SJC-438

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STATE OF CALIFORNIA
DEPARTMENT OF FISH AND GAME

FISH BULLETIN No. 114

AN EVALUATION OF STOCKING HATCHERY-REARED STEELHEAD RAINBOW TROUT (*Salmo gairdnerii gairdnerii*) IN THE SACRAMENTO RIVER SYSTEM

By RICHARD J. HALLOCK,
WILLIAM F. VAN WOERT, and LEO SHAPOVALOV

1961

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Typical catch of Sacramento River steelhead. *Photograph by Richard J. Hallock.*

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FOREWORD

Inadequate basic information about steelhead populations has long hampered their management. Factors such as current harvest rates, safe harvest rates, percentage survival of hatchery-reared juveniles, and best planting procedures have usually been subject to guesswork.

Uncertainties breed controversy. And so, dispute over the relative importance of natural vs. hatchery reproduction of steelhead led to the birth of this project. Now the study is done, and the facts gained have resolved the dispute and add considerably to knowledge of Sacramento River steelhead, to the substantial benefit of future management.

Seasons and bag limits may be set with greater assurance, knowing approximately the size of the run and the harvest rate of adults. Future hatchery programs may be planned and conducted more objectively, knowing approximately how many of the planted yearlings will return as adults, how many will be caught, and how much it will cost to put one in the creel through stocking. The added information about best times, places, and sizes for stocking hatchery fish will also be of considerable practical value, although more information on these subjects would be desirable.

This study has already paid handsome unexpected dividends in California. The scope of steelhead hatchery programs relating to dams on the Klamath, Trinity, Feather, and Mokelumne rivers was based in large part on survival rates of marked yearlings released in the Sacramento River. Other comparable benefits are anticipated here and elsewhere in the future.

We present this report to all those interested in steelhead, hoping that it will contribute to the conservation and enhancement of these noble fish wherever they occur.

ALEX CALHOUN
May, 1961

ACKNOWLEDGMENTS

The success of the Sacramento River steelhead study was due to the efforts of many people in California. Particular appreciation is due Henry Clineschmidt, founder of both California Kamloops, Inc. and Steelhead Unlimited, who as president of these organizations helped instigate the study and spearheaded sportsmen's participation in it, and to John Pelnar, District Supervisor, U. S. Fish and Wildlife Service, who as head of Coleman National Fish Hatchery provided use of hatchery facilities and much valuable assistance.

Thanks are also due to several members of the California Department of Fish and Game. The authors are especially indebted to Donald H. Fry, Jr., Senior Research Analyst, who made a memorable contribution through assistance with the final preparation of the manuscript for publication. In this, he was ably assisted by William R. McAfee. Alex Calhoun, Chief, Inland Fisheries Branch, was instrumental in furthering the progress of the study. Harry A. Hanson and Elton D. Bailey headed the program during the first two years, and the latter also critically reviewed the manuscript. Don A. LaFaunce, Joseph Patterson, and the late David Glenn worked many long days developing, operating, and maintaining the fish traps. John Riggs helped with the trapping, supervised Mill Creek Counting Station, and assisted with marking and creel censusing. William and Mira Cunningham maintained Mill Creek Counting Station nine months each year, mounted all steelhead scales for reading, and typed the manuscript. Cliffa Corson prepared the graphs and maps in final form for publication.

Many members of the press also contributed to the success of the program, and it is fitting that special thanks be given to those whose timely articles led to a better understanding of the program by sportsmen and to greater tag returns. Among these are Robert Hurst, Chico *Enterprise Record;* Marion Walker, Red Bluff *Daily News;* Paul Bodenhamer, Redding *Record-Searchlight;* Robert Reedy, Sacramento *Union;* Glen Spuller, Sacramento *Bee*.

Tremendous assistance was given the study by the many sporting goods stores, fishing resorts, and fishing camps along the Sacramento River between Redding and Meridian, who donated valuable prizes for the return of steelhead tags. Finally, thanks are due the counties of Shasta, Tehama, Butte, Glenn, and Colusa for contributing county fish and game fine monies to help pay the steelhead food bill at Coleman Hatchery.

RICHARD J. HALLOCK
WILLIAM F. VAN WOERT
LEO SHAPOVALOV

An Evaluation of Stocking Hatchery Reared Steelhead Rainbow Trout, *Salmo gairdnerii gairdnerii*, In the Sacramento River System[1]

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INTRODUCTION

During the past fifteen years the Sacramento River has become one of the most popular fishing streams in California for steelhead rainbow trout, *Salmo gairdnerii gairdnerii* Richardson. Each fall, fishermen in ever increasing numbers travel from all parts of California, as well as from neighboring states, to participate in the harvest of this prized western game fish.

The increase in the numbers of anglers has been brought about by an accumulation of events, foremost of which has been an explosive growth in California's population and in the numbers of people seeking outdoor recreation. Construction of Shasta Dam, with its stabilizing and cooling effect upon the upper Sacramento, has produced an environment better suited for steelhead. The Sacramento is also a favorite steelhead stream of many anglers because the best fishing is enjoyed during balmy days in the fall, rather than during the cold periods so typical of most winter-run steelhead fishing areas.

This expanding popularity made it essential that the Sacramento River steelhead management program be evaluated to determine whether or not it is adequate to insure continued good fishing in the face of these mounting demands upon the resource.

Provision of good steelhead fishing despite the inroads by man is a problem which faces conservation agencies along the Pacific Coast. The State of Washington has attempted to offset this increase in fishing pressure principally by a long-range management program consisting of releases of migrant-sized steelhead (yearling fish averaging 6 to 8 inches in length) to supplement depleted and heavily fished runs, coupled with protective regulations and installation of fishways and fish screens to protect the runs. The stocking of migrant-sized steelhead during their normal period of seaward migration has definitely built up the runs of sea-run fish in Washington streams, according to Larson and Ward (1955).

In California it had been the policy for many years prior to 1940 to stock coastal streams with fingerling steelhead in the summer months. The results of this program shed considerable doubt on the effectiveness

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[1] This work was performed as part of Dingell-Johnson Project California F-7-R, "Sacramento-San Joaquin River Salmon and Steelhead Study", supported by Federal Aid to Fish Restoration funds.

[2] The first two listed authors transferred to the Marine Resources [illegible] upon completion of the study.

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FIGURE 1. A 13½-pound steelhead landed in Battle Creek, a tributary of the upper Sacramento River. This was the second largest steelhead recorded during the study. *Photograph by Richard J. Hallock, September, 1957.*

of this type of artificial stocking (Shapovalov and Taft, 1954). An experimental program at California's Waddell and Scott creeks from 1932 through 1942 revealed that only extremely small returns of sea-run fish may be expected from releases of fingerling steelhead, but that on the average approximately 2 to 5 percent may be expected to return as adults when allowed to descend to sea as yearlings at their normal migration time (Shapovalov and Taft, *loc. cit.*).

Until the start in 1952 of the study described herein, the management program for Sacramento River steelhead had consisted primarily of protective regulations and installation of fish protective devices such as fish screens and fishways. There had been no artificial stocking of steelhead. The only previous significant investigation of Sacramento River steelhead was included in a study of the sport fishery, which was made between 1947 and 1949 (Smith, 1950). Prior to 1952 considerable knowledge had bee[illegible]ned through the years about steelhead in the smaller coastal stream[illegible] California, but relatively little was known concerning the life history of Sacramento steelhead or the merits of planting

migrant-sized steelhead in the Sacramento River. Therefore, it was decided to examine this important resource more thoroughly and to find out if artificial stocking of large numbers of migrant-sized steelhead in the Sacramento was a feasible method of maintaining or improving fishing for adult steelhead. In 1952 the California Department of Fish and Game's Bureau of Fish Conservation (now Inland Fisheries Branch) initiated a project to determine the effectiveness and economics of supplementing natural steelhead production in the Sacramento River with yearling, hatchery-reared fish. Secondary objectives were to study the fishery and the life history of Sacramento steelhead. It was originally planned to have the field work continue until 1960 but was found possible to complete it by 1958.

The study was carried out as a cooperative program between the California Department of Fish and Game and several other organizations which recognized the need for an evaluation of steelhead stocking in the Sacramento River. Two sportsmen's organizations, California Kamloops, Inc. and Steelhead Unlimited, volunteered to pay for the food fed to the fish at the hatchery and awarded one thousand dollars over a five-year period to fishermen who returned tags to the Department of Fish and Game. Three thousand dollars in merchandise rewards for tag returns were donated by several sporting goods stores and fishing resorts along the Sacramento River between Redding and Meridian. The United States Fish and Wildlife Service trapped and spawned adult steelhead in Battle Creek and reared the resulting young to yearling size at Coleman National Fish Hatchery on the same stream. The Department of Fish and Game paid a small part of the food costs for rearing the fish, marked the yearlings, released them, and evaluated the returns.

SACRAMENTO RIVER SYSTEM

The Central Valley of California is roughly 400 miles long by 45 miles wide. It is bordered by the Sierra Nevada and the Cascade Range on the east, the Coast Ranges on the west, the Klamath Mountains and the Cascade Range on the north, and the Tehachapi Mountains on the south. The two principal rivers of the Central Valley are the Sacramento and San Joaquin. These two rivers, along with their many tributaries, form the largest stream system in California. The Sacramento River drains the northern part of the Valley, and the San Joaquin drains the southern part. They flow towards each other and merge in the Sacramento-San Joaquin Delta, a maze of leveed channels and sea-level islands. The combined waters then flow into Suisun Bay, San Francisco Bay, and the Pacific Ocean.

The headwaters of the Sacramento River are located on the slopes of Mount Eddy, one of the peaks of the Scott Mountains. About 12 miles downstream and some 420 river miles from San Francisco the infant river is joined by Wagon Valley Creek, a spring-fed stream originating near the southwest base of Mount Shasta. From the standpoint of both water supply and fishery resources, the Sacramento, above its confluence with the Feather River, is the most important stream in the Central Valley. This is the section with which this [illegible]ort is primarily concerned. The portion of stream below the mouth [illegible]e Feather has been designated as the "lower Sacramento" and the portion between the mouth of the Feather and Keswick Dam as the "upper Sacramento".

Since the completion of Shasta and Keswick dams, the upper Sacramento has been harnessed (Figure 2). Keswick Dam, located about five miles above Redding, presents a complete block to anadromous fish migrations.

Between Redding and Hamilton City, a stretch which includes the principal steelhead angling area, the Sacramento River drops 350 feet in 96.4 miles, an average of 3.6 feet per mile. In the 47.3-mile stretch between Redding and Red Bluff, the average gradient is 4.4 feet per mile.

Above Hamilton City the Sacramento is a rather wide, moderately swift stream with alternating long, tree-lined pools and short gravel riffles. During normal flows it varies in width from 600 feet in some of the pool areas and at a few riffles down to 200 feet in many narrower sections. It is even less than 100 feet in some channels. The average width is probably between 350 and 400 feet. There are few places where "white water", similar to that found in the McKenzie and Rogue rivers of Oregon, may be encountered.

In the 79-mile section between Redding and Vina there are numerous riffle areas of widely varying sizes. Nearly all are fished for steelhead during the fall months.

The daily mean flow of the Sacramento River at Red Bluff during most of the year, except in periods of heavy runoff, is usually less than 11,000 cubic feet per second. During the fall months it is usually between 5,000 and 7,000 cubic feet per second. The maximum daily discharge at Red Bluff (1902 to date) occurred on February 28, 1940, when 291,000 cubic feet per second was recorded.

The principal tributaries in the upper river system, insofar as steelhead fishing is concerned, all enter the valley from the east; they are Mill, Deer, and Battle creeks. Many smaller tributaries are also used by steelhead for spawning, and limited fishing takes place in most of them.

SACRAMENTO RIVER STEELHEAD

Adult Migrations

During the course of the study, a series of large wire fyke traps was operated in the Sacramento River just above the mouth of the Feather River, near Fremont Weir. These traps were operated to examine sea-run steelhead for fin marks and to tag fish for population and sport catch estimates. Construction and operation of the traps has been described by Hallock, Fry, and La Faunce (1957).

The time pattern of the migration of sea-run steelhead into the upper Sacramento River was determined as a by-product of the operation of the traps, which were fished continuously, except for brief periods of high water, from July, 1953, through March, 1955. By then the pattern of migration had been established, and the traps were operated each year thereafter only from July until the onset of high water, sometime in December.

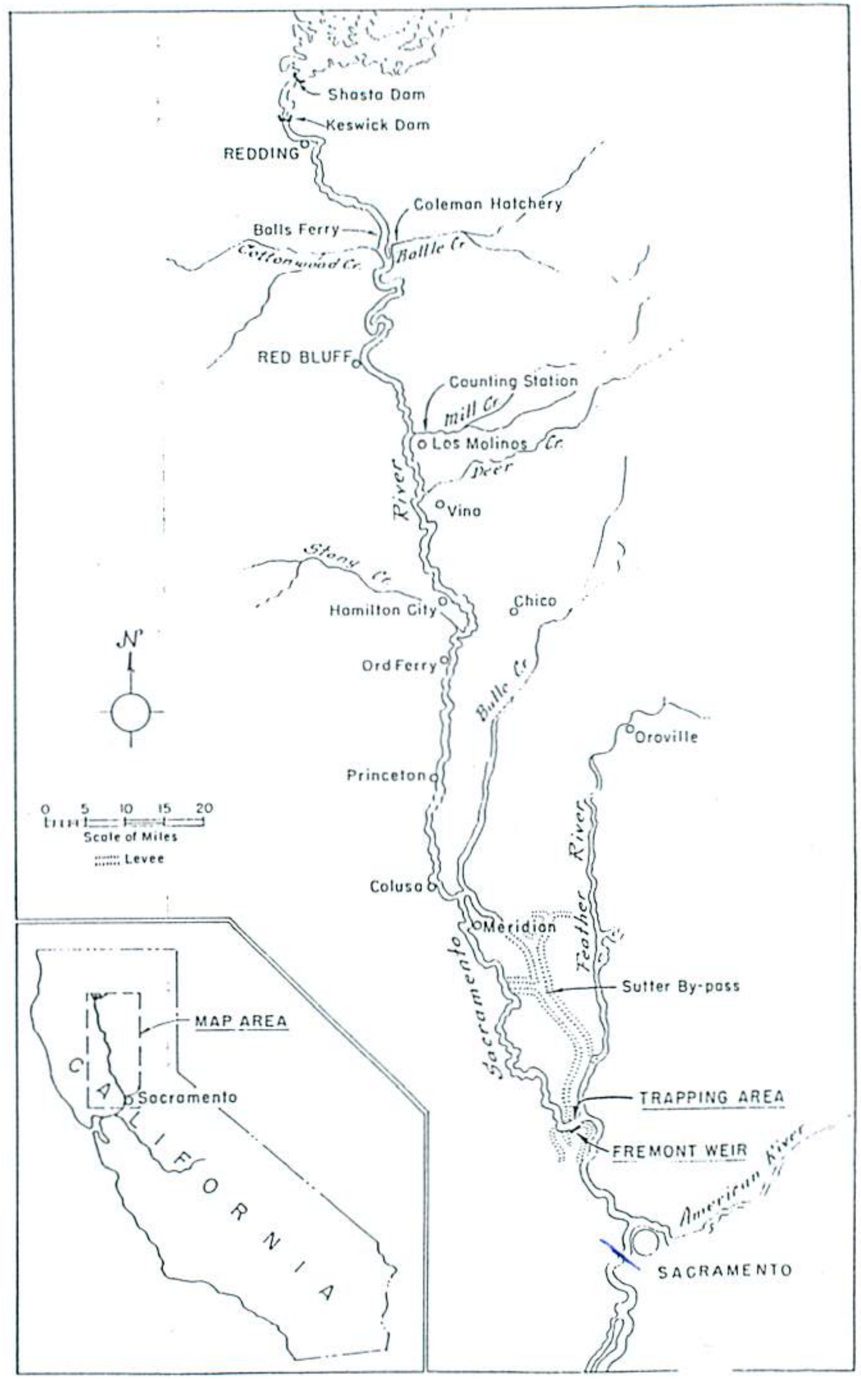

FIGURE 2. Map of the Sacramento River system, showing the area where the steelhead studies ...

It was found that steelhead migrate into the upper Sacramento River during most months of the year in one continuous run (Figure 3). Each season the first of the migration passes the mouth of the Feather River in July. The run in 1954 and 1955 was continuous until the middle of the following March. In 1954 very few, if any, adult steelhead moved from the Delta into the upper Sacramento between the middle of March and the middle of June. The bulk of the run passes the Feather River between early August and late November, and the peak of the migration usually occurs near the end of September.

Above the mouth of the Feather River, most of the early migrant steelhead remain in the main stem of the Sacramento until about the middle of November or until flows increase sufficiently in tributary streams to encourage ingress. During October and November they concentrate on riffles occupied by spawning king salmon, *Oncorhynchus tshawytscha* (Walbaum), and near the mouths of the larger tributary streams, principally between Hamilton City and Redding. Usually by the middle of November rain has swollen the entire river system, permitting the steelhead and the salmon which have not already spawned to fan out into spawning areas of the numerous tributaries.

Immediately after spawning, most steelhead start the long journey back to sea. During March and April, spawned-out steelhead are particularly noticeable in catches along the upper Sacramento River. In May they are also in evidence in good quantities in the Sacramento-San Joaquin Delta. As late as 1957 commercial gill netting for American shad, *Alosa sapidissima* (Wilson), was permitted in the Delta during April and May. With the mesh sizes employed it was almost impossible to fish nets for shad without catching steelhead as well. The catch of steelhead in commercial nets was particularly noticeable in the spring of 1955, when shad fishermen sent in 36 tags. All tags were from steelhead that had been tagged during their spawning migration the previous fall.

Juvenile Migrations

An attempt to determine the time pattern of the juvenile steelhead migration past the mouth of the Feather River was made by trapping. This method proved unsuccessful, because insufficient numbers of fish were captured. However, in the upper river all evidence indicates a heavy seaward migration of yearlings in the spring and a much smaller one in the fall. Creel census work also showed an increase in numbers of juvenile steelhead in the upper Sacramento in the late winter and early spring. It is thought that this periodic influx of small fish represents the annual hordes of juveniles moving out of the tributaries towards the sea. This conclusion is verified to some extent by the results obtained from the operation of a downstream trap for juvenile steelhead at Clough Dam on Mill Creek. It was found that young fish migrated downstream during most months of the year, but the peak periods for yearling and two-year-old fish were reached during the first heavy runoff of fall and again in early spring. A similar situation was found to prevail in California's coastal streams (Shapovalov and Taft, *loc. cit.*). However, the migration in the Sacramento River appears to be a little [illegible]ier than in Waddell Creek, where the coastal study was made. Sacra[illegible]to fish are known to be moving seaward in good quantities as early as February, a month earlier than most Waddell Creek

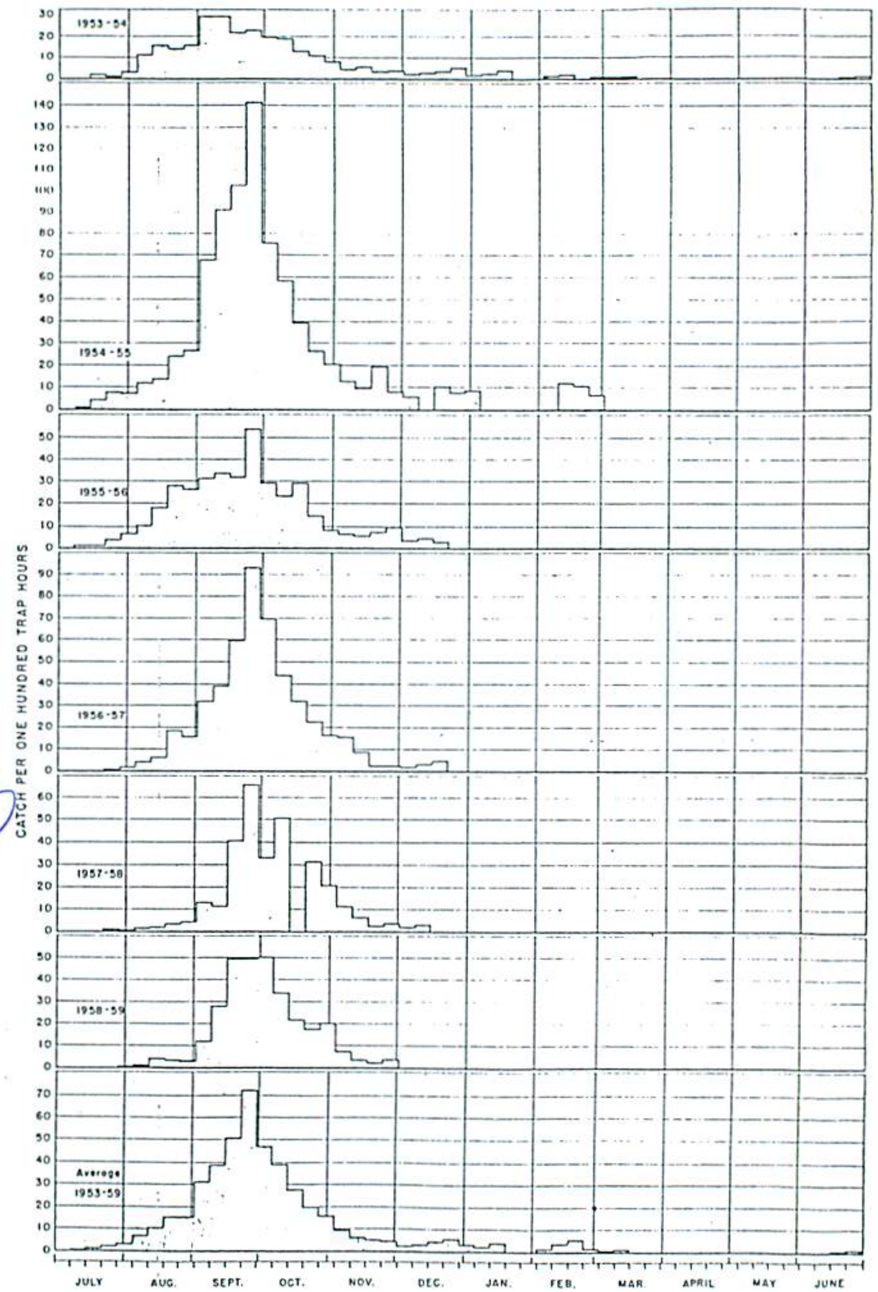

FIGURE 3. Time pattern of Sacramento River adult steelhead migrations. Migration times were determined by trapping upstream migrants in the Sacr[illegible]nto River one-half mile above its confluence with the Feather River, near [illegible]ont Weir.

fish. When released in the spring, hatchery-reared steelhead of a size larger than 10 to the pound usually move downstream rapidly. This was first observed in 1955, when fish averaging seven to the pound were released at Princeton Ferry in January and several were landed by striped bass fishermen three weeks later at Sacramento, 112 miles downstream. In 1959, fish averaging seven to the pound were released in Mill Creek, about one mile above its confluence with the Sacramento, and within an hour were spilling over a shallow bar into the Sacramento River.

Age

Ages of Sacramento River steelhead were sampled by reading scales from 100 fish. Scales used in the age study, and later for calculation of growth in length, were selected to include all size groups from the scales of 400 steelhead trapped in the Sacramento River near the mouth of the Feather River during the fall of 1954. They do not include hatchery fish.

Examination of the scales revealed that 70 of the 100 fish had spent two years in fresh water before entering the ocean, 29 had spent one year, and one had spent three years. Included in the 100 scale samples were scales from 17 two-year-old fish, 41 three-year-olds, 33 four-year-olds, six five-year-olds, two six-year-olds, and one seven-year-old. The two-year-old steelhead had spent one year in fresh water and one year in salt water. Thirty (73 percent) of the three-year-old fish had spent two years in fresh water and one in salt water, and 10 (24 percent) had stayed one year in the river and two in the ocean. Twenty-six (79 percent) of the four-year-olds had lived two years in fresh water and two years in salt water.

The age distribution of Sacramento River steelhead populations is somewhat similar to that in California's coastal streams, but the percentages of older fish are much smaller in the Sacramento than in Washington streams. For example, Pautzke and Meigs (1940) found that of 100 mature steelhead caught by anglers in Green River, Washington, 13 were three-year-olds, 60 four-year-olds, 23 five-year-olds, and four six-year-olds.

Spawning

Steelhead spawning extends over a period of several months and may take place any time from the latter part of December through April. February is usually the peak month for taking steelhead eggs at Coleman Hatchery. They spawn in practically every tributary of the upper Sacramento River and appear to do so in numbers more or less proportionate to the amount of runoff. Large streams such as Mill, Deer, and Battle creeks have the largest runs; smaller streams are used by fewer fish. Actual numbers of steelhead spawning in the main stem of the Sacramento River and in most tributaries are unknown.

Examination of the steelhead scale samples collected during the fall of 1954 revealed that 83 of the 100 fish were spawning for the first time, 14 for the second time, and two for the third time. One fish, a 27.8-inch male, was spawning for the fifth time. These findings are similar to those of Shap~~alov and Taft (*loc. cit.*), who found that of 3,888 adult steelhead tra[illegible]d in Waddell Creek, California, 15 percent were spawning for the second time and 2 percent for the third time. However,

Meigs and Pautzke (1941) found that in Green River, Washington, only 5 percent of the mature steelhead caught by anglers in 1940 and 6.9 percent in 1941 were spawning for the second time.

Size

Sacramento River steelhead are generally smaller than those found in other California streams, except the Klamath River. During the six years that the traps were operated near the mouth of the Feather River, over 19,000 steelhead were captured. Fork length measurements were made of 18,671 of these fish. The measurements showed that during most years there was a bimodal length distribution; one mode was 15.5 inches and the other 20.5 inches (Figure 4). The smaller fish consist principally of age classes which have spent two years in fresh water and one year at sea. The larger steelhead are primarily fish which have spent two years in fresh water followed by two years in the ocean. Including lengths of all fish measured, the average size of a Sacramento River steelhead was found to be 18.1 inches in fork length, with a rather large standard deviation of 3.4 inches. Omitting fish under 14 inches in length, a good portion of which are apparently seaward bound instead of ascending the river, the average length becomes 18.7 inches.

Sacramento steelhead average about three pounds in weight. Fish up to eight pounds are common, while those over 13 pounds are rare. The largest steelhead recorded during the study weighed 15½ pounds.

Growth in Length

Data presented on growth in length of wild or naturally-produced steelhead were obtained from the examination of scale samples and include calculated lengths based on scale measurements, as well as lengths secured at the time of capture. All scales were taken from fish trapped in the Sacramento River near the mouth of the Feather River. The scale samples were removed from steelhead ranging from 11.0 to 27.8 inches in fork length. Scales were removed from an area between the lateral line and dorsal fin on the left side of each fish. A few scales in each sample were inspected with the aid of a binocular microscope, and those without regenerated centers were washed and mounted on glass slides in clear Karo syrup. The mounted scales were examined with a microprojector at a magnification of 40X. The center of the focus, each annulus, the margin of the scale, and the point at which the fish entered salt water were marked along the edges of white cards. The distances between these points were measured to the nearest millimeter and recorded on the cards. All measurements were made in the anterior field of each scale, along a radial line which was perpendicular to the anterior edge of the unsculptured posterior field.

Of the 100 scale samples originally selected, only the 83 from steelhead on their first spawning migration were used to determine the relationship between fork length and anterior radius of the scales, or body-scale relationship (Figure 5). The fitting of a least squares line to the means of fork lengths, grouped by one-inch intervals, and means of the corresponding scale radii, yielded the following equation:

$$L = 1.04 + 0.22S$$

Where:

L = Fork length in inches

S = Magnified anterior radius of fish scale in millimeters.

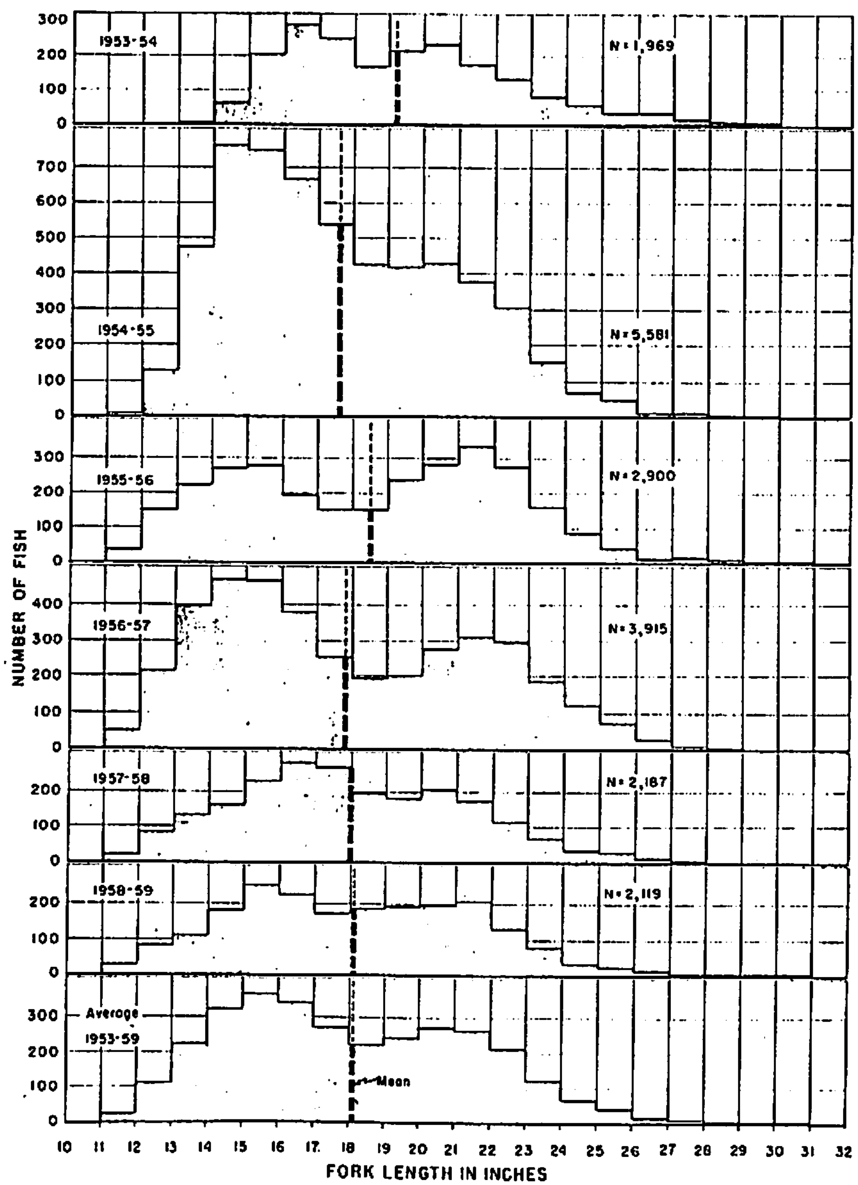

FIGURE 4. Ler composition of Sacramento River steelhead populations. Measurements were m of upstream migrants trapped in the Sacramento River one-half mile a. its confluence with the Feather River, near Fremont Weir.

The following formula then was used for a more accurate calculation of fish lengths (Lagler, 1952):

$$L_1 = \frac{S_1 (L_2 - 1.04)}{S_2} + 1.04$$

Where:

L_1 = Length of fish at any annulus

S_1 = Length of scale at any corresponding annulus

L_2 = Length of fish at capture

S_2 = Length of scale radius when scale was taken from the fish.

Calculated fish lengths were obtained by substituting average scale measurements in place of measurements of individual fish in the preceding formula (Table 1). This procedure eliminated the necessity of calculating the growth of individual fish (Van Oosten, 1953). In wild steelhead the greatest annual length increment occurs during the first year of life in the ocean. Most of the steelhead scales showed some "intermediate growth"—growth formed during the season of migra-

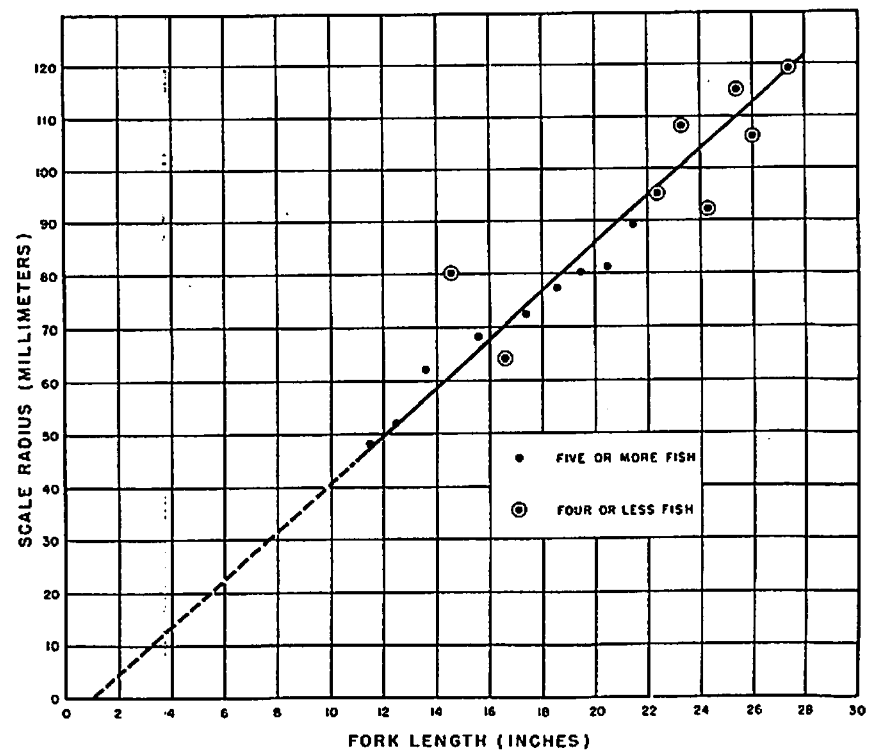

FIGURE 5. Relationship between fork length of fish and magnified anterior scale radius (40X) of steelhead from the Sacramento River. The dots are the means of fork lengths, grouped by 1-inch intervals, and the corresponding means of scale radii; the slope of the line is the mean body-scale ra[illegible].

TABLE 1

ulated Average Fork Lengths and Length Increments (in inches) of Wild (Naturally-Produced) 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

		Year of life															
		1		2						3						4	
Age of returning adults*	Number of fish	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	3.0	**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.

tion to the sea, prior to entry into salt water. Fish which had spent two years in fresh water showed smaller amounts of intermediate growth and entered salt water at a greater length than fish that had spent only one year in fresh water. This indicates that the two-year stream fish, having attained a larger size, migrated to salt water at a faster rate than fish which entered the ocean after only one year in fresh water. Young steelhead which had spent one or two years in fresh water generally entered salt water at a fork length of seven to nine inches. The considerable amount of intermediate growth shown by most downstream migrants was probably acquired during their journey of about 240 miles to brackish water plus an additional 80 miles through brackish and salt water before entering the ocean.

Sacramento River steelhead grow faster in fresh water and slower in salt water than steelhead from Green River, Washington. Growth studies by Meigs and Pautzke (*loc. cit.*) showed that Green River steelhead reached mean total lengths of 3.48 inches by the end of their first year in fresh water and 6.50 inches by the end of their second year. Green River downstream migrants entered salt water at a mean total length of 8.43 inches. In Washington, mature steelhead attained mean total lengths of 18.54 inches after one summer in the ocean and 25.68 inches after two summers in the ocean.

Length-Weight Relationship

During the period from August 1 to November 20, 1956, fork length measurements and weights were taken of 484 steelhead trapped in the Sacramento River near the mouth of the Feather River. These fish ranged from 12.8 to 27.2 inches in length and from 14 to 172 ounces in weight. The length-weight relationship curve was fitted to the average weights and lengths of these fish, grouped by half-inch intervals of length. Each length group was represented by five or more fish. The relationship between weight in ounces and fork length in inches for steelhead from the Sacramento River is expressed by the equation:

$$\text{Log } W = -2.205 + 3.063 \log L$$

Where:

W = Weight in ounces

L = Fork length in inches.

The length-weight relationship curve is shown in Figure 6. In general, there is good agreement between averages of actual and calculated weights. The data were not separated according to sex, maturity, or life history of the fish.

METHOD OF EVALUATING STEELHEAD STOCKING

The plan for evaluating steelhead stocking was to release large numbers of marked yearling or migrant-sized steelhead in the Sacramento River and then determine the numbers of sea-run adults produced, their cost, and their contribution to the natural runs and to the fishery. No attempt was to be made to evaluate any contribution to runs of adults which may have been derived from natural r---roduction of hatchery fish.

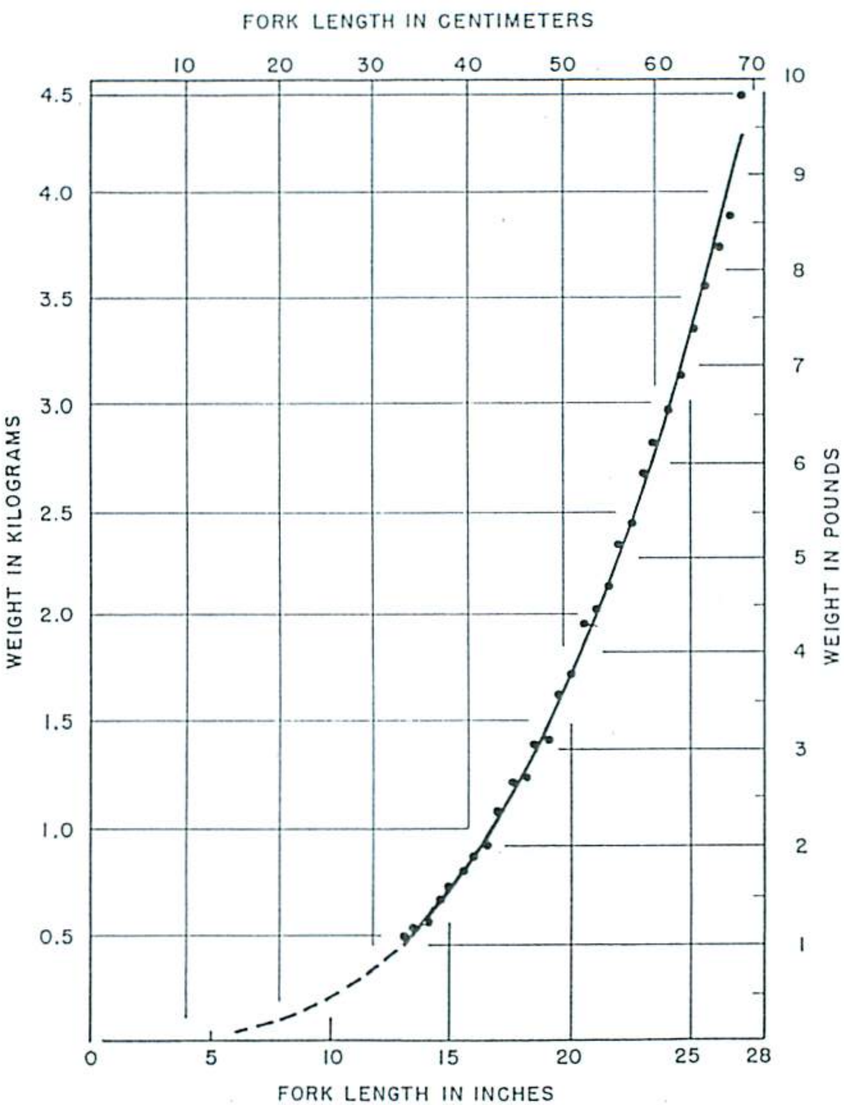

FIGURE 6. Length-weight relationship of Sacramento River steelhead. Lengths and weights were obtained from upstream migrants trapped in the Sacramento River one-half mile above its confluence with the Feather River, near Fremont Weir. The curve is the graph of the length-weight equation; the dots represent averages of actual weights and lengths grouped by half-inch intervals in length.

Adult steelhead were trapped on their spawning migration in Battle Creek and spawned artificially. The resulting young were reared to approximately one year of age, marked by clipping off various combinations of f and released in the upper Sacramento River system, ordinarily c ng their normal seaward migration period. In this report, the words "marking" and "fin-clipping" are used interchange-

many as possible were trapped in the lower Sacramento River and examined for marks. All fish in good condition were tagged and al- lowed to proceed upstream. The site selected for adult steelhead trap- ping was such that population estimates and other data for the most part apply only to the Sacramento River system above its confluence with the Feather River, and in particular exclude the American and Feather rivers. Examination of large numbers of fish showed the per- centage of the run which consisted of hatchery fish, but did not reveal their total number. Since it was impossible to trap all of the steelhead, in order to find out how many hatchery fish were actually in the run each season it was also necessary to determine the total size of the run. This was done by a tag and recovery method. The key to this evaluation, then, is the annual adult steelhead population estimate, and each year's determination of the total numbers of sea-run hatchery fish in the run is only as accurate as the computed total population. The sport catch of both wild and hatchery fish is estimated from the numbers of tags returned by sportsmen. Costs involved in rearing and stocking the fish, as well as fishermen expenditures, were applied to present a picture of the economics involved.

The original plan called for three annual releases, commencing in 1953, of approximately 200,000 marked yearlings or a total of 600,000 fish. The five years following the last release were to be used for eval- uating the returns of adults. Field work for the study would then ter- minate in 1960. However, this plan was altered when it became appar- ent that the observation period following an annual release of marked fish could be shortened somewhat without materially affecting an eval- uation of the results. Therefore, the plan was changed to consist of four annual plants of marked fish and an evaluation period to extend only two years beyond the last release. Thus, the project field work was terminated in the winter of 1958, instead of the original target date of 1960.

POPULATION ESTIMATES

As previously stated, a tag and recovery procedure was used to de- termine the size of the steelhead population in each year. This method of population estimation requires that a known number of fish be tagged at one point along their migration route, and allowed to pro- ceed upstream. From the ratio of tagged to untagged fish observed in the river system above it is possible to compute the size of the spawn- ing run, provided that this ratio is representative of the entire popu- lation.

Trapping of Adults

The previously mentioned large wire fyke traps were operated in the Sacramento River just above the mouth of the Feather River, near Fremont Weir, to sample adult steelhead populations migrating into the upper Sacramento, so that large numbers could be obtained for tagging and could be examined for fin-clipped hatchery fish (Figure 7). This trapping site was not ideally located for a tag and recovery type population estimate because of its great distance from the tag recovery area. However, the seven traps used were very effec · in capturing large numbers of adult steelhead. The percentage the total run trapped each season varied from 10 to 20 and averaged about 16.

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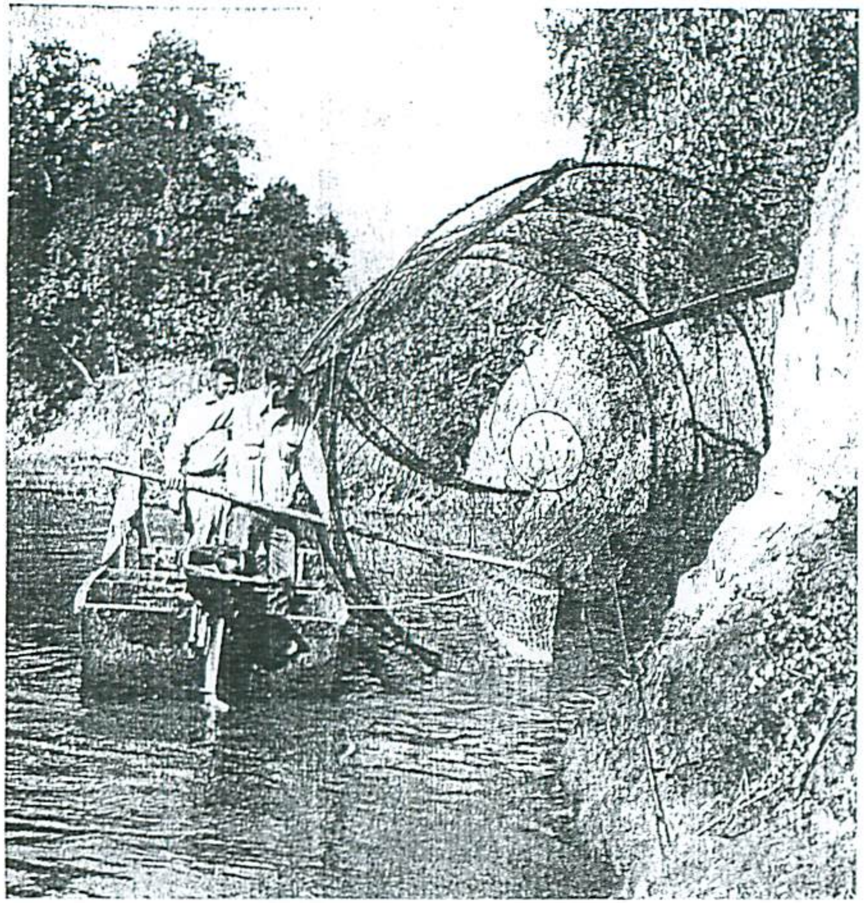


FIGURE 7. Removing captured steelhead from a wire fyke trap. Seven traps were operated each season in the Sacramento River one-half mile above its confluence with the Feather River, near Fremont Weir. *Photograph by Richard J. Hallock, October, 1952.*

Captured fish were in excellent condition, even when left in the traps as long as three days. During the six years from 1953 through 1958, a total of 19,404 steelhead was trapped, including 17,085 fish 14 inches and over in fork length and 2,319 under 14 inches.

The traps were only slightly selective with regard to sizes of steelhead captured. When the run consisted of a large number of comparatively small individuals, a greater percentage of the total run was captured. A good cross section of the steelhead populations was trapped each season. This was indicated by comparative ratios of tagged fish observed each season in several areas above the trapping site.

Tags Used

Since this i[illegible]t a report on various types of fish tags, let it suffice to present a s[illegible] description of the two tags used with equal success, and to say that some study was also given to other [illegible]

to the determination of the best location for attaching tags to a steelhead's body (Figure 8).

A majority of the steelhead were tagged with Petersen disk tags (Calhoun *et al.*, 1951). The individual disks were made of laminated cellulose nitrate, one-half inch in diameter and 0.040 inch thick. Although the printed legend varied somewhat from year to year, the disk for one side of each fish was inscribed with a number and a request that the tag be sent to a designated office of the Department of Fish and Game, while the disk on the opposite side of the fish was plain. A small number of tags were attached to fish with tantalum wire, but the great majority of disks were fastened with stainless steel wire. Variously colored disks were used, including red, yellow, and white, all with black lettering and numbering. After considerable experimentation, it was found that the best results were obtained by running the wire through the fish's body just under the anterior portion of the dorsal fin.

The second type of tag used was the tubing or so-called "spaghetti tag" (Collyer, 1954). The outside diameter was generally about 0.085 inch. The tubing was made of a vinyl plastic. This plastic is now known to be carcinogenic to rats (Oppenheimer *et al.*, 1955). However, though probably not made of a desirable material, the tubing tags did serve the purposes of the study, and no ill effects were noted insofar as tag

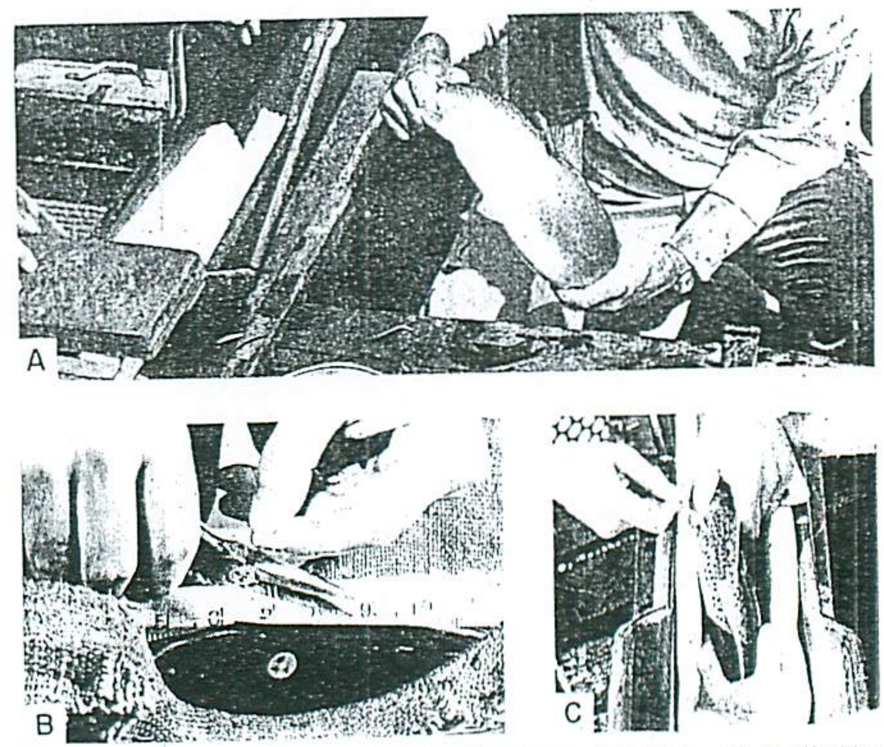


FIGURE 8. Tagging steelhead. A, plastic tubing tag in place on a [illegible]; B, attaching Petersen disks with a double strand of monofilament nylon; C, attaching a plastic [illegible]

returns were concerned. When first used, a number and return address were inscribed on the tubing itself, but after the first season a Petersen disk, with an inscribed legend, was crimped around the tubing. Tubing tags were attached through the body of the fish just under the posterior section of the dorsal fin.

The effectiveness of the two types of tags was about equal and no significant difference in returns by anglers was observed.

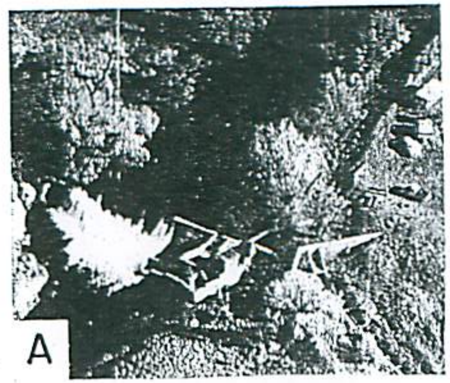
Effective Numbers of Fish Tagged

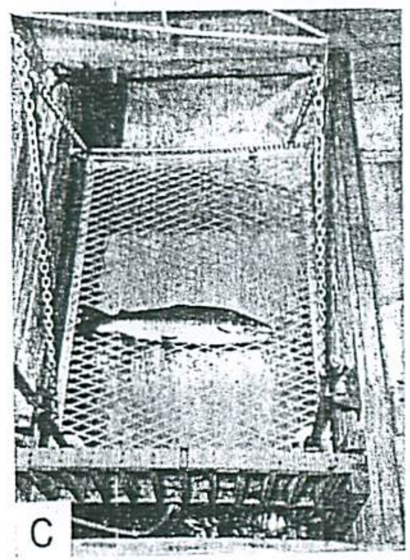
Population estimates were made during each of the six seasons, 1953 through 1958. During this period 16,192 steelhead, an average of 2,699 a year, were tagged. All tagged fish did not migrate upstream immediately following release. Many were landed by anglers below the tagging site, particularly at the mouths of the American and Feather rivers. Others were caught farther downstream and in the Delta by both commercial and sport fishermen. Some tagged steelhead entered the American and Feather rivers and were recovered at varying distances from the Sacramento. In all, 478 tags, an average of 80 a year, were recovered below the tagging area. Of these 478 tags, 79 were taken from fish smaller than 14 inches in length and 399 were taken from fish 14 inches and over in length. Of the tags attached, only seven were recovered in the ocean, all off the California coast.

In order to arrive at the "effective" number of tagged fish released each season, those recovered below the trapping area during the season in which they were tagged were subtracted from the total tagged that year. A close examination of the tagging and recovery data also revealed that, although a considerable number of steelhead under 14 inches in length were tagged, and although fish as small as 12 inches migrated from the Delta into the upper Sacramento, relatively few of these small tagged steelhead were observed above the trapping area. Anglers landed a much higher proportion of these fish which were tagged when under 14 inches in length. In addition, almost half of the small tagged fish caught during the season of tagging were landed below the tagging area. This indicates that many of the smaller fish were actually migrating seaward and were unavailable to the upper river steelhead fishery until the season after tagging. Therefore, all tags attached to fish under 14 inches in length were also subtracted from the total tags attached each season in order to arrive at the "effective" number of fish tagged. Population estimates are thus for fish 14 inches and over in length. Therefore, the population estimates are minimal, since unknown numbers of small fish have been eliminated. The computed returns of sea-run hatchery fish also become minimal, since some marked fish were less than 14 inches long.

Examination of Steelhead Above the Tagging Site

In order to find out what percentage of the run had been tagged, and to determine the ratio of marked to unmarked fish, as many steelhead as possible were examined in the upper Sacramento River system each fall and winter during and following the tagging period. Steelhead were exam[illegible] in Mill Creek at a counting station on Clough Dam (Figure 9), [illegible] the Coleman hatchery holding ponds on Battle Creek, in the Keswick Dam fish trap on the upper Sacramento, and in the





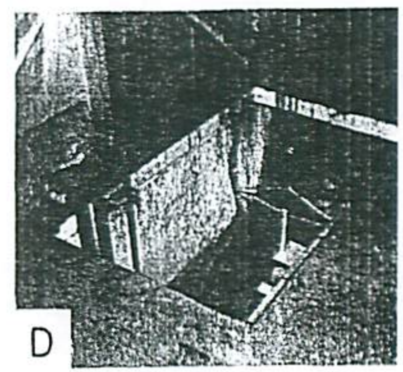


FIGURE 9.; Mill Creek Counting Station. A, aerial view of Clough Dam, showing th fishway and house trailer which is used as a residence by the fish counter; B, el vator type bottom used in trap, so that captured fish could be raised for better view ing; C, trap in use, showing how steelhead were raised to examine them for marl and tags; D, the trap in fishing position in the fishway. *Photographs by John E. Rigg*

course of creel census work along the Sacramento and its tributari between Meridian and Redding. During the six years in which popul tion estimates were made, 15,579 steelhead 14 inches and over in lengt were examined above the tagging site. Of this number, 1,888 had bee tagged during the season in which they were recovered. Including bot fish trapped and fish observed above the trapping site, one out of ever four adult steelhead in the population was handled each season b those making the study.

Method of Computing Populations

Two methods of computing the steelhead populations were consi the Petersen method (Ricker, 1958). Since both are standard techniques, they are described herein only briefly.

The use of tagging data to provide statistics on populations of fish generally implies that (1) either the tagging or sampling after tagging (or both) is done at random, (2) tagged fish suffer the same mortality as untagged ones, (3) tagged fish do not lose their tags and, (4) tagged fish are as vulnerable to the fishery as untagged ones. However, Schaefer (1951) takes into account the possibility that steelhead (or any other species of fish) may not necessarily be a single, homogeneous, completely mixed population, and the "mixing" of these fish between the time and place of tagging and that of subsequent sampling may not be complete. To reduce errors which might be introduced into population estimates, due to the probability that all parts of the population may not have the same tag ratio or to the probability that the inclusion of a given fish in a sample is a function of the time of sampling and therefore a function of the time of tagging, the tagging and recovery data are divided by Schaefer into convenient periods of time during the season. This provides an estimate of the population present in successive time intervals, both at the tagging site and in the recovery area, as well as the total population, or the sum of the interval estimates. However, when either the tagging or the sampling is "uniform", and the probability of a fish being tagged or recovered is constant, the more cumbersome formula proposed by Schaefer for computing fish populations (purposely omitted since, as will be explained later, it was not used) reverts to the simple Petersen formula:

$$N = \frac{MC}{R}$$

Where:

N = Size of the population
M = Number of fish tagged
C = Number of fish sampled
R = Number of tagged fish in the sample.

In general, the Petersen formula for calculating fish populations tends to approach the correct size of the populations more closely as the sample size is increased. If either the tagging sample or the recovery sample is random, an unbiased estimate of the total population can be obtained. If both tagging and sampling are selective, the estimate may be biased. In effect, when all parts of the population have the same tag ratio, it makes no difference whether or not subsequent samples represent various parts of the population equally. In addition, if the population is randomly sampled after tagging, so that the probability of a given fish being sampled is not a function of time of sampling or time of tagging, any uneven distribution of tags due to the time of migration will have no effect.

Chi-square tests were applied to the tagging and tag recovery data to compare the size distribution of all fish which were tagged with the size distribution of the samples of tagged fish recovered in traps at Clough Dam, Keswick Dam, and Coleman hatchery, and in creel censuses on the ramento River. Combination of the recovery data obtained at all ar localities revealed significant discrepancies between the observed and expected numbers of tagged fish in [illegible]

gories. Analysis of tag recoveries from each location revealed that only the creel census data exhibited the expected distribution of tags by size groups. Chi-square tests were also made to determine whether or not fish examined at the four localities showed a consistent ratio of tagged to untagged individuals. This was done by testing the recovery samples against the border totals. Statistically significant differences were found in the tag ratios at the four localities during five of the six years analyzed. Clough Dam and Coleman hatchery showed the least uniform tag ratios; usually more tags were observed than expected at Clough Dam and fewer at Coleman hatchery. These tag ratios were statistically inconsistent, even though annual differences between percentages of tags in all recovery areas varied from only 3 percent in 1957 to 8 percent in 1956, and averaged 5.7 percent. However, sampling over a large area, as was done in the Sacramento River system, as well as examination of fish throughout the entire season, would tend to compensate for discrepancies in tag ratios between areas when computing population estimates.

A similar problem of inconsistency between tag ratios and the distribution of tags in the recovery samples was noted in the computation of sockeye salmon (*Oncorhynchus nerka*) populations (Howard, 1948). Chi-square analysis of the sockeye sampling data demonstrated significant differences in the tag ratios with respect to time, area, and sex of fish. However, the over-all tag ratio gave an accurate measure of the population. In the case of the sockeye salmon, where the tag recovery was from dead fish after spawning, the numerous causes of variations in numbers of tags recovered compensated one another, provided that the sampling was complete with regard to both time and area.

The 1956-57 steelhead tagging and tag recovery data were submitted to both the Schaefer and Petersen methods. The resulting population estimates were nearly the same. This was not surprising since, as was revealed in tabulation by the Schaefer method, the probability of a fish being tagged as well as being recovered remained fairly constant throughout most of the season and, as previously stated, under either of these conditions the Schaefer formula reverts to the Petersen formula. Because the two procedures produced similar estimates, it was decided to abandon the more time-consuming Schaefer method, particularly since the population sizes entering the upper river were not being sought on a time basis. Instead, a slight modification of the method proposed by Petersen was adopted. With ordinary or direct sampling, when the size of the sample or samples is fixed in advance or is controlled by fishing success, etc., the Petersen formula tends to over-estimate the true population (Ricker, *loc. cit.*). Therefore, the following modified Petersen formula proposed by Bailey (1951), which according to Ricker gives an almost unbiased estimate, was used to compute the steelhead populations in this report:

$$N = \frac{M\,(C + 1)}{R + 1}$$

During the six seasons 1953-54 through 1958-59 th lult steelhead population in the upper Sacramento River averaged 2 ,0 fish (Table 2). In the two peak seasons of 1954-55 and 1955-56 it was about 28,000.

Since then the population has declined and in 1958-59 it was down to about half that of the peak years. These figures include hatchery as well as naturally-produced steelhead.

To find out how far the computed steelhead populations might be expected to differ from the actual populations, 95 percent confidence limits, as advocated by Chapman (1948, equation no. 55), were determined for each computed population (Table 2).

TABLE 2

Sacramento River Steelhead Population Estimates. The Calculations are for Fish 14 Inches and Over in Fork Length, Migrating Upstream Past the Mouth of the Feather River

Season	Effective number of fish tagged	Number of fish sampled above the tagging site	Number of tagged fish in the sample	Number of fish in the population	95 percent confidence limits: Lower limit	95 percent confidence limits: Upper limit
1953-54	1,451	882	88	14,400	11,960	17,760
1954-55	4,473	2,901	456	28,400	26,170	30,980
1955-56	2,270	3,081	246	28,320	25,240	32,070
1956-57	2,082	3,060	407	18,380	17,000	19,970
1957-58	1,824	2,078	279	19,410	17,420	21,780
1958-59	1,735	2,668	322	14,340	12,980	15,910

RELEASES OF MARKED FISH

The releases of marked yearling steelhead were designed primarily to give returns of sea-run adults which would permit an over-all evaluation of the total fish stocked from each brood year and also to determine the size of yearlings released that results in the best returns of adults. Information on the best time and locality to stock fish, though recognized as highly desirable, was necessarily sought only as a secondary objective, principally because of the nature of the program and limited study period.

Sportsmen with limited funds paid steelhead food costs at Coleman hatchery. A fixed amount was available each year for this purpose. Whereas it was practical to make early releases, it was not always feasible to hold fish for extended periods before stocking, due to the extra food cost. In addition, the hatchery production was devoted primarily to king salmon. Large numbers of this species were held through the summer. Because of the limited number of outside ponds, holding large numbers of steelhead for extended periods would have interfered with the salmon program.

Egg Sources

At first, all eggs were taken from wild steelhead trapped in Battle Creek. However, later in the study they were also obtained in Battle Creek from returning sea-run, hatchery-reared steelhead. A small percentage of the eggs was also obtained from steelhead captured during the regular fall-run king salmon trapping operations on the Sacramento River at Keswick Dam. All steelhead were spawned artificially at Coleman [illegible]hery (Figure 10).

FIGURE 10. Steelhead spawning operations at Coleman National Fish Hatchery. A, taking eggs from an anesthetized female; B, fertilizing eggs (note tagged fish); C, dipping a spawned-out fish in a fungicide solution (malachite green) before releasing it in Battle Creek. *Photographs A and C by John E. Riggs; and B, by Richard Hallock.*

Shortly after the study began there was some doubt as to whether or not the smaller fish being captured in Battle Creek for spawning purposes had been to sea. To be certain of this point, scales were taken and examined for ocean growth before any fish were used for spawning. Only those known to be sea-run fish were spawned. This was done for the 1954 and 1955 brood years. Adults from subsequent runs were spawned on the basis of size, since scales from virtually all fish over 21 inches in length showed ocean growth.

Marking

The 1952 brood year steelhead were marked in the fall of 1952, several months before they were released. This necessitated a re-count at the time of planting. Fish from most succeeding brood years were marked in the spring, just prior to release (Figure 11). All fish were

FIGURE 11. M[illegible]g a yearling steelhead at Coleman National Fish Hatchery. The right ventral fin is being clipped. One other fin also will be excised to complete the [illegible]

anesthetized before being marked. Anesthetics used included urethane (ethyl carbonate), chloretone (chlorobutanol), and M. S. 222 (tricaine methanesulfonate). Most fish were marked with the aid of M. S. 222. Chloretone was used only sparingly during one season. The use of urethane was abandoned early in the study because of its carcinogenic properties (Wood, 1956). Each of the anesthetics worked satisfactorily, but M. S. 222 appeared to cause less marking loss if the fish were properly exposed to the anesthetizing solution. Usually about 15 women were hired each year to do the fin clipping. During the marking period, fish were sampled daily for correctness of marks. The marks were not repeated oftener than every other year.

Grading

Juvenile steelhead were segregated by size at the hatchery to promote maximum growth and to prevent cannibalism. A standard Morton fish grader, capable of separating fish into five size categories simultaneously, was used. Grading was done three times during the period that each brood year's fish remained at the hatchery. They were first divided, about six weeks after hatching, into two groups: one group two inches and under in length and the other over two inches in length. In midsummer and usually again in the fall they were graded into four size groups: under 2½ inches, 2½ to 3½ inches, 3½ to 4½ inches, and over 4½ inches. If the fish were fairly uniform in size in the fall, they were separated at that time into only three size groups instead of four. The fish were not graded again at the time of marking, except for the 1952 brood year fish, which were marked in the fall. The fish to be given separate marks were selected from the previously-graded groups, often by combining two or more of the groups containing the most nearly equal-sized individuals. The fish were hand counted and the total weight of each marked lot was obtained at the time of release. At the time of stocking, length measurements were also taken of representative samples from each lot marked (Figure 12).

Numbers Released

During the period 1953 through 1958, a total of 1,041,754 steelhead was marked and released (Table 3). Only the 663,240 fish fin-clipped during the first four years were marked as part of the evaluation program. The remaining 378,514 yearlings were released as part of a new program initiated in 1957 by California Kamloops, Inc. and Steelhead Unlimited in cooperation with the Fish and Wildlife Service and the Department of Fish and Game. There was to be no evaluation of these releases. They were marked in 1957 and 1958 to avoid confusion between hatchery and naturally-produced fish during the last two years of the evaluation study. It was also hoped that some substantiating data might be gained from the continued marking, even though the evaluation of returns would be limited by time.

Area of Stocking

In 1953, the first year that steelhead were released, there was only one size group and all fish were given the same mark[illegible]ey were split into four lots and planted in Battle and Mill creeks a[illegible] in the Sacra-

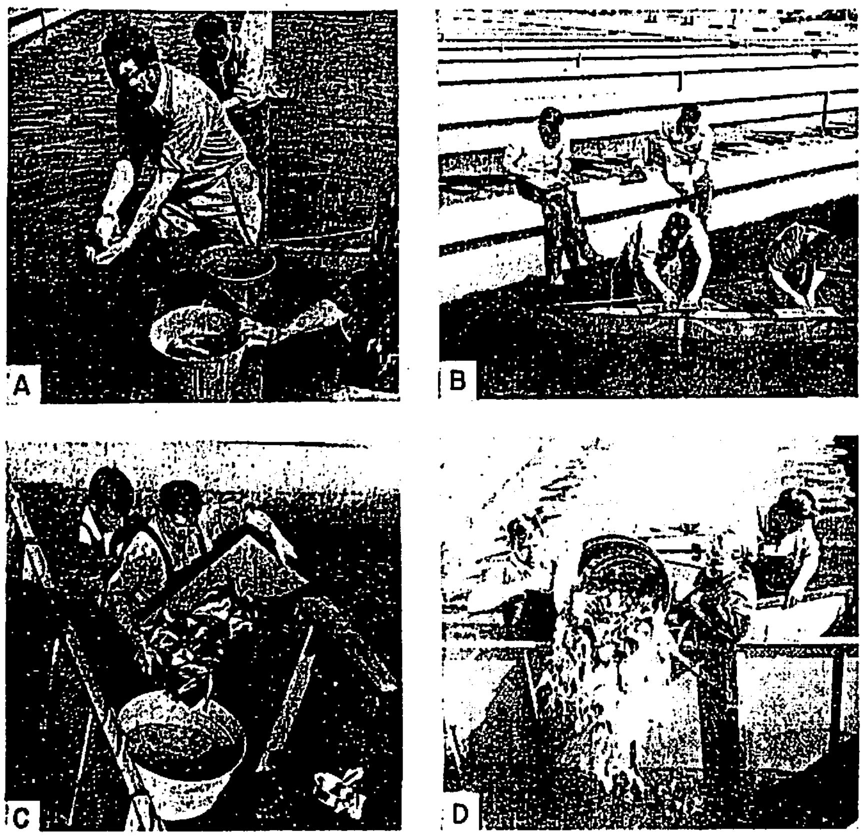


FIGURE 12. Handling marked yearling steelhead at Coleman National Fish Hatchery. A, hand counting fish; B, measuring fish; C, weighing fish prior to release; D, releasing fish into the channel which connects the hatchery holding ponds with Battle Creek. *Photographs by John E. Riggs.*

mento River at Ord Ferry and Princeton (Figure 13). This rather widespread stocking was carried out to get some idea of what returns of adults might be expected from releases of yearlings subjected in part to the summer "trout" fishery, or at least stocked in the trout fishing area. Creel censuses on the opening day of the 1953 trout season at Battle and Mill creeks showed that all of the stocked steelhead had not migrated to the sea. Many limits and near limits of marked fish were taken. Therefore, since the principal evaluation was to be made on the basis of adults produced from releases of known numbers of yearlings, all steelhead planted between 1954 and 1956 were stocked in the Sacramento River at Princeton, some 110 miles downstream from the mouth of Battle Creek. This is below the general trout fishing area. Very few yearlings were caught prior to entry into the ocean when liberated in this portion of the river. During the spring of 1957, when the second cooperative sportsmen's steelhead stocking program was started, marked fish re released in the Sacramento River at Princeton and

TABLE 3

Hatchery-Reared Steelhead Released in the Sacramento River System

Mark[1]	Brood year	Place of release	Date of release	Number per pound	Average fork length (inches)	Number released: Individual releases	Number released: Total brood year releases
Ad-RV	1952	Battle Creek	March, 1953	8	6.0	25,430	
		Mill Creek		7		12,990	
		Sacramento River at Ord Ferry		10		12,690	
		Sacramento River at Princeton	March & April 1953	9		12,480	63,590
Ad-BV	1953	Sacramento River at Princeton	January, 1954	4	8.0	6,570	
BV			March, 1954	18	4.8	145,278	151,848
Ad-LV	1954	Sacramento River at Princeton	January, 1955	7	6.8	46,252	
Ad-RV			February, 1955	26	4.3	131,007	177,259
Ad-BV	1955	Sacramento River at Princeton	December, 1955	6	6.5	67,651	
BV			March, 1956	10	5.8	143,137	
Ad-LMax			March, 1956	22	4.6	59,755	270,543
D-LV	1956	Sacramento River at Princeton	December, 1956	6	7.2	32,177	
D-RV		Battle Creek	January, 1957	7	7.0	26,629	
Ad-RV		Sacramento River at Redding	January, 1957	12	5.9	60,979	
Ad-LV		Mill Creek	January, 1957	30	4.3	107,328	227,113
Ad-RMax	1957	Sacramento River at Princeton	October, 1957	86	2.7	18,285	
Ad-BV			December, 1957	7	6.8	33,531	
BV			January, 1958	12	5.7	51,243	
D-Ad			January, 1958	22	4.4	40,727	
Ad-LMax			April, 1958	6	7.3	1,615	151,101
Totals						1,011,751	1,011,751

[1] Abbreviations are as follows: D—dorsal; V—ventral; L—left; R—right; B—both; Ad—adipose; Max maxillary.

Redding and also in Mill and Battle creeks. As in 1953, catches of marked juvenile fish were so great in the upper river system that all fish released in 1958 again were stocked at Princeton.

RETURNS OF SEA-RUN HATCHERY STEELHEAD

Since sport fishing for steelhead was permitted below as well as above the trapping area, returns of sea-run hatchery fish to the upper Sacramento were lowered by an unknown quantity landed by fishermen in the lower river and Delta. No successful effort was made to determine either the numbers of hatchery steelhead in the run, or the landings by fishermen below the trapping site. Only a minor steelhead sport fishery exists below the city of Sacramento, and most of the fish caught are landed by striped bass anglers. However, between Sacramento and the trapping area large numbers of steelhead are landed by sport fishermen, particularly at the mouths of the American and F   ier Rivers. The former commercial gill net fishery for salmon in the Delta also took con-

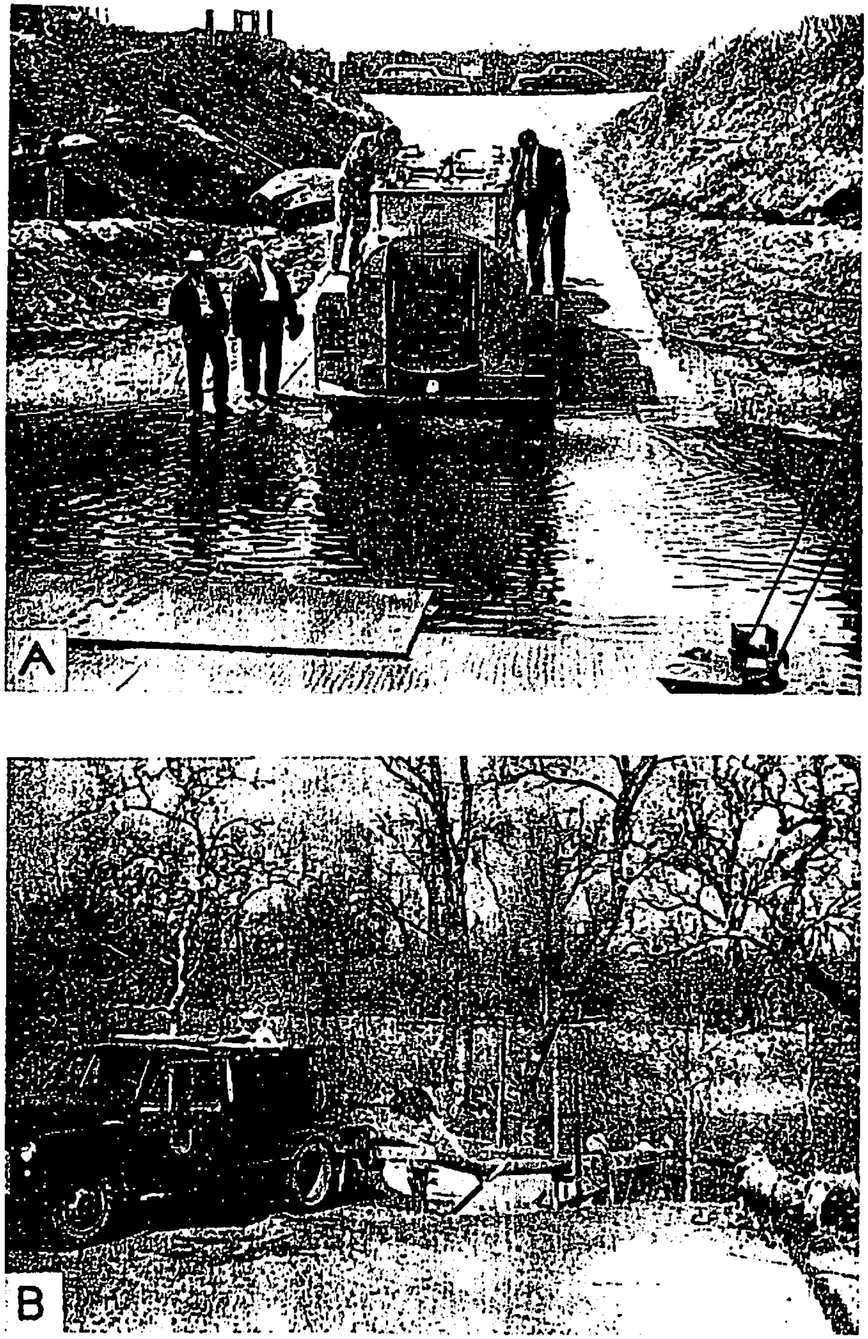


FIGURE 13. Releasing marked steelhead. A, liberating fish in the Sacramento River at the Princeto[illegible] Ferry slip; B, stocking fish in Mill Creek, Tehama County. *Photographs A, by* [illegible] *. La Faunce, March, 1953; and B, by John E. Riggs, March, 1959.*

siderable numbers of steelhead in the fall, as indicated by tag returns and observations. This fishery was abolished at the end of the 1957 season by the State Legislature.

Since returning fish bearing the same fin mark were at least two years apart in age, a method of separating identically marked sea-run hatchery fish into their proper brood years was devised. This could have been accomplished by taking scales from the marked fish trapped and determining their ages; however, this procedure would have been rather time consuming. Instead, identically fin-clipped fish were established in correct brood years by length measurements, a procedure which almost eliminated the necessity of scale reading (Table 4). Most of the fin-clipped steelhead trapped in the lower Sacramento were measured. In 1955 identically marked fish from two brood years (1952 and 1954) returned together from the sea for the first time. Fork length measurements of these fish revealed two distinct size groups. Through the following years, continued measurements showed that there was practically no overlap in lengths of identically fin-clipped hatchery steelhead, so long as the mark was not repeated oftener than every other brood year. Among the three- and four-year-old marked fish, however, there were a few whose lengths were such that scales were read to be certain of the brood year.

The examination of steelhead trapped in the lower Sacramento River provided only the percentage of the entire run consisting of hatchery fish; the total numbers of hatchery fish in the run were calculated by multiplying the total population by the percentage of marked fish observed in the traps.

Methods of Presenting Returns

Data on survival of yearling steelhead to time of return as sea-run adults may be presented in several ways. Three methods are used in this report:

The most common method is to compare the numbers of yearlings released in a river with the numbers of sea-run adults returning in subsequent years to that river. Returns of adults resulting from releases of variously-sized fish provide data on the best size of fish to stock. Returns from fish planted at different seasons of the year reveal information on the best times to stock. In some instances release of fish at different locations in a river system may provide additional information on stocking localities which result in the best returns. There are, of course, several combinations of fish size, and time and place of release, which makes it difficult to separate the dominant factor governing a particular return.

A second method is to compare the numbers of adult steelhead used for artificial spawning with the numbers of sea-run adults produced. The returns permit a simple comparison between the efficiency of artificial and natural reproduction, if the natural reproduction rate is known.

A third method is to compare the numbers of steelhead used for artificial spawning and/or numbers of yearlings released with the resulting numbers of sea-run hatchery fish taken by anglers. The first two methods show the numbers of sea-run steelhead [illegible] in the population by artificial propagation (providing it is not just a replacement), while the third [illegible]

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TABLE 4

Lengths of Sea-Run Hatchery Steelhead Returning to the Upper Sacramento River. The Length Measurements Were Made of Marked Fish Captured by Trapping in the Sacramento River, One-Half Mile Above its Confluence With the Feather River Near Fremont Weir, and Illustrate the Reliability of Separating Steelhead From Different Brood Years on the Basis of Length Alone

Item	Brood year	Date of release	Approximate age at time of release (months)	Number per pound at time of release	Number and length at time of release	Returning Sea-Run Steelhead 1953-54	1954-55	1955-56	1956-57	1957-58	1958-59
Ad-RV	1952	March and April, 1953	13	8							
Number measured					1,114	47	277	11	2		
Range (inches)					3.1-13.7	14.4-19.3	14.8-25.8	20.2-24.8	25.0-25.9		
Average fork length (inches)					6.0	16.2	20.0	23.3	25.4		
Standard deviation					2.0	1.1	2.2	1.2	0.6		
Ad-RV	1954	Feb., 1955	11	26							
Number measured					3,488			35	94	1	1
Range (inches)					1.7-7.9			11.3-16.5	13.3-24.8		
Average fork length (inches)					4.3			13.3	19.3	18.4	25.0
Standard deviation					1.0			1.4	2.4		
Ad-RV	1956	Jan., 1957	10.5	12							
Numbered measured					900					12	41
Range (inches)					4.4-8.5					12.2-15.9	15.7-23.4
Average fork length (inches)					5.9					14.4	19.4
Standard deviation					0.8					1.0	1.9
Ad-BV	1953	Jan., 1954	10.5	4							
Numbered measured					495		74	13	2		
Range (inches)					3.8-13.1		13.1-20.0	16.7-25.8	24.9-25.5		
Average fork length (inches)					8.0		15.7	21.2	25.2		
Standard deviation					1.7		1.4	2.2	0.4		
Ad-BV	1955	Dec., 1955	9.5	6							
Numbered measured					1,027				221	46	2
Range (inches)					3.0-10.6				11.9-19.4	17.5-25.5	22.7-24.6
Average fork length (inches)					6.5				15.8	21.3	23.6
Standard deviation					1.3				1.3	1.6	1.3
Ad-BV	1957	Dec., 1957	10	7							
Numbered measured					850						12
Range (inches)					3.9-10.3						13.0-18.0
Average fork length (inches)					6.8						16.0
Standard deviation					1.1						1.4
BV	1953	March, 1954	13	18							
Numbered measured					2,844		129	223	44		
Range (inches)					2.6-8.9		11.6-18.4	13.3-24.2	19.1-27.1		
Average fork length (inches)					4.8		14.3	19.9	22.9		
Standard deviation					1.1		1.2	2.2	1.8		
BV	1955	March, 1956	13	10							
Numbered measured					2,026				173	114	4
Range (inches)					3.0-9.3				11.3-16.5	15.6-24.6	20.7-24.3
Average fork length (inches)					5.8				14.1	20.8	22.0
Standard deviation					1.2				1.0	1.6	1.7
BV	1957	Jan., 1958	11	12							
Numbered measured					1,198						10
Range (inches)					3.2-8.7						12.0-16.3
Average fork length (inches)					5.7						14.5
Standard deviation					0.9						1.3
Ad-LV	1954	Jan., 1955	11	7							
Numbered measured					1,200			242	126	7	
Range (inches)					3.5-11.6			11.6-20.5	15.2-26.1	20.1-25.7	
Average fork length (inches)					6.8			15.6	21.7	24.0	
Standard deviation					1.4			1.6	1.9	1.9	
Ad-LV	1956	Jan., 1957	11	30							
Numbered measured					750					5	18
Range (inches)					2.5-5.9					12.0-13.2	15.6-21.4
Average fork length (inches)					4.3					12.7	18.0
Standard deviation					0.7					0.5	1.4
Ad-LMax	1955	March, 1956	13	22							
Numbered measured					1,216				5	16	2
[illegible]ge (inches)					2.7-7.8				11.6-13.5	16.7-24.8	18.5-19.9
[illegible]age fork length (inches)					4.6				12.6	20.1	19.2
[illegible]ndard deviation					1.0				0.9	2.1	1.0
Ad-LMax	1957	Apr., 1958	14	6							
Numbered measured					285						
Range (inches)					3.9-10.1						
Average fork length (inches)					7.3						
Standard deviation					1.2						

TABLE 4—Continued

Lengths of Sea-Run Hatchery Steelhead Returning to the Upper Sacramento River. The Length Measurements Were Made of Marked Fish Captured by Trapping in the Sacramento River, One-Half Mile Above its Confluence With the Feather River Near Fremont Weir, and Illustrate the Reliability of Separating Steelhead From Different Brood Years on the Basis of Length Alone

Item	Brood year	Date of release	Approximate age at time of release (months)	Number per pound at time of release	Number and length at time of release	Returning Sea-Run Steelhead					
						1953-54	1954-55	1955-56	1956-57	1957-58	1958-59
D-LV	1956	Dec., 1956	9	6							
Numbered measured					900					79	25
Range (inches)					4.3-12.2					13.0-18.6	15.9-24.0
Average fork length (inches)					7.2					16.1	21.5
Standard deviation					1.2					1.1	1.9
D-RV	1956	Jan., 1957	10.5	7							
Numbered measured					453					21	12
Range (inches)					4.1-11.9					12.9-17.3	17.3-22.9
Average fork length (inches)					7.0					15.4	20.7
Standard deviation					1.2					1.3	1.7
Ad-RMax	1957	Oct., 1957	7	86							
Number measured					684						
Range (inches)					1.9-4.9						
Average fork length (inches)					2.7						
Standard deviation					0.4						
D-Ad	1957	Jan., 1958	11	22							
Numbered measured					600						3
Range (inches)					2.4-6.7						15.0-17.9
Average fork length (inches)					4.4						16.8
Standard deviation					0.8						1.0

The first two methods are presented in this section of the report, and the third is discussed in the section on "Steelhead Sport Catch".

Returns of First Time Spawners and Repeat Spawners

Examination of the scales of 175 marked hatchery steelhead showed that in the Sacramento system the proportion of fish which spawn more than once is much lower among hatchery-reared individuals than among wild fish. It appears that over 96 percent of the adult hatchery-reared fish taken in the river are on their first spawning migration and that most, if not all, of the remainder are on their second. None were encountered which were returning for a third or later spawning, but the sample was not large. By way of comparison a sample of 100 wild adults showed 17 repeat spawners (see page 16.)

In this paper, each time a steelhead returned it was treated as a separate individual on the basis that a fish which makes two spawning runs is exposed to the fishery twice and, if it survives, spawns twice, etc. If each fish were treated as a single individual, regardless of its number of spawning migrations, the result would be to lower the total number of adult "returns" by a little less than 4 percent, and to increase the cost of putting adult steelhead in the run by a similar amount. There would be no change in the cost per steelhead in the creel because obviously a fish can die only once. The cost of rearing steelhead will be discussed later.

Comparison Between Yearlings Released and Sea-run Adult Returns

During the first four years of the study, 663,240 marked yearling steelhead were liberated. From these releases, including all sizes of fish planted, there were 13,055 sea-run steelhead returns to the upper river. The percentage return of adults from an average brood year was thus about 2 percent of the yearlings stocked (Table 5.) Stating this in another way, it took about 50 average-sized hatchery yearlings to produce one adult steelhead return. Therefore, if naturally-spawned steelhead had the same survival rate as hatchery fish, an average of a little over 1,000,000 juvenile steelhead a year migrated out of the upper Sacramento River during the study to maintain the average run of 20,542 adults.

It is obvious even after a quick glance at Table 5 that considerable variation exists in returns of adults from releases of fish of different sizes. By re-arranging these figures and grouping the fish released into two main size categories, a somewhat different picture is presented (Table 6). Fish weighing eight to the pound and larger resulted in an average return of 4 percent as adults; i.e., one adult steelhead return for each 25 yearlings released. On the other hand, fish weighing between 10 and 26 to the pound when stocked produced average returns of slightly over 1 percent. From the standpoint of numbers of returning fish, it is thus much more desirable to stock fish of a size larger than 10 to the pound.

There is some variation in the returns of adults from the stocking of equal-sized yearlings under apparently similar conditions. Because 1952 brood year fish were released in the upper Sacram[illegible] River and in two tributaries prior to the opening of the trout seas[illegible] and because of the large catches of these marked fish in Mill and Battle creeks be-

TABLE 5

Returns of Sea-Run, Hatchery Steelhead to the Upper Sacramento River System, Showing Numbers of Yearling Hatchery Fish Released, Arranged in Chronological Order, and Calculated Percentages and Total Numbers of Adults Produced

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	59,755	--	--	--	--	--	--	--	--	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	[illegible]	0.59	--	--	--
D-RV	1956	Battle Cr.	Jan., 1957	7	7.0	10½	26,629	--	--	--	--	--	--	--	--	169	0.63	[illegible]	0.34	--	--	--
Ad-RV	1956	Sac. River	Jan., 1957	12	5.9	10½	60,979	--	--	--	--	--	--	--	--	80	0.13	[illegible]	0.51	--	--	--
Ad-LV	1956	Mill Cr.	Jan., 1957	30	4.3	11	107,328	--	--	--	--	--	--	--	--	--	--	[illegible]	0.12	--	--	--
Ad-RMax	1957	Sac. River	Oct., 1957	86	2.7	7	18,285	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ad-BV	1957	Sac. River	Dec., 1957	7	6.8	10	33,531	--	--	--	--	--	--	--	--	--	--	[illegible]	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	--	--	--	--	--	--	--	--	--	--	25	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 6

Returns of Sea-Run Hatchery Steelhead to the Upper Sacramento River System, Showing Numbers of Yearling Hatchery Fish Released, Grouped into Two General Size Categories, and Calculated Percentages of Adults Produced

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 Battle Creek Mill Creek	Mar. & Apr. 1953	8	6.0	63,590	0.64	2.33	0.20	0.02	3.2	
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	
[illegible]Max	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.

fore their seaward migration, returns of adults were not expected to approach those from equal-sized fish planted during the three following seasons below the trout fishing area at Princeton.

Additional unaccountable differences also exist in returns of adults from some groups of fish released at Princeton. Returns from the 1955 brood year fish, for example, were considerably lower than from the previous three brood years. Part of the 1955 brood year fish were stocked just prior to floods in the Sacramento River. The relationship between fish release times and floods in the Sacramento River was studied. A clear-cut correlation between times when steelhead were stocked, flooding in the river and in the several bypasses, and later returns of adults was not evident. However, the fish released in December, 1955, were stocked immediately prior to a period of extreme flooding and did return fewer adults than were expected. Although not conclusive, the evidence at hand suggests that considerable losses may occur when yearlings are liberated during periods of high water. In any event, the evidence is sufficient to withhold stocking of fish at such times, at least until facts are gained to the contrary.

Comparisons between returns from several of the releases of marked fish are not feasible, since two variables exist: planting time and size of fish. The two best returns were from fish planted in January, and one of these groups consisted of the largest fish planted. Plants from December through March appear to give satisfactory returns but more tests are needed to be certain of the best month in which to release steelhead.

Comparison Between Adults Spawned and Returning Sea-run Adults

During the first four years, 458 females were used for artificial spawning purposes. As previously stated, 13,055 sea-run adult returns were subsequently produced, or 28 sea-run adults in the runs for each female used for artificial spawning (Table 7). Since the number of males used at the hatchery for artificial spawning was only slightly less than the number of females, there were 15 steelhead returns for each fish spawned at the hatchery.

The natural populations of steelhead in the Sacramento River fluctuated considerably during the study (Table 2). However, since the runs are barely holding their own, it is obvious that natural reproduction is on the order of 1 to 1. That is, for each adult another adult will be produced. Thus, hatchery production of sea-run steelhead, based on all sizes of yearlings released from an average brood year, is roughly 15 times greater than natural production. This, of course, applies only to the limited number of steelhead handled at Coleman hatchery during the study. A greatly increased steelhead population could be expected to result in lower survival rates of both hatchery and wild fish. At the existing population levels it does not seem likely that any serious depressing of the survival rate of wild fish throughout the upper Sacramento River system could have been caused by the planting of hatchery fish in the numbers used in this project.

The average female steelhead spawned at Coleman hatchery yielded 2,808 eggs d 'ng the first four years of the study. This is not an indication of a ge fecundity, since many smaller fish were not used.

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TABLE 7

Comparison Between Numbers of Steelhead Used for Artificial Spawning and Calculated Numbers of Sea-Run Hatchery Steelhead Produced

Brood year	Males spawned	Females spawned	Total spawned	Eggs taken	Yearlings released	Returns by year 1953	1954	1955	1956	1957	1958	Total returns	Ratio of females spawned to total returns
1952	78	64	142	167,964	63,590	404	1,482	125	11	0	0	2,022	1:32
1953	129	80	209	272,458	151,848		833	2,657	260	0	0	3,750	1:47
1954	106	158	264	379,563	177,259			2,441	1,238	79	7	3,765	1:24
1955	88	156	244	465,970	270,543				1,696	1,762	60	3,518	1:23
Totals	401	458	859	1,285,955	663,240	404	2,315	5,223	3,205	1,841	67	13,055	
Average													1:28
1956	69	169	238	501,342	227,113					1,035	724	..	..
1957	89	286	375	600,000	151,401						151	..	..
Totals	158	455	613	1,101,342	378,514					1,035	875		
Grand totals	559	913	1,472	2,387,297	1,041,754	404	2,315	5,223	3,205	2,876	942		

Although an average over-all 2 percent survival from yearling to sea-run adult was obtained, the survival from egg to returning adult was only 1 percent.

Distribution of Sea-run Hatchery Steelhead

It is of interest to note the spawning distribution of returning hatchery-reared steelhead released in the Sacramento River at Princeton. These fish were mainly of Battle Creek stock, all reared at Coleman hatchery on Battle Creek, but released 110 miles downstream from the mouth of Battle Creek. Adults attributable to the Princeton plants returned for spawning purposes in significant numbers to Battle Creek, the parent stream, but at the same time dispersed considerably throughout the upper Sacramento River system.

During the 1955-56 season, 18 percent of all steelhead migrating into the Sacramento River were hatchery fish stocked at Princeton. However, after these same fish had distributed themselves among the tributaries, 27 percent of the steelhead in Battle Creek and only 2 percent of those in Mill Creek were hatchery fish. In the 1956-57 season, when the total run included 17 percent hatchery fish, a similar pattern was followed. The steelhead in Battle Creek consisted of 37 percent hatchery fish, while the Mill Creek run again included only 2 percent hatchery fish. Therefore, by stocking yearling steelhead at Princeton (below the general trout fishing area) during the normal migration period of wild fish, sufficient returns were obtained at the hatchery on Battle Creek to continue a moderate artificial stocking program; at the same time, there was some natural dispersion of adults throughout the upper Sacramento River system.

GROWTH IN LENGTH OF HATCHERY STEELHEAD

The wide range of lengths found in hatchery fish prior to their release, and again when they were recaptured during subsequent seasons as sea-run adults, indicates that growth rate was quite variable (Table 8). The data presented on growth in length of marked steelhead include only lengths obtained at the time of release (at about one year of age) and when trapped in the Sacramento River near the mouth of the Feather River during the fall of succeeding years. Calculated lengths, based on scale measurements at the end of the several years of life, are not included. Thus, the determined length increments show only approximate annual growth. A comparison of lengths of tagged fish at the time of tagging and at time of recapture in January at Mill Creek Counting Station shows that they continued to grow during the spawning migration. On the average, steelhead tagged in the fall increased three-fourths of an inch by the end of January, which approximates the end of a year of life, at least insofar as the growing season is concerned.

The greatest length increment generally took place in the second year of life, during the first summer after release. A comparison between sizes of fish when released and after the second summer's growth shows that in only one instance did a group of fish fail to more than double in length d--ing the second year. The length increment of fish both larger and ller than 10 to the pound when stocked was approximately the same during their second year, averaging about nine inches.

TABLE 8

Average Fork Lengths and Approximate Annual Length Increments of Hatchery-Reared Steelhead, in Two General Size Categories, Released in the Upper Sacramento River System and Captured by Trapping in the Sacramento River One-Half Mile Above Its Confluence With the Feather River *

Category and lot	Brood year	Number per pound at time of release	Number and length at time of release	Year of life			
				2	3	4	5
Fish 10 per pound and smaller							
Ad-LV	1956	30					
Number measured			750	5	18		
Average fork length (inches)			4.3	12.7	18.0		
Standard deviation			0.7	0.5	1.4		
Growth increment (inches)				8.4	5.3		
Ad-RV	1954	26					
Number measured			3,468	35	94	1	1
Average fork length (inches)			4.3	13.3	19.3	18.4	25.0
Standard deviation			1.0	1.4	2.4		
Growth increment (inches)				9.0	6.0		
D-Ad	1957	22					
Number measured			600	3			
Average fork length (inches)			4.4	16.8			
Standard deviation			0.8	1.6			
Growth increment (inches)				12.4			
Ad-LMax	1955	22					
Number measured			1,216	5	16	2	
Average fork length (inches)			4.6	12.6	20.1	19.2	
Standard deviation			1.0	0.9	2.1	1.0	
Growth increment (inches)				8.0	7.5		
BV	1953	18					
Number measured			2,844	129	223	44	
Average fork length (inches)			4.8	14.3	19.9	22.9	
Standard deviation			1.1	1.2	2.2	1.8	
Growth increment (inches)				9.5	5.6	3.0	
BV	1957	12					
Number measured			1,198	10			
Average fork length (inches)			5.7	14.5			
Standard deviation			0.9	1.3			
Growth increment (inches)				8.8			
Ad-RV	1956	12					
Number measured			900	12	41		
Average fork length (inches)			5.9	14.4	19.4		
Standard deviation			0.8	1.0	1.9		
Growth increment (inches)				8.5	5.0		
BV	1955	10					
Number measured			2,026	173	114	4	
Average fork length (inches)			5.8	14.1	20.8	22.0	
Standard deviation			1.2	1.0	1.6	1.7	
Growth increment (inches)				8.3	6.7	1.2	
Average growth increments (inches)				9.1	6.0	2.1	

TABLE 8—Continued

Average Fork Lengths and Approximate Annual Length Increments of Hatchery-Reared Steelhead, in Two General Size Categories, Released in the Upper Sacramento River System and Captured by Trapping in the Sacramento River One-Half Mile Above Its Confluence With the Feather River *

Category and lot	Brood year	Number per pound at time of release	Number and length at time of release	Year of life 2	3	4	5
Fish larger than 10 per pound							
Ad-RV	1952	8					
Number measured			1,114	47	277	11	2
Average fork length (inches)			6.0	16.2	20.0	23.3	25.4
Standard deviation			2.0	1.1	2.2	1.2	0.6
Growth increment (inches)				10.2	3.8	3.3	2.1
Ad-LV	1954	7					
Number measured			1,200	242	126	7	
Average fork length (inches)			6.8	15.6	21.7	24.0	
Standard deviation			1.4	1.6	1.9	1.9	
Growth increment (inches)				8.8	6.1	2.3	
Ad-BV	1957	7					
Number measured			850	12			
Average fork length (inches)			6.8	16.0			
Standard deviation			1.1	1.4			
Growth increment (inches)				9.2			
D-RV	1956	7					
Number measured			453	21	12		
Average fork length (inches)			7.0	15.4	20.7		
Standard deviation			1.2	1.3	1.7		
Growth increment (inches)				8.4	5.3		
Ad-BV	1955	6					
Number measured			1,027	221	46	2	
Average fork length (inches)			6.5	15.8	21.3	23.6	
Standard deviation			1.3	1.3	1.6	1.3	
Growth increment (inches)				9.3	5.5	2.3	
D-LV	1956	6					
Number measured			900	79	25		
Average fork length (inches)			7.2	16.1	21.5		
Standard deviation			1.2	1.1	1.9		
Growth increment (inches)				8.9	5.4		
Ad-BV	1953	4					
Number measured			495	74	13	2	
Average fork length (inches)			8.0	15.7	21.2	25.2	
Standard deviation			1.7	1.4	2.2	0.4	
Growth increment (inches)				7.7	5.5	4.0	
Average growth increments (inches)				8.9	5.3	3.0	2.1

* The annual growth increments are approximate, since all measurements were made during the fall, before the end of a year of life.

Growth was not as rapid during the third year of life, and there was a tendency at this age for the fish which were small when stocked to grow more than those released at the larger sizes. The growth rate decreased during the fourth year of life. The small number of hatchery fish captured during their fifth year of life precluded a reliable estimate of growth at that age, although the length increment appears to be small.

RESIDENT TROUT

A comparison was made each season between the ratios of marked to unmarked steelhead migrating upstream past the mouth of the Feather River and fish caught in the upper Sacramento. It was anticipated that if a resident population over 14 inches in length existed in the upper river, or if there were many steelhead in this size category which had not yet migrated to sea, the dilution caused by these fish would be sufficient to effect a noticeable decrease in the marked fish ratio in the upper river. During the five seasons, 1954 through 1959, creel censuses showed that the over-all ratio of marked fish, including only steelhead 14 inches and over in length, was higher at the trapping site than in the upper river. The percentage difference between the two areas varied from 2 percent in 1954 to 7 percent in 1956, indicating that a sizable population of trout exists in the upper river during some years, in addition to those which come in from the sea. When the ratios of individual fin marks were compared between the two areas, again including only fish 14 inches and over in length, it was found that significant differences generally occurred only among groups in which the steelhead were smaller than 20 inches, indicating that the trout which did not migrate to sea during a particular season and any resident fish were principally between 14 and 20 inches in length. Their numbers were generally in inverse proportion to their lengths. There are, in addition, considerable but unknown numbers of trout under 14 inches in length in the upper river at all times.

COSTS OF SEA-RUN HATCHERY STEELHEAD IN THE RIVER

The returns of sea-run adults from hatchery production have been presented in preceding sections without regard to hatchery production costs. To properly evaluate artificial stocking of migrant-sized steelhead it is desirable to know not only returns in terms of numbers of adult fish but also costs of producing yearlings and returning sea-run adults.

The average cost of producing a yearling steelhead, including expenditures associated with taking eggs, rearing, and stocking, varied from 3 cents to 18 cents, with an over-all average of 6 cents during the four-year study (Table 9). These figures include all rearing costs except capital investment and capital improvements at the hatchery, and administrative overhead. They do not include costs of marking or of evaluating returns. Generally speaking, the larger the yearlings are when released, the more it costs, per fish, to produce them. Costs of rearing yearling steelhead at Coleman hatchery compare favorably with costs of rearing catchable-sized rainbow trout to the same size at California Department of Fish and Game hatcheries. Dur[illegible] the fiscal year 1955-56 for example, the average cost to rear and st[illegible] [illegible]atchable-sized rainbow trout weighing six to the pound was 13.6 cents each (Macklin

Types of Fishing

Steelhead are caught in the upper Sacramento by a variety of fishing techniques, which vary with the season and other factors.

During October, November, and December, when fall-run king salmon are spawning, steelhead congregate with the salmon on riffles, both in the main Sacramento and its tributaries. Examination of steelhead stomachs taken at riffles on which salmon are actively spawning usually reveals a good quantity of eggs, and if fishermen are present often both fresh and cured eggs. At other times, the stomach contents consist of salmon eggs in various stages of development, which were probably dug up by one salmon excavating a nest on top of another. There is no evidence to indicate that steelhead dig up a salmon nest for food. In addition, the steelhead themselves do not prepare nests on top of salmon nests in the fall, since they do not spawn at that time. It is not known whether or not the steelhead actually rob a salmon nest by darting in and grabbing unattended eggs, but it is thought that most eggs are picked up after they drift out of the nest, since most steelhead are hooked *behind* spawning salmon.

Although Shapovalov and Taft (1954) report that adult steelhead do not commonly feed during their spawning migration in coastal streams, those in the Sacramento River definitely do. There is evidence that they continue to eat until the time of spawning in the Sacramento, since at Coleman hachery adult steelhead trapped in Battle Creek and placed in holding ponds continue to feed on salmon roe up to the time they are spawned artificially and released.

When salmon are actively spawning, steelhead in the vicinity strike voraciously at almost any small object, especially one resembling a salmon egg, which drifts through the nests. Under these conditions most fish are hooked by drifting single salmon eggs and salmon roe clusters through the riffles (Figure 14). Several artificial lures which resemble salmon eggs have also been developed and are increasing in

FIGURE 14. S... ushing for steelhead on Ohm Riffle in the Sacramento River, near Red Bluff. Creel checks showed that over 100 steelhead were landed on this riffle in

popularity among Sacramento River anglers. One type utilizes a ball of red fluorescent yarn tied to the hook (glow bug), and another is made by attaching a small, spherical piece of red sponge rubber to the hook.

Many steelhead and salmon also congregate near the mouths of tributary streams, awaiting suitable flow conditions before ascending the creeks. Steelhead are caught by several methods of fishing in these places. At the mouth of Deer Creek, for example, drifting with single eggs is the predominant method, while at the mouth of Mill Creek still fishing with salmon roe clusters and casting with metallic artificial lures are the most popular methods.

When the fall-run salmon have completed their spawning, steelhead become scarce on riffles in the Sacramento. However, many steelhead then seek their own spawning areas in tributary streams. By January of each year, most steelhead fishing has shifted to the tributary streams. Most of the steelhead landed during this latter part of the fishing season in the tributaries are caught by drifting single eggs and casting artificial metallic lures.

Fishing Gear

Spinning equipment is the fishing gear most commonly employed. A rod 6 to $7\frac{1}{2}$ feet long is preferred by most fishermen. The line is generally monofilament nylon of 6- to 8-pound test, with 8-pound line being the most common. Most types of spinning reels on the market today have been observed at one time or another on the Sacramento; however, those with a full bail line pickup predominate. Fly rods and reels are rarely used.

Many fishermen tie the hook or lure directly to the line, while others attach a leader of lower breaking strength than the line, to insure minimum loss of line should the hook or lure become snagged. At times when the water is especially clear, a thin leader is used. Sinkers are sometimes attached directly to the line or leader, especially when split shot is used. Many anglers prefer a pencil sinker and attach it to the line through the use of a small swivel or a drop loop in the line itself. Occasionally, anglers attach a weight to the line in such a way that it is free to slide along the line to a desired distance from the hook. This "sliding sinker" arrangement is more commonly used by those who "still fish" than by those who drift their bait through the water. In any event, in drift fishing the weight is small enough so that it will keep bouncing along the bottom until the line has straightened out, downstream from the angler. In this way the fisherman can drift his bait down the entire length of the riffle, only a few inches off the bottom.

Fishing Access

Most land bordering the upper Sacramento River is privately owned. However, many land owners permit anglers to cross their property to reach the steelhead fishing riffles. In these instances the fishing areas are usually but a short walk from the end of a road. Other riffles may be reached only by boat or by walking a considerable distance. During the study period, there was a tremendous increase in the numbers of boats used by steelhead anglers. One of the big pro... s of a boat owner is that of finding a suitable launching site in the area where he wants to fish. [illegible]

Game, through the Wildlife Conservation Board, has installed several concrete boat launching ramps and automobile parking areas at key points along the upper Sacramento. These ramps are maintained by the county in which they are located. Those installed to date (June, 1960) are located at Redding, Balls Ferry, Bend, Red Bluff, and Vina.

Practically all land bordering the tributary streams is also privately owned and, as on the Sacramento, fishing access is permitted by many land owners. In the tributaries anglers do almost no boating but sometimes walk considerable distances along the creeks.

STEELHEAD SPORT CATCH

The steelhead sport catch each season was determined by dividing the number of tags sent in by the fraction of the total run known to have been tagged. This quotient would obviously be a minimum figure for total landings, unless some correction were made for the number of tags taken from steelhead but not returned to the Department of Fish and Game. An estimate of nonreturn of tags thus becomes an essential element in computing total catch, when using the method described herein. However, since a measure of nonreturn is purely an estimate based on human behavior, it is believed desirable to first present the minimum catch statistics derived from actual tag returns, and then show the same data corrected by percentages of nonreturn. The numbers of hatchery fish in the catch and their costs, based on different percentages of nonreturn of tags, are shown in the section on "Nonreturn of Tags, and Adjusted Catch and Cost Figures".

Numbers of Steelhead Landed, Based Upon Uncorrected Tag Returns

On the basis of actual tag returns between 1953 and 1959, anglers landed an average of about 6,100 steelhead each season in the upper Sacramento River system, or close to 30 percent of the entire run. The catch has varied from 20.1 percent of the run in 1953-54 to 36.5 percent in 1958-59 (Table 11). About 70 percent of the steelhead landed from each annual run are caught in October and November. Thus, the best steelhead fishing has usually passed each season in the Sacramento before it commences in many of California's coastal streams.

Numbers of Sea-run Hatchery Steelhead Landed and Their Cost in the Creel, Based Upon Uncorrected Tag Returns

The numbers of hatchery-reared steelhead appearing in anglers' creels each season were determined by multiplying the computed numbers of sea-run hatchery fish in the total population by the fraction of the run caught. It is assumed that hatchery fish are caught as readily as wild fish and that they are taken in approximately the same proportions in which they appear in the population. Chi-square analysis of the tagging and creel census data shows that these assumptions are valid.

It is also obvious that since the percentage of the run caught is based upon tag re[illegible]rns, a measurement of nonreturn of tags also plays an important [illegible] in determining total numbers of sea-run hatchery fish in the catc[illegible] [illegible]d their costs. Whereas the total catch would be a bare

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TABLE 11

Upper Sacramento River Steelhead Sport Catch. Annual Landings Are Based on Actual Angler Tag Returns. All Fish Are 14 Inches and Over in Fork Length

Month	1953-54		1954-55		1955-56		1956-57		1957-58		1958-59	
	Number of fish caught	Percentage of catch	Number of fish caught	Percentage of catch	Number of fish caught	Percentage of catch	Number of fish caught	Percentage of catch	Number of fish caught	Percentage of catch	Number of fish caught	Percentage of catch
July	--	--	--	--	--	--	--	--	--	--	--	--
August	--	--	9	0.1	86	1.1	--	--	10	0.2	--	--
September	168	5.8	485	5.3	727	9.3	301	4.7	75	1.5	262	5.0
October	1,002	34.6	4,078	44.6	3,032	38.8	2,520	39.4	1,468	29.3	2,429	46.4
November	1,010	34.9	2,460	26.9	2,298	29.4	2,040	31.9	2,084	41.6	1,466	28.0
December	318	11.0	604	6.6	774	9.9	499	7.8	722	14.4	497	9.5
January	119	4.1	604	6.6	297	3.8	435	6.8	386	7.7	230	4.4
February	229	7.9	622	6.8	273	3.5	358	5.6	130	2.6	157	3.0
March	9	0.3	18	0.2	148	1.9	32	0.5	20	0.4	42	0.8
April	--	--	137	1.5	86	1.1	70	1.1	20	0.4	26	0.5
May	40	1.4	101	1.1	39	0.5	70	1.1	75	1.5	47	0.9
June	--	--	27	0.3	16	0.2	6	0.1	--	--	11	0.2
Month unknown	--	--	--	--	39	0.5	64	1.0	20	0.4	68	1.3
tals	2,895	100.0	9,145	100.0	7,815	100.0	6,395	100.0	5,010	100.0	5,235	100.0
Percentages of run caught	20.1		32.2		27.6		34.8		25.8		36.5	

minimum figure without correction for nonreturn of tags, costs of putting sea-run hatchery steelhead in the run and in the creel would be maximum figures, since they increase as the numbers of fish decrease.

Of 663,240 yearlings released during the study, 3,882 eventually ended up in anglers' creels as sea-run steelhead (Table 12). Thus, with a 2 percent return to the upper Sacramento of the yearlings released, on an average about 0.6 percent found their way into an angler's creel. Dividing the total cost of producing the yearlings released by the total adults put in creels as a result of these released fish, on the average it cost $10 to put a hatchery steelhead in the creel (Table 12).

As previously stated, returns of sea-run hatchery fish to the upper Sacramento from the 1955 brood year fish were much lower than for those from the three previous years. If returns to the creel from only the 1952, 1953, and 1954 brood years are used, the average cost of putting a sea-run steelhead in the creel was $7.48, instead of $10.

Nonreturn of Tags, and Adjusted Catch and Cost Figures

The importance of measuring nonreturn of steelhead tags has already been pointed out. However, in this study the main effort was concentrated on getting all tags back, by offering a chance to win a valuable prize for each tag returned, rather than on measuring the degree of nonreturn. Nevertheless, it is believed that sufficient information is on hand to make a fairly reliable estimate of nonreturn of tags.

In 1954 an indirect effort to get some idea regarding numbers of tags taken from steelhead by sportsmen but not sent in was made by offering $500 in prizes for the return of tags. No awards had been made during the 1953 season. The prizes were awarded at a drawing for all tag numbers returned, and theoretically the more tags sent in by an angler, the greater would be his chances of winning. Although there was a significant increase in tag returns during 1954, it was impossible to differentiate that portion representing an actual increase in fishing pressure and in the catch from that indicating nonreturn. Also, other factors were involved, including a better understanding of the program by sportsmen in 1954, which no doubt led to greater returns.

During 1955, a more direct attempt to determine nonreturn was made at the time anglers were being interviewed during creel censuses. However, the data gathered were not considered entirely reliable because of the reluctance of many sportsmen to admit readily that they had previously failed to send in tags.

In the striped bass fishery of the Sacramento-San Joaquin Delta, a measurement of nonreturn of tags was determined by using comparable quantities of $5.00 reward and nonreward tags during the same season (Chadwick, 1960). It was found that about 45 percent of the nonreward tags taken by sportsmen from striped bass were not sent in. This method of evaluation assumes that the $5.00 reward is incentive enough to assure the return of all reward tags taken, or at least enough to reduce to insignificance any error in resulting calculations. However, it is believed by the writers that this method tends to overestimate nonreturn, esp[illegible]lly after anglers understand that there are two types of tags out, [illegible] ctually discouraging the return of tags for which no

TABLE 12

Upper Sacramento River Sport Catch of Sea-Run Hatchery Steelhead, and the Average Cost of Putting One in the Creel. Annual Landings Are Based on Actual Tag Returns. All Fish Are 14 Inches and Over in Fork Length

	Yearlings released			Sea-run hatchery steelhead caught							
Brood year	Number per pound	Number released	Cost of yearlings released	1953-54	1954-55	1955-56	1956-57	1957-58	1958-59	Total	Cost per adult in creel
1952	8	63,590	$7,081.36	81	477	35	4			597	$11.86
1953	4	6,370	$1,197.00		114	44	4			162	$7.39
1953	18	145,278	5,522.30		154	689	87			930	5.94
Totals		151,848	$6,719.30							1,092	
Average											$6.15
1954	7	46,252	$4,119.28			649	247	18		914	$4.51
1954	26	131,007	3,156.42			25	183	3	3	214	14.75
Totals		177,259	$7,275.70							1,128	
Average											$6.45
1955	6	67,651	$7,056.00				401	118	5	524	$13.47
1955	10	143,137	8,945.92				189	295	11	495	18.07
1955	22	59,755	1,737.60					41	5	46	37.77
Totals		270,543	$17,739.52							1,065	
Average											$16.66
Grand totals		663,240	$38,815.88	81	745	1,142	1,115	475	24	3,882	
Grand averages											$10.00

money is received. This would abnormally widen the gap between returns of $5.00 reward tags and those of no cash value.

During the steelhead study, including the 1954 season and each year thereafter until its conclusion, an annual tag drawing was held for nearly $500 in cash and merchandise prizes offered by sportsmen's organizations, fishing resorts, and sporting goods stores for tags returned to the Department of Fish and Game (Figure 15). Under this plan it was, of course, advantageous to return all tags, in order to have each tag number registered for the drawing. Considerable publicity was given the prize drawing and study program each season through local

FIGURE 15. 'h annual steelhead tag drawing. The tag drawings were sponsored jointly by ornia Kamloops, Inc. and Steelhead Unlimited. Each year at Redding over $. was awarded to sportsmen for returning steelhead tags to the California [illegible]

television and radio appearances, state-wide press releases, local n papers, illustrated talks at sportsmen's and service clubs and Dep mental meetings, use of tag return posters located at key riffles resorts, and interviews with anglers during creel census work. F the beginning of the study, all tags sent in were returned to the an along with a commendation card and a letter explaining the pur of the tagging and (beginning in 1954) pointing out that his tag n ber had been entered in a drawing for valuable prizes. To further the return of tags, postage-free, self-addressed envelopes were sup to fishing resorts and sporting goods stores along the Sacramento Ri

The 1954 and 1955 studies indicated that the percentage of nonret of steelhead tags was considerably lower than that shown for str bass. Nonreturn of steelhead tags appeared to be about 20 percent. this figure was selected as an estimate of nonreturn for steelhead t The sport catch and cost figures were re-evaluated accordingly.

By re-arranging the catch figures and presenting them on the l of different percentages of nonreturn of tags, a somewhat diffe picture of numbers caught and of costs to put a sea-run steelhea the creel is seen (Tables 13 and 14). For example, on the basis uniform 20 percent nonreturn of tags during the study, an ave 36.9 percent, instead of 29.5 percent, of the population was harve each season, and anglers harvested about 45.6 percent of the ru 1958 instead of the 36.5 percent obtained without correction for return. Also, if allowance for a 20 percent nonreturn of tags is m the average cost of putting an adult steelhead in the creel was $8 ins of $10. If a 20 percent nonreturn and returns of adults from only first three brood years of yearling steelhead released are used, the of putting a sea-run steelhead in the creel drops from $7.48 to $

CREEL CENSUS

Steelhead creel censuses were designed to provide the average c per angler hour, length of the average angler day, and county of dence of the fishermen, and to see as many steelhead as possible in o to help establish tagged to untagged and marked to unmarked fish ra in the upper Sacramento River system. As previously mentioned, attempt was made to determine total catch by means of creel cen since this was done on the basis of tagging and tag return data. W total catch, catch per hour, and number of hours in the average an day had been determined, total fishing efforts and fishermen days computed.

During most months of the year, creel census work was carried with only a moderately controlled sampling scheme. However, du the fall months, when the bulk of the steelhead are caught and w most of the fishing effort for sea-run fish is expended, an inten method of securing data on angling was used (Figure 16). The census procedure was directed toward obtaining a satisfactory sam of the total fishing effort and also securing as large a sample as poss in interviewing anglers. It was definitely not a complete census, du the many access points and to the limited manpowe' 'ailable. Altho the censuses were not strictly random it is believe at the data g ered present a reasonably representative picture of angling effort,

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TABLE 13

Upper Sacramento River Steelhead Sport Catch. Annual Landings Are Computed With Different Percentages of Nonreturn of Tags. All Fish Are 14 Inches and Over in Fork Length

Season	Percentage of nonreturn									
	0		10		20		30		40	
	Number of fish caught	Percentage of run caught	Number of fish caught	Percentage of run caught	Number of fish caught	Percentage of run caught	Number of fish caught	Percentage of run caught	Number of fish caught	Percentage of run caught
1953-54	2,895	20.1	3,217	22.3	3,619	25.1	4,136	28.7	4,825	33.5
1954-55	9,145	32.2	10,161	35.8	11,431	40.3	13,064	46.0	15,241	53.7
1955-56	7,815	27.6	8,683	30.7	9,769	34.5	11,164	39.4	13,025	46.0
1956-57	6,395	34.8	7,106	38.7	7,994	43.5	9,136	49.7	10,658	58.0
1957-58	5,010	25.8	5,567	28.7	6,263	32.3	7,157	36.9	8,350	43.0
1958-59	5,235	36.5	5,817	40.6	6,544	45.6	7,479	52.1	8,725	60.8
Average percentage of runs caught	29.5		32.8		36.9		42.1		49.2	

TABLE 14

Upper Sacramento River Sport Catch of Sea-Run Hatchery Steelhead, and the Average Cost of Putting One in the Creel. Annual Landings and Costs Are Computed With Different Percentages of Nonreturn of Tags. All Fish are 14 Inches and Over in Fork Length

Yearlings released				Percentage of nonreturn									
				0		10		20		30		40	
Brood year	Number per lb.	Number released	Cost of yearlings released	Total hatchery adults caught	Cost per adult in creel	Total hatchery adults caught	Cost per adult in creel	Total hatchery adults caught	Cost per adult in creel	Total hatchery adults caught	Cost per adult in creel	Total hatchery adults caught	Cost per adult in creel
1952	8	63,590	$7,081.36	597	$11.86	663	$10.68	746	$9.49	853	$8.30	995	$7.12
1953	4	6,570	$1,197.00	162	$7.39	180	$6.65	202	$5.93	231	$5.18	270	$4.43
1953	18	145,278	5,522.30	930	5.94	1,033	5.35	1,162	4.75	1,329	4.16	1,550	3.56
Totals		151,848	$6,719.30	1,092		1,213		1,364		1,560		1,820	
Averages					$6.15		$5.54		$4.93		$4.31		$3.69
1954	7	46,252	$4,119.28	914	$4.51	1,015	$4.06	1,142	$3.61	1,306	$3.15	1,523	$2.70
1954	26	131,007	3,156.42	214	14.75	238	13.26	268	11.78	306	10.32	357	8.84
Totals		177,259	$7,275.70	1,128		1,253		1,410		1,612		1,880	
Averages					$6.45		$5.81		$5.16		$4.51		$3.87
1955	6	67,651	$7,056.00	524	$13.46	582	$12.12	655	$10.77	749	$9.42	873	$8.08
1955	10	143,137	8,945.92	495	18.07	550	16.27	619	14.45	707	12.65	825	10.85
1955	22	59,755	1,737.60	46	37.77	51	31.07	58	29.96	66	26.33	77	22.57
Totals		270,543	$17,739.52	1,065		1,183		1,332		1,522		1,775	
Averages					$16.66		$15.00		$13.32		$11.66		$9.99
Grand totals		663,240	$48,815.88	3,882		4,312		4,852		5,547		6,470	

Figure 16. Creel checking a steelhead angler on the Sacramento River near Jellys Ferry. *Photograph by Richard J. Hallock, October, 1956.*

The steelhead fishing area was divided into three general sections, the centers of which are Hamilton City, Los Molinos, and Balls Ferry (Figure 2). Seasonal employees were used to do a good portion of the creel census work and usually traveled by automobile, stopping at the fishing resorts and riffles. Between Vina and Red Bluff, the Sacramento River was covered by the project skiff, as well as by automobile. The creel census work was also cooperative. Department of Fish and Game salmon survey crews, drifting designated sections of the Sacramento daily betwe[illegible] Redding and Vina each fall and winter, also creel checked steelhead fis[illegible]rmen along the way. At key points, people living in the [illegible]

FISHING EFFORT

Starting in 1954, the creel census data were sufficient to determin the average catch per hour and number of hours in the average angle day for each month and each season throughout the remainder of th study. It was then only necessary to know the numbers of steelhea caught, including both adults and juveniles, to compute total angl hours and total angler days expended each month and each seaso The catch of sea-run fish, as described previously, was derived from ta returns by anglers, while landings of juveniles computed in this sectio are weighted figures based on ratios of fish under 14 inches in lengt to larger individuals observed during creel censuses.

Most fishing for sea-run steelhead in the upper Sacramento tak place from September through the following February. Fishing effo is particularly intense in October and November. Adult fish lande from March through August are usually caught only incidentally b those seeking other species of fishes, or while angling for juvenil steelhead and resident trout. Since this report is concerned primaril with the fishery for sea-run fish, creel census data presented herei include only those collected during months when the main fishin effort was for sea-run fish, i.e., September through February. Betwee 1954 and 1958, over 10,000 steelhead anglers were interviewed an their catches inspected during these months. Whenever a fisherma planned to continue fishing after being creel checked, he was given self-addressed, stamped post card on which there was but one request the total hours he fished that day. About 30 percent of these card were not returned, although all fishermen had consented to send the in. In all, close to 6,000 completed fishing efforts were obtained an indicated that the average steelhead angler fishes 4.1 hours during a average day (Table 15). Lengths of the average angler day remaine fairly constant throughout the study period and even throughout va ious months of any particular year. However, in the fall, when mos

TABLE 15

Upper Sacramento River Steelhead Sport Catch and Angling Effort. Numbers of Fish 14 Inche and Over in Length (Adults) Were Computed With a 20 Percent Nonreturn of Tags. Juvenile Steelhead Caught Are Based on the Ratio of Juveniles to Adults Observed While Creel Censusing

Season*	Number of fishermen interviewed	Average total catch per angler hour	Average hours per completed angler day	Catch			Angler hours	Angler days
				Juveniles	Adults	Total		
1954-55	1,316	0.1108	4.1810	1,703	11,068	12,771	115,196	27,552
1955-56	2,063	0.1373	3.8794	2,309	9,289	11,598	84,459	21,771
1956-57	1,999	0.0867	4.3794	1,486	7,778	9,264	106,819	24,301
1957-58	2,414	0.1611	4.0259	4,853	6,103	10,956	68,002	16,891
1958-59	2,702	0.1444	4.0007	3,649	6,389	10,038	69,536	17,381
Totals	10,494			14,000	40,627	54,627	444,012	107,986
Averages	2,099	0.1230	4.1117	2,800	8,125	10,92[illegible]	88,802	21,597

* September through February only.

sea-run fish are caught, lengths of the average angler day were greatest. During October and November, for example, when steelhead are the most vulnerable, fishermen spend more time angling for them. This vulnerability is indicated by observations and by the average catch per angler hour, which was typically higher in October and November than during other months of the season. This pattern was constant from year to year. Smith *(loc. cit.)* also noted during the 1948-49 season that Sacramento River steelhead landings depended upon availability of fish. This was revealed by the catch per hour, which increased or decreased with the total catch in all but three of the 13 months studied.

The number of steelhead angler days spent annually on the upper Sacramento averaged 21,597 from 1954-55 through 1958-59 (Table 15). Although observations and creel checks indicate an increase in numbers of individuals fishing for steelhead each season, the angler days, or total fishing effort spent by these fishermen in pursuit of steelhead, show a decrease through the years which is proportionate to the decline in populations of fish. The total annual fishing effort each season is particularly influenced by the availability of fish in October and November, since these are the months when most fish are caught and when the greatest effort is expended. If the run is large and fish are available during these months, the annual fishing effort is substantial. In addition, the fishing emphasis shifts towards the smaller trout when sea-run fish are scarce. This was particularly noticeable in 1957 and 1958 when anglers, realizing that the larger fish were not present in sufficient quantities, kept many small trout, which normally they would have released (Table 15).

The number of hatchery fish in the catch of juveniles during the months of September through February has varied during the course of the study. It has depended mainly on the location of the plants of hatchery fish. In 1957 and 1958, years in which upstream plants of hatchery fish had been made, the hatchery fish formed a little over 6 percent of the catch of juveniles, while in other years, in which only downstream plants of hatchery fish had been made, they comprised less than 1 percent of the catch of juveniles.

RESIDENCE OF ANGLERS

Steelhead anglers travel from all parts of California to fish the upper Sacramento each fall. In the five-year period, 1954 through 1958, over 7,000 anglers were interviewed in the months of October and November alone. It was found that, on the average, those fishing the upper Sacramento each fall are residents from 40 of California's 58 counties. By grouping these counties it is seen that 96 percent of the fishermen travel from three principal areas in California: (1) Sacramento Valley, (2) San Francisco Bay and Sacramento-San Joaquin Delta, and (3) southern California (Figure 17). Although the steelhead season extends over a longer period, most anglers fishing during months other than October and November are residents of the Sacramento Valley, indicating that fishermen will travel great distances only when fishing ' t its peak.

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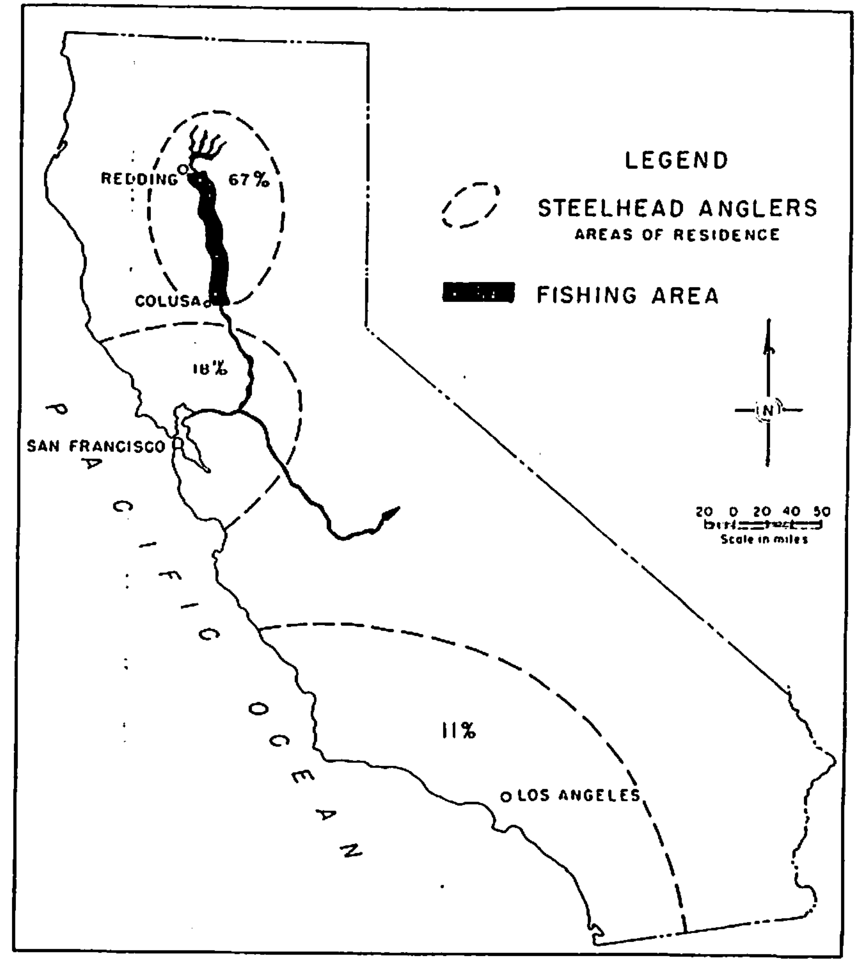

FIGURE 17. The three principal areas in California in which Sacramento River steelhead anglers reside, showing the percentage of total anglers from each area.

The importance of steelhead and salmon fishing is also reflected in the growth of commercial boat landings and fishing resorts along the Sacramento River betwen Hamilton City and Redding. In 1945 there were no commercial boat landings in the upper river area. The first organized sportsman's landing and boat rental was established in 1946 (Smith, *loc. cit.*). Only three such establishments were operating in 1947. However, at the close of the 1948 season eight boat landings were in operation, and three additional ones opened for business early in 1949. At present there are 18 establishments along the upper river offering such facilities as cabins, house trailer space, boat launching, boat dockage, and boat rental. In some establishments complete lines of fishing tackle, as well as boats and motors, are for sale.

VALUE OF THE FISHERY

A sport fishery is worth at least the amount of money that anglers spend in pursuit of it. An economic survey by the Department of Fish and Game in 1953 indicated that the average daily expenditure by a California steelhead angler was $18.11 (Pelgen, 1955). Steelhead fishing expenses included transportation, food and lodging, services and supplies, equipment, and licenses. To bring the $18.11 estimated average daily amount spent by California steelhead anglers in 1953 up to values for the succeeding years of this study, the 1953 figure was multiplied by appropriate annual factors derived from consumer price indexes for San Francisco, published by the United States Department of Labor. The corrected daily expenditures were then in turn multiplied by total annual angler days expended, to arrive at a total minimum annual value for the fishery (Table 16). Thus, the minimum average annual value for the upper Sacramento River steelhead fishery was a little under $390,000 from 1954 through 1958.

As previously noted, the average steelhead fisherman spends 4.1 hours a day while angling for steelhead. Taking all sizes of fish caught into consideration, on the average he fishes two angler days for each steelhead he lands. Therefore, the average fisherman spends almost $40 for each fish landed. Whereas it costs $8 on the average to produce each sea-run hatchery steelhead ending up in a creel, an angler is willing to spend almost five times that amount to catch one.

TABLE 16

Minimum Annual Expenditures of Sacramento River Steelhead Fishermen

Season*	Total angler days	Expenditure per angler day	Total amount spent by anglers
1954-55	26,434	$18.14	$479,513
1955-56	20,918	18.02	376,942
1956-57	23,392	18.45	431,582
1957-58	16,236	19.19	311,569
1958-59	16,766	19.87	333,140
Averages		$18.73	$386,549

* September through February only.

CONDITION OF THE RUNS

During the six seasons, 1953-54 through 1958-59, the steelhead populations of the upper Sacramento River averaged 20,542 fish. The annual runs of naturally-spawned or wild fish alone averaged about 18,000 fish (Table 17). An examination of the wild populations also reveals a jump from 14,000 in 1953-54 to 26,000 in 1954-55, followed by a decline to 13,000 in 1958-59. The total population (including hatchery fish) shows a similar rise and decline. The trend since 1955-56 is definitely downward in either case. Whether or not this is part of a natural cycle in abundance is not known, since the period of study was not long enough to determine this. Close observation of the populations should be made durir he next few seasons to determine whether they are passing throug . natural fluctuation, or whether there is a genuine decline in the runs.

TABLE 17

Breakdown of Annual Upper Sacramento River Steelhead Populations, Showing Numbers of Hatchery and Wild (Naturally-Produced) Fish. All Fish Are 14 Inches and Over in Fork Length

Season	Hatchery fish	Wild fish	Total run
1953-54	404	13,996	14,400
1954-55	2,315	26,085	28,400
1955-56	5,223	23,097	28,320
1956-57	3,205	15,175	18,380
1957-58	2,876	16,534	19,410
1958-59	942	13,398	14,340
Averages	2,494	18,048	20,542

In the Columbia River, where both winter and summer runs of steelhead occur, the summer-run populations have gone through a series of fluctuations in recent years which suggest six-year cycles (Oregon Fish Commission, 1957). Peaks in the populations were reached in 1940, 1946, and 1952, with low points being registered in 1943 and 1949. The summer run averaged 227,000 fish from 1938 through 1956, and the spawning escapement averaged about 53 percent of the total population from 1949 through 1956. Both commercial and sports fisheries for steelhead exist in the Columbia River. The size and spawning escapement of the winter run are unknown.

The spawning escapement of adult steelhead entering the upper Sacramento River and tributaries has averaged about 63 percent during the past six years. It is not known what percentage of the total run destined for the upper Sacramento is taken by sports fishermen in the lower river (below the mouth of the Feather River). It is thought to be no greater than 10 percent, in which event the average spawning escapement would be at least 53 percent, a figure which is the same as that which is considered adequate for maintenance of the Columbia River runs.

The fairly concentrated summer sports fishery in the Sacramento for the juvenile steelhead or resident trout may necessitate a larger spawning escapement of adults to perpetuate the runs that would normally be required were year-round fishing not permitted.

CONCLUSIONS

It may be concluded from this study that stocking hatchery-reared yearling steelhead is a valid method of supplementing natural steelhead production in the Sacramento River. Natural reproduction by steelhead during the study period was on the order of 1 to 1 (i.e., for each adult one other was produced), while artificial propagation produced about 15 fish for each one spawned. This, of course, holds true only for the limited numbers of steelhead spawned at Coleman hatchery. Presumably, a great increase in artificially-spawned adults would depress the survival rates of both hatchery and wild fish, but ther no evidence to indicate at what level this might become serious. The ..dition of fish to the populations was particularly noticeable in [illegible] at the beginning of the study insufficient adults were available to take the required number of eggs, while at the conclusion excess fish were being turned away to spawn naturally.

To obtain the greatest returns of sea-run hatchery steelhead in the upper Sacramento, the yearlings should be stocked during the normal seaward migration period of wild steelhead in the late winter and early spring at a size larger than 10 to the pound. Under such conditions the steelhead released from Coleman hatchery produced an average of one sea-run adult return for each 25 yearlings stocked. However, if the entire hatchery production from an average of the brood years involved is considered, only one sea-run adult return was produced for each 50 yearlings released. Stocking of yearlings at Princeton, downstream from the general trout fishing area, produced greater returns of adults than stocking of yearlings in the upper river system.

Although the initial cost of rearing and stocking a yearling steelhead was only six cents, the average cost of each sea-run hatchery steelhead return to the upper Sacramento was 50 times greater, or $3.00. At first glance this cost appears exorbitant. However, the average adult steelhead weighs three pounds, so in effect the cost of each adult fish may be figured by including the initial production cost of yearlings stocked, minus the value attributed to losses of fish between stocking time and return to the upper Sacramento, plus the value of any river and ocean growth gained by the survivors. From this viewpoint, the average adult hatchery steelhead was put in the run for $1 a pound, a figure not far above the cost of producing and planting "catchable" rainbow trout in California.

Whereas the cost of each yearling steelhead stocked was only six cents, the average cost of each sea-run hatchery steelhead landed by anglers was nearly 140 times greater. However, the value of each steelhead to a fisherman is almost five times greater than the cost of putting one in his creel by hatchery methods. This value of a steelhead is reflected by sportsmen's expenditures, which indicate that anglers are willing to spend $40 for each steelhead landed on the upper Sacramento River. Since an average of only 36.9 percent of the adult steelhead are harvested each season (assuming a 20 percent nonreturn of tags), and it costs about $3 on the average to put a sea-run hatchery steelhead in the run, it costs about $8 to put one in the angler's creel.

The upper Sacramento River steelhead sport fishery is of considerable magnitude and provides tremendous economic and recreational assets to the people living in many areas of California. Because of this importance, the fishery as well as the populations of fish should be studied periodically so that the management plan may be altered, if necessary, to insure the best possible fishing.

SUMMARY

In 1952 the California Department of Fish and Game initiated a study on the Sacramento River to determine the effectiveness of supplementing natural steelhead production with yearling, hatchery-reared fish. Secondary objectives were to study the steelhead sport fishery and life hi y of Sacramento steelhead. This was a cooperative study. Others par..cipating included the sportsmen of California through two of their organizations, California Kamloops, Inc. and Steel Unlimited, and the United States Fish and Wildlife Service thr its facilities at Coleman National Fish Hatchery on Battle Creek.

The Sacramento River upstream from its confluence with the Fea River, the area with which the study was primarily concerned, is most important of all streams in the Central Valley of Califo from the standpoint of both water supply and fishery resources. daily mean flow near Red Bluff is usually less than 11,000 cubic per second and is generally between 5,000 and 7,000 cubic feet second in the fall, when most steelhead are caught. The princ steelhead fishing tributaries are Mill, Deer, and Battle creeks.

Adult steelhead migrate into the upper Sacramento principally f July through the middle of the following March. There is but annual run, the bulk of which passes the mouth of the Feather Ri near the end of September.

The time pattern of juvenile steelhead moving seaward out of Sacramento was not definitely established, although all evidence i cates that peaks occur in the spring and late fall.

Ages of Sacramento River steelhead were sampled by reading scale samples. It was found that there were 17 two-year-old f 41 three-year-olds, 33 four-year-olds, six five-year-olds, two six-yc olds, and one seven-year-old.

Steelhead spawn in the upper Sacramento River and in most tri taries from the latter part of December through April. Scale samp collected in 1954 indicated that 83 percent of the fish were spawni for the first time, 14 percent for the second time, and 2 percent for third time.

Although a bimodal distribution appeared in length measureme of the annual adult population during most years of the study, average size of a Sacramento steelhead was determined to be 18.1 incl in fork length. The average fish weighed about 3 pounds.

The body-scale relationship of wild or naturally-produced steelhe was determined, and lengths and length increments of steelhead various ages, as well as lengths at which they enter salt water, we calculated. Steelhead which spend one or two years in fresh wat generally migrate into the ocean after attaining a fork length of to 9 inches.

The length-weight relationship of Sacramento steelhead was calc lated from a sample of 484 fish trapped during the fall of 1956 in t Sacramento River, one-half mile above its confluence with the Feath River. In general, there was good agreement between averages actual and calculated weights.

The plan for evaluating the steelhead stocking was to release lar numbers of marked (fin-clipped) yearling, hatchery-reared steelhe and then determine the numbers of sea-run adults produced, their cos and their contribution to the natural runs and to the fishery. Evalu tion of returns was accomplished by trapping in the lower Sacramen to determine the percentage of hatchery fish in the populations, ar then by tagging and tag recovery (including angler returns) to dete mine total numbers and angler take. Hatchery pr tion cost figur were applied to the returns to present a picture . he economics i volved.

During the six years 1953 through 1958, a total of 19,404 steelhead was trapped in the Sacramento River just above the mouth of the Feather River and examined for hatchery fish. Fish in good condition were tagged and released. Two types of tags were used on the adult steelhead trapped, Petersen disk and tubing or "spaghetti" tags. During the study, 15,714 steelhead 14 inches and over in fork length were "effectively" tagged. In all, 15,579 steelhead 14 inches and over in fork length were examined above the trapping site for tags and marks.

Two methods of computing the steelhead populations were studied, (1) the Schaefer method for stratified or changing populations and (2) the Petersen method. Although both methods produced similar results, the Petersen method was used because it was less cumbersome. During the years 1953 through 1958 the adult steelhead populations averaged 20,542 fish. Confidence limits were computed for the population estimates each season and indicate that the population estimates were reasonably accurate.

Releases of marked yearling steelhead were designed to provide returns of sea-run adults which would permit an over-all evaluation of the total fish produced from each brood year stocked, and also to determine the size of yearlings released that would result in the best returns of adults.

Practically all eggs for the study were taken from wild fish trapped in Battle Creek. A few eggs were taken from wild fish trapped at Keswick Dam and from returning hatchery steelhead.

Most of the yearling steelhead were marked by clipping off two fins in various combinations. The fish were anesthetized before marking. In all, 1,041,754 steelhead were fin-clipped and released during the six-year study; however, only the returns from the 663,240 released during the first four years were evaluated. Identical marks were not repeated oftener than every other year. Fish from the 1952 brood year were released in the upper Sacramento River system in several localities. Fish from the three remaining brood years evaluated were stocked at Princeton, below the general trout fishing area. Returning sea-run hatchery fish, identically marked, were established in correct brood years by length measurements.

An examination of scales from 175 of the hatchery-reared sea-run adults indicated that slightly over 96 percent were on their first spawning migration. Most, if not all, of the remainder were returning for the second time.

The 663,240 yearlings released during the first four years produced 13,055 sea-run hatchery fish returns to the upper Sacramento, an average return of 2 percent. Fish weighing eight to the pound and larger when released produced an average 4 percent return, while those weighing between 10 and 26 to the pound resulted in an average return of slightly over 1 percent.

In all, 859 steelhead were spawned at the hatchery and produced 13,055 sea-run adult returns, a return of 15 adults for each fish spawned at the hatchery. In natural reproduction, generally only one is produced for each steelhead in the run.

Stocking of [illegible]arling steelhead in the Sacramento River at Princeton resulted in s[illegible]ent sea-run adult returns to the hatchery on Battle Creek to continue a moderate artificial stocking program and at the

same time to produce some natural dispersion of hatchery steelhead throughout the upper Sacramento River system.

The growth rate of yearling hatchery steelhead is variable. Greatest growth occurs during the first summer after release; the fish more than double their length during the second year of life, adding about nine inches. The fish which are smaller when stocked grow more rapidly during the third year than those stocked at the larger sizes. The average-sized steelhead is generally about 20 inches long at the end of its third year of life. The growth rate decreases rapidly after the third year.

Differences in ratios of marked fish between the trapping site and the Sacramento River above the trapping site indicate that a sizable trout population occurs in the upper river during some years, in addition to sea-run fish.

The costs of producing yearling steelhead varied from three cents to eighteen cents each and averaged six cents. Since a return of only 2 percent as adults was realized from the average group of yearlings released, the cost of producing each sea-run steelhead return to the upper Sacramento was about $3.00.

Steelhead fishing in the Sacramento River is purely for sport. Most steelhead are caught in the fall on riffles occupied by spawning king salmon. The most popular method of angling consists of drifting single eggs and lures which resemble eggs. Steelhead also collect near the mouths of tributaries in the fall and many are caught in these localities, as well as in the tributaries. The principal fishing gear is spinning equipment. Fly fishing equipment is seldom used. Seventy percent of the steelhead caught each season are landed in October and November.

The sport catch was based primarily on angler tag returns. Without correcting for tags which were not sent in, the figure showed that an average of about 30 percent of the run was harvested each season, and also that there was an increase in the catch from 20.1 percent in 1953 to 36.5 percent in 1958. It was estimated that about 20 percent of the tags taken by anglers were not returned. Correcting for a 20 percent nonreturn of tags, the anglers harvested 45.6 percent in 1958 instead of 36.5 percent.

On the basis of uncorrected tag returns, the release of 663,240 yearlings eventually produced 3,882 sea-run hatchery steelhead in anglers' creels. Thus, whereas 2 percent of the average yearlings released returned to the upper Sacramento as adults, only 0.6 percent ended in anglers' creels. On the average, it cost $10 to put a sea-run hatchery steelhead in the creel. By correcting this figure for a 20 percent nonreturn of tags, the average cost of putting an adult steelhead in the creel was $8.00.

Creel censuses were conducted to determine average catch per angler hour, length of the average angler day, and county of residence of anglers, and to see as many steelhead as possible in order to help establish the tagged and marked fish ratios in the upper Sacramento. From 1954 through 1958, over 10,000 steelhead anglers were interviewed. The average angler day was determined to be about 4.1 hours. The average annual number of steelhead angler days spent on the upper Sacramento from 1954 through 1958 was 21,597. On the [illegible]rage, fishermen from 40 of California's 58 counties fish for steelhe[illegible]n the upper

Sacramento River annually. Ninety-six percent come from three general areas in California: (1) Sacramento Valley, (2) San Francisco Bay and Sacramento-San Joaquin Delta, and (3) southern California.

A sport fishery is worth at least the amount of money that anglers spend in pursuit of it. The minimum average annual expenditure by Sacramento River steelhead fishermen was a little under $390,000 from 1954 through 1958. The average steelhead fisherman spends almost $40 for each steelhead landed.

The populations of wild or naturally-produced steelhead in the Sacramento River showed a 50 percent decrease during the last four years of the study. It is not known whether this represents a natural fluctuation in abundance or a real decline in the runs.

Five general conclusions regarding Sacramento steelhead are made: (1) stocking hatchery-reared yearling steelhead is a valid method of supplementing natural steelhead production, (2) greatest returns of sea-run hatchery steelhead are obtained by stocking yearlings larger than 10 to the pound below the general trout fishing area, (3) on a poundage basis the cost of putting a sea-run hatchery steelhead in the run is not far above the cost of producing and planting "catchable" rainbow trout, (4) the value of each steelhead to a fisherman is almost five times greater than the cost of putting one in his creel by hatchery methods, (5) the Sacramento River steelhead sport fishery is of considerable importance, and the management plan for the fishery should be evaluated periodically to insure the best possible fishing.

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