UPPER SACRAMENTO RIVER STEELHEAD
,Oncorhynchus mykiss, 1952-1988

A report to the
U.S. FISH AND WILDLIFE SERVICE

by

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INTRODUCTION

Steelhead trout, Oncorhynchus mykiss, (formerly Salmo gairdnerii gairdnerii and Salmo mykiss) populations have declined drastically in the Upper Sacramento River System above the mouth of the Feather River (Figure 1). Many known changes are in evidence which are, or could be, adversely affecting steelhead abundance but the relative importance of these changes is unknown.

One reason that the effects of most known changes are unknown is because of the lack of interest in steelhead i.e., more interest displayed elsewhere, by administrators. For example, the only comprehensive steelhead research program ever carried out on the Upper Sacramento River System was canceled in the late 1950's. Unfortunately this cancellation occurred immediately prior to when Coleman National Fish Hatchery (CNFH) yearling steelhead releases were increased from 166,000 to 1.5 million annually. No evaluation of this tremendous change was permitted, so the effects of the increased releases on naturally produced steelhead remain a mystery.

Since the 1950's, Upper Sacramento River steelhead studies have been piecemeal, primarily related to Red Bluff Diversion Dam (RBDD), CNFH production and periodic attempts to determine harvest. Because of the lack of steelhead research, there is now not enough available data to enable development of a comprehensive Upper Sacramento River System steelhead management plan. However, there is enough information available to suggest some immediate steps that may be taken which could help stem, at least temporarily, the decline.

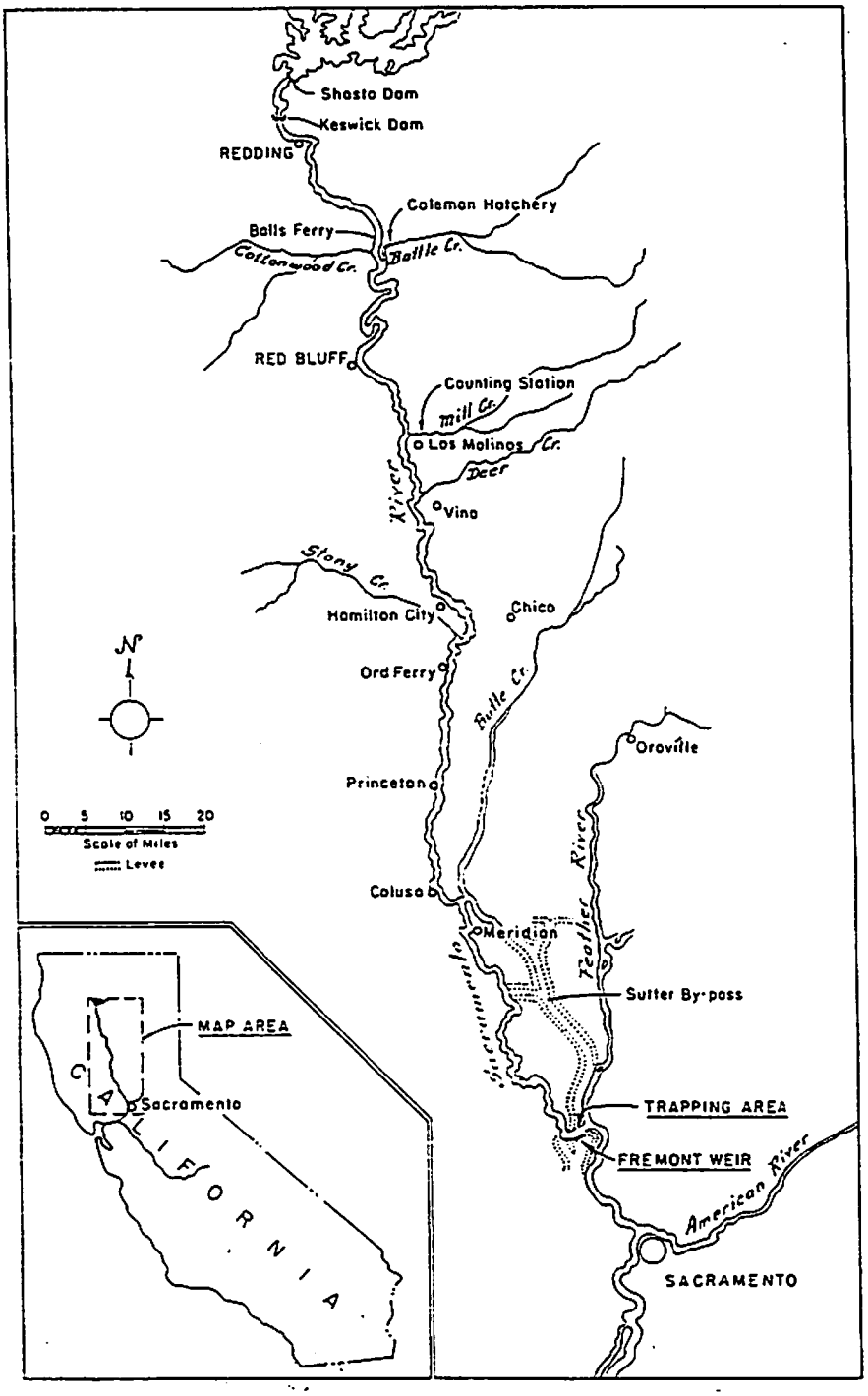

Figure 1. Map of the Sacramento River System, Showing the Area Above the Confluence of the Sacramento and American Rivers. From Hallock, Van Woert and Shapovalov, 1961.

The purpose of this report is to, (1) summarize readily available information on Upper Sacramento River steelhead, and on several known changes that have occurred which are, or might be, contributing significantly to the decline, and (2) to suggest actions which could be taken both to reach an immediate goal of steming the decline, and a long range goal of restoring the population to a satisfactory level. This report is by no means intended as a comprehensive evaluation of the steelhead problem.

LIFE HISTORY

Adult Migration

Adult steelhead migrate into the Upper Sacramento River System from July through the middle of the following March. There is but one annual run, the peak of which passes the mouth of the Feather River near the end of September. During some years a few steelhead also migrate into the upper river in June (Figure 2).

Between 1969 and 1982 the fish trapping at RBDD, located on the Sacramento River more than 120 miles upstream from the mouth of the Feather River, showed an almost identical migration pattern, but with the run extending into May. The peak of the migration at RBDD averages close to one week later than at the mouth of the Feather River (Figure 3). During some years a few steelhead also pass RBDD in June.

The few steelhead migrating in June hint of a possible spring run, but if such a run exists it appears to be only sporadic.

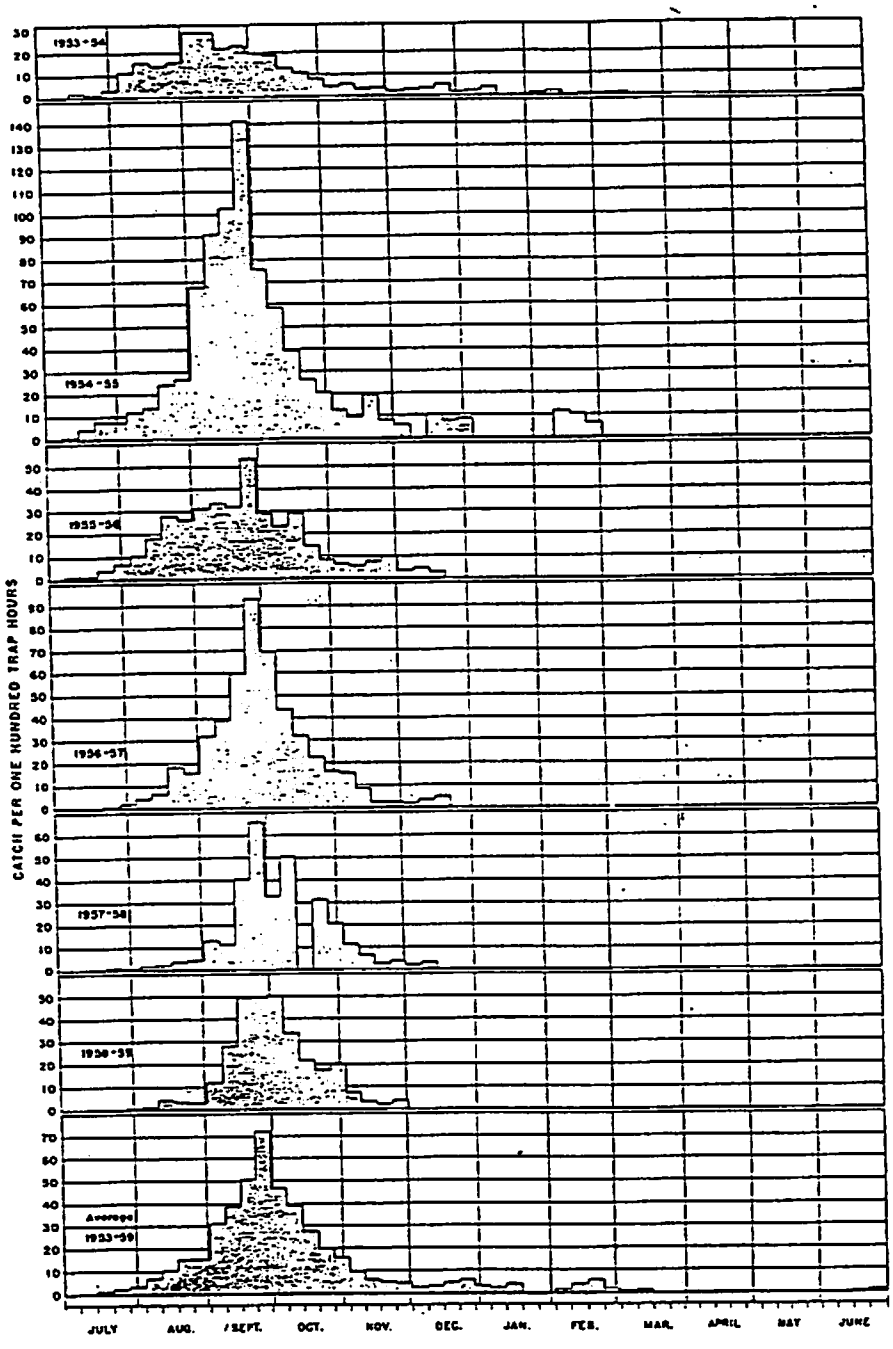

Figure 2. Time Pattern of Upper Sacramento River Adult Steelhead Migrations. Migration Times were Determined by Trapping Upstream Migrants in the Sacramento River one-Half Mile Above its Confluence with the Feather River, Near Fremont Weir. From Hallock, Van Woert and Shapovalov, 1961.

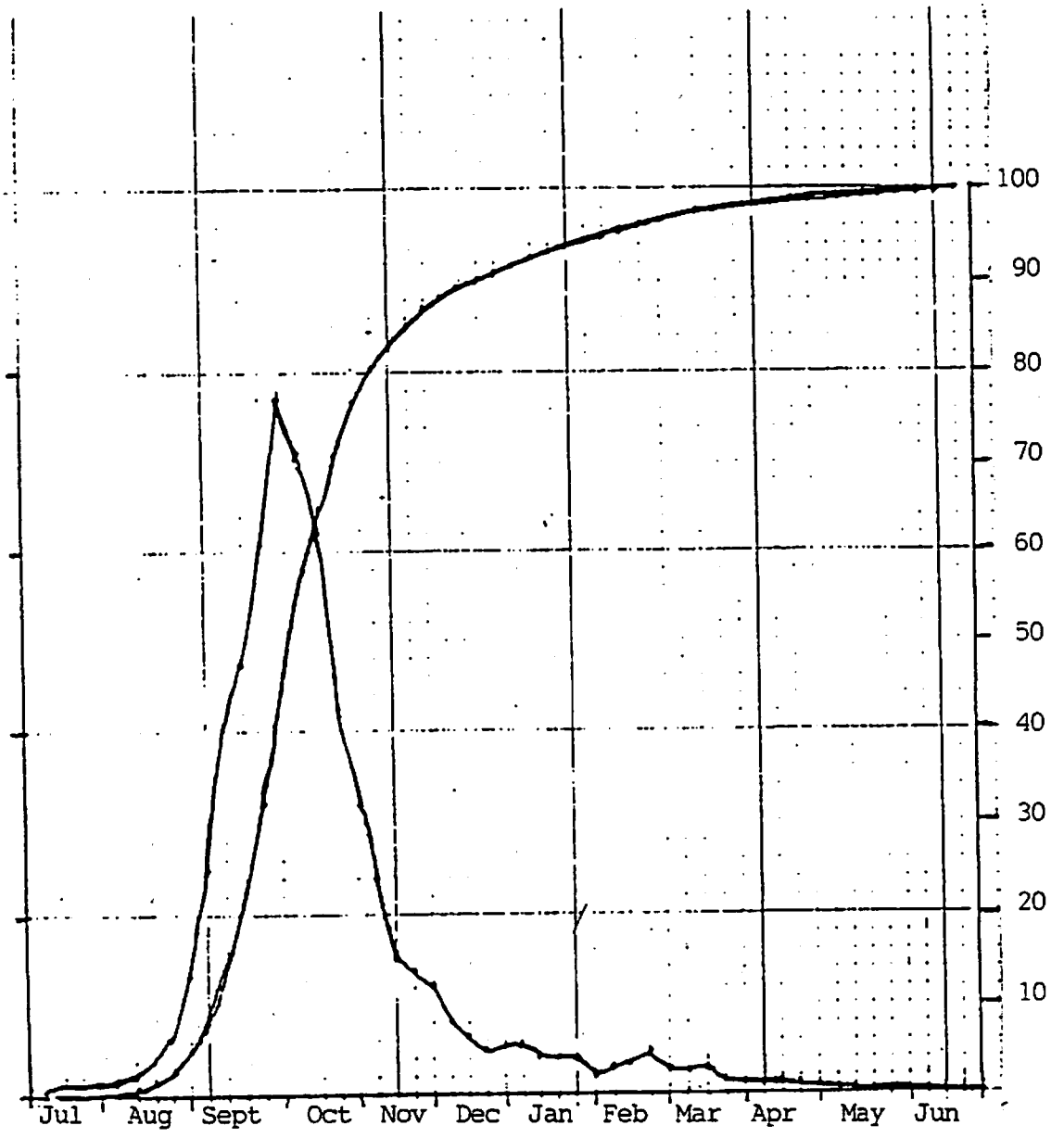

Figure 3. Weekley Average Number of Steelhead, and Cumulative precent of the Run, Passing Red Bluff Diversion Dam, 1969-1982. From DFG Files, Prepared by F.W. Fisher.

Length - Distribution

During six years of trapping steelhead migrating past the mouth of the Feather River, into the Upper Sacramento, almost 19,000 were measured. During most years there is a bimodal length distribution; one mode at 15.5 inches and the other at 20.5 inches (Figure 4). The smaller fish consisted primarily of age classes that spent two years in freshwater and one year at sea. The larger steelhead were principally fish which had spend two years in freshwater followed by two years in the Ocean. When omitting fish under 14 inches in length, a good portion of which are either seaward bound or at least do not continue upstream to spawn, the average steelhead length becomes 18.7 inches and the average weight about 3 pounds.

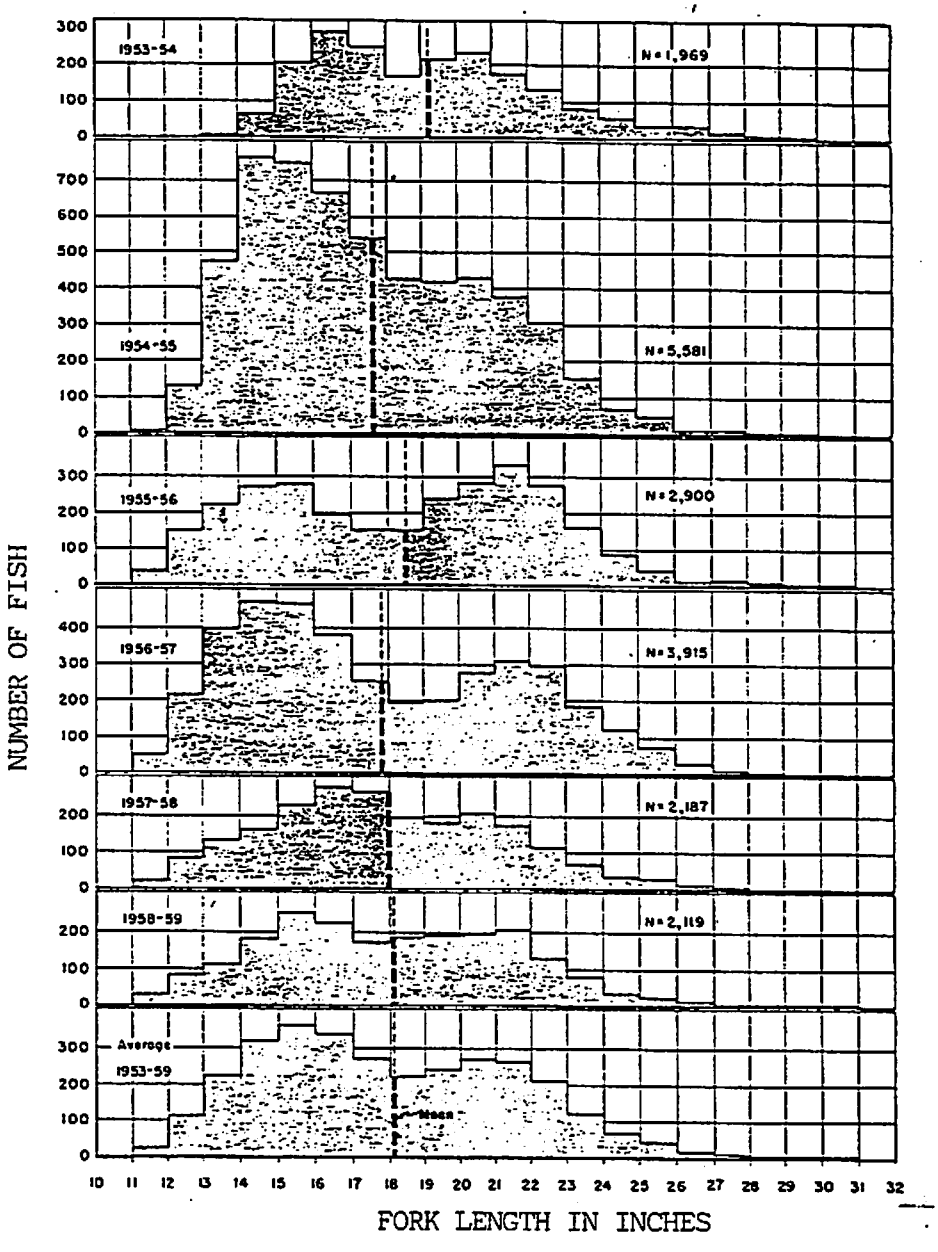

Figure 4. Length Composition of Upper Sacramento River Steelhead Populations. Measurements were made of Upstream Migrants Trapped in the Sacramento River One-Half Mile Above its Confluence with the Feather River, Near Fremont Weir. From Hallock, Van Woert and Shapovalov, 1961.

Length - Weight Relationship

In the fall of 1956, length and weight measurements were made of 484 steelhead as they migrated past the mouth of the Feather River into the Upper Sacramento. They ranged from 14 to 172 ounces (about 11 pounds) in weight, and from 12.8 inches to 27.2 inches in length. From these data, a length-weight relationship for Sacramento River steelhead was calculated (Figure 5).

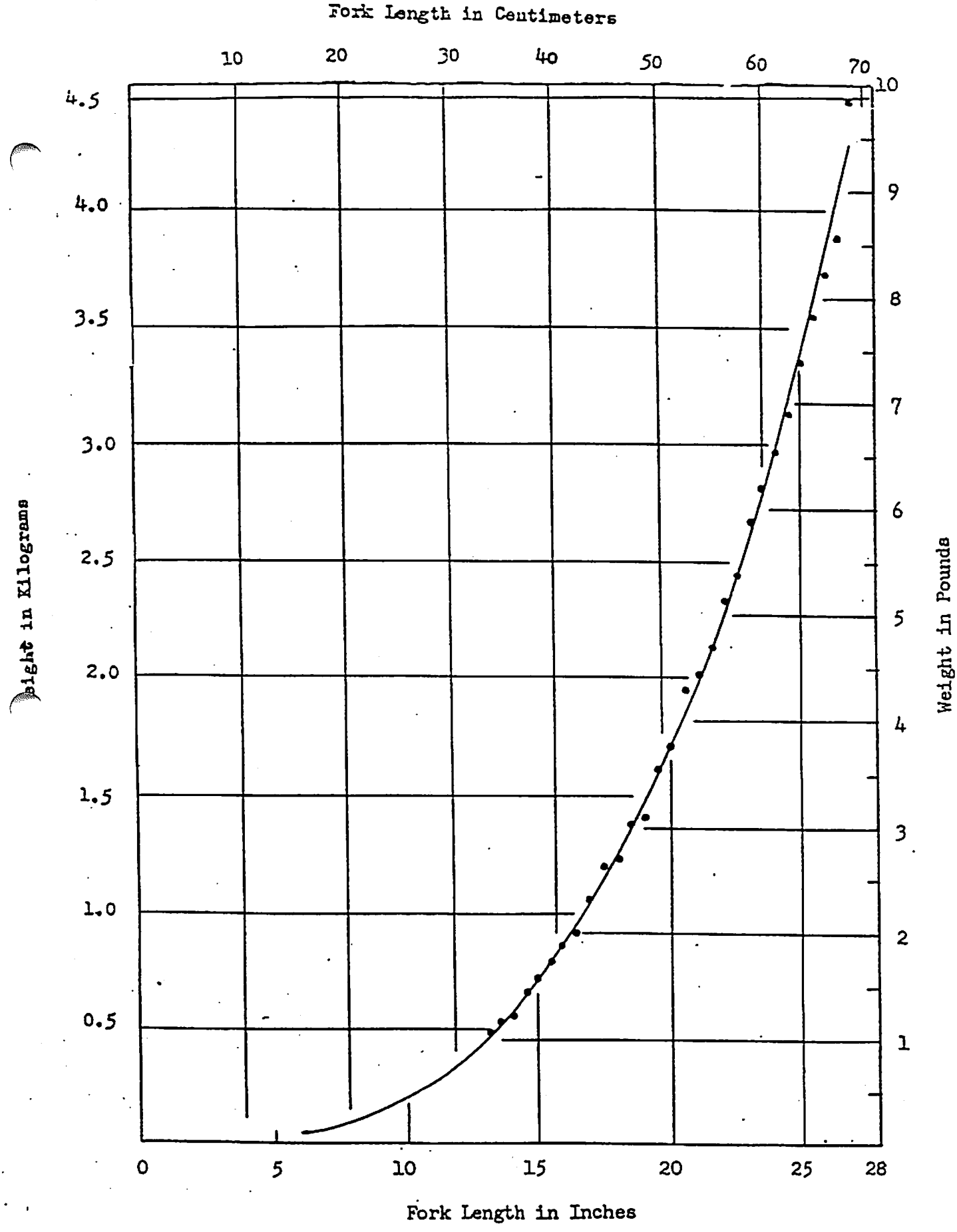

Figure 5. Length-Weight Relationship of Upper Sacramento River Steelhead. The Curve is a graph of the Calculated Length-Weight Equation; the Dots are Averages of Actual Lengths and Weights grouped by One-Half Inch Intervals of Length. From Hallock, Van Woert and Shapovalov, 1961.

Naturally Produced Fish

The 1950's studies showed that naturally produced sea-run steelhead returning to the Upper Sacramento river consist of 17% two-year-old fish, 41% three-year-olds, 33% four-year-olds, 6% five-year-olds and 2% six-year-old fish. The returning steelhead consisted of 70% that had spent two years in freshwater before entering the ocean, 29% that had spent one year in freshwater before entering the ocean and 1% that had spent three years in freshwater before entering the ocean.

Hatchery Fish

Production at CNFH in the 1950's of yearlings averaging 10 per pound and smaller (10/lb-26/lb) produced sea-run adult returns to the Upper Sacramento that averaged 20% two-year-old fish, 75% three-year-olds and 5% four-year-old fish. The returning adults consisted of 16% that had spent one year in freshwater and one year at sea, 80% that had spent one year in freshwater and two years at sea, and 4% that had spent one year in freshwater and three years at sea. However, those steelhead released at a size larger than 8/lb resulted in adult returns to the Upper Sacramento consisting of 63% two-year-old fish, 34% three-year-olds and 3% four-year-old fish.

Spawning

Steelhead spawning extends over a period of several months and may take place any time from the latter part of December through April or May. February is usually a peak month for taking steelhead eggs at CNFH. Steelhead spawn in most tributaries to the Upper Sacramento and appear to do so in proportion to creek size as measured by the amount of runoff. Actual numbers of steelhead that spawn in the main stem of the Sacramento (if any) and in each tributary are unknown.

Repeat Spawners

Naturally Produced Fish

In the fall of 1954 scale samples of naturally produced steelhead revealed that 83% were spawning for the first time, 14% for the second time, 2% for the third time and 1% for the fourth time.

Hatchery Fish

The proportion of hatchery steelhead which spawn more than once (4%) is much lower than among naturally produced fish (17%). Ninety-six percent of the hatchery steelhead taken in the Sacramento River were on their first spawning migration and only 4% were on their second. No hatchery steelhead were encountered which were returning for a third or later spawning.

During fiscal year 1970-71 a total of 3,679 steelhead were handled at CNFH and only 40 (1.1%) had entered the hatchery the previous year. This was indicated by adult steelhead that were marked prior to release after spawning (DFG unpublished data).

Juvenile Migration

All evidence indicates a heavy seaward migration of yearlings out of the Upper Sacramento River system in the spring and a much smaller one in the fall i.e., peak periods of yearling and two-year-old steelhead occur during the first heavy runoff in the fall and again in early spring, starting as early as January. Naturally produced yearlings enter salt water at a length varying from 7 to 9 inches (Table 1).

Table 1

Calculated Average Fork Lengths and Length Increments (in inches) of wild (Naturally-Produced) Upper Sacramento River Steelhead Returning From the Ocean To Spawn For the First Time. All Fish Were Captured by Trapping in the Sacramento River One-Half Mile Above its Confluence with the Feather River. From Hallock, Van Woert and Shapovalov, 1961.

Age of returning adults*	Number of fish	Year of life															
		1		2						3						4	
		Annual length increment	Length at end of year	Intermediate length increment	Length when entering salt water	Salt water length increment	Annual length increment	Length when captured	Length at end of year	Intermediate length increment	Length when entering salt water	Salt water length increment	Annual length increment	Length when captured	Length at end of year	Annual length increment	Length when captured
1/1	17	4.8	4.8	3.2	8.0	5.0	**8.2	13.0									
1/2	10	4.8	4.8	2.4	7.2	6.0	8.4		13.2			7.3	**7.3	20.5			
2/1	30	4.2	4.2				3.6		7.8	1.2	9.0	7.0	**8.2	16.0			
2/2	26	3.7	3.7				3.4		7.1	1.3	8.4	8.1	9.4		16.5	**6.8	23.3

* The "/" sign separates years in fresh water and years of ocean life. Total age of the fish in years is obtained by adding the numerals. For example a 1/2 fish spent one year in fresh water, two in the ocean, and is three years old.

** These length increments represent only approximate annual growth in length, since all fish were captured in the fall, and not at the end of the growing season.

Growth in Length

Among naturally produced steelhead, the greatest annual length increment occurs during the first year of life in the ocean (Table 1). Those juveniles which had spent two years in freshwater prior to entering salt water did so at a greater length than fish which had spent only one year in freshwater; and they also migrated faster toward salt water i.e., their scales showed no intermediate growth.

Hatchery produced fish also grow fastest during their first year in the ocean, more than doubling their length during their second year of life.

CHANGES IN ADULT POPULATION, HATCHERY PRODUCTION AND CATCH

Population Size Based on Tagging Studies

Between 1953 and 1958 the total Upper Sacramento River System steelhead population averaged 20,540. At that time releases of yearling steelhead from CNFH averaged 166,000 annually. In the early 1960's CNFH releases were increased to 1.5 million yearlings annually. Population estimates were not made immediately after initiating the increased CNFH releases, but creel census studies showed that the average Upper Sacramento River System steelhead catch had increased from 7,600 in the 1950's to more than 19,000 in the late 1960's. Thus with the increased CNFH releases, the catch in the late 1960's had become almost equal to the entire population in the 1950's. Between 1953 and 1958 an average of 37% of the population was harvested by sport fishermen. If this 1950's percent of the average catch is applied to the late 1960's average catch of 19,000, the total steelhead population in the late 1960's would have averaged close to 51,000 fish. The only other tagging study aimed at determining the Upper Sacramento River System steelhead population size was conducted between 1971 and 1974. This study showed that the population at that time averaged only 21,000 i.e., it was about as great as the catch in the late 1960's. All indications are that the population has been declining steadily since the late 1960's.

Red Bluff Diversion Dam Counts

The Upper Sacramento River System steelhead population

decline is emphasized by the steelhead counts at RBDD, where the numbers migrating upstream have decreased from more than 17,000 in 1967 to just over 400 in 1988 (Table 2).

Table 2

ESTIMATED AND CALCULATED STEELHEAD POPULATIONS AND CATCH FROM THE SACRAMENTO RIVER ABOVE THE FEATHER RIVER

Year	RBDD Counts	Estimated Population *1 *2	Calculated Population	Estimated Catch *3 *4 *5	Calculated Catch	Coleman Trapping
1953		14,400		3,619		424
1954		28,400		11,431		960
1955		28,320		9,769		1,063
1956		18,380		7,994		889
1957		19,410		6,263		962
1958		14,340		6,544		816
1959						992
1960						1,653
1961						1,739
1962			18,172	6,410		1,486
1963			25,938	10,720		1,737
1964			34,497	15,470		2,965
1965			33,290	14,800		1,643
1966	13,011		36,955		16,834	1,532
1967	17,416		46,480	22,120		3,229
1968	13,648		31,565	13,843		4,939
1969	11,590		44,600	21,077		4,046
1970	10,876		31,643	13,886		3,742
1971	5,641	25,510		11,460		1,486
1972	7,978	24,444		10,561		2,645
19..	6,101	17,334		4,247		1,834
19..	5,205	19,136		4,953		1,099
1975	8,196		25,957		10,731	2,162
1976	5,928		20,775		7,855	1,834
1977	2,467		12,870		3,468	1,099
1978	3,487		15,200		4,761	2,162
1979	10,994		32,347		14,277	2,069
1980	2,898		13,854		4,014	697
1981	2,394		12,703		3,375	865
1982	3,150		14,611		4,334	4,264
1983	1,969		11,733		2,837	1,118
1984	4,404		17,296		5,924	945
1985	3,358		14,903		4,595	938
1986	2,809		13,648		3,899	529
1987	1,796		11,336		2,616	2,565
1988	432		8,222		818	2,604
						850
						915
						286

*1 1953-58 from Fish Bull. 114.
*2 1971-74 Preliminary office data.
*3 1953-58 from Fish Bull. 114.
*4 1962-65 from Dralle & Van Woert Admin. Rept.
*5 1967-74 from Rowell, AFB office rept.

Population Size, Calculated

The void in steelhead population and catch information between years when no tagging or creel census studies were conducted, was filled in by calculating the annual numbers (Table 2). With the method of calculation used, the late 1960's population would then have averaged only 41,000 instead of 51,000. However, because two linear regression relationships were used to make the calculations, it is probable that the average calculated populations since the late 1960's are high; and that the population has declined more than indicated. This probability is especially emphasized by the sharp decline in both RBDD counts and counts at CNFH since 1984.

CALCULATE STEELHEAD TOTAL POPULATION
RELATIONSHIP TO TOTAL STEELHEAD CATCH

Y= -3674.63 + 0.55x
r= .88

Year	Total Catch	Calculated Population
1962	6,410	18,172
1963	10,720	25,938
1964	15,470	34,497
1965	14,800	33,290
1967	22,120	46,480
1968	13,843	31,565
1969	21,077	44,600
1970	13,886	31,643

CALCULATE TOTAL COUNT AT R.B.D.D.
RELATIONSHIP TO TOTAL STEELHEAD CATCH

Y= 340.61 + 1.267x
r= .84

Year	R.B.D.D. Count	Total Calculated Catch	Calculated Population
1966	13,011	16,834	36,955
1975	8,196	10,731	25,957
1976	5,928	7,855	20,775
1977	2,467	3,468	12,870
1978	3,487	4,761	15,200
1979	10,994	14,277	32,347
1980	2,898	4,014	13,854
1981	2,394	3,375	12,703
1982	3,150	4,334	14,611
1983	1,969	2,837	11,733
1984	4,404	5,924	17,296

Figure 6. Relationship Between Upper Sacramento River Adult Steelhead Population and Catch; and Between Red Bluff Diversion Dam Adult Steelhead Counts and Catch. Equasions used to Calculate Population and Catch Appearing in Table 2. From DFG Files; Prepared by F. W. Fisher.

Hatchery vs. Natural Populations

There is some evidence that large scale stocking of hatchery steelhead, if it leads to a preponderance of hatchery fish spawning with naturally produced fish, may cause a decline in the natural populations. It is thought by some that hatchery fish have a reduced reproductive capacity when compared with naturally produced fish because adverse hereditary changes have evolved due to a lack of natural selection in a hatchery. This problem has never been evaluated in the Upper Sacramento River System, but unless large numbers of hatchery fish are straying into the tributaries where most naturally produced steelhead spawn, the genetic effect of large scale stocking by CNFH should not adversely affect the natural population.

Following are estimates of the changes in numbers of adult naturally produced and hatchery fish in the Upper Sacramento steelhead populations between the 1950's and early 1980's. In the 1950's (1953-55) the average Upper Sacramento River adult steelhead population consisted of 86% (20,400) naturally produced fish and 14% (3,300) hatchery fish. CNFH yearling releases averaged 166,000 annually (Figure 7). Between 1967 and 1969 the population changed to where 27% (11,000) were naturally produced and 73% (30,000) were hatchery fish. Colemen National Fish Hatchery releases of yearlings had been increased to 1.5 million annually (Figure 8). By the early 1980's (1981-83) the naturally produced fish made up only 17% (2,200) of the population and hatchery fish 83% (10,800) of the population (Figure 9).

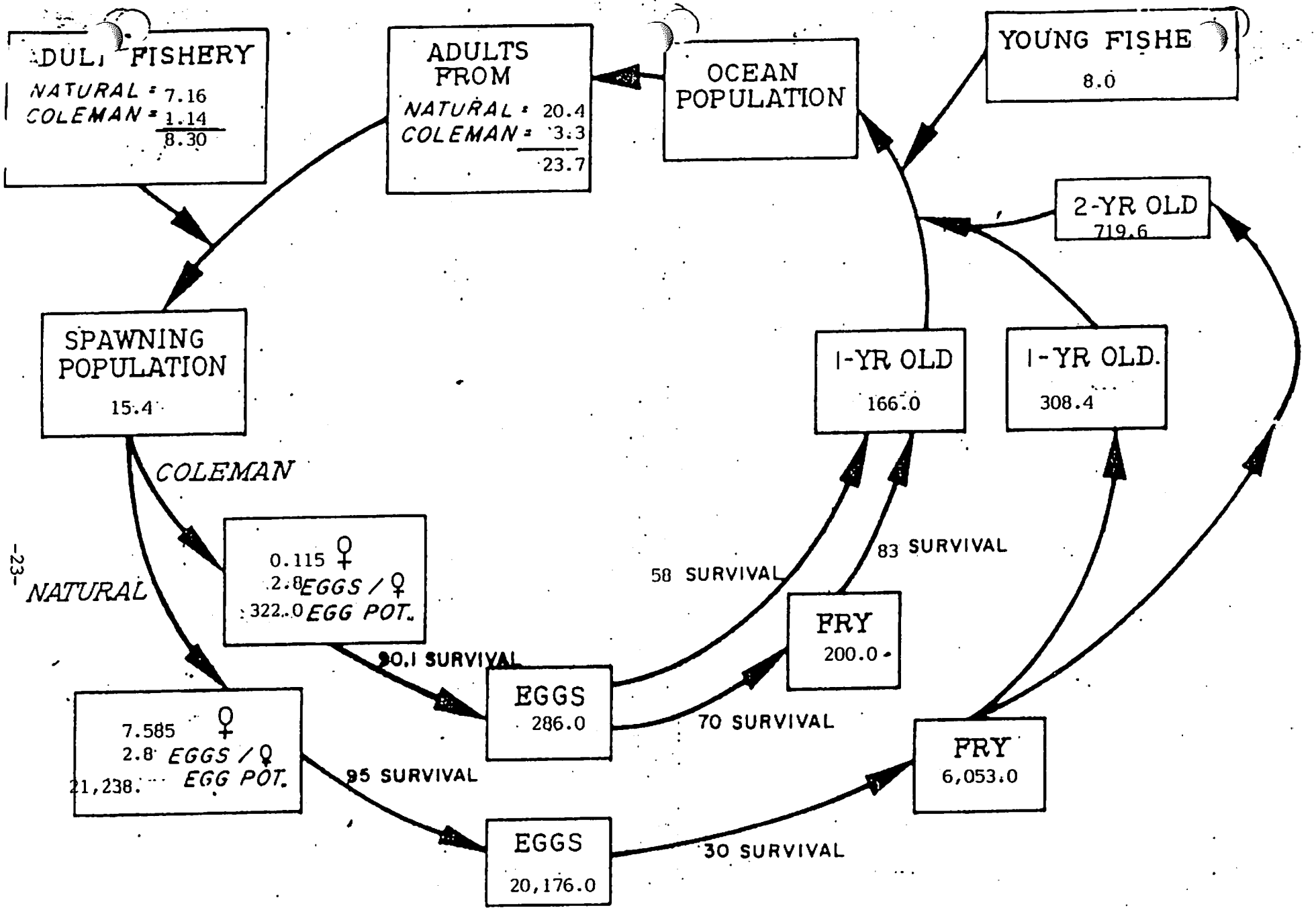

Figure 7. Estimated Steelhead Trout, Sacramento River and Tributaries above Chico Creek Stabilized at 1953-55 Average, In Thousands. Freshwater Survival is in Percentage.

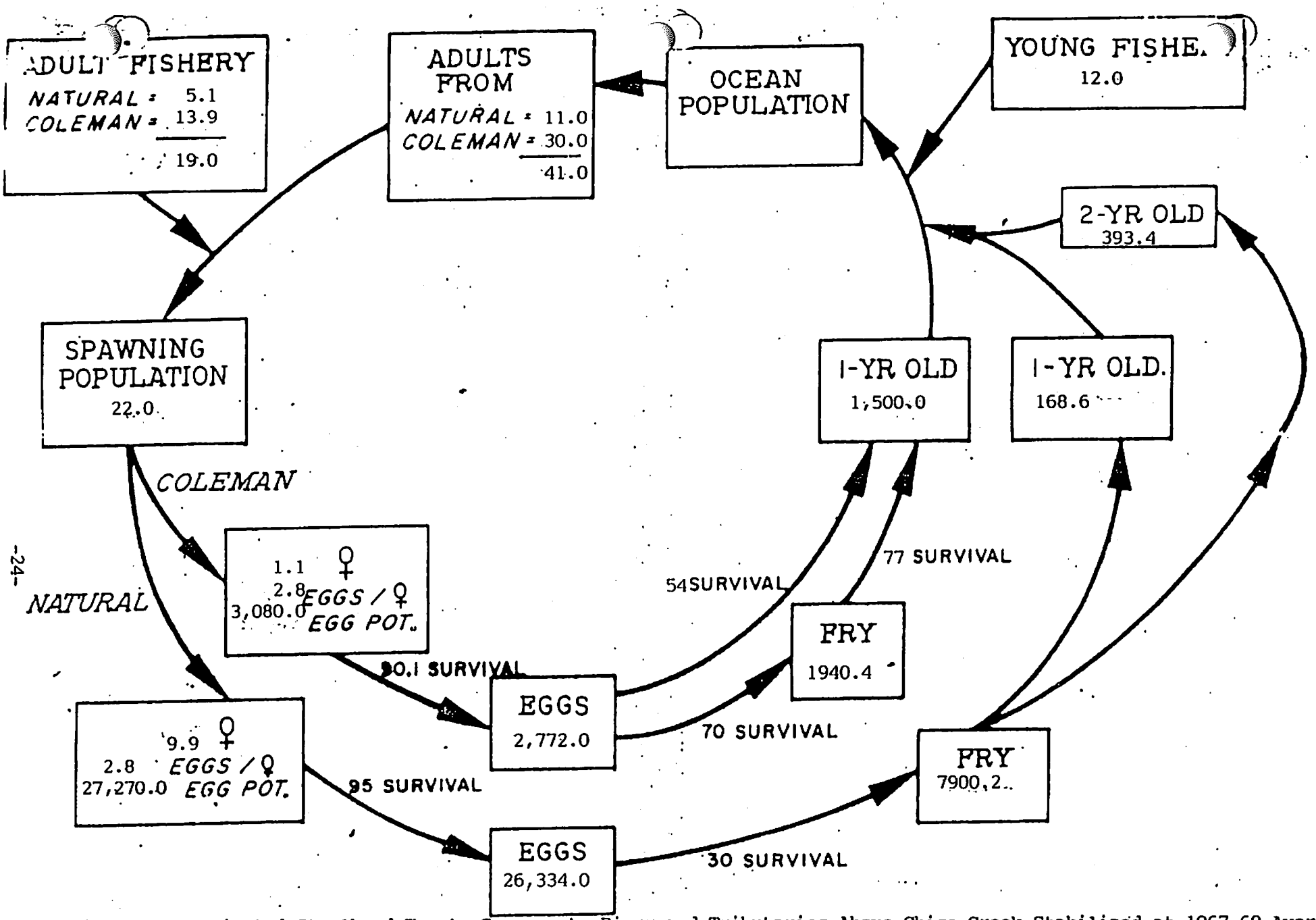

Figure 8. Estimated Steelhead Trout, Sacramento River and Tributaries Above Chico Creek Stabilized at 1967-69 Average, In Thousands. Freshwater Survival is in Percentage.

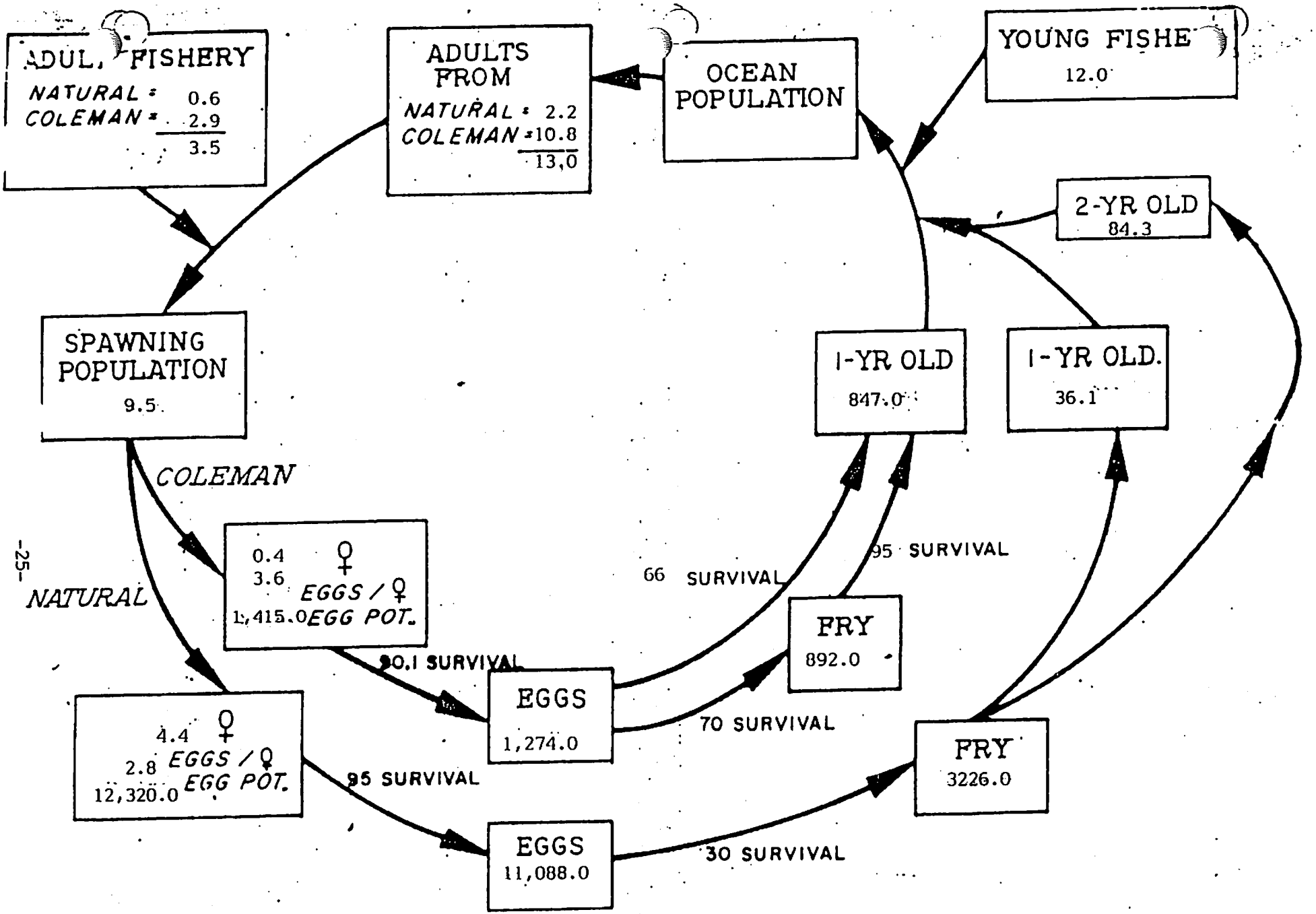

Figure 9. Estimated Steelhead Trout, Sacramento River and Tributaries Above Chico Creek Stabilized at 1981-83 Average, In Thousands. Freshwater Survival is in Percentage.

Mill Creek Natural Population

There is very little data available on the size of natural steelhead populations in various tributaries, although it is known that steelhead spawn in most Upper Sacramento River tributaries. Some information is available relative to Mill Creek where adult steelhead counts were carried out at Clough Dam between 1953 and 1963 (Table 3). In Mill Creek the upstream migration of adult steelhead begins with the first heavy runoff in the fall, and ends when the stream flows become low or non existent at the mouth of the creek due to irrigation diversions. There are two peak periods in the upstream migration. About 60% of the run migrates past Clough Dam in October-December and 30% in January-February (Table 4).

TABLE 3

Adult Salmon and Steelhead Counted Upstream Through the Fishway at Clough Dam During the Ten Seasons 1953-54 Through 1962-63. From DFG Files; Prepared by F.W. Fisher

Season	Fall-run king salmon	Spring-run king salmon	Steelhead
1953-54	3,744	1,789	715
1954-55	2,901	2,967	1,492
1955-56	1,722	2,233	1,213
1956-57	131	1,203	1,443
1957-58	1,341	2,212	1,301
1958-59	1,140	1,590	790
1959-60	65	2,368	417
1960-61	66	1,245	742
1961-62	88	1,060	1,222
1962-63	811	1,315	2,269
Totals	12,000	18,572	11,604

Table 4

Adult Steelhead Counted Upstream Through the Fishway at Clough Dam on Mill Creek During the Ten Seasons, 1953-54 Through 1962-63, Illustrating Two Peak Migration Periods. From DFG Files; Prepared by F.W. Fisher.

Period	Number of	Percentage	Cumulative percentage
Sept. 17–23	9	0.08	
Sept. 24–30	52	0.45	
Oct. 1–7	102	0.88	
Oct. 8–14	225	1.94	
Oct. 15–21	369	3.18	
Oct. 22–28	1,315	11.33	
Oct. 29–Nov. 4	822	7.08	
Nov. 5–11	1,088	9.38	
Nov. 12–18	609	5.25	20.0
Nov. 19–25	625	5.39	33.4
Nov. 26–Dec. 2	737	6.35	48.6
Dec. 3–9	438	3.77	55.5
Dec. 10–16	441	3.80	60.9
Dec. 17–23	403	3.47	
Dec. 24–30	80	0.69	
Dec. 31–Jan. 6	74	0.64	
Jan. 7–13	238	2.05	
Jan. 14–20	103	0.89	
Jan. 21–27	282	2.43	
Jan. 28–Feb. 3	278	2.40	
Feb. 4–10	577	4.97	11.0
Feb. 11–17	701	6.04	15.6
Feb. 18–24	254	2.19	21.5
Feb. 25–Mar. 3	407	3.51	25.0
Mar. 4–10	296	2.55	29.8
Mar. 11–17	322	2.78	
Mar. 18–24	221	1.90	
Mar. 25–31	208	1.79	
Apr. 1–7	119	1.02	
Apr. 8–14	82	0.71	
Apr. 15–21	26	0.22	
Apr. 22–28	16	0.14	
Apr. 29–May 5	13	0.11	
May 6–12	17	0.15	
May 13–19	32	0.28	
May 20–26	14	0.12	
May 27–June 2	1	0.01	
June 3–9	2	0.02	
June 10–16	1	0.01	
June 17–23	2	0.02	
June 24–30	4	0.03	
Totals	11,605		

Sport Catch

Adult

Although most of the sport catch estimates lack confidence limits, what information is available indicates that the annual Upper Sacramento River System adult steelhead sport catch increased from 7,600 in the 1950's to 19,000 in the late 1960's, only to decline to about 3,000 in the mid 1980's (Table 5). The percent of the run harvested annually paralleled the population and catch figures, increasing from 37% in the 1950's to 47% in the late 1960's, and declining to 25% in the mid 1980's.

Table 5

Estimated number and percent of adult steelhead population caught in the Upper Sacramento River, 1953-88

year	Number of fish	Percent of population
1953-58	7,600*	37*
1962-65	11,850	42
1967-69	19,000	47
1971-74	7,800*	36*
1975-79	8,220	32
1980-84	4,100	29
1985-88	2,980	25

*Estimates based on tagging studies. Other figures are calculated numbers (see table 2 and figure 6).

Juvenile

In the 1950's (1954-59) an estimated average of 2,800 juvenile "trout" were caught each fall and winter in the Upper Sacramento, an unknown percent of which were juvenile steelhead.

Only two studies have been conducted to determine the sport catch of juvenile steelhead migrating down the Sacramento river, both with CNFH-reared yearlings. The percent landed ranged from 2.7% of the outmigrants in 1973-74 to 0.5% in 1984.

In 1973-74 a total of 5,993 CNFH steelhead averaging 10.4/lb were tagged with Carlin, or Swedish trailer disc, tags and released between December 18, 1972 and April 17, 1983; 3,000 in Battle Creek and 2,993 in the Sacramento River at Balls Ferry. A majority of those released were caught by sportsmen downstream from and within 50 miles of the release site. It was concluded that 2.7% of the yearlings released were caught before they reached the Sacramento-San Joaquin Delta. If it is assumed that 2% of the total yearlings released (average weight 10.4/lb) from CNFH in 1974 (1,448,610) would return as sea-run adults to the Upper Sacramento River, a 2.7% catch of the yearlings on their way to the sea would reduce adult CNFH returns to the upper river by 782 fish.

In the spring of 1984 a total of 1,790 CNFH yearling steelhead, averaging 4/lb, were tagged with Carlin tags and released; 893 in Battle Creek and 897 in the Sacramento River at Red Bluff. It was concluded from the tag returns that 0.5% of the yearlings released were caught before they reached the Sacramento-San Joaquin Delta. If it is assumed that 4% of the

total yearlings of this larger size would return as sea-run adults to the Upper Sacramento River, a 0.5% catch of the yearlings on their way to the sea would reduce total hatchery returns to the upper river from a 1.5 million yearling release by 300 fish.

When comparing the 1973-74 and 1984 yearling steelhead catch data, the 82% reduction in catch sustained by those released in 1984 may reflect in part a more rapid outmigration by the larger sized yearlings, making them available to the fishery for a shorter time.

COLEMAN HATCHERY STEELHEAD

Returns to River From Hatchery Releases

In the 1950's most of the yearling steelhead that were marked to evaluate the steelhead rearing program at CNFH were released in the Sacramento River at Princeton Ferry. Adult returns to the Upper Sacramento only from these releases were estimated from tagging studies.

Only two other studies have been conducted, one in the late 1950's and the other in the early 1970's, where marked yearlings were released at CNFH and their adult returns to the Upper Sacramento River evaluated (Table 6). Most yearling steelhead were released from CNFH in February, a normal period for juvenile steelhead downstream migration.

Between 1957 and 1959 a study was conducted with CNFH 7/lb yearlings which were released in Battle Creek. Adult returns to the Upper Sacramento totaled 1% of those released. A similar study with 8/lb CNFH yearlings was carried out between 1971 and 1976 which resulted in adult returns to the Upper Sacramento of 0.78% of those released in Battle Creek. Two other studies were conducted (1973-77 and 1985-88) where marked CNFH yearlings were released in Battle Creek but no evaluations of total returns to the upper river were made.

Table 6

Adult steelhead returns to the Upper Sacramento River and to Coleman Hatchery from yearlings released at the hatchery

year	yearling size at release	adult returns, (in percent)		adult returns needed to repeat program, (in percent)
		river	hatchery	
1957-59	7/lb	1.0	0.20	0.125
1971-76	8/lb	0.78	0.16	0.125
1973-77	8/lb		0.09	0.125
1985-88	5/lb		0.18*	0.125

*No fishing permitted in Battle Creek.

Returns to Hatchery From Hatchery Releases

A return of about 0.125% of the yearlings released at CNFH is required to continue a viable stocking program. Between 1957 and 1988 only four studies were conducted where marked or tagged CNFH juvenile steelhead were released in Battle Creek and adult returns to the hatchery evaluated (Table 6). These studies indicated a hatchery return ranging from 0.09% of those released in the early 1970's to 0.20% of those released in the late 1950's. The high return in the 1985-88 period (0.18%) was no doubt aided by an adult steelhead fishing closure in Battle Creek.

December vs. February Release

Between 1973 and 1977 a study was made to determine if releasing migratory sized steelhead from CNFH in December rather than the usual time in February and March was a desirable hatchery policy. The evaluation was based on adult returns to the hatchery from comparative releases made at CNFH during the two time periods. A total of 59 adults returned from the December releases and 273 (4.6 times more) from the February releases.

Returns vs. Size at Release

Studies conducted with CNFH steelhead between 1953 and 1959, the juveniles of which averaged between 4/lb and 26/lb, showed that releasing the juveniles in the Sacramento River at Princeton Ferry resulted in an average adult return to the Upper Sacramento of almost 2% of those released (Table 7). Thus with average CNFH production in the 1950's every 50 yearlings released at Princeton produced one sea-run adult return to the Upper Sacramento. However, for those juveniles averaging 8/lb and larger when released the average return of adults was about 4% of those released, while adult returns from those juveniles released at a size 10/lb and smaller averaged only about 1% (Table 8). Thus from a standpoint of total number of adult returns alone it is much more desirable to release steelhead at a size larger than 8/lb.

It is also more desirable to release the larger size steelhead, based on age composition of the adult returns. For example, the larger size juveniles not only produce greater total adult returns, but for any equal number of juveniles released, the larger size juveniles produce 12 times more two-year-old fish, 2.1 times more three-year-olds and 2.4 times more four-year-old sea-run fish.

Table 7

Returns of Sea-Run Hatchery Steelhead to the Upper Sacramento River System, Showing the Numbers of Yearling Coleman Hatchery Fish Released, arranged in Chronological Order, and Calculated Percentages and Total Numbers of Adults Produced. From Hallock, Van Woert and Shapovalov, 1961.

Mark	Brood year	Place of release	Date of release	No. per pound	Average fork length (inches)	Approximate age (months)	No. released	Percentages and numbers of returns by seasons												Total returns		
								1953-54		1954-55		1955-56		1956-57		1957-58		1958-59		No.	%	
								No.	%	No.	%	No.	%	No.	%	No.	%	No.	%		By mark	By brood year
Ad-RV	1952	Sac. River Battle Cr. Mill Cr.	Mar. and Apr., 1953	8	6.0	13	63,590	404	0.64	1,482	2.33	125	0.20	11	0.02	--	--	--	--	2,022	3.2	3.2
Ad-BV	1953	Sac. River	Jan., 1954	4	8.0	10½	6,570	--	--	353	5.37	159	2.42	11	0.17	--	--	--	--	523	8.0	2.5
BV	1953	Sac. River	Mar., 1954	18	4.8	13	145,278	--	--	480	0.33	2,498	1.71	249	0.17	--	--	--	--	3,227	2.2	
Ad-LV	1954	Sac. River	Jan., 1955	7	6.8	11	46,252	--	--	--	--	2,350	5.08	712	1.54	69	0.15	--	--	3,131	6.8	2.1
Ad-RV	1954	Sac. River	Feb., 1955	26	4.3	11	131,007	--	--	--	--	91	0.06	526	0.40	10	0.01	7	0.01	634	0.5	
Ad-BV	1955	Sac. River	Dec., 1955	6	6.5	9½	67,651	--	--	--	--	--	--	1,153	1.70	458	0.68	15	0.02	1,626	2.4	1.3
BV	1955	Sac. River	Mar., 1956	10	5.8	13	143,137	--	--	--	--	--	--	543	0.37	1,145	0.79	30	0.02	1,718	1.2	
Ad-LMax	1955	Sac. River	Mar., 1956	22	4.6	13	50,755	--	--	--	--	--	--	--	--	159	0.27	15	0.02	174	0.3	
Totals							663,240	404		2,315		5,223		3,205		1,841		67		13,055		
Averages																					2.0	2.0
D-LV	1956	Sac. River	Dec., 1956	6	7.2	9	32,177	--	--	--	--	--	--	--	--	786	2.44	189	0.59	--	--	--
D-RV	1956	Battle Cr.	Jan., 1957	7	7.0	10½	28,029	--	--	--	--	--	--	--	--	169	0.63	90	0.34	--	--	--
Ad-RV	1956	Sac. River	Jan., 1957	12	5.9	10½	60,070	--	--	--	--	--	--	--	--	80	0.13	309	0.51	--	--	--
Ad-LV	1956	Mill Cr.	Jan., 1957	30	4.3	11	107,328	--	--	--	--	--	--	--	--	--	--	136	0.12	--	--	--
Ad-RMax	1957	Sac. River	Oct., 1957	80	2.7	7	18,285	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ad-BV	1957	Sac. River	Dec., 1957	7	6.8	10	33,531	--	--	--	--	--	--	--	--	--	--	83	0.25	--	--	--
BV	1957	Sac. River	Jan., 1958	12	5.7	11	54,243	--	--	--	--	--	--	--	--	--	--	45	0.08	--	--	--
D-Ad	1957	Sac. River	Jan., 1958	22	4.4	11	40,727	--	--	--	--	--	--	--	--	--	--	23	0.06	--	--	--
Ad-LMax	1957	Sac. River	Apr., 1958	6	7.3	14	4,615	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Totals							378,514									1,035		875				
Grand totals							1,041,754	404		2,315		5,223		3,205		2,876		942				

Table 8

Returns of Sea-Run Hatchery Steelhead to the Upper Sacramento River System, Showing Numbers of Yearling Coleman Hatchery Fish Released, Grouped Into Two General Size Categories, and Calculated Percentages of Adults Produced. From Hallock, Van Woert and Shapovalov, 1961.

Mark	Brood year	Place of release	Date of release	Number per pound	Average fork length (inches)	Number released	Percentage returns					
							First year	Second year	Third year	Fourth year	Total	
Fish larger than 10 per pound												
Ad-RV	1952	Sacramento River	Mar. & Apr. 1953	8	6.0	63,590	0.64	2.33	0.20	0.02	3.2	
		Battle Creek										
		Mill Creek										
Ad-BV	1953	Sacramento River	Jan., 1954	4	8.0	6,570	5.37	2.42	0.17	--	8.0	average 4.0
Ad-LV	1954	Sacramento River	Jan., 1955	7	6.8	46,252	5.08	1.54	0.15	--	6.8	
Ad-BV	1955	Sacramento River	Dec., 1955	6	6.5	67,651	1.70	0.68	0.02	--	2.4	
D-LV	1956	Sacramento River	Dec., 1956	6	7.2	32,177	2.44	0.59	--	--	--	
D-RV	1956	Battle Creek	Jan., 1957	7	7.0	26,629	0.63	0.34	--	--	--	
Ad-BV	1957	Sacramento River	Dec., 1957	7	6.8	33,531	0.25	--	--	--	--	
Ad-LMax	1957	Sacramento River	Apr., 1958	6	7.3	4,615	--	--	--	--	--	
Fish 10 per pound and smaller												
BV	1953	Sacramento River	Mar., 1954	18	4.8	145,278	0.33	1.71	0.17	--	2.2	
Ad-RV	1954	Sacramento River	Feb., 1955	26	4.3	131,007	0.06	0.40	*	*	0.5	average 1.2
BV	1955	Sacramento River	Mar., 1956	10	5.8	143,137	0.37	0.79	0.02	--	1.2	
Ad-LMax	1955	Sacramento River	Mar., 1956	22	4.6	59,755	--	0.27	0.02	--	0.3	
Ad-RV	1956	Sacramento River	Jan., 1957	12	5.9	60,979	0.13	0.51	--	--	--	
Ad-LV	1956	Mill Creek	Jan., 1957	30	4.3	107,328	--	0.12	--	--	--	
Ad-RMax	1957	Sacramento River	Oct., 1957	86	2.7	18,285	--	--	--	--	--	
BV	1957	Sacramento River	Jan., 1958	12	5.7	54,243	0.08	--	--	--	--	
D-Ad	1957	Sacramento River	Jan., 1958	22	4.4	40,727	0.06	--	--	--	--	

* The computed total fish were 10 in the 3rd year and 7 in the 4th year, making the calculated percentages zero, when carried out to only 2 decimals.

Predation by Released Juvenile Steelhead

Yearling steelhead released from CNFH into Battle Creek in February and March destroy large numbers of naturally produced salmon as the fry emerge from the Battle Creek spawning beds downstream from the hatchery. As one example, more than 600,000 CNFH steelhead yearlings were released during February and March 1975, and sampling of these steelhead in Battle Creek indicated they averaged 1.4 juvenile salmon per steelhead stomach (Table 9). Had each of the 600,000 yearlings eaten but one salmon before leaving Battle Creek, the loss would have been more than one-half million salmon fry.

TABLE 9. Stomach Analysis of Yearling Steelhead in Battle Creek after They were Released From Coleman Hatchery. From Menchen, 1980.

	Steelhead Sampled									Salmon Fry and Eggs in Total Steelhead Sampled	
	Grouped by Principal Food in Stomach 1/										
Date	Hatchery Food	Insects	Steelhead Eggs	Salmon Bait Eggs	Salmon Natural Eggs	Salmon Fry	Misc. Food	Empty	Total	Fry	Eggs
2-20	30	2	1	1			4	16	54		
2-21	26	35	1		3	1		19	85	4	4
2-24		44		2	5		4	2	57		12
2-25		29	1	3	13	2	2		50	17	30
2-26		42			5	3			50	12	18
2-27		27	1		2	5		2	37	5	18
2-28		15			2	13			37	52	10
3-3		20			5	4	1		30	24	38
3-4		23				5		2	30	26	
3-6		27						3	30		
3-7	1	26						5	32		
3-14		6	1					3	10		
3-17		4	1						5		
3-24		0		1		2			3	12	
4-1		26							50		
4-2		37	2					24	50		
4-3		37			1			11	40		1
4-4		38			1	1		2	40	1	5
4-7		7				24			31	640	
4-8		7				23			30	144	
4-9		18				12			30	163	
4-10		27				3			30	19	
4-11		30							30		
4-15		12							12		
4-16		19				1	4		24	1	
4-17		11				3	2	2	18	4	
4-18		12				1	1		15	1	
TOTALS	57	581	9	7	37	103	18	91	910	1125	136

REVIEW OF TWO FACTORS AFFECTING THE POPULATION

Red Bluff Diversion Dam

Description

Red Bluff Diversion Dam, completed in 1964, is located on the Sacramento River two miles downstream from Red Bluff (Figure 10). It was constructed and is operated by the U.S. Bureau of Reclamation to divert water from the Sacramento River into the Tehama-Colusa Canal and to the Corning Canal Pumping Plant. Water levels are controlled by eleven dam gates, and water is released downstream from the dam by raising one or more gates. A fishway, with facilities to count adult steelhead (and other species) is incorporated into the left bank fishway. The fishery problems at RBDD are primarily related to passage of both adult and juvenile salmonids, and to predation on juveniles by Sacramento squawfish in the turbulent waters immediately below the dam.

Effects on Juveniles

Studies with CNFH juvenile steelhead between 1973 and 1977 showed that survival of yearlings was increased by 25% if they were released below RBDD rather than in Battle Creek, or above the dam (Table 10).

Effect on the Total Population

It is estimated that RBDD has caused a decline of 6,000 sea-run steelhead in the Upper Sacramento River between 1967 and 1982. This is pointed out by a comparison between the 1967-68 average adult steelhead count past RBDD (prior to the effect of the dam on the adult population) and the 1962-82 average count. The actual counts indicate a decline of 8,490 (58%) and the counts

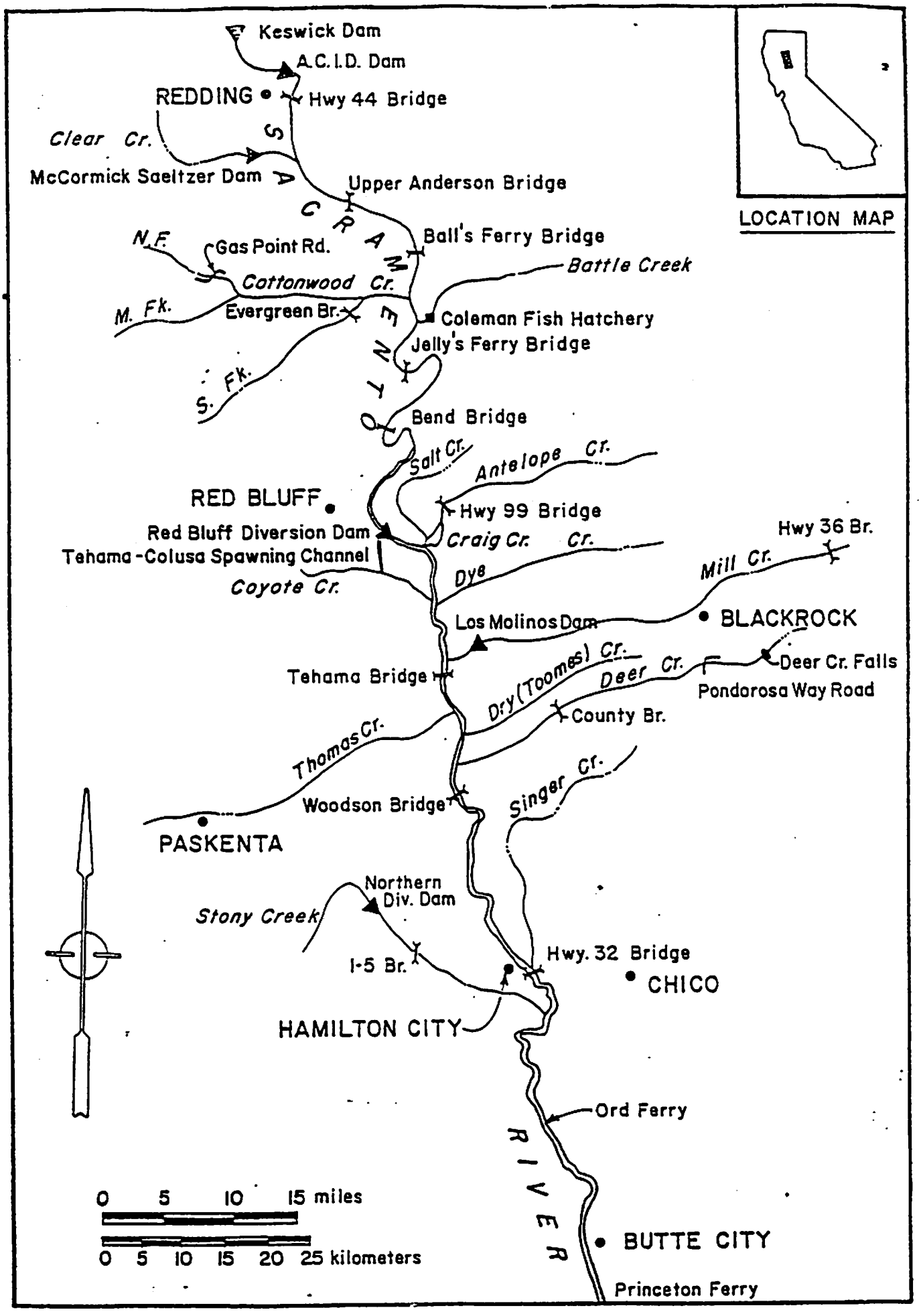

FIGURE 10 Upper Sacramento River above Princeton Ferry.

Table 10

Survival *2 of Coleman Hatchery Reared Salmon and Steelhead Released above and Below Red Bluff Diversion Dam. From Hallock and Fisher, 1985.

Release Area	(on going study) Late-Fall-Run Salmon					(on going study) Fall-Run Salmon			(completed study) Fall-Run Salmon				(completed study) Steelhead	
	Returns by Release Year					Returns by Release Year			Returns by Release Year				Returns by Release Year	
	Release Year	1979	1980	1981	1982	Totals	1981	1982 1/	Totals	1975	1976	1977	Totals	1973-75	Tota
Battle Creek		197	592	183	37	1,009	184	11	195						27
2 mi. above Dam										91	95	39	225		
Above Dam gate											111	148	259		
Below Dam gate											145	242	387		
½ mi. below Dam		283	814	332	45	1,474	364	6	370	546		39	495		37

1/ Two-year old fish only.

*2/ Marked salmon recovered in the ocean fishery landings of California, Oregon, and Washington and marked adult steelhead recoveries at Coleman Hatchery.

SUMMARY				
Species	Total Released		Survival	Increase in survival by Releasing below the Dam
Salmon	above Dam	1,257,654	1,688 (.13%)	46%
	below Dam	1,134,934	2,726 (.24%)	
Steelhead	above Dam	301,948	273 (.09%)	25%
	below Dam	302,864	372 (.12%)	

calculated from regression indicate a decline of 6, 287 (51%), or 26% per generation (Table 11 and Figure 11).

Adult Counts

There has been a fluctuating but steady decline in the adult steelhead counts at RBDD since the dam was put into full operation (Table 12 and Figure 12).

Squawfish Predation

Between 1978 and 1985 the number of Sacramento Squawfish counted annually as they passed through the fishways at RBDD ranged from a low of 13,000 in 1983 to a high of 25,000 in 1978, and averaged about 18,000 (Figure 13). Squawfish concentrate below RBDD in the spring and early summer where they prey on juvenile salmonids on their way to the sea. Turbulance caused by water flowing under the dam gates disorients the juveniles (which also pass under the dam gates) and increases their vulnerability to predation immediately below the dam.

To control squawfish at RBDD an electronic shocking device was installed in the left bank fishway and tested in 1985. This device was quite successful in destroying adult squawfish in the fishway as they were migrating upstream. However, its operation had an adverse effect on adult salmon migration so use of the electronic shocker was discontinued. Apparently when squawfish, and some other species, are under stress a warning odor is emitted. In 1987 another device was tested which was aimed at reducing stress by capturing the squawfish alive in the left bank fishway, but destroying them elsewhere. This device was also unsuccessful in removing significant numbers of

Table 11

Actual Counts, and Calculated Counts From Regression of the Actual Counts, of Adult Steelhead Passing Red Bluff Diversion Dam Showing a Comparison Between the Average Numbers Passing the Dam Between 1967-69 and 1969-82. From Hallock and Fisher, 1985.

Averages

Year	Ex	N	Mean Population
1967-68	29151	2	14,576
1969-82	85197	14	6,086
		Decline	-8,490 (-58%)

Regression

Log Y = 4.151512-0.043569x; r = -.78

Year	Caculated Population		Decline per Generation Number	Percent
1967	12,822	x		
1968	11,589	one		
1969	10,491	generation		
1970	9,489	x	3333	26
1971	8,583		3015	26
1972	7,764		2727	26
1973	7,023		2466	26
1974	6,353		2230	26
1975	5,746		2018	26
1976	5,197		1826	26
1977	4,701		1652	26
1978	4,252		1494	26
1979	3,846		1351	26
1980	3,480		1221	26
1981	3,148		1104	26
1982	2,847		999	26

Year	Ex	N	Mean Population
1967-68	24420	2	12,210
1969-82	82920	14	5,923
		Decline	-6,287 (-51%)

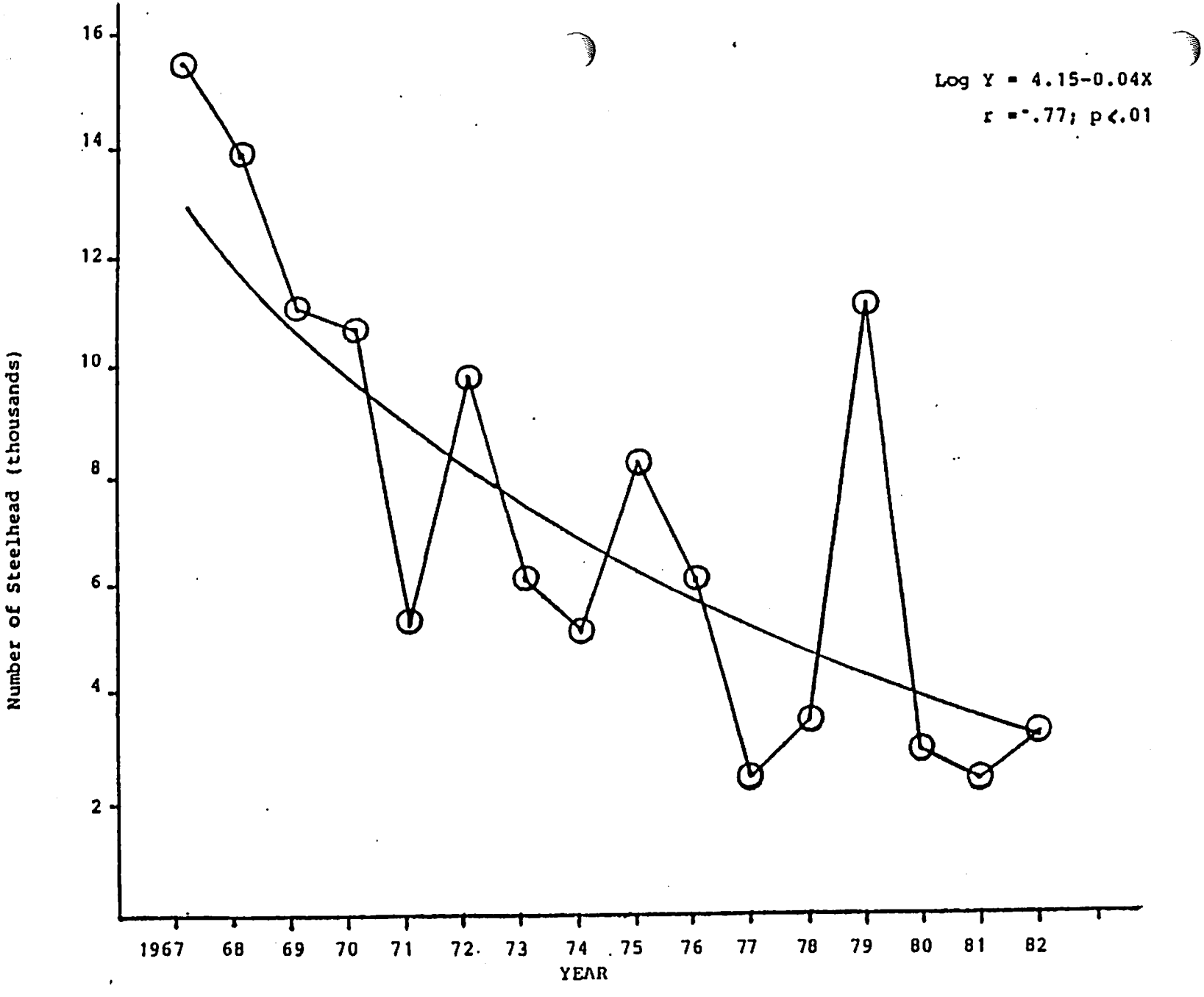

FIGURE 11 . This is the calculated regression for numbers appearing in Table 12. The 1967-68 average steelhead count past Red Bluff is compared with the 1969-82 average. The difference between values of the regression line values indicates a total decline of 6,287 (51%), or 26% per generation. This regression is significant. From Hallock and Fisher, 1985.

Table 12. Adult Steelhead Counts at Red Bluff Diversion Dam

Year	Number of Fish
1967	17416
1968	13648
1969	11560
1970	10876
1971	5614
1972	7978
1973	6101
1974	5205
1975	8196
1976	5928
1977	2467
1978	3487
1979	10944
1980	2898
1981	2394
1982	3294
1983	1969
1984	4404
1985	3358
1986	2809
1987	1796
1988	432

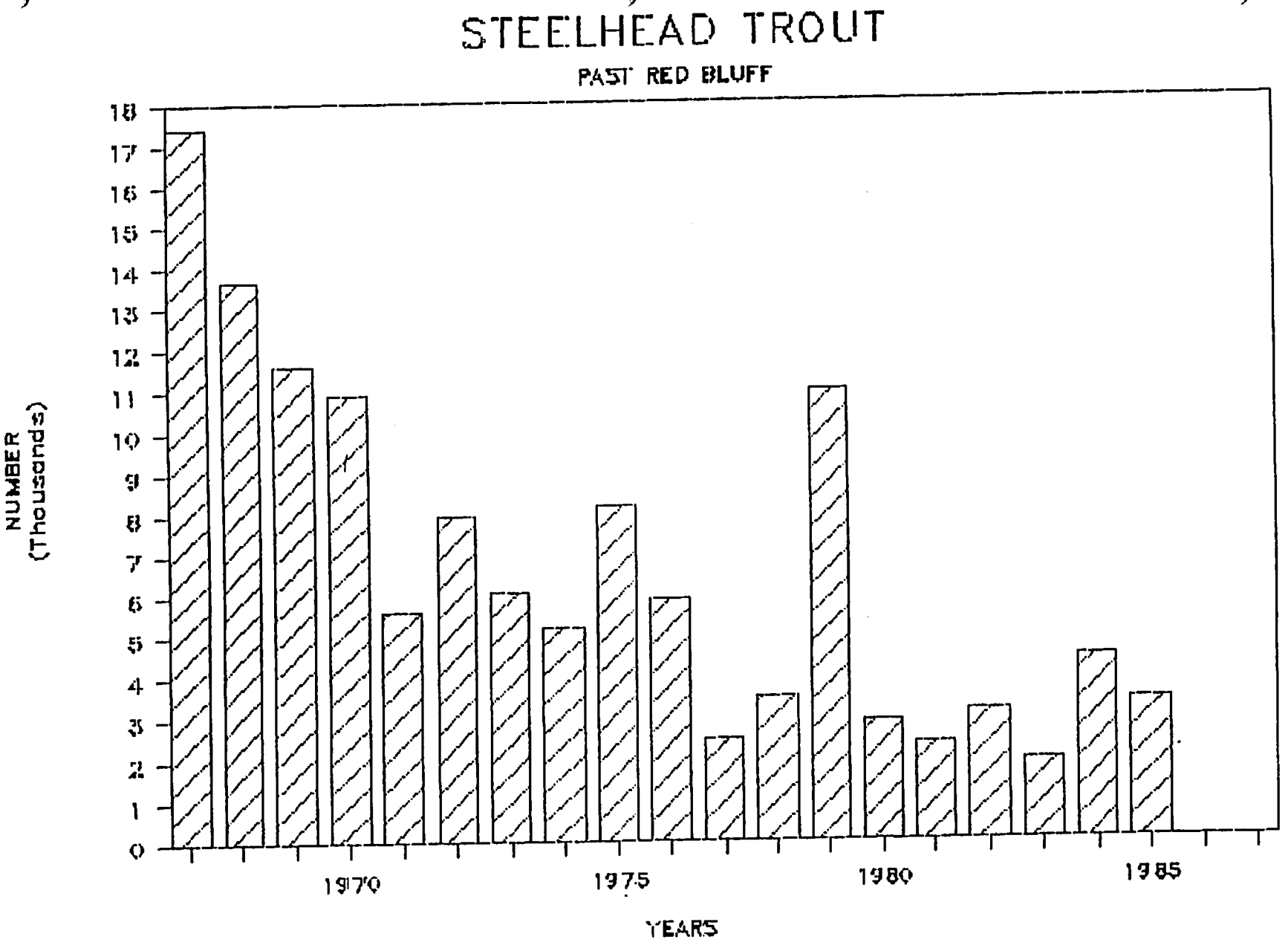

FIGURE 12. Number of steelhead trout counted at Red Bluff Diversion Dam. From DFG Files, Prepared by F.W. Fisher.

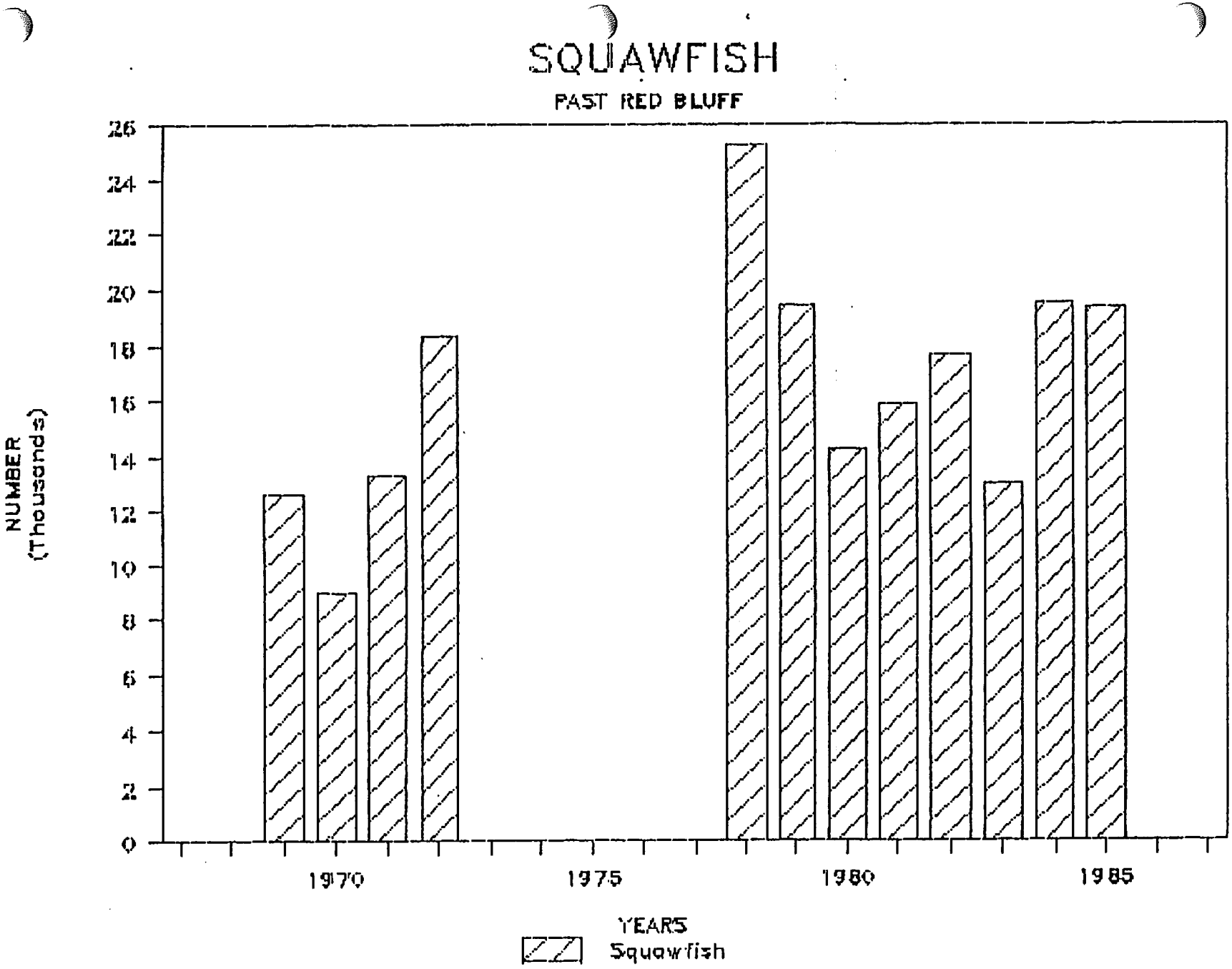

FIGURE 13. Numbers of Sacramento Squawfish counted at Red Bluff Diversion Dam. From DFG Files, Prepared by F.W. Fisher.

squawfish. Since then, the National Marine Fisheries Service (NMFS) has funded a study which demonstrated the feasibility of developing a commercial fishery for squawfish at RBDD, and a contract has been let to a commercial fisherman to remove squawfish for marketing purposes. Unfortunately, dioxin has been detected in squawfish so they can not be sold, at least for human consumption. No one from any agency has been assigned specifically to this problem, and no solution is in sight.

North Pacific Squid Fishery

Studies were initiated in 1956 by the International North Pacific Fisheries Commission (INPFC) to determine the distribution and origin of salmon in the North Pacific Ocean. Some steelhead trout Oncorhynchus mykiss (formerly Salmo gairdnerii and Salmo mykiss) were tagged incidentally during the initial study period. However, since 1978 steelhead have been specifically included in these studies, primarily as a result of changes brought about by the establishment of national 200-mile fishery zones. According to Light, Fowler and Dahlberg (1988), the steelhead marking and tagging studies have demonstrated that steelhead stocks from Alaska to California are widely dispersed and "extensively intermingled" in the North Pacific Ocean in an area east of 167° E longitude and north of 41° N latitude, i.e., east of Dutch Harbor, Alaska and north of the California-Oregon border (Figure 14). Steelhead sampling was carried out over a much greater area of the North Pacific Ocean than the steelhead distribution area determined by the catch data, and the deliniated distribution area is thought to reflect the temperature range preferred by steelhead.

Between 1978 and 1986 nearly 76 million North American juvenile steelhead were marked (in various ways) or coded wire tagged (CWT) and released inland as seaward migrants. Most of the marked and CWT juvenile steelhead released inland consisted of hatchery-reared fish, so any ocean recoveries would primarily reflect the ocean distribution of hatchery fish which may or may not be the same as that of naturally produced fish.

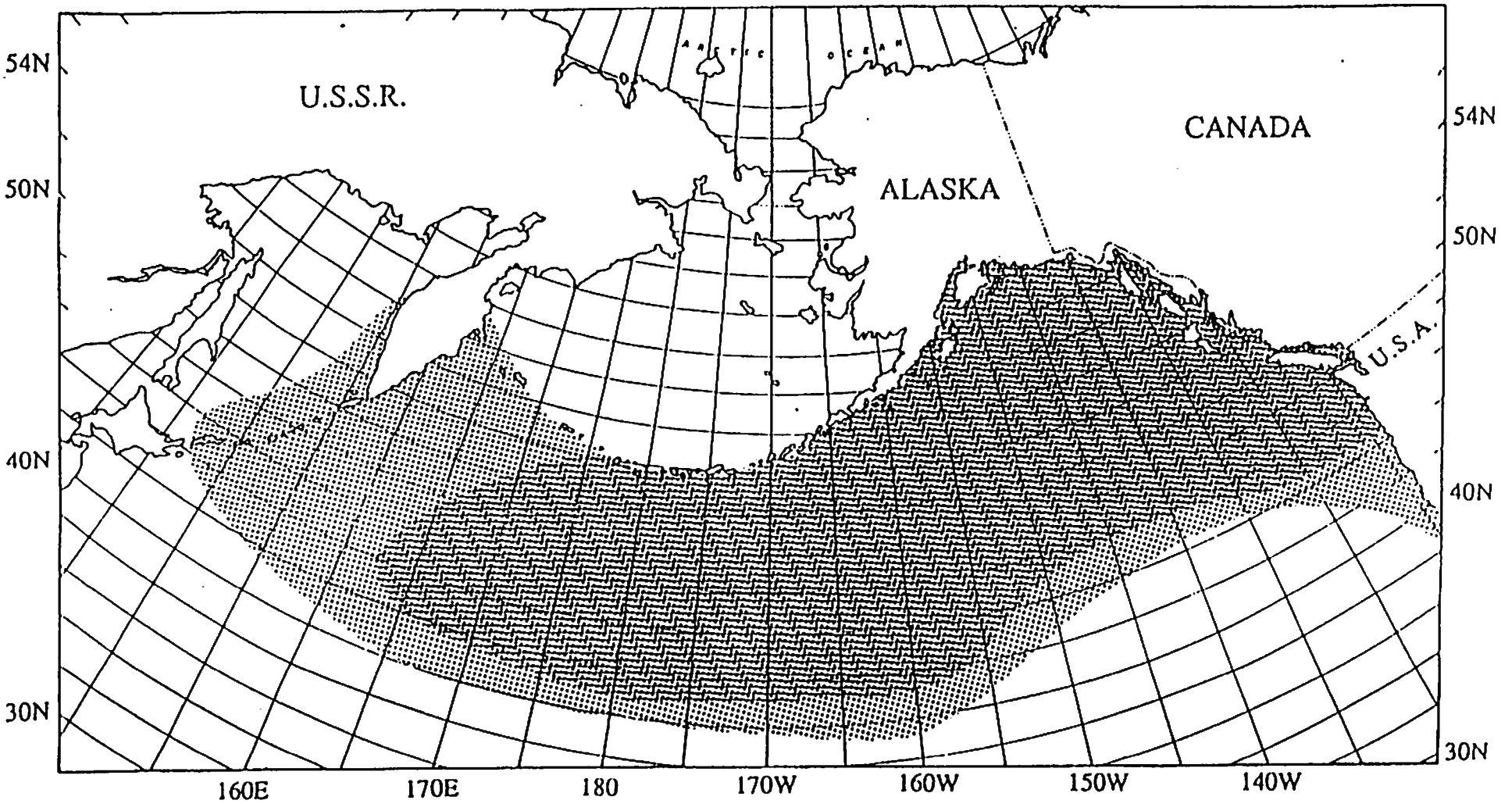

Figure 14. Known distribution of North American steelhead as evidenced by recoveries of marked or tagged fish within the larger distribution of steelhead determined from catch data. From Light, Fowler and Dahlberg, 1988.

Steelhead Tagged in California Recovered in North Pacific

Only one CWT steelhead from California has been recovered in the North Pacific even though about 1,288,000 yearlings were tagged and released in the Sacramento River System alone between 1980 and 1988 (Table 13). The one California CWT steelhead recovered in the North Pacific was from a group of 44,280 yearlings averaging 2.4 to the pound which were tagged and released in the Feather River at Boyd's Pump in March, 1983. It was recovered by a purse seiner at Petersburg, Alaska in August, 1983, indicating a very rapid northward movement during its first year at sea.

Steelhead tagged in North Pacific Recovered in California

Between 1956 and 1986 a total of 1,532 steelhead were captured in the North Pacific Ocean during INPFC tagging studies, with the aid of purse seiners and surface long lives, tagged (primarily with Petersen discs) and released. Of the total tagged steelhead released, 73 were later recovered in North American spawning streams, including nine in California (Table 13). All Petersen disc tagged steelhead recovered in the streams of coastal Oregon and California were released in the Eastern North Pacific Ocean east of 160° W longitude and north of 45° N latitude i.e., east of Unimak Island, Alaska and north of Portland Oregon (Figure 15). Some steelhead recovered in California had been tagged as far north as latitude 53° N (Sutherland, 1973). All steelhead recovered in California and southern Oregon were tagged north of the point of recovery, indicating a southeasterly directional movement from summer to winter.

Table 13. Release and recovery information for California steelhead tagged on the high seas during Japanese, U.S., U.S.S.R., and Canadian research vessel cruises, 1956-1988 (n=9). From Jeffery T. Light, Fisheries Research Institute, University of Washington, Personal Communication.

DISK TAGS (tagged offshore, recovered inshore)

RELEASE			RECOVERY				Elapsed Time	Distance Travelled	Travel Rate	Growth	
Date	N. Latitude	Longitude	Date	N. Latitude	Longitude	Location Name	(Days)	(km)	(km/day)	(Δ mm)	(mm/day)
42863	45°56'	137°52'W	71063	41°50'	124°25'W	Crescent City	73	1,561	21.4	50	0.68
62161	49°42'	156°50'W	22264	40°30'	124°00'W	Van Duzen River	194	3,740	19.3		
52663	49°00'	141°04'W	11064	40°55'	124°06'W	Unknown	229	2,083	9.1	34	0.15
42763	48°06'	136°00'W	122563	39°29'	123°46'W	Unknown	242	1,659	6.9	104	0.43
52564	47°05'	145°45'W	12765	36°30'	123°00'W	Carmel River	247	2,775	11.2	171	0.69
51563	50°00'	139°00'W	22964	40°37'	124°15'W	Unknown	290			59	0.20
72062	53°01'	142°52'W	12564	39°00'	123°41'W	Alder Creek	310				
62262	47°15'	156°57'W	122663	39°05'	123°12'W	Russian River	553				
52465	47°00'	137°30'W	11367	40°06'	123°48'W	Unknown	600			212	0.35

CODED-WIRE TAGS (tagged inshore, recovered offshore)

RELEASE		RECOVERY		Elapsed Time	Distance Travelled	Travel Rate	Growth	
Date	Location	Date	Location	(Days)	(km)	(km/day)	(Δ mm)	(mm/day)
32383	Feather River	8-83	Near Petersburg, SE Alaska					

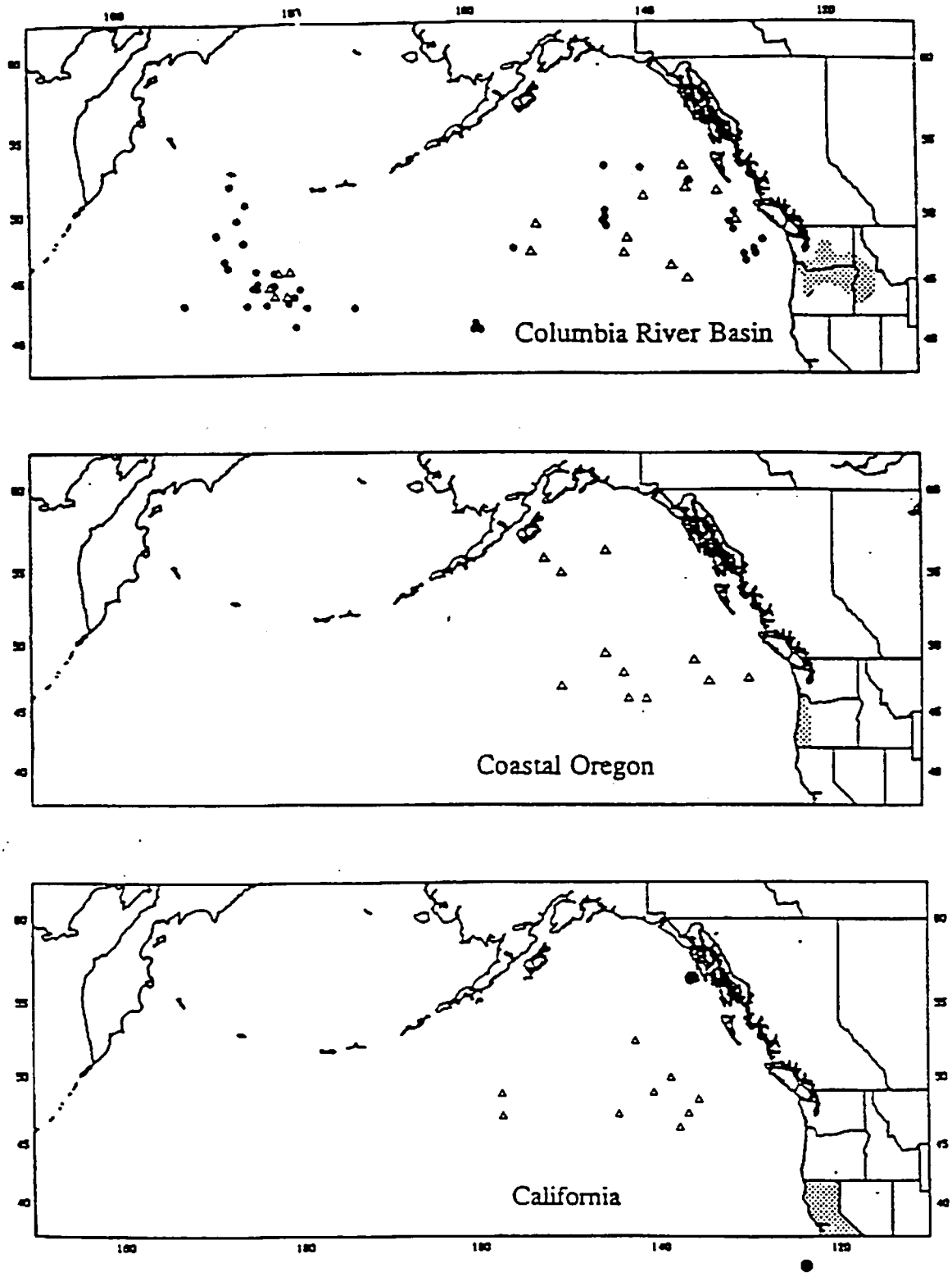

Figure 15. High seas distribution of steelhead trout from the Columbia River Basin, coastal Oregon, and California, as evidenced by recoveries of disk tags (△) and coded-wire tags (●) during INPFC-related research, 1956-1987. From Light, Fowler and Dahlberg, 1988.

During the 14 year year period, 1953-67, the NMFS fished 33,319 shakles of gill net during 1,282 sets in the North Pacific and caught 1,341 steelhead and 141,125 salmon (five species). This would indicate that the relative abundance of steelhead in relation to all species of salmon averaged 1:105. However, the average relative abundance of steelhead to chinook salmon (Oncorhynchus tshawytscha) alone was about 2.4:1. According to LeBrasseur, Hargreaves and Gjernes (1988), 41% of the steelhead caught in the North Pacific Ocean during June and July, 1988 by the Canadian research vessel W.E. Tucker, had the adipose fin clipped. This does not mean that 41% of the steelhead in the North Pacific had CWT's since some agencies release adipose clipped steelhead that do not have CWT's. However, even though the sample was small (36 total; 15 adipose clips) it does indicate a high percent of hatchery steelhead in the North Pacific since most, if not all, steelhead with an adipose missing would be of hatchery origin. None of the CWT steelhead recovered during this particular cruise by the W.E. Tucker were from California (Terry Gjernes, (personal communication).

Driftnet vessels from Japan, Taiwan and South Korea now fish for squid in the central North Pacific Ocean, in an authorized zone which overlaps the known distribution of North American steelhead (Figure 16). In 1988, this fairly recent (primarily after 1980) and expanding fishery included more than 800 vessels, each fishing 20 to 30 miles of netting daily. It is reported to be the largest fishing fleet in the world, utilizing more than one million miles of net consisting of a mesh size which is ideal for

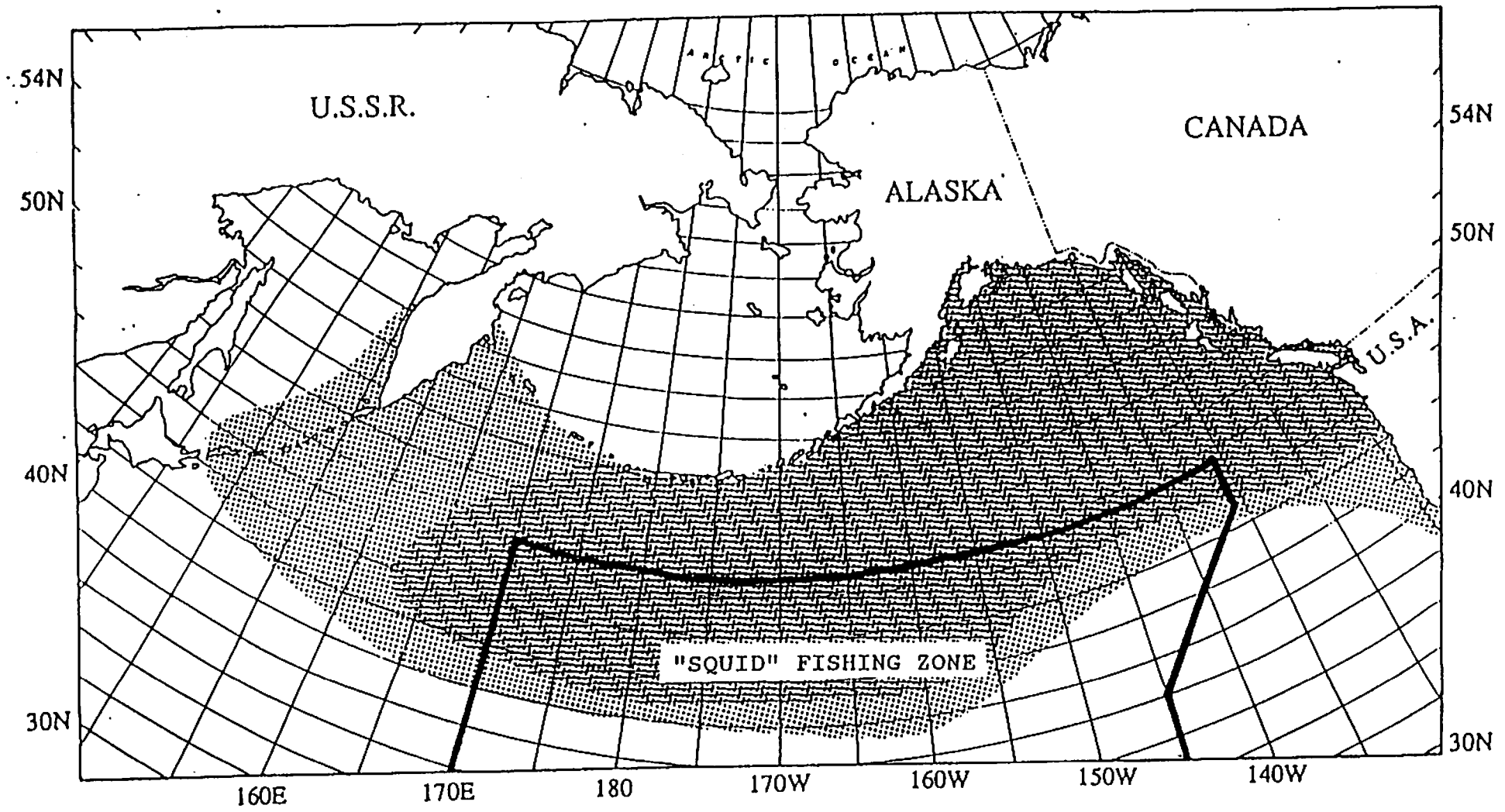

Figure 16. Known distribution of North American steelhead as evidenced by recoveries of marked or tagged fish within the larger distribution of steelhead determined from catch data. The known 1988 SquidFishery Zone is outlined in Black. North American Steelhead Encounter 25,000 Miles of Net Daily. From Light, Fowler and Dahlberg, 1988.

capturing immature salmon the steelhead.

In addition, squid vessels have been observed fishing hundreds of miles outside the authorized fishing zone. Even though there are established boundaries for the North Pacific squid fishery, it is a fishery which is not subject to international regulation such as the salmon drift net fishing that is regulated by INPFC.

Because the squid fishery is unregulated, there is only meager observer information available. According to Lonnie Haughton, acting president of the South Eastern Alaska Cooperative Opposing Piracy of Salmonids (SEACOPS) in a letter to Governor Deukmejian of California dated December 23, 1988, his organization has no evidence that California's chinook salmon are being intercepted by the North Pacific squid fishing fleets, but is is believed by SEACOPS that California Steelhead comprise a significant portion of their estimate of 200,000 three-pound steelhead "killed" by the foreign gill net fishermen each year.

If it is assumed that the 1,532 steelhead tagged and released in the Eastern North Pacific during the 1956-86 period consisted of a random sample of North American steelhead only, and that the chances of recovering a tagged steelhead in California streams was as good as the chances of a tagged steelhead being recovered in streams north of California, 12.3 percent (9 ÷ 73) of the steelhead in the Eastern North Pacific are from California. If this were true, the portion of the 200,000 steelhead estimated by SEACOPS as being annually destroyed by the North Pacific squid fishery would include 24,600 California steelhead. However, it is suggested by

Jeffery Light of the University of Washington's Fisheries Research Institute, who has analyzed data relative to the North Pacific squid fishery, that even though the information is meager the legal squid fishery may not be having a detrimental effect on North American steelhead stocks (personal communication). Mr. Light, however, does wonder about the effects on North American steelhead populations of a combination of the legal and the vast illegal net fisheries.

According to an editorial in the Sacramento Bee (3-26-89), "the National Marine Fisheries service currently has eight cases pending against Taiwanese drift net fishing vessels that have been caught selling and shipping salmon illegally. Officials of the U.S. State Department as well as the National Marine Fisheries Service are already meeting with their counterparts in Asia to try to persuade them to discontinue use of the Nets." "Ultimately a new treaty or other formal international agreement will have to be struck".

CURRENT SACRAMENTO RIVER STUDY PROGRAMS

U.S. Fish and Wildlife Service Action Study Programs

Three action study programs aimed at implementing solutions to the fishery problems at RBDD were completed by the U.S. Fish and Wildlife Service (FWS) in 1988. If the three principal recommendations resulting from these studies are all carried out there should be considerable improvement in total numbers of salmon and steelhead, and in their distribution above and below the dam. These recommendations include (1) a new positive fishscreen at the entrance to the Tehama-Colusa Canal (already under construction), (2) increased effort towards controlling squawfish and other predators below RBDD and (3) enlarge the present fishway at RBDD. It was also recommended that the left bank fishway be further enlarged to provide an exit flow which would be at least 10% of any seven day sustained flow past the dam, up to 50,000 cubic feet per second.

Upper Sacramento River Steelhead Technical Committee

This committee was initiated by the FWL (Dave Vogel) in February, 1984 as the "Sacramento River Steelhead Management Committee". Sixteen people attended the first meeting; twelve from the Department of Fish and Game (DFG) and four from the FWS. Before the next meeting, held on June 5, 1984, the committee name was changed to "Upper Sacramento River Steelhead Technical Committee", and the membership was reduced to four; two from the DFG and two from the FWL.

The immediate purpose of the committee was to develop a constructive plan to reverse the Upper Sacramento River System steelhead decline. The long range goal was to develop an overall steelhead management plan for the Upper Sacramento River System.

The technical committee has met off and on during the past five years; three times in 1984, seven times in 1985, two times in 1986, none in 1987 and 1988 and only once in 1989. The committee proposed four specific immediate studies to gain information for increasing the steelhead populations:

1. A time, size and place of release study with CNFH yearlings.

2. An attempt to increase CNFH steelhead survival by crossing Mill Creek females with CNFH males.

3. Increasing natural steelhead runs in Mill Creek by rearing Mill Creek juveniles in ponds in Upper Deer Creek, and then returning the yearlings produced to Mill Creek for release.

4. Increasing CNFH steelhead survival by a genetic broodstock section program (blue ribbon steelhead program) whereby only sea-run fish would be used for CNFH production (a program initiated in the 1950's but since abandoned).

To date, only one brood year (BY) of tagged yearlings has been released from CNFH relative to the time, size and place of release study. This release was made in 1985 (Table 14). In 1986, over 200,000 tagged yearlings were unnecessarily destroyed because whirling disease was detected among a small percentage of the yearlings. The cost of tagging these fish was more than $16,000. This needless tragedy has resulted in a tremendous reduction in the Upper Sacramento River steelhead sport fishery as well as the steelhead population. No release of tagged steelhead was made in 1987 either.

The genetic broodstock selection program was initiated with releases of CWT yearlings in the spring of 1988. This program was to be repeated in 1989, but unfortunately the released yearlings were not tagged so there will be no evaluation of the 1989 BY releases. It is planned to continue the genetic broodstock selection program by tagging the yearlings to be released in the spring of 1990, but the number to be tagged is small, because of limited production at CNFH. The studies involving Mill Creek steelhead did not materialize. Although the committee in five years was unable to reach their long range goal of developing a management plan, in 1984 they did compile a list of information needed to develop such a plan (Figure 17). What the committee members apparently did not do was either change their own program priorities and budgets or see that their particular agencies did so, in order to create and budget a research unit which would obtain the needed information.

Table 14

Coleman National Fish Hatchery return rates (%) for coded-wire tag groups of steelhead/resident trout released at Battle Creek and the Sacramento River at Princeton Ferry on February 19 and 25, 1985 at sizes of four and six to the pound.

Release site	Release size (fish/lb)	Release number	2-yr olds All Returns /1 Recovery number	2-yr olds All Returns /1 Return Rate	3-yr olds All Returns Recovery number	3-yr olds All Returns Return Rate	3-yr olds Steelhead only 2/ Recovery number	3-yr olds Steelhead only 2/ Return Rate	4-yr old All Returns /3 Recovery number	4-yr old All Returns /3 Return Rate
Battle	5.9	50803	0	0.00	57	0.11	31	0.06	2	0.00
Creek	4.2	49259	6	0.01	104	0.21	80	0.16	4	0.01
	Combined	100062	6	0.01	161	0.16	111	0.11	6	0.01
Princeton	5.9	54542	1	0.00	50	0.09	46	0.08	0	0.00
Ferry	4.2	46240	3	0.01	117	0.25	103	0.22	0	0.00
	Combined	100782	4	0.00	167	0.17	149	0.15	0	0.00
Combined	5.9	105345	1	0.00	107	0.10	74	0.07	2	0.00
	4.2	95499	9	0.01	220	0.23	181	0.19	4	0.00
	Combined	200844	10	0.00	327	0.16	260	0.13	6	0.00

1/ Scales not available
2/ Based on scale analysis
3/ based on scale analysis all returns were identified as resident trout and averaged only 445 mm (17.5 inches)

1. Evaluate/review existing data, literature, studies.
   a) Hatchery steelhead.
      1) Juvenile steelhead harvest.
      2) Time, size, and site of release (present study).
      3) Hatchery vs. Lake California vs. below RBDD release.
      4) Flow vs. survival evaluation.
      5) Evaluate effects of density independent factors on survival.
      6) List and compile existing published and unpublished upper Sacramento River steelhead data.
      7) Evaluate steelhead early life history.
      8) Read and evaluate existing steelhead scale data.
      9) Impact of Coleman steelhead stocking on wild stocks of trout, steelhead and salmon--impacts in both Battle Creek and in the Sacramento River.
   b) Wild steelhead.
      1) Flow vs. survival evaluation.
      2) Evaluate effects of density independent factors on survival.
      3) List and compile existing published and unpublished upper Sacramento River steelhead data.
      4) Evaluate steelhead early life history.
      5) Read and evaluate existing steelhead scale data.
2. Future data/study needs.
   a) Hatchery steelhead.
      1) Total adult harvest and population (above Feather River).
      2) Adult harvest above RBDD (via tagging at RBDD).
      3) Stock transfer and selective breeding.
      4) Diversion impact evaluation: 1) locate, 2) enumerate, 3) evaluate.
      5) Fin clip vs. CWT survival.
      6) Impact of Coleman steelhead stocking on wild stocks of trout, steelhead and salmon--impacts in both Battle Creek and the Sacramento River.
      7) Evaluation of the Coleman strain (that may include Kamloops) compared to other strains.
   b) Wild steelhead.
      1) Total adult harvest and population (above Feather River).
      2) Juvenile steelhead harvest.
      3) Adult harvest above RBDD (via tagging at RBDD).
      4) Principal tributary evaluation (harvest and population).
      5) Diversion impact evaluation: 1) locate, 2) enumerate, 3) evaluate.
      6) Stream habitat survey.
      7) Impact of Coleman steelhead stocking on wild stocks of trout, steelhead and salmon--impacts in both Battle Creek and in the Sacramento River.
      8) Evaluation of different run times and relationships, i.e. Mill Creek has had November and February runs; do these intermingle?
3. Management actions without data.
   a) Increase effort on juvenile steelhead rescue.
   b) Fish ladder improvements.
   c) Increase RBDD monitoring.
4. Policy/regulations.
   a) Review policy on steelhead vs. catchable trout (Mill, Deer, Antelope, upper Battle Creek).
   b) Evaluate steelhead punch card system.
   c) Review existing angling regulations.
5. Overall management plan.
   a) Develop outline for steelhead management plan.

gure 17. Information Needs for Development of an Upper Sacramento River Steelhead Management Plan. Developed by the Upper Sacramento River Steelhead Technical Committee on September 19, 1984.

RESEARCH DEVELOPMENT AND EXTENSION PROGRAM

A solution to obtaining at least part of the information needed for developing a comprehensive Sacramento River steelhead management plan might be to adopt a Research Development and Extension program (RD&E) i.e., assign certain areas of research to university scientists (Vondracek, Bruse and Callaham (1987). A ten-year RD&E to solve 35 of the most critical problems facing anadromous salmonids in California is already available, along with cost estimates. This RD&E program, although strongly aimed at solving salmon problems in California, could be dissected and applicable parts researched to help develop an Upper Sacramento steelhead management plan.

YEARLING MASS TRANSPORTATION

Sacramento River

Coleman Hatchery

Between 1954 and 1988 several mass transportation studies were conducted in the Sacramento River System with CNFH yearling steelhead, to compare adult returns to the Sacramento River and to the hatchery, resulting from hatchery releases and releases at several locations on the Sacramento river. In each study the released yearlings received but a single imprint or cue to homing i.e., they were reared in Battle Creek water. However, those released at the hatchery were imprinted further as they traveled downstream and were subjected to water entering the Sacramento River from each tributary. The transported yearlings were trucked in Battle Creek water and were not subjected to any homing cues between the hatchery and the release site.

Adult Straying

In the mid 1950's and again in the mid 1980's comparative releases of CNFH yearlings in (1) Battle Creek and in (2) the Sacramento River at Princeton Ferry showed that releasing at Princeton Ferry does not cause straying by returning adults to the extent that returns to the hatchery are adversely affected. Comparative releases of CNFH yearlings in Battle Creek and in the Sacramento river below RBDD in the early 1970's also demonstrated that adult returns to the hatchery are not decreased by releasing the yearlings below RBDD. However, comparative releases of yearling steelhead, in Battle Creek and in the Sacramento River at Rio Vista during the 1970's demonstrated that adults returning from those released at Rio Vista strayed to such an extent that returns to CNFH were not great enough to continue a viable stocking program (Table 15).

The data on hand show that with the yearling imprinting methods used to date, and with the method of transport used (trucking), releasing CNFH yearlings either at Princeton or below RBDD does not adversely effect adult hatchery returns, but that releasing at Rio Vista does.

The natural straying by considerable numbers of CNFH reared steelhead, even by those released in Battle Creek, indicates that we are not dealing with genetically separate hatchery stocks in the upper and lower Sacramento River System. For example, the 1970's marking studies revealed that .02% of the yearlings released at CNFH showed up as adults at Nimbus Hatchery and .01% entered Feather River Hatchery (Table 16). When these percentage

Table 15

Comparative Releases of Coleman Hatchery Yearling Steelhead and Adult Returns to the Upper Sacramento River and the Hatchery

Year	Release Location	Size at Release (No. per lb)	Adult Returns (in percent)	
			River	CNFH
1954-59	Princeton	16	1.84	0.15
1955-58	Princeton	7	7.00	0.45
1957-59	Battle Cr.	7	1.00	0.20
1971-76	Battle Cr.	8	0.78	0.16
1971-76	Rio Vista	8	0.28	0.02
1973-77	Battle Cr.	8	-	0.09
1973-77	RBDD	8	-	0.12
1985-88	Battle Cr.	5	-	0.18*
1985-88	Princeton	5	-	0.17*

* No fishing permitted in Battle Creek.

Table

Summary of Adult Returns from Three Brood Years of Steelhead Released at Rio Vista and at Coleman Hatchery. From Hallock, 1980

Releases					Returns									
					Nimbus Hatchery		Feather River Hatchery		Fremont Weir 4/		Red Bluff Diversion Dam 3/		Coleman Hatchery	
Brood Year	Area	Number 1/	Date	Av. wt. (g)	Number	Percent 2/	Number	Percent 2/	Number	Percent 2/	Number	Percent 2/	Number	Perce
1969	Rio Vista	118,186	Feb.-Apr., 1970	48										
1970	Rio Vista	211,653	Feb.-Mar., 1971	47										
1971	Rio Vista	201,783	Feb.- 1972	38										
	Totals	531,622			114	0.02	59	0.01	1,519	0.28	267	0.05	112	0.0
1969	Battle Cr.	119,036	Feb.-Apr., 1970	50										
1970	Battle Cr.	213,398	Feb.-Apr., 1971	49										
1971	Battle Cr.	201,706	Jan.-Feb., 1972	37										
	Totals	534,140			13	0.002	3	0.0006	4,140	0.78	1,819	0.34	836	0.1

1/ Rio Vista releases marked Ad-RP; Battle Creek releases marked Ad-LP.
2/ Percent of number released.
3/ Estimate from sampling a portion of fish counted through the fishways.
4/ Estimate from Petersen-type mark-recapture study.

returns are applied to the annual 1.5 million yearling releases made at CNFH during the 1970's, an average of 30 CNFH steelhead returned as adults to Nimbus Hatchery and 10 to Feather River Hatchery each year.

Adult Returns

The data on hand show that by releasing yearling steelhead at Princeton Ferry instead of at CNFH total adult returns to the Upper Sacramento River System were 7 times greater; but that by releasing at Rio Vista instead of at the hatchery, adult returns to the Upper Sacramento River System were decreased by 2/3 (Table 16). However, there are indications of probable greater total adult returns to the entire Sacramento River System from the Rio Vista releases; 13 times greater in the Sacramento River sampling at Miller Park and 6 times greater in the sampling at Clarksburg (Table 17).

There are thus indications of greater total adult returns to the entire Sacramento River System from Rio Vista releases, when compared with CNFH releases, but excessive straying by adults returning from the Rio Vista releases (with the imprinting methods used) nullified the attempt to increase adult returns to the Upper Sacramento River and to CNFH.

Table 17

Annual Adult Returns from Three Brood Years of Steelhead Released at Rio Vista and at Coleman Hatchery. From Hallock, 1980.

Year	Return Location.	Returns from Rio Vista Release		Returns from Hatchery Release	
		Actual	Calculated	Actual	Calculated
1971-72	Miller Park	14	2,521[1]	1	187[1]
	Nimbus Hatchery	33	33	10	10
	Feathery R. Hatchery	35	35	2	2
	Fremont Weir	75	638[1]	155	1,319[1]
	Red Bluff Dam	21	122[2]	116	676[2]
	Coleman Hatchery	58	58	212	212
1972-73	Clarksburg	67	2,285[1]	12	411[1]
	Nimbus Hatchery	70	70	2	2
	Feather R. Hatchery	19	19	1	1
	Fremont Weir	13	738[1]	41	2,325[1]
	Red Bluff Dam	25	107[2]	205	876[2]
	Coleman Hatchery	50	50	493	493
1973-74	Nimbus Hatchery	11	11	1	1
	Feather R. Hatchery	5	5	0	0
	Fremont Weir	4	116[1]	17	496[1]
	Red Bluff Dam	10	33[2]	76	247[2]
	Coleman Hatchery	2	2	127	127
1974-75	Nimbus Hatchery	0	0	0	0
	Feather R. Hatchery	0	0	0	0
	Fremont Weir	1	27[1]	0	0
	Red Bluff Dam	1	5[2]	4	20[2]
	Coleman Hatchery	2	2	4	4

1/ Estimate from Petersen-type mark-recapture study.
2/ Estimate from sampling a portion of the fish counted through the fishways.

Discussion

The mechanisms of homing and the factors which are essential and critical to imprinting and homing cues are not thoroughly understood. A single imprint i.e., rearing yearlings in Battle Creek water apparently is not sufficient to guarantee adequate adult returns to the upper river or to CNFH if the yearlings are trucked or barged in Battle Creek water, in a close system. Natural (or sequential) imprinting cues the fish released at the hatchery as they migrate downstream; each tributary stream apparently helps establish a series of "signposts" to aid during the trip back. Sequential imprinting i.e., the step by step process as the yearlings migrate downstream also results when the fish are barged, since water is circulated through the barge as it moves down the river. Trucked fish are generally imprinted from a single source only, but this could be altered by stopping at various points along the Sacramento River and changing water in the truck, or they could be collected during migration; for example at Red Bluff Diversion Dam.

Columbia River

The Program

A standard procedure on the Columbia and Snake Rivers is to collect downstream migrant steelhead at dams and transport them either by truck or barge to release sites in the lower Columbia River below Bonneville Dam. The collection systems at these dams often permit capturing 50% of the downstream migrants. These collection systems are located in front of the turbine entrances at each dam since most of the river flows through the turbines much of the year. This mass transportation program uses trucking primarily in the fall when the numbers of captured fish are small, and barging in the spring when the numbers of captured fish are greatest, since not many trucks are available and the barge capabilities are much greater.

The primary dams involved in the mass transportation program are Lower Granite and Little Goose on the Snake River, and McNary and Bonneville on the Columbia (Figure 18). On the Snake and Columbia Rivers there is also a squawfish predation problem below the dams, similar to that on the Sacramento River below RBDD, but much greater.

Studies on the Columbia and Snake River systems have demonstrated that mass transportation works better (greater adult returns) with steelhead than with salmon. Some yearling steelhead are captured 60 miles below the hatchery where they were released, and barged below Bonneville Dam, without effecting returns to the hatchery.

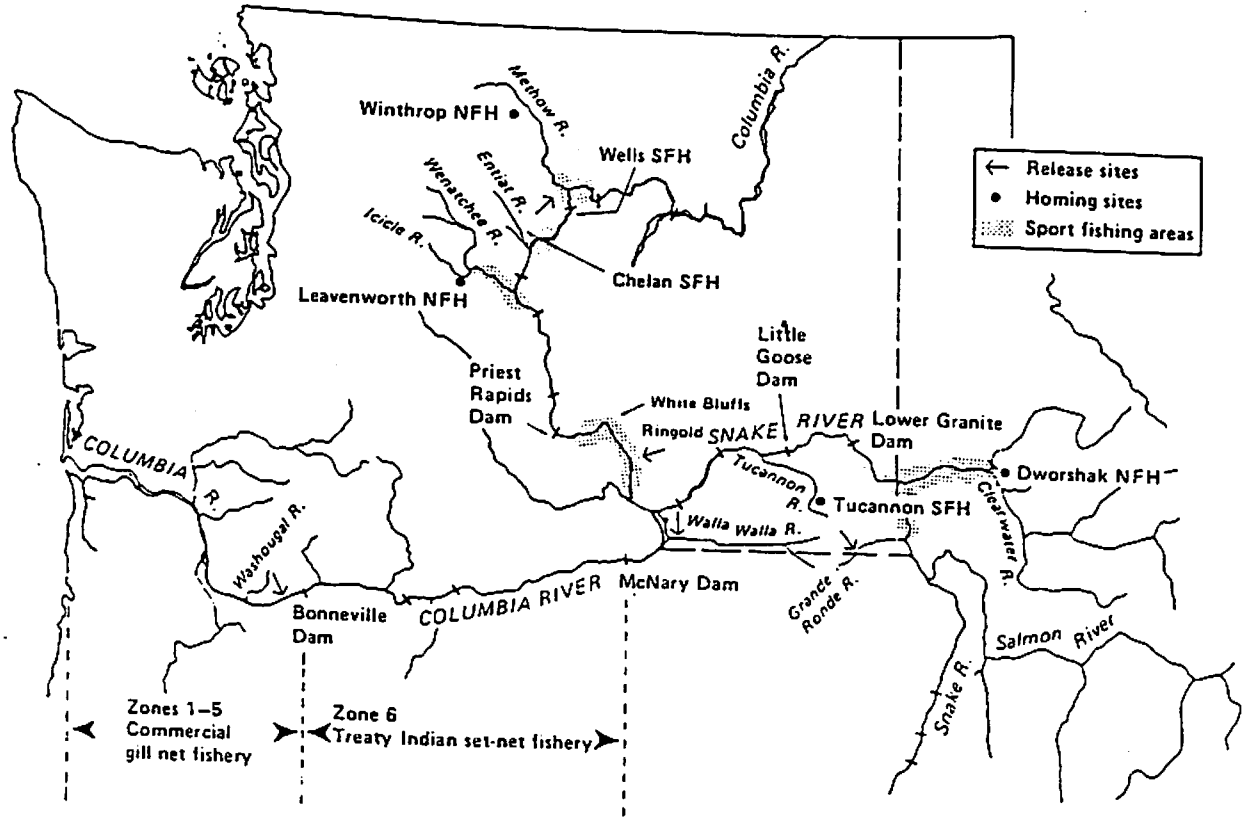

Figure 18. Study Area Germane to Homing Experiments with Steelhead.

Dworshak Hatchery

In 1978, steelhead smolts from Dworshak National Fish Hatchery (Dworshak NFH) on the Clearwater River, a tributary to the Snake river in Idaho, were released to compare adult returns to the river system, the fishery and the hatchery; (1) from the hatchery, (2) trucking to below Bonneville Dam and (3) barging to below Bonneville Dam. The imprint method applied to each of the yearling test groups was different; (1) the hatchery release was normal hatchery production reared in reconditioned North Fork of Clearwater River water and released in the North Fork of Clearwater River, (2) those trucked were normal hatchery production held in raw North Fork of Clearwater River water 48 hours and then trucked in North Fork of Clearwater River water directly to below Bonneville Dam and (3) those barged were also normal hatchery production held in raw North Fork of Clearwater River water to a barge in the Clearwater River at Lewiston, Idaho, held overnight, and then barged to below Bonneville Dam. The barge utilized a regulated "flow-through" water system as it moved downstream (Table 18).

Table 18

Steelhead trout marked in 1978 at Dworshak NFH indicating test number, date released, type of imprint, and treatment for various groups. From Slatick, Gilbreath, Harmon, Bjornn, Ringe, Walsh, Novotny and Zaugg, 1988.

Test control	Date released	Homing imprint	Treatment
Control	21 Apr	natural migration	Released with normal hatchery production into North Fork Clearwater River.
Test 1	01 May	Single	Normal production treatment. Held in raw North Fork water 48 h and then trucked in North Fork water directly to below Bonneville Dam.
Test 2	26 Apr	Sequential	Normal production treatment. Held in raw North Fork water 48 h, trucked in North Fork water to a barge in the Clearwater River at Lewiston, held overnight, and then barged down river to below Bonneville Dam.

Adult Straying and Returns

Adult returns revealed that the barged and trucked fish (test fish) produced adult returns to the area below Bonneville Dam 3½ to 4½ times greater than the steelhead released at the hatchery (control fish). As the adult test fish continued upstream toward the hatchery, the trucked fish strayed much more than the barged fish. The numbers of barged fish were 1.8 times greater at McNeary Dam, 2.5 times greater at Lower Granite Dam, 4 times greater in the Snake and Clearwater River sport fisheries and 1.4 times greater in returns to the hatchery than the trucked fish (Table 19). However, the barged fish also produced slightly greater returns to the hatchery than did those released at the hatchery. Thus the enhanced survival resulting from both trucking and barging provided greater numbers of adults for the fishery and natural spawning without adversely affecting hatchery returns.

If these same Dworshak (NFH) percentage returns (Table 19) are applied to a 1.5 million yearling steelhead release by CNFH, those released at the hatchery would result in a return to the hatchery of 4,170 adults, those trucked would return 4,500 adults and those barged would return 6,435 (2,265 more adults than those released at the hatchery).

Table 19

Returns to Five Sampling Locations and to the Dworshak NFH Homing Site of Steelhead from Control and Test Releases of Smolts Imprinted to the Dworshak NFH in 1978. Recoveries were From September, 1979 to May 12, 1981. From Slatick, Gilbreath, Harmon, Bjornn, Ringe, Walch, Novotny and Zaugg, 1988.

Recovery area and experiment[a/]	Juveniles released		Adult returns		
	No.	Date	No.	%[b/]	T/C ratio
Bonneville Dam[c/]					
Dworshak - control	100,600[d/]	21 Apr	13	0.043	-
Trucked to Bonneville	20,661	01 May	16	0.324	7.53:1 NS
Barged to Bonneville	24,006	26 Apr	9	0.157	3.65:1 NS
Indian fishery[e/]					
Dworshak - control			75	0.075	-
Trucked to Bonneville			44	0.213	2.84:1 **
Barged to Bonneville			61	0.254	3.39:1 **
McNary Dam[c/]					
Dworshak - control			21	0.070	-
Trucked to Bonneville			4	0.088	1.26:1 *
Barged to Bonneville			9	0.158	2.26:1 *
Lower Granite Dam[c/]					
Dworshak - control			198	0.658	-
Trucked to Bonneville			19	0.373	0.57:1 **
Barged to Bonneville			50	0.932	1.42:1 **
Clearwater and Snake River sport fishery[e/]					
Dworshak - control			76	0.076	-
Trucked to Bonneville			8	0.039	0.51:1 NS
Barged to Bonneville			22	0.154	2.02:1 **
Dworshak homing site[e/]					
Dworshak - control			280	0.278	-
Trucked to Bonneville			62	0.300	1.08:1 NS
Barged to Bonneville			103	0.429	1.54:1 **

a/ Because of differences in sampling intensity (efficiency) at each trapping site, results are not comparable between sites.

b/ Adjusted for the differences in detectability between binary and color-coded wire tags as indicated by returns to Dworshak hatchery.

c/ Data from branded fish only.

d/ A total of 100,600 were wire tagged for the hatchery control releases. Of this number only 30,074 were branded for Inriver adult evaluation.

e/ Data from coded wire tags only.

NS = Nonsignificant

* = Significant difference between the test and control group ($P < 0.05$, df = 1).

** = Significant difference between the test and control group ($P < 0.01$, df = 1).

RECOMMENDATIONS

A separate steelhead research and management unit should be created, fully staffed and adequately budgeted. During the past 40 years no combined salmon and steelhead research unit or combined anadromous fish research unit has devoted more than a minor fraction of their effort and funds toward steelhead research and management; the published reports indicate that salmon and striped bass have received the lion's share. The proposed steelhead research and management unit should take immediate steps to stem the decline (some of which steps are suggested in this report), and to initiate studies to gather information needed for developing a comprehensive Upper Sacramento River steelhead management plan, which would include naturally produced as well as hatchery steelhead populations.

To speed up the collection of research data needed to develop a comprehensive Upper Sacramento River management plan a Research Development and Extension Program (RD&E), whereby certain areas of needed research would be assigned to university scientists, should be initiated.

Encourage, cooperate and participate in studies aimed at determining the losses of California steelhead in the North Pacific Squid Fisheries. Although DFG has stated that "we have no evidence that California-origin salmon and steelhead are being impacted by foreign fisheries interceptions on the high seas" (letter from Pete Bontadelli, (DFG) to Alan Lufkin, (SEACOPS) dated August 8, 1989), the evidence suggests that the North Pacific Squid Fisheries are adversely impacting California

steelhead.

At CNFH a firm policy of rearing and releasing one million 4/lb yearling steelhead should be adopted. This means obtaining eggs from other Sacramento River System fish hatcheries when needed. To carry out this policy, without a reduction in the present or proposed salmon production program, additional rearing ponds will be necessary. The survival of adult steelhead being held prior to spawning must be increased. This may include feeding the adults being held with roe as was done in the 1950's as well as the use of drugs relative to disease. Grading the yearlings into proper size groups and securing the rearing ponds from bird predation will be necessary to increase juvenile survival. Yearling steelhead should not be released in Battle Creek when juvenile salmon are emerging from the spawning beds.

At CNFH the genetic broodstock selection program (blue ribbon program) initiated in 1987, should be adequately funded and the research relative to this program continued.

Efforts must be made to use the genetics of hatchery fish and time and place of stocking to separate or isolate hatchery and wild fish in the same waters during spawning time. There should be no stocking of hatchery ~~fish~~ steelhead in the Upper Sacramento River tributaries that impact a natural Run.

Reevaluate a mass transportation program with Coleman Hatchery yearling steelhead, a program so successful in the Columbia River system. Research must include various methods of imprinting yearlings prior to release and during transport. Such a program, if perfected in the Sacramento River System, will

become increasingly important in view of future anticipated water conditions. At RBDD a fish collection facility should be installed, similar to those being successfully used at dams on the Snake and Columbia Rivers, where as many as 50% of the downstream migrants are trapped above the dams for mass transportation programs.

A fish collection and holding facility should be constructed within the fish screen bypass system at RBDD. All steelhead (and salmon) successfully screened should be temporarily held and released into the river only at night, to avoid squawfish predation. If screened fish are to be released during daylight hours, multiple outlets should be incorporated into the bypass system to reduce predation by squawfish and other species. The collection facility could also be used for marking studies and mass transportation.

Both fishways at RBDD should be enlarged. As recommended by the FWL, the left bank fishway should be further enlarged to "provide an exit flow which would be at least 10% of any seven day sustained flow past the dam, up to 50,000 cubic feet per second". If these recommended fishway changes do not produce the desired results, a formerly proposed canal to bypass fish and boats around the east side of the dam (Bureau of Reclamation, 1962) should be reevaluated as a possible solution to any remaining fish passage problems.

Increase efforts towards developing a program which will minimize or eliminate squawfish (and other species) predation on yearling steelhead and salmon at RBDD.

The steelhead fishery should be managed as an adult fishery. This will entail stopping fishing for juvenile steelhead in the Upper Sacramento River tributaries i.e., no trout fishing in steelhead streams or sections of steelhead streams where juveniles rear. In addition, there should be no catchable trout stocking in designated steelhead streams or steelhead rearing areas of these streams (DFG) Steelhead Trout Policy, 8-15-75). The present exceptions to the steelhead trout policy, relative to catchable trout stocking, should be voided.

Limit the total adult catch and at the same time spread the catch among more individuals. This can be accomplished by using a punch card system similar to that used in other states. Consider restricting the catch of naturally produced steelhead, by marking all hatchery production and limiting the take to marked fish only, as a temporary measure to help restore the natural population.

An analysis of the effect of the State and Federal delta pumping plants on the Upper Sacramento River steelhead should be made. This has not been done with steelhead. The numbers of yearlings handled at these pumping plants varies considerably from year to year but as many as 17,000 were handled at the State pumping plant between February and April, 1982, and almost 3,000 at the Federal pumping plant between February and March, 1981.

REFERENCES

Azevedo, R.L. and Z.E. Parkhurst. 1978. The Upper Sacramento River Salmon and Steelhead Maintenance Program, 1949-1956. U.S. Fish and Wildlife Service, Mimeographed, 96pp.

Bureau of Reclamation. 1962. Passage of Small Boats, Red Bluff Diversion Dam. Bureau of Reclamation, Region 2, Sacramento, Calif. 30pp.

Hallock, R.J., W.F. Van Woert and Les Shapovalov. 1961. Evaluation of Stocking Hatchery-Reared Steelhead Rainbow Trout (Salmo gairdnerii gairdnerii) in the Sacramento River System. Calif. Dept. of Fish and Game, Fish Bull. No. 114, 73pp.

Hallock, R.J. 1980. Returns form Coleman Hatchery Steelhead Trout (Salmo gairdnerii) Released at the Hatchery and at Rio Vista. Calif. Dept. of Fish and Game, AFB Office Report, 6pp.

Hallock, R.J. and F.W. Fisher. 1984. Estimated Losses of Salmon and Steelhead attributed to Red Bluff Diversion Dam. Calif. Dept. of Fish and Game, Anad. Fish. Br., Interoffice Report.

Harmon, J.R. and E. Slatick. 1987. Use of a Fish Transportation Barge For Increasing Returns of Steelhead Imprinted for Homing. Annual Report of Research, 1986. National Oceanic and Atmospheric Administration, Seattle, Washington.

Le Brasseur, R.J., N.B. Hargreaves and T. Gjernes. 1988. Canadian Mid-Ocean Salmon Studies, W.E. Ricker, 1-June-12 July, 1988. Document Submitted to the Annual Meeting of

the International North Pacific Fisheries Commission, Tokyo, Japan, October, 1988. 19pp.

Light, J.T., S. Fowler and M.L. Dahlberg. 1988. High Seas Distribution of North American Steelhead as Evidenced by Recoveries of Marked or Tagged Fish. Document Submitted to the International North Pacific Fisheries Commission. Fisheries Research Institute, University of Washington, Seattle. FRI-UW-8816. 21pp.

Menchen, R.S. 1980. Estimated Freshwater Sport Catch of Coleman Hatchery Yearling Steelhead, (Salmo gairdnerii), in 1973. Calif. Dept. of Fish and Game, AFB Office Report, November, 1980.

Park, D.L. 1985. A Review of Smolt Transportation to Bypass Dams on the Snake and Columbia Rivers. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Seattle, Washington. 65pp.

Slatick, E., L.G. Gilbreath, J.R. Harmon, T.C. Bjornn, R.R. Ringe, K.A. Walch, A.J. Novotny and W.S. Zaugg. 1988. Imprinting Hatchery Reared Salmon and Steelhead Trout For Homing, 1978-83, Vols. I and II. National Oceanic and Atmospheric Administration, Seattle, Washington.

Smith, S.H. 1950. Upper Sacramento River Sport Fishery. Special Scientific Report-Fisheries, No. 34. U.S. Fish and Wildlife Service. 44pp.

Sutherland, D.F. 1973. Distribution, Seasonal Abundance, and Some Biological Features of Steelhead Trout, (Salmo gairdnerii) in the North Pacific Ocean. National Marine

Fisheries Service, Seattle Washington. Fish. Bull. 71 (3): 787-826.

Van Woert, W. 1965. Central Valley Salmon and Steelhead Sport Catch, 1963-64. Calif. Dept. of Fish and Game, Marine Resources Admin. Report No. 65-6. 6pp.

Vondracek, B. and R.Z. Callaham. 1987. California's Salmon and Steelhead Trout - A Research and Extension Program. University of California, Wildland Resources Center, Berkeley, California. Report no. 13. 33pp.