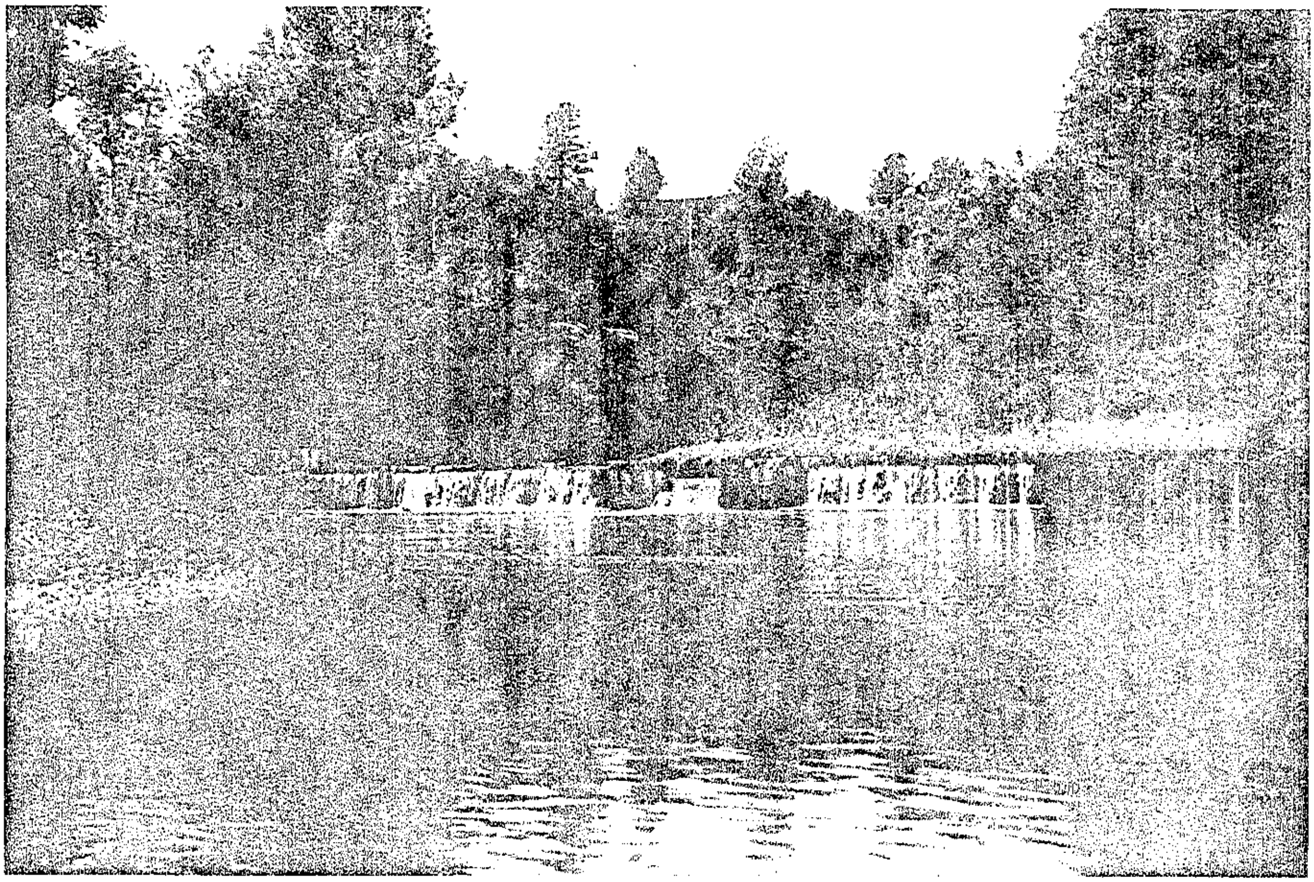
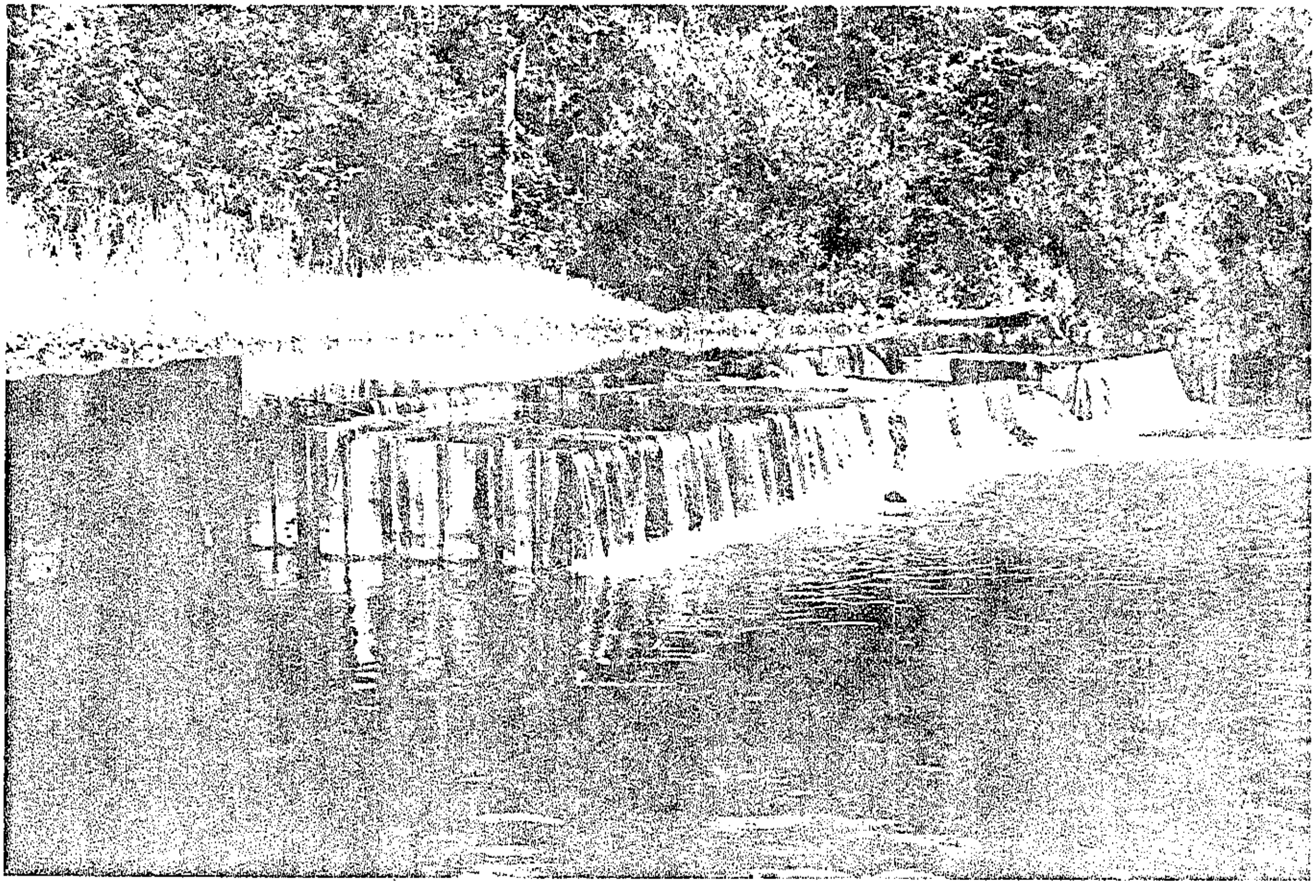


Figure 5. Two views of A.C.I.D. siphon check dam at RK 2.2 on Clear Creek, Shasta County



The ladder was built by tunnelling through bedrock and is not lighted. It has a maximum capacity of 0.42 m^3/s (15 ft^3/s) and is designed to operate at flows up to 113m^3/s (4,000 ft^3/s). Original orifice designs provided for entrance velocities ranging between 0.05 and 0.10 m/s (0.17 and 0.33 ft/s) for ladder discharges of 0.11 to 0.23 m^3/s (4 to 8 ft^3/s). The ladder construction conformed to all but one of the specifications of the Division of Architecture design of 1957. The downstream entrance was originally designed to have an additional 1.8-m (6-ft) long pool and weir and a different alignment.

During the first four years of operation, (1958-61), no salmon was observed using the ladder. In addition, Warner (1956) estimated that over 6,000 adult salmon could utilize the habitat upstream. Therefore studies to evaluate fish passage were initiated in the fall of 1962. Work began with removal of a rock barrier immediately downstream that may have impeded fish migrating upstream. Afterwards, DFG placed 23 adult salmon in the lower end of the ladder to see if fish would swim up the ladder. The ladder entrance was blocked behind the fish and a trap was placed at the exit. Although no fish was found in the trap or in the upper end of the ladder, results were inconclusive since neither the trap nor the fishway entrance was fish-tight. Numerous modifications of the entrance and the lower two pools were made to increase and alter the direction of entrance velocities. Again the result of these modifications was inconclusive because abnormally large releases of water from Whiskeytown Dam destroyed flashboards and caused silt to fill in the lower pools. The ladder was rendered unusable by salmon. Repair of the ladder and a final alteration of the entrance was made. It increased entrance water velocity to 1.2 m/s (4 ft/s), but no further test was made to find out if this would attract fish. Although the ladder did not work, DFG continued to maintain and operate the

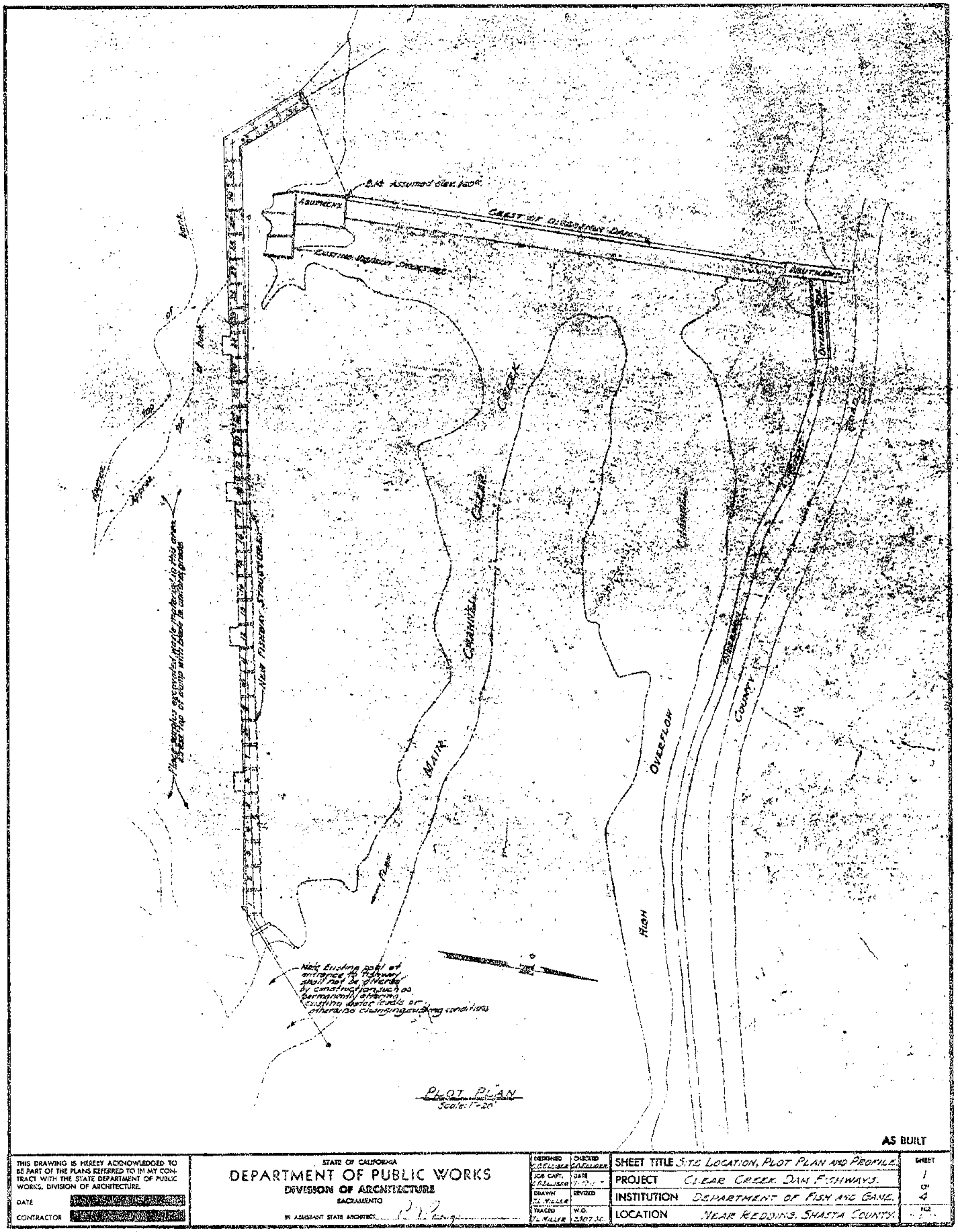


FIGURE 6: Site location and plot plan of the McCormick-Saeltzer Dam fishway.

the ladder until the mid-1970s. In spawning surveys from 1964 to 1969, no salmon was seen in the ladder or above McCormick-Saeltzer Dam. No spawning survey was conducted from 1970 to 1975. Despite no verification that the ladder was a viable fishway, the results were reported and a number of conclusions was made (Radovich, 1964):

1. The pool and weir design of Clear Creek fishway is basically sound. Its design and operating characteristics conform to similar pool and weir-type ladders that function satisfactorily.
2. Ineffectiveness of this ladder is due primarily to insufficient water velocity to attract fish into its entrance under existing hydraulic conditions. Fish cannot find or enter this ladder. This can be corrected by increasing velocities to 1.2 to 2.4 m/s (3.9 to 7.9 ft/s).
3. This ladder will be nonfunctional any time weir boards are not installed in the lower three or four pools. This has occurred in the past.
4. Results of experiments designed to determine whether salmon spawners would pass through a 113-m (370-ft) ladder without light were inconclusive.
5. Permanent modification should provide for addition of attraction water through an adequate diffuser system. Engineering assistance will be required to determine the most feasible method and cost of introducing attraction water into the lower-most ladder pool. Due to the importance of quantity of attraction flow, the downstream portal opening should be as large as possible while maintaining the desired velocity.
6. Weir boards should be installed permanently between all pools and adjusted to a proper height. It is most important that boards be maintained in all pools at all times to assure passage of fish.

7. The channel between the ladder fish exist and stream channel should be kept as deep as possible during adult fish migration. This will assure maximum ladder flow and unrestricted passage for fish leaving the fishway. Studies should be undertaken to determine the most effective way to eliminate the sandbar formation at the exit.

8. Consideration should be given to providing skylights at intervals along the tunnel roof if salmonids should reject this ladder because it is not lighted.

The fish ladder is presently inoperable. Numerous weir boards are missing and large amounts of debris choke the ladder in many places including the entrance. Many pools are completely filled with silt. Water cannot enter the ladder due to massive silt deposition at the exit. A dense growth of riparian vegetation prevents silt from moving downstream. There has been no recent effort to repair or reoperate the ladder.

I agree with some conclusions drawn by previous biologists. My own observations and conclusions are:

1. The misalignment of the entrance, contrary to the original designs, may have had a significant effect on fish attraction. The entrance is at least 5.5 m (19 ft) from the velocity barrier. Fish ladder entrances should be located close to points of heaviest flow since salmonids will be attracted to the areas. I inspected the ladder entrance during a streamflow of 3.6 m^3/s (125 ft^3/s). At this flow, a back-eddy with current moving upstream against the entrance is created. Even if flows within the ladder reach 0.43 m^3/s (15 ft^3/s) with an orifice velocity of 1.2 m/s (4 ft/s) (expected maximum capacity), attraction flows could be dissipated due to the location of the entrance and the

back-eddy effect. At greater flows, the back-eddy effect could be more pronounced.

2. Maximum stable flow through the ladder should be maintained during the spawning season. Deepening the exit or increasing the dam height while preventing the sandbar from forming at the exit may remedy this.
3. Debris enters the ladder and accumulates in louvres and weirs. Frequent removal of debris from the ladder is required to maintain favorable flow conditions. A mechanical debris deflector placed upstream from the exit would minimize maintenance in the ladder.
4. Literature suggests that fish ascend fishways faster in darkness than in light under similar hydraulic conditions (Long, 1959). Hydraulic conditions appear to be of greater importance in determining fishway use than lighting (USCE, 1948). However, chinook salmon consistantly use ladders with poor hydraulic conditions in most parts of northern California. They do not use tunnel ladders in this area (P. Warner, California Department of Fish and Game, Personel Communication). The cause of failure of the Clear Creek fish ladder may be unfavorable hydraulic conditions and/or lack of light. If the fish ladder is adequately repaired and altered to provide fish passage, an additional 5.5 kilometres (3.4 miles) of stream above McCormick-Saeltzer Dam would be accessible to anadromous fish. (The potential to rehabilitate this reach is discussed in Chapter 11.)

CHAPTER 7. JUVENILE CHINOOK SALMON EMIGRATION

Methods

A variable mesh fyke net (Figure 7) (1 m x 2 m x 6 m -- 3 ft x 5 ft x 20 ft) adapted from a midwater trawl was placed in Clear Creek near the mouth (kilometre 0.3 -- mile 0.2) to capture emigrating salmonids. A perforated aluminum box (0.5 m x 0.5 m x 1.0 m -- 1.6 ft x 1.6 ft x 3.3 ft) was attached to the downstream end of the net to retain captured fish. The net was fished continuously from January 27 through June 11, 1982, except during weekends and extremely high flows. The net was placed midstream in the fastest current and suspended just below the surface. Captured fish were counted and fork lengths of a representative sample of each species were measured.

Results

Juvenile salmon were first caught on January 27, 1982--the first day of sampling. The weekly catch of juvenile salmon fluctuated greatly (Figure 8). Weekly fyke net catches did not correlate with either flow or temperature ($r \leq 0.01$; $r \leq 0.01$).

The length-frequency distribution (Figure 9) shows that most juvenile salmon in Clear Creek emigrate at sizes ranging from 30 mm to 75 mm (1.2 in to 3.0 in) with most averaging around 35 mm to 40 mm (1.4 in to 1.6 in). Most of the fall-run progeny emigrated until May 7, 1982. Afterwards smaller fish (30-40 mm 1.2-1.6 in) were again more prevalent in the weekly catch, indicating progeny from the late fall-run. Most of the late fall-run juveniles had emigrated by June 11, 1982.

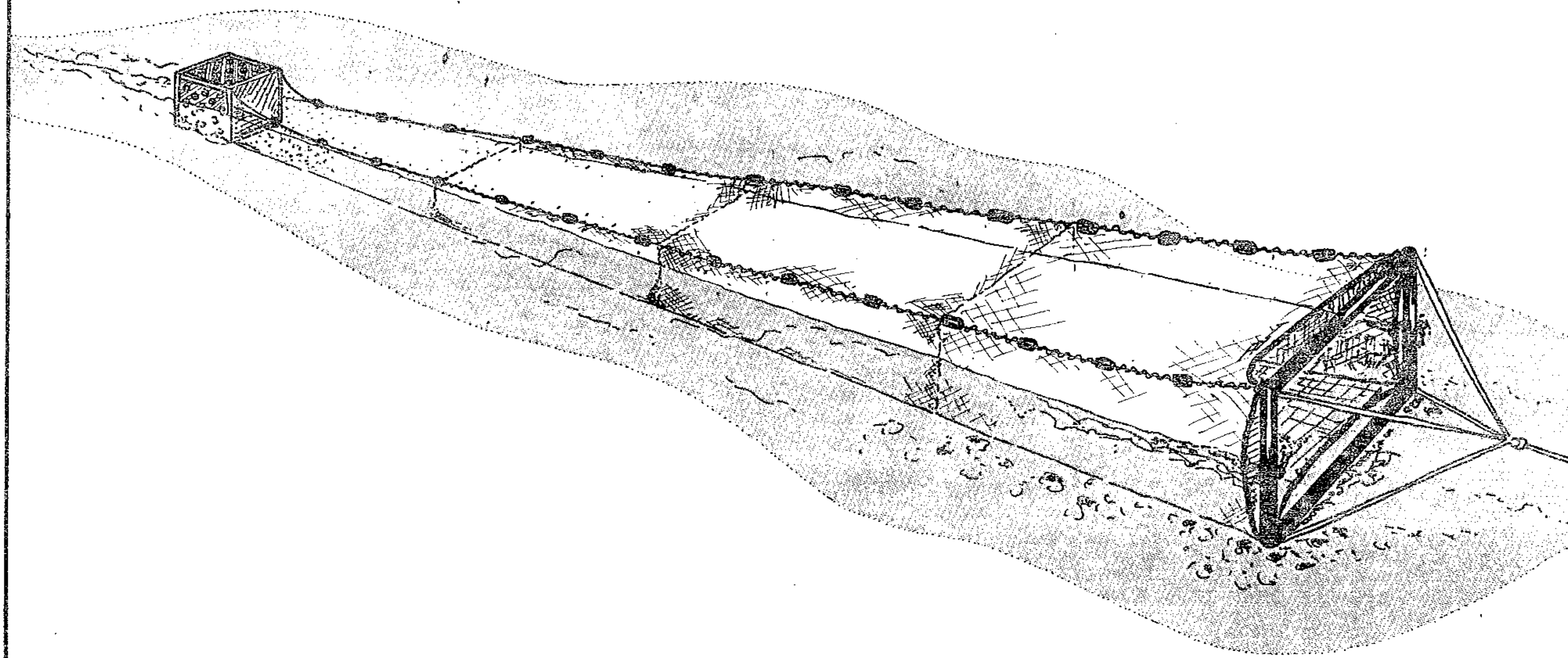


FIGURE 7 Fyke Net

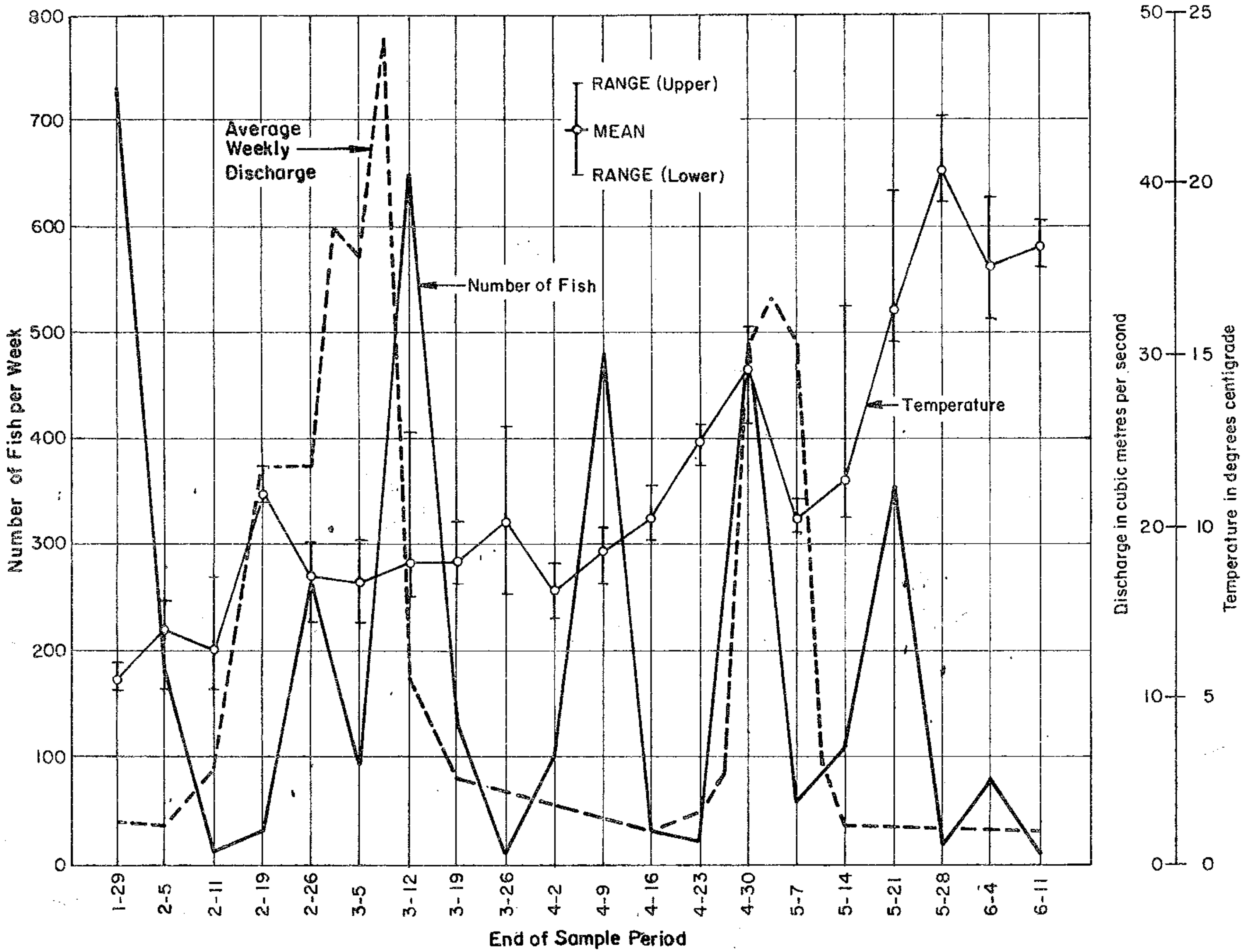


FIGURE 8: Weekly fyke net catches of juvenile chinook salmon emigrating from Clear Creek, Shasta County, January to June 1982.

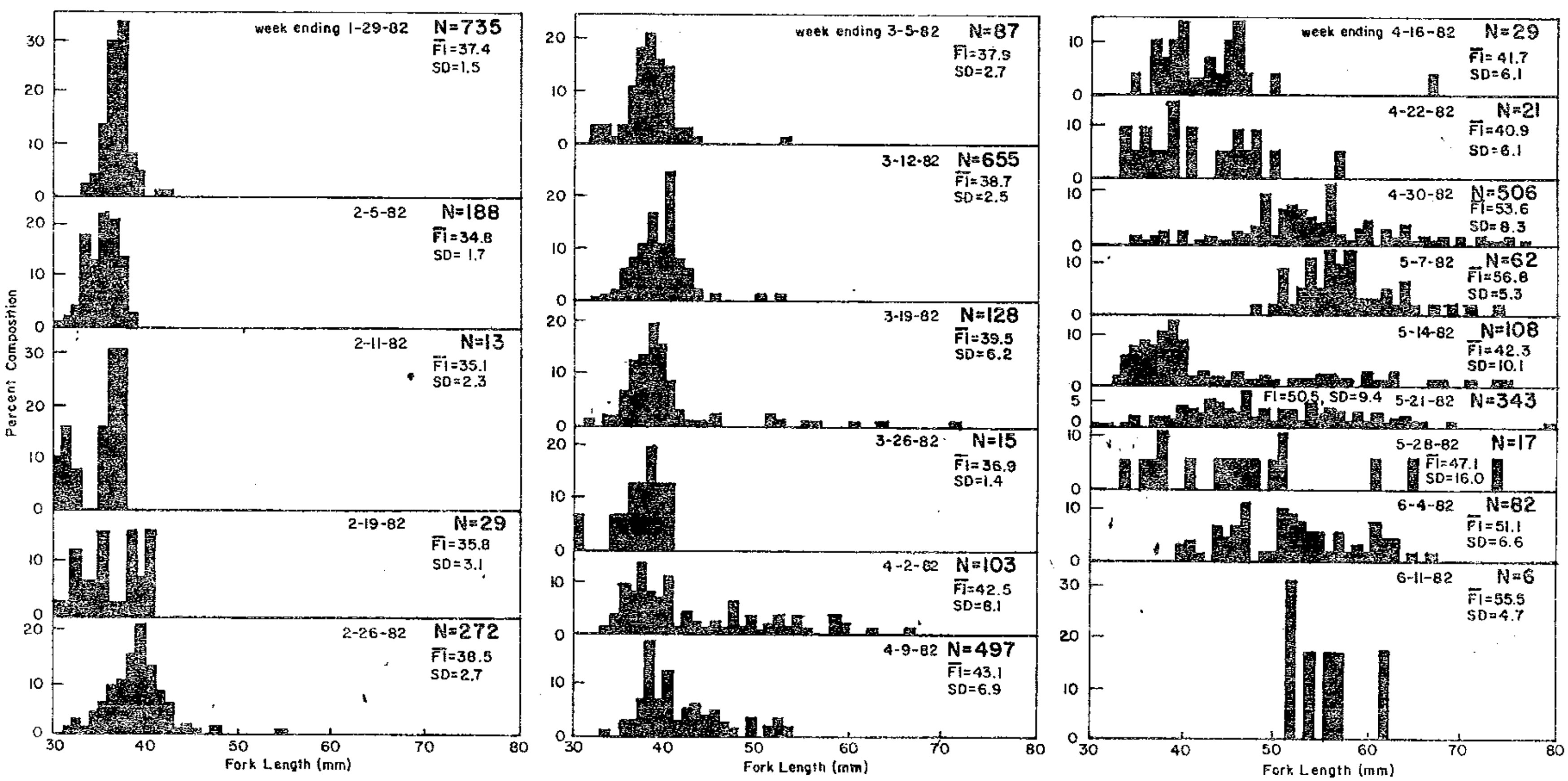


FIGURE 9. Length-frequency of juvenile chinook salmon emigrating from Clear Creek, Shasta County; January to June 1982.

Discussion

Although juvenile salmon were first caught on the first day of fyke netting, emigration probably began prior to that date. Fall-run juveniles could have been caught during early January 1982, which is approximately 50 to 60 days (average hatching time) after the first adult salmon was observed spawning on October 31, 1981.

The juvenile salmon increased in average fork length, which exhibits some growth during emigration. A shift of the size distribution to the larger sizes also occurred. Few juveniles are likely to survive in Clear Creek below McCormick-Saeltzer Dam after June since temperatures are usually too high during the summer months. However, nursery of juveniles is important during the months of emigration, January to June.

CHAPTER 8. RESIDENT FISH SURVEY

Methods

During fall 1981 and spring 1982, resident fish surveys were conducted in sections of Clear Creek between Clear Creek Road Bridge (kilometre 13.6--mile 8.5) and the mouth. Small riffles and pools were sampled with a backpack electroshocker. Larger pools were sampled with a boat electroshocker or seined. We observed fish by diving in areas that could not be electrofished or seined. Captured fish were identified, counted, measured, and released. Fish that were observed underwater by diving were identified and their sizes estimated. No population estimate was developed.

Results

Twenty-one species of fish were observed during surveys on Clear Creek (Table 10). Above McCormick-Saeltzer Dam, Sacramento sucker, Sacramento squawfish, and prickly sculpin were the most common nongame species, while rainbow trout were the most abundant game species. Below McCormick-Saeltzer Dam, sucker, squawfish, and hardhead were the most abundant nongame species.

Bluegill and green sunfish were the most abundant resident game fish in lower Clear Creek. Largemouth bass and smallmouth bass were also present in large numbers.

Discussion

Fishes that prey upon or compete for food and cover with juvenile salmon may have a significant impact on salmon survival. Any rehabilitation measures may not be effective if increased production is offset by losses of juvenile salmon to predation or competition. Sacramento squawfish, hardhead, resident rainbow trout, largemouth bass, smallmouth bass, bluegill, green sunfish,

TABLE 10

Fishes of Clear Creek, Shasta County

Common Name	Scientific Name	Above McCormick-Saeltzer Dam	Below McCormick-Saeltzer Dam
Pacific lamprey	*Lampetra tridentata*	NF1/	A1/
Chinook salmon	*Oncorhynchus tshawytscha*	NF	C1/
Rainbow trout	*Salmo gairdneri*	C2/	U1/2/
Steelhead	*Salmo gairdneri gairdneri*	NF2/	U2/
Speckled dace	*Rhinichthys osculus*	A	U
Carp	*Cyprinus carpio*	C	A
California roach	*Lavinia symmetricus*	U	C
Hitch	*Lavinia exilicauda*	U	U
Hardhead	*Mylopharodon conocephalus*	C	A
Sacramento squawfish	*Ptychocheilus grandis*	A	A
Sacramento sucker	*Catostomus occidentalis*	A	A
White catfish	*Ictalurus catus*	U	U
Black bullhead	*Ictalurus melas*	U	U
Brown bullhead	*Ictalurus nebulosus*	C	C
Mosquitofish	*Gambusia affinis*	A	A
Threespine stickleback	*Gasterosteus aculeatus*	C	C
Green sunfish	*Lepomis cyanellus*	C	C
Bluegill	*Lepomis macrochirus*	A	A
Smallmouth bass	*Micropterus dolomieui*	C	C
Largemouth bass	*Micropterus salmoides*	C	C
Tule perch	*Hysterocarpus traski*	U	C
Prickly sculpin	*Cottus asper*	A	C

1/ A = Abundant, C = Common
U = Uncommon, NF = Not Found

2/ Rainbow trout and juvenile steelhead were not differentiated. It was assumed that any steelhead/Rainbow trout found above McCormick-Saeltzer Dam was a resident rainbow trout.

catfish, and bullheads prey on juvenile salmon. The juveniles of these predator species may also compete for food and cover. In this study we were not able to quantify the magnitude of predation or competition. However, the potential exists and should be considered.

During late winter to spring, adult squawfish and hardhead migrate into Clear Creek to spawn. Predation potential would be highest since juvenile salmon are also emigrating during this period.

Squawfish and hardhead predation on salmon would likely occur in areas of high flow diversity such as in back-eddies, waterfalls, and heads of pools. The spillway at the ACID check dam (kilometre 2.2--mile 1.4) would be an example of such an area.

Adult largemouth bass, smallmouth bass, bluegill, and green sunfish are resident throughout the year and can be found in virtually every pool in Clear Creek. These fishes are concentrated mainly in two pools located at kilometre 0.8 (mile 0.5) and kilometre 1.1 (mile 0.7). It is in these areas that these fish spawn and rear. In addition to normal feeding behavior, predation is enhanced by the aggressive behavior of spawning fish, especially during spring months.

Rainbow trout, bullheads, and catfish are scarce in the lower creek and would contribute negligible predation.

Predation on juvenile salmon by the various species of resident fishes is a normal occurrence in the Sacramento River and its tributaries. However, if excessive predation exists, then proper management strategies could be implemented. Such methods range from trapping predators to operating flows to disfavor spawning and rearing of undesirable fishes.

CHAPTER 9. ARTIFICIAL PROPAGATION

Discussion

There are several means of propagating fish to rehabilitate or perhaps even enhance runs in Clear Creek. Although this list is not exhaustive, it represents alternatives with the highest potential.

Hatchery

For many years, the Department of Fish and Game has examined potential hatchery sites in the upper Sacramento River below Keswick Dam for mitigating and enhancing salmon and steelhead populations. One of those sites is Clear Creek which could be a desirable site because of suitable water quality and a dependable source of eggs. However, Clear Creek presently lacks an adequate quantity of water to assure attraction of adults and downstream migration of juveniles.

1. It has an existing fall- and late fall-run of chinook salmon that could be used as sources of eggs.
2. Water can be developed and imported from the Trinity River via Whiskeytown Reservoir or possibly by pipe into a proposed hydroelectric plant site near McCormick-Saeltzer Dam.

Further plans to build and operate a hatchery in Clear Creek must consider:

1. Fall- or late fall- and winter-run chinook salmon or steelhead could be propagated in a hatchery.
2. The annual average escapement in Clear Creek is about 2,500 salmon. To double this escapement figure, a hatchery should be sized to produce about 10,000 adult salmon. (This assumes a catch-escapement ratio of 2.75 to 1; Richard Hallock, personal communication.) Assuming that the fall-run is approximately four times the size of the late fall-run (based on the 1981 estimates), the 2,500 escapement figure could be

adjusted to 2,000 fall-run and 500 late fall-run. Assuming a survival of 0.1 percent, the hatchery should be built to rear and release at least 2.5 million smolts (2 million fall-run and 0.5 million late fall-run). Further consideration must include raising these fish to yearling size prior to release. The latter alternative would require increasing holding capacity and cost.

3. Estimates of construction, operation, and maintenance could range from $10 to $20 million, depending on size and species to be propagated. The source of funding for a Clear Creek fish hatchery would require identification. Funding by DFG is extremely unlikely. Perhaps the basic cost for a hatchery could be from mitigation for other water projects, or from special monies allocated for enhancement purposes. Enhancement would require cost sharing. The problem of providing better fish passage in the Red Bluff Diversion Dam would have to be resolved before interest in a new fish hatchery would become acceptable by DFG.

Rearing Ponds

Rearing ponds could be feasible and used to raise yearling chinook salmon or steelhead to release as smolts. Rearing ponds would require an egg-taking and incubating facility or importation of surplus fish from an existing facility. Site location, water quality, operation, maintenance, and funding criteria would need to be considered.

DFG Region 1 personnel conducted a long-term bioassay to determine the feasibility of raising salmon smolts in water from the Sacramento River. A rearing pond was built in Redding near the DFG headquarters. It used water diverted from the Sacramento River by the ACID Canal. About 18,000, 18/lb salmon were raised in this pond. DFG released 15,000 below the Red Bluff Diversion Dam and 3,000 at Redding auditorium.

Another rearing pond was planned to be built by DFG in Clear Creek near the NEED Camp, just below Whiskeytown Dam. However, an initial bioassay proved to be fatal for the experimental fish due to chlorinated water. Plans for a rearing pond at this site depends on future funding. If water quality permits, those fish raised at the NEED Camp would be released in Clear Creek to initially "seed" the creek. If a portion of these fish return to spawn in Clear Creek, adequate spawning habitat should be provided.

CHAPTER 10. STEELHEAD

Although they have been occasionally seen, there is no major run of steelhead in Clear Creek. Their absence in Clear Creek may be attributed to the following factors:

1. Unfavorable water quality. Juvenile steelhead typically remain in their parental stream for up to three years , although two years is more typical for Sacramento River steelhead. During this time, they need adequate food, cover, and water quality. However, during the summer months temperatures in most of Clear Creek usually exceed the optimum range required by juvenile steelhead. DWR (1981) found that for the reach between the mouth and McCormick-Saeltzer Dam, water temperatures during the summer of 1982 ranged from 22.2 to 26.7 C (72 to 80 F) in riffles and 21.1 to 25.6 C (70 to 78 F) in pools. According to Moyle (1976) the optimum range for rainbow trout is from 12.8 to 21.1 C (55 to 70 F). However, Bell (1973) states that the preferred temperatures for juvenile steelhead rearing in the Sacramento River range from 10.0 to 14.4 C (50 to 58 F). They may survive higher temperatures than these, but usually exhibit much reduced biomass per area. Generally, their metabolic rates increase dramatically with higher increases of temperature and consequently reduces their survival rates.

2. Poor food supply. DWR (1982) reports that benthic macroinvertebrate populations in Clear Creek are depressed and that total number of organisms and species were low in all eight collection locations. Although these depressed populations may be attributed to a natural emergence before the collection or high seasonal streamflows, the

presence of coarse, granitic sand may be limiting the benthic populations to some extent.

3. Limited spawning gravel. Adult steelhead require smaller spawning gravel than chinook salmon. In addition, the gravels must be clean and not compacted. In Clear Creek most of the salmon-spawning riffles are compacted and do not conform to steelhead spawning gravel criteria.

In order to establish a viable steelhead run in Clear Creek, several items would be required. However, each element must be weighed against its effect on salmon or other instream needs.

1. Spawning and rearing flows. These flows must provide adequate depths and velocities for spawning and optimum temperature for rearing through the critical summer months.
2. Spawning gravel. Spawning gravels of suitable size composition must be provided in riffle areas with optimum depths and velocities.
3. Access to upstream areas. Steelhead could ascend Clear Creek above McCormick-Saeltzer Dam to spawn in constructed riffles or they could utilize existing habitat for spawning and rearing. If such a scenario is desired, then the fishway at McCormick-Saeltzer Dam must be improved.
4. Importation of steelhead. The race and origin of imported steelhead must be considered. The following items must be evaluated:
   - o Will the race of steelhead selected survive and utilize the habitat provided in Clear Creek?
   - o How much straying and dilution of other stocks of Sacramento River steelhead will there be?
   - o What source of steelhead can be used without damaging the genetic integrity of other Sacramento steelhead stocks?
   - o Should adult spawners or juvenile fish be imported?

Conclusions

Because of the previous factors; unfavorable water quality, poor food supply, lack of spawning gravel and inaccessibility to the upper creek, creation of a steelhead·run in Clear Crek would be difficult. The concensus of DFG personnel with management responsibility for this stream is that efforts to alter or improve anadromous fish habitat in Clear Creek would be best utilized by improving salmon habitat.

CHAPTER 11. RECOMMENDATIONS FOR A REHABILITATION PROGRAM

Although there have been some wide fluctuations from year to year, the salmon runs of Clear Creek have declined since construction of Whiskeytown. The reasons for this decline are numerous and occur outside Clear Creek as well as in the immediate watershed.

The most critical factors in Clear Creek that have contributed to the decline of chinook salmon are: (1) the lack of suitable spawning gravels (quantity and quality), (2) less than optimum flow conditions (adequate depths and velocities), and (3) lack of flushing flows.

This and previous studies have shown that the quantity and quality of suitable spawning gravels is decreasing. In addition, less than optimum flow conditions are apparent as evidenced by a flow study conducted by DWR and DFG. Resolution of these two elements should be the first consideration in any rehabilitation program. Once these primary habitat components are restored, then other problems can be dealt with and restoration can be pursued.

Enhancement measures following a complete rehabilitation program, artificial propagation methods, such as rearing ponds or hatcheries should not be used as a substitute for a highly productive, well-managed, naturally reproducing fishery. These measures could be used to initially "seed" the creek while restorative options are used to eventually return the creek to a self-sustaining fishery. Only then would enhancement be valid.

The rehabilitation program recommended is one that would be accomplished in four phases (Figure 10). The success of each phase would determine whether or not to proceed with the next.

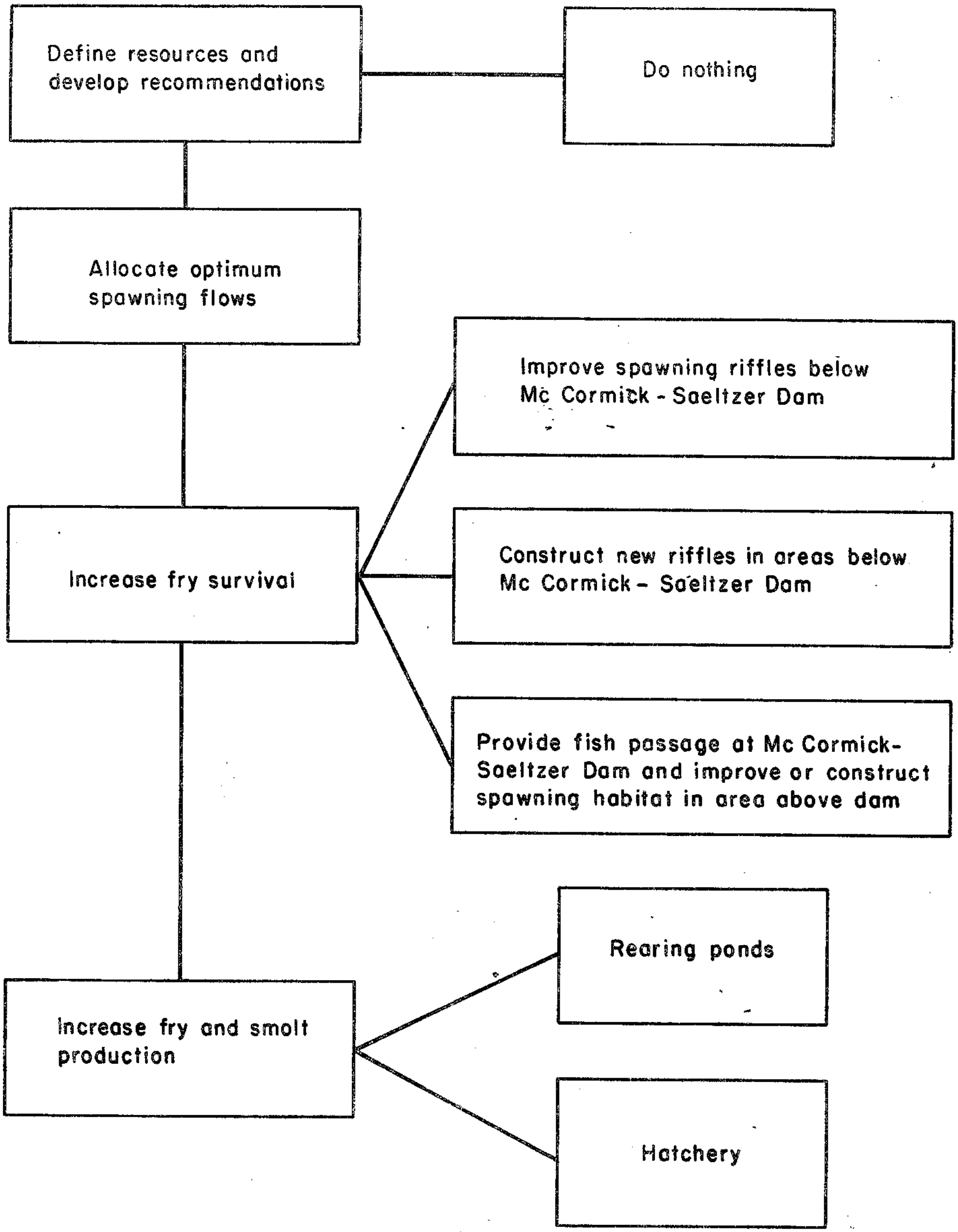


FIGURE 10. Flow diagram of rehabilitation, restoration, and enhancement program for chinook salmon runs in Clear Creek.

Rehabilitation Program

Phase I: Define Resources and
Develop Recommendations

Objective: Define the fishery resources and develop recommendations aimed at improving habitat conditions for chinook salmon.

Status: This report presents results of two years of study to define the fishery resources, and to develop recommendations that would lead to restoring salmon runs in Clear Creek.

Phase II: Determine and Seek Optimum
Flow for Chinook Salmon Spawning

Objective: Determine optimum flows for fall- and late fall-run chinook salmon and seek appropriation of these flows.

Justification: Allocation of a proper flow regime should result in an increase of available spawning habitat for chinook salmon. Remedial instream measures for fisheries use generally take on the form of reallocating flows. At present the release from Whiskeytown is 2.83 m^3/s (100 ft^3/s) for spawning during November and December and is allocated for fall-run chinook spawning. However, the late fall-run would require a spawning flow schedule extending through January and February.

Because gravel compaction is also a significant problem, flow reallocation coupled with gravel improvements in several "key" riffles is suggested. It is unlikely that flow allocation would be of a magnitude to flush out deposition of fine materials out of the desirable substrates and that some gravel improvements would be necessary.

Status: An instream Flow Incremental Methodology (IFIM) study was conducted by DWR and DFG[1]. Five discreet reaches of stream were identified and representative transects within the reaches were chosen. The year 1983

1/ DWR carried out the field work and major part of the data processing.

proved to be extremely wet with flows peaking near 566 m^3/s (20,000 ft^3/s). This flow changed the character of the stream in at least three of five sample reaches. These sample reaches were remeasured in July 1983 while the other two reaches will be reevaluated to if data are still valid.

Phase III: Increase Egg-to-Fry Survival

Element 1

Objective: Increase egg-to-fry survival by improving the quality of substrate in existing spawning riffles below McCormick-Saeltzer Dam.

Justification: Data show that most gravels in spawning riffles below McCormick-Saeltzer Dam are marginal in quality--laden with sand and compacted. Improving the permeability of the substrates by removing fine sediments would increase egg-to-fry survival (Cooper, 1965; Andrews, 1980). Andrews (1980) shows that a two- or three-fold increase in salmon production is obtainable by gravel cleaning. In Clear Creek riffles that did not meet minimum standards should be rehabilitated by gravel cleaning. This would be a recurring process, required every few years.

Methods: Various gravel-cleaning methods have been employed to restore salmonid-spawning habitat. The following list of gravel-cleaning methods represents the most feasible. A list of studies describing these and other similar methods is described in Appendix I. A thorough feasibility and cost analysis of each method should be conducted prior to implementation.

1. Velocity-Segregation Method (Andrews, 1980; Heiser, 1972)
   This method is also known as "ripping". Substrates are rolled and lifted by a bladed bulldozer to dislodge fine materials. Fines are then carried downstream by the current to settle out in areas that can be excavated or do not need to be cleaned.

2. Vibrated-Bucket Method (Andrews, 1980)

The discharge of fines into a stream from gravel-cleaning operations can be minimized by use of a technique that permits burial of the fine material removed from the gravel. In this method, a 2.1-m (7-ft) wide gradall digging bucket is modified by addition of a vibrator and by replacing the solid steel bottom with a 1.9-cm (0.75-in) wire screen. A cam-operated hydraulic vibrator is mounted to provide a throw of 3.8 cm (1.5 in) at the cutting edge at a frequency of 240 cpm.

Gravel is dug from the streambed with this bucket, which is then dipped in and out of the water while being vibrated. This action causes the fines to drop through the screen and into the hole in the streambed from which the gravel was removed. The cleaned material is then spread on top of the fines in a layer about 30.5 cm (12 in) deep.

3. Mechanical Air-Water Jetting Method (Gravel Gertie) (Andrews, 1980; Mih, 1980)

This involves using a mobile platform to carry machinery with high velocity water jets to flush and then remove the silt to off-stream areas. This method has worked in some spawning channels but its use is usually limited by cost and its inability to clean large amounts of substrate.

Element 2

Objective: Replace spawning gravels that have been scoured from riffle areas below McCormick-Saeltzer Dam.

Justification: Because of dam construction and subsequent lowered flows and riparian encroachment, there is little gravel recruitment into riffles. These riffles should be reconstructed by restoring gravels suitable for spawning.

Methods: It would require importing gravels for reconstruction and restoration of spawning riffles. The substrates could come from two sources:

1. Local Gravel-Mining Operations

   Pre-sorted or graded-out substrates from the gravel companies located within the flood plain could contribute an ample supply of gravel for riffle reconstruction. Substrates would need to be transported by truck and spread with bulldozers or earthmovers.

2. Adjacent to Active Floodway

   Much gravel is located adjacent to the active floodway. It would require moving gravel into the stream with a bulldozer or front-end loader. These substrates are compacted with sand and would require clearing before the spawning season.

Element 3

Objective: Provide passage for salmon above McCormick-Saeltzer Dam and improve or construct spawning riffles in these areas.

Justification: Successful restoration of the spawning habitat in lower Clear Creek should be followed by extending spawning habitat upstream above McCormick-Saeltzer Dam. A 5.5-kilometre (3.4-mile) reach of stream has potential for chinook salmon spawning. However, the substrates in this area are similar to those below the dam--compacted with sand while many potential riffles are scoured. Some restoration would be required here also.

Methods: Abandon the lower section of the ladder and break through the tunnel with a step and pool entrance at the base of the dam.

Once adequate fish passage is provided, then gravel cleaning and riffle restoration can take on the form of methods described in Elements 1 and 2.

Phase IV: Artificial Propogation

Objective: Increase the fry/smolt production of Clear Creek for the purposes of enhancement.

Justification: Once rehabilitation of salmon habitat in Clear Creek has been attained, and restored to pre-Whiskeytown Dam levels, then measures to increase the runs could be considered. Artificial propagation should only be used if natural production does not increase as a result of habitat improvements.

Methods: Methods to enhance the salmon fishery could include building a hatchery, operating rearing ponds, or initiating a system of rearing fish in "doughboy" pools.

ACKNOWLEDGEMENTS

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