DIVISION OF FISH AND GAME OF CALIFORNIA
FISH BULLETIN NO. 17
Sacramento-San Joaquin Salmon (Oncorhynchus tschawytscha) Fishery of California

BY

G. H. CLARK

BUREAU OF COMMERCIAL FISHERIES

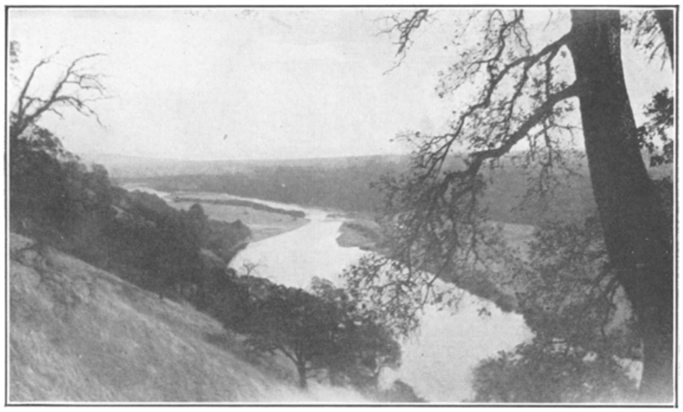

FIG. 1. American River east of Sacramento looking toward Folsom, California.

FIG. 1. American River east of Sacramento looking toward Folsom, California

CONTENTS

1. INTRODUCTION

1.1. Problem

This investigation under the authority of the Bureau of Commercial Fisheries, Division of Fish and Game of California, was started in the fall of 1927. The paper, while all on the general subject of Sacramento salmon, is in three parts, each of which is a separate problem.

The first part, "Historical and Statistical Review of the Sacramento-San Joaquin Salmon Fishery," takes into consideration the early investigations, history, and statistics of the fishery, artificial propagation, legislation, water supply, prices, and the causes of depletion, with suggested remedies.

The second problem, "Survey of Salmon Spawning Grounds in the Sacramento-San Joaquin River Systems," shows the available salmon spawning grounds in the systems as contrasted with the extent of the grounds in the early days. Each stream in the systems is taken up individually to show runs, spawning time and beds, obstructions to the fish, and abundance.

The last part is on the "Determination of the Age of Maturity of the Sacramento-San Joaquin Salmon (Oncorhynchus tschawytscha)," and deals with the methods of age determination, the age of maturity, and age classes in relation to sex and types.

1.2. Material

The historical and statistical data are taken from the Reports of the U. S. Commissioner of Fisheries, the Biennial Reports of the California Fish and Game Commission, Bulletins of the U. S. Bureau of Fisheries, and the California fish and game magazine. Water supply statistics are from the U. S. Geological Survey, San Francisco. The price figures are from the fish dealers and the Sacramento fishermen's union at Pittsburg.

Material for the survey of spawning grounds was gathered almost entirely from observation done in the field. Some of the data on the abundance are taken from the various publications mentioned above. Data on development of power and irrigation projects are from various technical journals devoted to that field.

The material used in the age determination is a collection of scale samples, salmon fry, and fingerlings which the Division of Fish and Game of California has on hand.

1.3. Acknowledgments

The writer wishes to acknowledge his indebtedness to Prof. J. O. Snyder of Stanford University, whose guidance and advice have been of great help in carrying on this work; Dr. W. H. Rich and Mr. H. B. Holmes of the U. S. Bureau of Fisheries, and Mr. N. B. Scofield and Mr. W. L. Scofield of the Division of Fish and Game of California, who have all freely given helpful suggestions and criticisms from time to time during the course of the work. To the fish dealers of Pittsburg and the Sacramento fishermen's union, the writer is indebted for price records and many valuable data. The writer is indebted to the Pacific Gas and Electric Company for the privileges granted him at their dams on the Pit River.

2. PART I
HISTORICAL AND STATISTICAL REVIEW OF THE SACRAMENTO-SAN JOAQUIN SALMON FISHERY

This paper has been prepared with the purpose of working up the historical and statistical side of the salmon fishery of the Sacramento and San Joaquin rivers. It is well known that the salmon fisheries of these rivers, as well as of the entire state, are greatly depleted. It has been the intention of this paper to bring to light some of the causes of depletion. The various phases that have a bearing on the fishery are discussed and a complete review of the fishery is attempted.

2.1. Review of salmon investigations

Girard (1858) mentions the Sacramento River salmon in the "Pacific Railroad Survey" under "Fishes, IV," and Suckley (1858) goes more into detail in a description of the species in the same general report under the heading of "Report of the Fishes of Pacific Railroad Survey."

Stone (1872–73), who established the first salmon hatchery on the coast, leaves us some very valuable information on the early conditions in the river, and on the salmon runs and migrations. Contributions to the natural history of the Pacific salmon and its habits and to the early fishing methods and practices, as well as articles on artificial propagation, are some of the valued reports lefty by Stone.

In 1880–81, the U. S. Commission made a complete survey of the fish and fisheries industries of the United States. This investigation was carried on by Goode (1880–81) as general director. Jordan and Gilbert did the work on the Pacific coast. The two aspects of the survey were: Section I, "History of Aquatic Animals," and Section IV, "History and Methods of Fishery." In the first section, Jordan, with notes by Livingston Stone, describes the various species of salmon of the Pacific, giving something of their life history, distribution and habits. In Section IV, Jordan and Gilbert give an account of the salmon fishing and canning industries on the Sacramento River. A great deal of our early information as to the number of fishermen, their gear and their value, and the catch and pack records of that time come from this report.

Scofield (1900) in two reports records his observations on the movements of salmon fry in the coastal streams of Marin County and of the movements in down-stream migration in the Sacramento River. In this latter report the rate of growth of the migrating fingerling salmon is obtained.

Rutter (1902) completed an investigation of the natural history of the salmon started by Scofield in 1897. Extremely valuable and lasting results were contributed by Rutter and Scofield on the salmon of the Sacramento River.

In another report Rutter (1904) gives his views of the artificial propagation of salmon on the Sacramento River and tells why he upholds them. There is an addenda to this report by the California Commission which supports Rutter and adds a few facts to the report.

Gilbert, assisted by Scofield (1913), started an investigation on the Sacramento River. Marking experiments with young salmon were carried on. Unfortunately few results came of this experiment. The overflow basins of the Sacramento River, it was discovered, were destroying large numbers of fish. The results of this investigation were reported by Scofield.

Scofield (1913) in another report gives his observations on young salmon and steelhead trout, which he towed from Sacramento to the sea in a live car.

Rich (1920) reports an investigation of "The Early History and Seaward Migration of Chinook Salmon in the Columbia and Sacramento Rivers."

The salmon investigation work for the Division of Fish and Game of California is now in charge of Snyder. Snyder (1920) has been carrying on the investigation since 1917 in the several rivers of California and in the ocean. Very little work has been done on the Sacramento River. The Klamath River has been the main source of investigation, together with the landing points for ocean fishing such as Monterey, Fort Bragg and Eureka.

McGregor (1922) conducted an investigation for the Division of Fish and Game at the Redding Dam, working under Snyder's direction in connection with a law suit against the Anderson-Cottonwood Irrigation Company, whose dam was obstructing the spawning migration of salmon.

McGregor (1923) also made a study of "The Anatomical Characters of Chinook Salmon of the Sacramento and Klamath Rivers" to find a possible separation of river races in ocean-caught fish.

The results of the several marking experiments carried on by the Division of Fish and Game under Snyder's direction have been extremely beneficial. Snyder (1923) has shown that the range of salmon from a given river is much greater than was supposed. For instance, the marked fish of the Klamath River range as far south as Monterey. From the returned marked fish, it has been possible to check the age reading by means of fish scales. The early history of the salmon is also shown by scale readings. Numerous other facts of great value have been brought to light in this investigation.

2.2. Sacramento-San Joaquin salmon fishery

The first commercial salmon fishing of which we know occurred about 1850, but at that date no definite records were kept. We know there was commercial fishing by means of gill nets and seines in the Sacramento and San Joaquin rivers and in parts of Suisun and San Pablo bays at that time. The salmon were reported to be very plentiful prior to the discovery of gold in California. The Indians and Spanish colonists took what salmon they might need for food and allowed the rest to continue their natural life.

As early as 1864 we are able to find partial records of the catch in the rivers. In that year G. W. and William Hume and Andrews S. Hapgood started the fist salmon cannery on the Pacific coast at Washington, in Yolo County, on the banks of the Sacramento River. The rise of salmon canning is a story in itself. The industry grew by leaps and bounds until in 1881 there were twenty canneries operating along

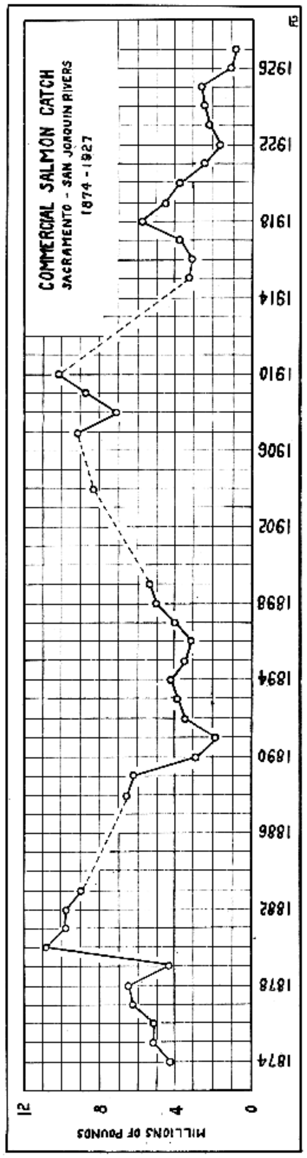
COMMERCIAL SALMON CATCH
SACRAMENTO - SAN JOAQUIN RIVERS
1874 - 1927
MILLIONS OF POUNDS
12
8
4
0
1874
1878
1882
1886
1890
1894
1898
1902
1906
1910
1914
1918
1922
1926

FIG. 2

FIG. 2

the river and bay. (See Table I in Appendix.) The number of cases packed gives us some measure of the catch. However, the pack is only a part of the catch, as a great many pounds were sold fresh each year to the local markets, and some salted fish to foreign trade. The canning industry, after it reached its peak in 1882, began a gradual decline with a slight revival in 1902 to 1906. After 1906 the canning of salmon on the Sacramento amounted to very little. In 1919 it was discontinued. (See Table I in Appendix.)

In 1874 we are able to get the total catch records. These records include the total salmon catch of the Sacramento-San Joaquin rivers, including those canned and sold fresh. The figures are complete from 1874 to 1915, with the exception of a few missing years.[1] (See Table II in Appendix.) From 1915 to the present time (1928) the total catch data are complete and reliable.[2] (See Fig. 3.)

Beginning in 1874 the fishing began to increase year by year, reaching a maximum for the early years in 1880. The fishery held its own

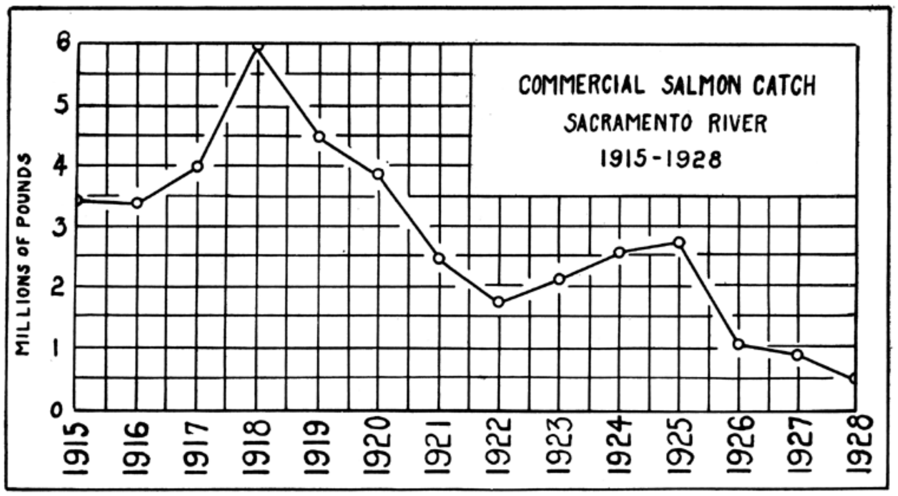

FIG. 3.

FIG. 3

quite well until 1889 when it dropped to a low level which continued until 1892. In 1898 the catch began a steady upward climb until 1907. In 1908 the catch dropped down some but reached a very high level in 1910. Since 1910 there was another sudden drop to 1915–1916, with a slight revival of the catch in 1918 during the war. From 1918 the catch dropped faster than ever until 1922, when it reached its lowest figure in the fishery's history. The fishing increased somewhat during the next three years, but in 1926 and 1927 dropped far below the former low catches. (See Fig. 3, and Table II in Appendix.)

The early methods of fishing and the fishing gear used were not unlike those used at the present time. The Indians, of course, caught their fish by means of spears, traps made of sticks, and handmade nets. Some of the early settlers in California brought gill nets and seines with them; others made nets after their arrival. Pounds, traps, weirs,

[1] Collected by government agents and recorded in the Reports of the U. S. Commissioner of Fisheries for the years 1872 to 1915.

[2] From issues of *California Fish and Game* for the years 1915 to 1927.

etc., were constructed in the river to capture fish, but the State Legislature prohibited these after 1881.

The prevailing method of capture was with a drift gill net. These nets were then about the same size mesh and length as they are now. Most of the fishermen used nets of 7½-inch mesh or over. These nets were about 300 fathoms long and 30 to 40 meshes deep. Such a gill net was operated by two men, one man to lay out the net and the other to row or sail the boat. After the net was laid out in the water, the fishermen would grasp one end of it and drift down the stream. At intervals the fishermen went along the net and picked out the salmon. When the net and boat had drifted the length of a particular fishing ground or "drift," the fishermen "picked up" the net and went to some other place to try for more salmon. The use of gill nets has changed but little since the early days. The methods of fishing now are the same, although regulations as to size of mesh and restriction of fishing grounds have been passed.

TABLE III

Comparative Table. Salmon Fishing Industry of the Sacramento and San Joaquin Rivers

Items	1872	1880	1889	1899	1909	1916	1924	1927
Number of fishermen	200	500	796	907	1,490	990	748	574
Number of boats	100	230	467	459	842	525	435	307
Number of gill nets	100	200	474	478	750	495	430	307
Number of seines	10	---	24	20	26	25	---	---
Salmon catch in lbs.	4,000,000	10,000,000	6,471,000	6,458,000	8,796,000	3,450,000	2,640,000	917,000

TABLE III

Comparative Table. Salmon Fishing Industry of the Sacramento and San Joaquin Rivers

Gill nets were most commonly used (see Table III); however, a few hand-haul seines were utilized in the upper river where there are what is known as seining bars. The haul seines were operated by several men. A rowboat was used to lay out the net, and the fishermen would haul the two ends of the net onto the beach or bar, sweeping everything in that part of the river into the net and onto the bar. These seines varied in length, depending on the size of the river where the net was being used. The use of seines has changed but little since the early days; however, a law was passed in 1924 prohibiting the use of seines for salmon.

The fishermen in the early history of salmon fishing used sail and rowboats and some fishermen, in addition to these, had large scows or houseboats on which they and their families lived. These scows could be anchored to the bank or moved at any time to follow the run of fish.

The sail and rowboats have undergone a gradual change and in the later years an increasing number of gasboats has taken the place of the sailboats. The power boats enable the fishermen to get from place to place much faster and increase the range of fishing.

The ocean trolling for salmon developed in Monterey as early as 1893, and came into prominence in the rest of California about 1914. Since 1914 this sea fishing has made rapid advances and has produced a larger catch of salmon for each year from 1916–1917 than any river fishing in California. (See Fig. 4.) The troll fish are both mature and immature, while the river-caught fish are all mature. In the river the fish that escape the nets will go up the river to spawn. On the other hand a great many of the salmon taken in the ocean are immature. The immature fish taken early in their lives, of course, will never get an opportunity to go up the streams and spawn. Consequently a great number of spawners are cut off in early life. Since the ocean trolling has become such a large fishery the Sacramento River catch has fallen off. (See Fig. 4.) It is shown that the Sacramento River fishery is depleted and part of the depletion is caused by ocean fishing for salmon. (See Figs. 2 and 4.) Evidence points towards the destructiveness of ocean trolling in that the immature fish are taken, so that it helps to deplete the river fisheries.

The status of the salmon fishery as a whole is very uncertain. The catch in California has fallen off very rapidly in the last few years

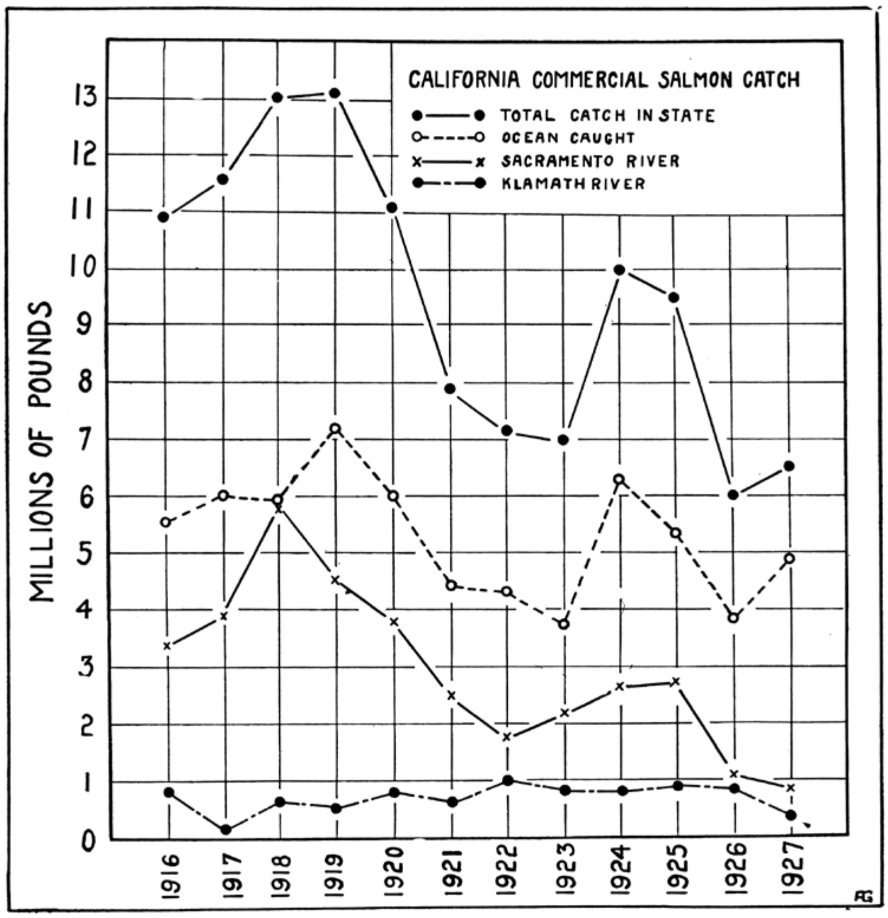

FIG. 4.

FIG. 4

(see Fig. 4) and will doubtless continue to decrease in the years to come.

The catch has fallen off in all localities except the ocean trolling districts and the Klamath River, but in these two places the effort put forth to catch the salmon has about doubled in the last eight years. (See Fig. 4.) These data are presented in graph form. (See Fig. 4.)

CORRECTIONS—**TABLE IV**

1916	Outside Salmon:	5,592,081	instead of	5,502,171
1922	Outside Salmon:	4,338,317	instead of	4,388,317
1926	Outside Salmon:	3,863,677	instead of	3,861,677
1920	Klamath River:	872,295	instead of	870,767
1926	Klamath River:	811,714	instead of	813,714

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CORRECTIONS—TABLE IV

TABLE IV

Table of Catch Figures of Salmon for Comparison of River and Ocean-caught Fish

Year	Total in state	Outside salmon	Sacramento River	Klamath River
1916	10,939,594	5,502,171	3,450,786	801,150
1917	11,060,581	6,083,991	3,795,486	265,537
1918	13,093,188	5,932,281	5,938,029	672,345
1919	13,145,727	7,208,372	4,529,222	535,198
1920	11,133,819	6,066,190	3,860,312	870,767
1921	7,990,932	4,483,100	2,511,127	614,247
1922	7,235,124	4,388,317	1,705,066	1,039,580
1923	7,090,260	3,736,924	2,243,945	824,291
1924	10,015,269	6,374,573	2,640,110	814,572
1925	9,525,753	5,481,537	2,778,846	956,082
1926	6,084,079	3,861,677	1,261,776	813,714
1927	6,511,929	4,921,600	917,525	408,081

TABLE IV

Table of Catch Figures of Salmon for Comparison of River and Ocean-caught Fish

The total catch of salmon has a very distinct and steep downward trend. The troll or ocean-caught fish have a very slight declining trend, making the curve appear almost level. The Sacramento River curve has a downward trend that is equal to that of the total catch. The Klamath River curve has a very even and constant trend, particularly on such a graph, because of the large scale used. However, it is evident from work done by Snyder that although the catch has remained fairly constant, the effort (number of fishermen, in this case) has increased many fold without an increase in catch. From the appearance of these curves supported by additional information from egg takes and fishing effort, it seems beyond a doubt that the salmon fishery is badly depleted.

2.3. Artificial propagation

Artificial propagation of salmon on the Sacramento River dates as far back as 1872. In that year Livingston Stone, an able fish culturist of the U. S. Commission of Fish and Fisheries, came to the western coast to locate a suitable place to erect a salmon hatchery. Salmon at that time were very numerous in the Sacramento River, and after making a survey of the streams of the Sacramento Basin, he selected a site on the McCloud River, a tributary to the Pit River, about a mile and a half from its mouth. Here the first salmon hatchery of the western coast was located and operations began in 1872.

The primary object of this station was to obtain eggs to be sent to eastern states for their introduction there as food fish. However, in almost every instance the attempts to introduce the Pacific salmon into eastern streams were failures. Several attempts were made to transport eggs to France and Germany and also to New Zealand. In all cases, except New Zealand, the salmon from California have not been able to survive. During the years 1872 to 1883 the greater part of the take of 69,069,525 eggs was sent out of California to eastern states and foreign waters, and very few were used to stock the native streams. (See Table VI in Appendix.) Hugh C. Mitchell, for a time connected with the Baird Station on the McCloud River, has said, "The McCloud River was systematically robbed of its salmon eggs." In 1884 the station had to be closed because of the scarcity of salmon and because of the railroad work being done along the Sacramento River. The station was reopened in 1888.

In 1885 the State of California, realizing the need of restocking the streams and tributaries of the Sacramento River, erected a state hatchery on Hat Creek, a tributary of Pit River. However, the location proved to be unsuitable, so the site was abandoned and a hatchery put up at Sisson on Spring Creek, a tributary to the Little Sacramento River, at the base of Mt. Shasta. Through an arrangement with the U. S. Bureau of Fisheries, the Mt. Shasta Hatchery (Sisson) was to

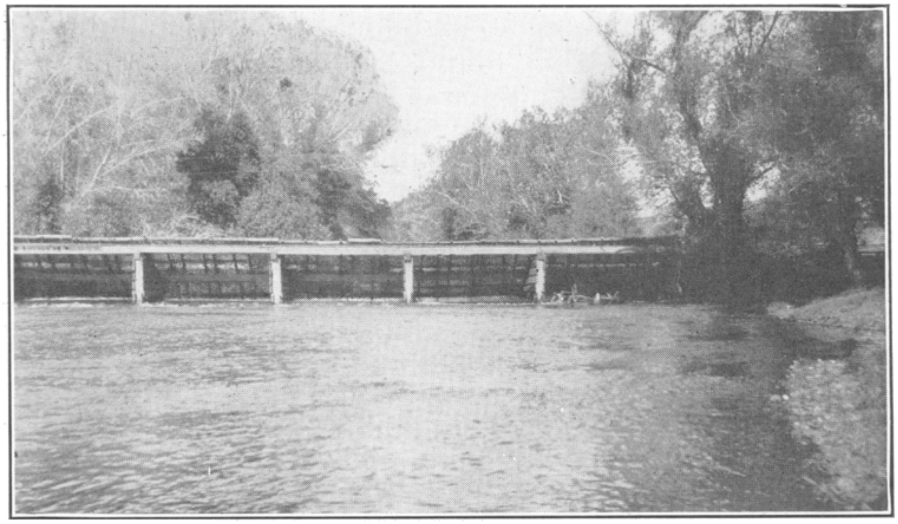

FIG. 5. Racks at the U. S. Bureau of Fisheries Station on Battle Creek. 1923. Photo by J. O. Snyder.

FIG. 5. Racks at the U. S. Bureau of Fisheries Station on Battle Creek. 1923. Photo by J. O. Snyder

receive eyed eggs from the Baird Hatchery, for which the state paid per thousand. The greater portion of the eggs received by the state and hatched at Mt. Shasta was planted in the Sacramento River, although some were sent to other streams in California. (See Table VI in Appendix.)

From 1888 very few fish were shipped out of the state. During the years 1888 to 1910 only 26,594,000 eggs were sent out of California by the U. S. Bureau of Fisheries stations, and the remainder were planted in state waters.

About this time (1888) the policy of holding the salmon fry and feeding them at the hatchery until they were large enough to take care of themselves, was started at the Mt. Shasta Hatchery. Some of the young were held and fed until late spring, then liberated. Others were held in rearing ponds until fall and liberated before the winter floods. This policy of holding and feeding the fry was undoubtedly an improvement over the old method of planting the fry when they had hardly absorbed the yolk sacs. In the earlier days even eyed eggs were dumped directly into the river when the hatchery space was crowded. (See Table VI in Appendix.)

In 1895 the state erected a spawn-taking station and small hatchery on Battle Creek in Tehama County. The next year the U. S. Bureau of Fisheries took over the Battle Creek Hatchery and built another with a capacity of 18,000,000 eggs. In return for the use of the land the U. S.

Bureau of Fisheries was to furnish enough eggs to the state to supply the Mt. Shasta Hatchery. "Arrangements were made to operate the station to its fullest capacity."[3] Everyone was beginning to realize that something must be done to save the salmon in the Sacramento River.

Great quantities of eggs were taken at Battle Creek, reaching such numbers as few people had even dreamed. There were one or two poor years, but most of the time the production was tremendous, reaching as high as 48,000,000 and 50,000,000 eggs for one year. (See Fig. 6.)

In order to take care of these large amounts of eggs a new hatchery was put up at Baird with a capacity for 20,000,000 eggs.

In the year 1901 the U. S. Bureau of Fisheries established a hatchery and egg-taking station for salmon on Mill Creek, a stream noted for its large run of salmon. This stream empties into the Sacramento on the east side, about a mile above the town of Tehama. The hatchery constructed there had a capacity of 10,000,000 eggs. A great many of the eggs were kept there until they reached the eyed stage, and then sent to other hatcheries.

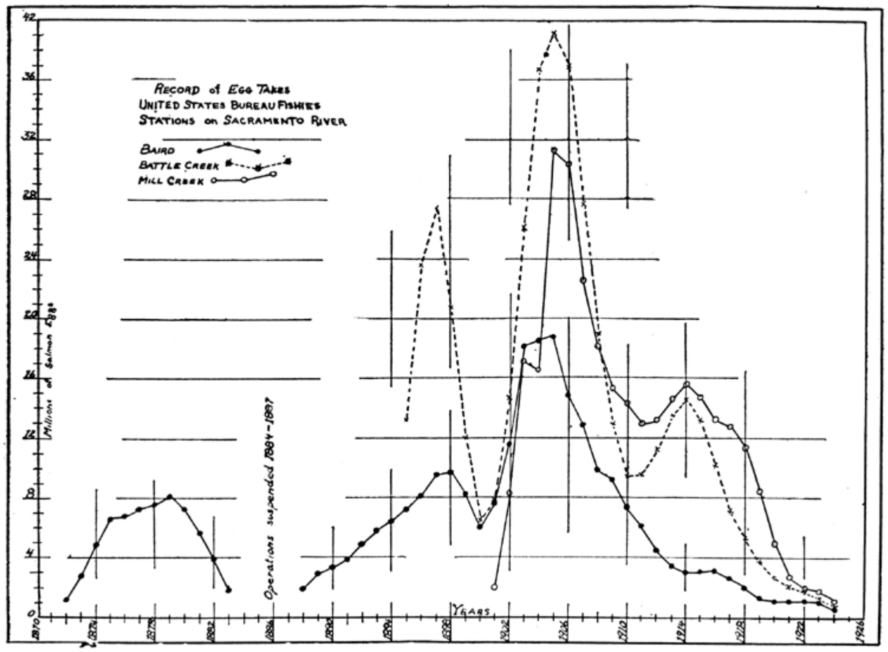

FIG. 6. Record of egg takes of salmon at stations on the Sacramento River operated by U. S. Bureau of Fisheries. Curves smoothed by 3's twice.

FIG. 6. Record of egg takes of salmon at stations on the Sacramento River operated by U. S. Bureau of Fisheries. Curves smoothed by 3's twice

At Baird both the spring and summer or fall runs were used in obtaining eggs. However, at Battle Creek and Mill Creek the weather was found to be too warm to hold the spring run; consequently only the fall runs were used at these two stations.

The three U. S. Bureau hatcheries had been doing their utmost to procure as many eggs as possible, and the station at Mt. Shasta had

[3] Report of the U. S. Commissioner of Fish and Fisheries for 1897, p. lxvii.

been hatching the greater amount of this egg-take and liberating them into the Sacramento River and its tributaries, as well as distributing millions of them over the state. By these intense activities a great many millions of salmon were being utilized in stocking the streams of California each year. (See Tables V, VI, VII in Appendix.) In 1905, 111,000,000 eggs were taken from Sacramento salmon, and most of them

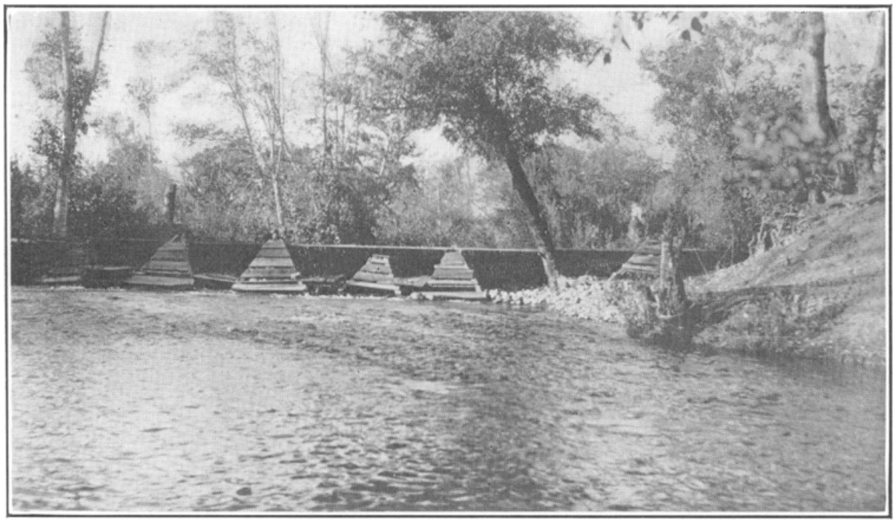

FIG. 7. Upper racks of pool at Mill Creek, U. S. Bureau of Fisheries Station. 1923. Photo by J. O. Snyder.

FIG. 7. Upper racks of pool at Mill Creek, U. S. Bureau of Fisheries Station. 1923. Photo by J. O. Snyder

were planted back into the Sacramento and its numerous tributaries. (See Fig. 6.)

Unfortunately the practice of holding and feeding the young salmon until spring and fall was discontinued in 1896, and was not taken up until 1911 when the state revived the practice, at which time this method was carried on extensively at the Mt. Shasta Hatchery.

The year 1905 was the high peak of the Sacramento River salmon egg production. From that time the stations have declined very rapidly in the number of eggs taken each year. The stations at Battle Creek and Mill Creek showed a sudden increase in 1914, 1915 and 1916, possibly due to the revival of pond holding in 1911. After 1915 all stations have been on a gradual decline in the number of eggs taken, until in 1925 the combined production of the three U. S. Bureau of Fisheries stations was only about 5,000,000 eggs a year.

The egg-take figures from the Bureau of Fisheries stations since 1924 are not available at the present time, but the three combined stations still take about 4,000,000 or 5,000,000 eggs each year. In recent years, the state has planted the surplus salmon from the Klamath River into the Sacramento. The eggs from the Klamath were hatched at Mt. Shasta Hatchery and the fingerlings were planted in the tributaries of the Little Sacramento River.

Following is a table of the plants made from eggs taken in the Klamath River:

TABLE VIII

Klamath Chinook Salmon Planted in the Sacramento River *

1926	11,248,000
1925	3,082,000
1924	3,021,000
1923	12,129,000
1922	12,311,000
1921	5,690,000
1920	5,270,000

TABLE VIII

Klamath Chinook Salmon Planted in the Sacramento River

Despite the state's and the U. S. Bureau's efforts to build up the run of salmon, the catches in the river still decrease. (See Fig 3.) Since 1920, when the first plants from the Klamath were made, there has been no noticeable increase, except that the catch for the years 1924–25 was somewhat better than for 1921–22. Since 1925 the catch has again decreased. The fishery seems to be at a point where it will require a great deal of concentrated effort on the part of the people of the state to protect it and if possible to build it up.

2.4. Salmon legislation

Laws pertaining to salmon fishing in the Sacramento and San Joaquin fishing districts were among the first passed under the California Fish and Game Commission. The Commission was established in 1870, at which time a few laws were passed that did something towards the protection of salmon. The law providing for a closed

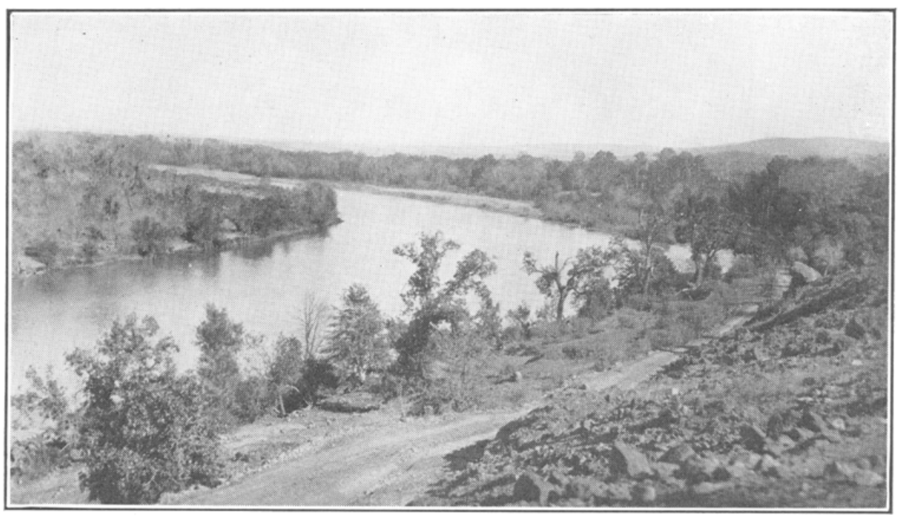

FIG. 8. Sacramento River near the mouth of Battle Creek. 1923. Photo by J. O. Snyder.

FIG. 8. Sacramento River near the mouth of Battle Creek. 1923. Photo by J. O. Snyder

season to all nets on trout and salmon trout in the state for the period from January first to June first of each year, protected the young from being destroyed on their down-stream migrations.

In 1871–72 a law was passed which forbade net fishing in Siskiyou County between August first and November first, thus giving some protection to spawning salmon and trout.

During the year 1873–79 no laws pertaining to salmon were enacted.

In 1880 a law was passed compelling the construction of fishways, and also a law which prohibited aliens from fishing in the waters of California.

In 1881–82 a closed season on salmon prohibited fishing between July thirty-first and September first. The use of pounds, traps, set nets and weirs was prohibited in capturing fish. No net fishing was allowed between Saturday at sunrise and noon on Sunday.

In 1883 the smallest size mesh for salmon nets was set at 7½ inches. The above laws of 1881–82–83 continued in effect until 1887.

In 1887 the closed season on salmon was made from August thirty-first to October first of each year. The Saturday-Sunday law was extended from sunrise Saturday until sunset Sunday. The smallest legal mesh for salmon remained 7½ inches.

These laws of 1887 were in effect until 1895–96, at which time the closed season was extended from August thirty-first to November first of each year. The Saturday-Sunday law has not been changed up to the present time (1928). The 7½-inch mesh was not changed until 1909.

In 1897 the closed season was changed to the period extending from September tenth to October sixteenth, and in addition was closed above tide water from October fifteenth to November fifteenth of each year. Tide water for the Sacramento River was defined as running from the river's mouth to Sacramento city. The tide water on the San Joaquin ran from the river's mouth to the Southern Pacific Railroad bridge near Lathrop.

The above laws were in force until 1907, when the closed season was changed somewhat to extend from September seventeenth to October twenty-third and further closed season, in tidewater only, extended from October twenty-third to November fifteenth.

This law continued until 1913 without change except in 1909 when the size mesh was lowered to 6½ inches. In 1911 the tidewaters of the Sacramento and the San Joaquin rivers were defined as extending only to where the rivers came into Suisun Bay.

In 1913 the state was divided into fish and game districts, and more districts have since been added as the need arose. (See Abstract of Fish and Game Laws, 1913–15, 1927–29.) Heretofore in this review of legislation the salmon laws have referred to the whole state. From here on the legislative changes will refer only to the districts where the salmon net fishery is carried on in the Sacramento, San Joaquin and bay regions.

In 1913 the closed season on salmon extended from September twentieth to November fifteenth of each year for all methods of capture except hook and line. The mesh size for nets was still 6½ inches. A law was passed prohibiting the sale of any chinook salmon under five pounds in weight.

These laws were continued until 1916 when the closed season was from September twenty-fifth to November fourteenth. The mesh size was decreased from 6½ inches to 5½ inches, at which size it has remained

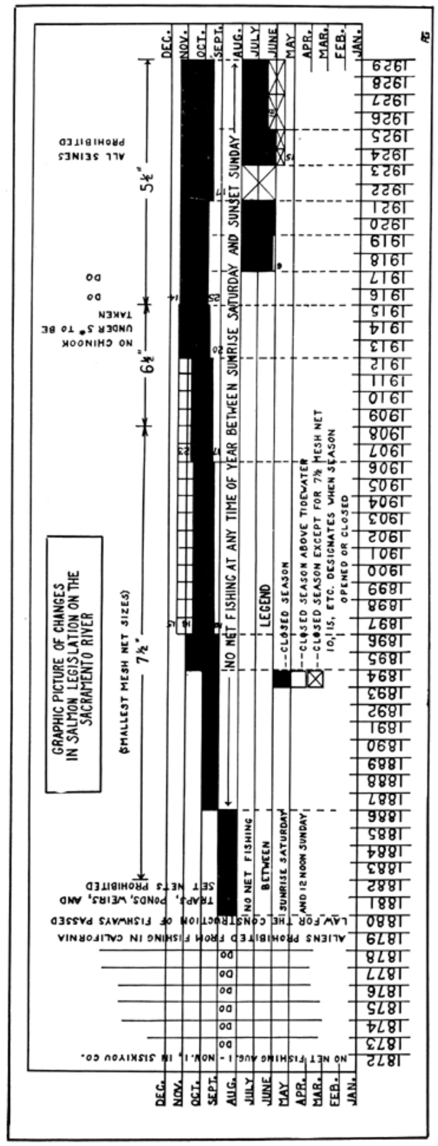
GRAPHIC PICTURE OF CHANGES IN SALMON LEGISLATION ON THE SACRAMENTO RIVER
LEGEND
NO NET FISHING AT ANY TIME OF YEAR BETWEEN SUNRISE SATURDAY AND SUNSET SUNDAY
(SMALLEST MESH NET SIZES)
ALL SEINES PROHIBITED
ALIENS PROHIBITED FROM FISHING IN CALIFORNIA
LAW FOR THE CONSTRUCTION OF FISHWAYS PASSED
SET NETS PROHIBITED
NO CHINOOK UNDER 5# TO BE TAKEN

FIG. 9.

FIG. 9

to the present. The law prohibiting the sale of chinook salmon under five pounds was in effect with the above law during 1916–17.

In 1918–19 there were two closed seasons with an open season intervening. The first closed season extended from June sixth to July thirty-first, the second from September twenty-fifth to November fourteenth. The law of "No sale of chinook salmon under five pounds" was repealed.

In 1920–21 the closed seasons were changed again. The first season extended from June first to July thirty-first, the second from September twenty-fifth to November fourteenth.

In 1922–23 another change was tried. The period from June first to July thirty-first was closed, except for fishermen using 7½ inch mesh nets. From September seventeenth to November fourteenth, the season was closed to all fishing.

In 1924–25 a period for fishing only with 7½ inch mesh nets was made from May sixteenth to May thirty-first. The closed periods were from June first to July thirty-first and from September seventeenth to November fourteenth. The use of beach seines for salmon fishing was prohibited.

In 1926–27 the seasons were changed once more. The period from May sixteenth to June fifteenth was for 7½ inch mesh nets only. From June sixteenth to July thirty-first and from September seventeenth to November fourteenth the season was closed to all fishing. The above law was continued without change for 1928–29. (See Fig. 9 for graphic picture of changes.)

There have been frequent extensions of the closed period on salmon fishing throughout the years. From 1872 to 1881 there was no closed season. From 1881 to 1887 the month of August as well as every Saturday was closed to fishing. From 1887 to 1895 the closed season was changed to September. From 1895 to 1897 both August and September were closed. From 1897 to 1907 the closed season extended from September tenth to October sixteenth, and from October sixteenth to November fifteenth except in tidewater. From 1907 to 1913 the closed season was changed slightly. It extended from September seventeenth to October twenty-third, and from October twenty-third to November fifteenth except in tidewater. From 1913 to 1916 the closed period was from September twentieth to November fifteenth. From 1916 to 1918 the closed season extended from September twenty-fifth to November fourteenth. From 1918 to 1920 there were two closed periods, one extended from June sixth to July thirty-first; the other from September twenty-fifth to November fourteenth. From 1920 to 1922 the spring closed season was during June and July, the fall period remaining the same. From 1922 to 1924, June and July were closed except for 7½ inch mesh nets and the season was entirely closed from September seventeenth to November fourteenth. From 1924 to 1926 the season was closed from May fifteenth to June first except for 7½ inch mesh nets. From June first to July thirty-first the season was entirely closed, and from September seventeenth to November fourteenth it was also closed. From 1926 to 1929 the closed season extends from May fifteenth to June sixteenth except for 7½ inch mesh nets, and is completely closed from June sixteenth to August first and from September seventeenth to November fourteenth.

Since 1887 fishing has been prohibited from sunrise Saturday to sunset Sunday. From 1883 to 1908 the minimum mesh size that could be used was 7 ½ inches. From 1909 to 1915 the size was lowered to 6 ½ inches because of the striped bass fishery[4] and again in 1916 to 1929 the size was lowered to 5 ½ inch mesh because of the striped bass fishermen. From 1913 to 1918 salmon under five pounds could not be sold. In 1924 the use of seines on the Sacramento River was prohibited. The graph of the changes shows an ever increasing tightening of the law. It is a recognition of the decreasing supply of salmon.

2.5. Water supply and catch

The influence of high or low water on the salmon catch appears to have some significance. The mean yearly discharge of the Sacramento and San Joaquin rivers (see Table IX) from 1919 to and including 1927 will show us, when compared to the total catch curve for the

TABLE IX

Water Supply. Sacramento and San Joaquin Rivers

	Yearly mean discharge in second-feet		
Year	*San Joaquin River**	*Sacramento River***	*Combined rivers*
1919	188	4,827	2,507
1920	1,495	8,306	4,900
1921	2,394	12,765	7,579
1922	5,072	9,034	7,053
1923	2,529	6,261	4,395
1924	284	4,927	2,605
1925	1,605	10,590	6,092
1926	1,091	9,457	5,274
1927	3,107	11,894	7,500

TABLE IX

Water Supply. Sacramento and San Joaquin Rivers

rivers during that period (see Fig. 10), that there is an inverse correlation in most points. This shows that during high water conditions, the catch is usually small. Perhaps this may be explained by the fact that in high water the fish are diffused and have more area to travel and thus avoid the nets; while in low water the area is more limited and the salmon more concentrated in some particular channel, thus making their capture easier.

Besides this feature of the catch, the water supply will affect the spawning beds. Low water will make it difficult for the salmon to reach the beds and in some cases it will cause the beds to be cut off entirely. On the other hand, high water helps the salmon in its migration and increases the beds.

2.6. Prices and salmon catch

The price of salmon (per pound live weight to the fishermen) generally seems to have no bearing on the fishery. However, the price depends on the amount that the fishery supplies. In the case of salmon, there is always a demand, so the supply is the controlling factor of the price. The demand does not increase the supply because the

[4] In order that the right commercial sizes of striped bass would be taken, the minimum size mesh limit was placed at 6 ½ inches in 1909, and in 1916 to 5 ½ inches. This mesh limit enabled the fishermen to get striped bass and also salmon, although the majority of fishermen used a much larger mesh for salmon, usually 7 ½ to 10-inch mesh in order to get the heavier fish and to make their fishing more effective.

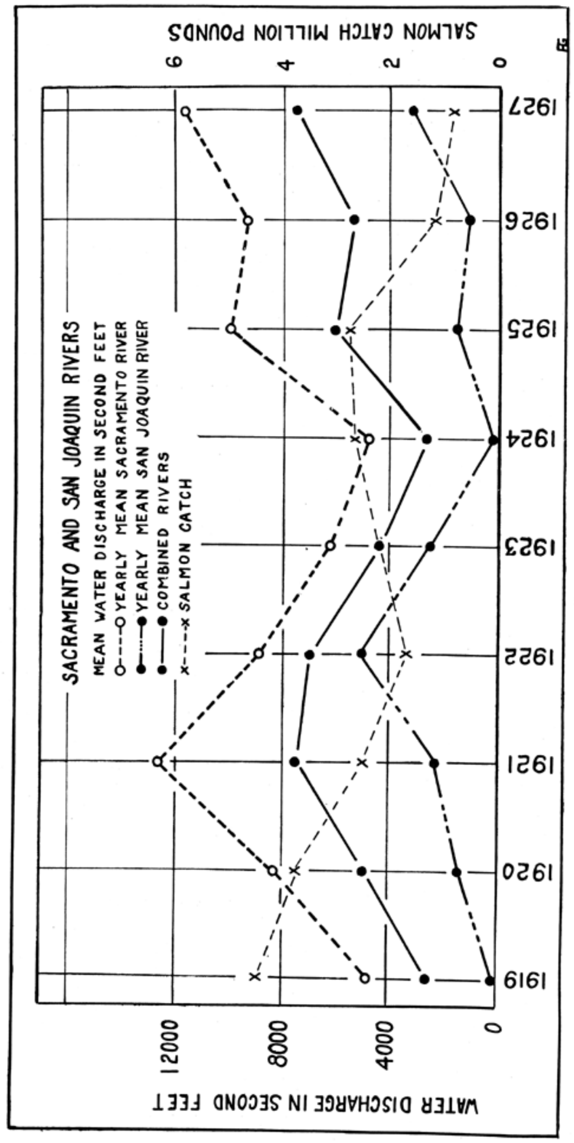
SACRAMENTO AND SAN JOAQUIN RIVERS
MEAN WATER DISCHARGE IN SECOND FEET
YEARLY MEAN SACRAMENTO RIVER
YEARLY MEAN SAN JOAQUIN RIVER
COMBINED RIVERS
SALMON CATCH
SALMON CATCH MILLION POUNDS
6
4
2
0
WATER DISCHARGE IN SECOND FEET
12000
8000
4000
0
1919
1920
1921
1922
1923
1924
1925
1926
1927

FIG. 10.

FIG. 10

fishery is being carried on to its capacity at all times in season. Table X gives the average yearly prices from 1920 to 1928 and the average

TABLE X

Salmon Prices. Sacramento and San Joaquin Rivers

Year	*Average yearly prices**	*Average prices from May 1 to Nov. 31***
1920	$0.17	$0.08½
1921	0.11	0.07
1922	0.15½	0.08
1923	0.16½	0.09½
1924	0.14½	0.07½
1925	0.15	0.08
1926	0.13½	0.10
1927	0.15½	0.10½
1928	0.15	0.11½

TABLE X

Salmon Prices. Sacramento and San Joaquin Rivers

prices from May first to November thirty-first (the time when the salmon are most abundant). The average yearly prices are influenced by the high prices during the winter months when salmon are scarce, the price during these months reaching as high as 20 cents a pound. Obviously, the weight of the winter months determines the average trend (see Fig 11), so the table and curve of the average price from May first to November thirty-first are the only ones of significance. (See Fig. 11.) These show an increase of prices for the years 1926, 1927 and 1928. The fishery controls the price and such evidence seems to point toward depletion.

2.7. Depletion

It is a foregone conclusion that the salmon fishery of the Sacramento-San Joaquin rivers is depleted. The facts brought forth in this paper prove and strengthen the case. The causes of this depletion and their corrections are now the important things.

The greatest single cause, and certainly the most important, is without doubt the extensive overfishing during the last fifteen or twenty years. (See Fig. 2.) The salmon fishery has been carried to the ocean without sufficient regulation or control.[5] The total amount of salmon caught increased tremendously after the ocean trolling came into prominence. The river catches have declined in about the same proportions. (See Fig. 4.) At present all the salmon fisheries in the state are on the decline. The ocean catch is the most steady because of the large area which it covers during various open seasons.

The curve of the egg-take (see Fig. 6) most certainly shows depletion of the salmon fishery. Whether artificial propagation of the salmon on the river, as claimed by some people, is one of the causes of this depletion is debatable. The fish culture work, considering its magnitude, should show better results. However, other contributing causes of depletion such as overfishing, dams, overflow basins, and fishes predatory on the young and eggs may have offset any good that artificial propagation has done. There is no evidence on either side conclusive enough to warrant making a definite statement as to the success or failure of artificial propagation.

[5] The Legislature passed laws to govern outside salmon trolling, portioning out districts along the coast and the open and closed seasons for the fishery. However, it has only been in recent years that the salmon trollers have been brought under the control of the laws passed to govern them.

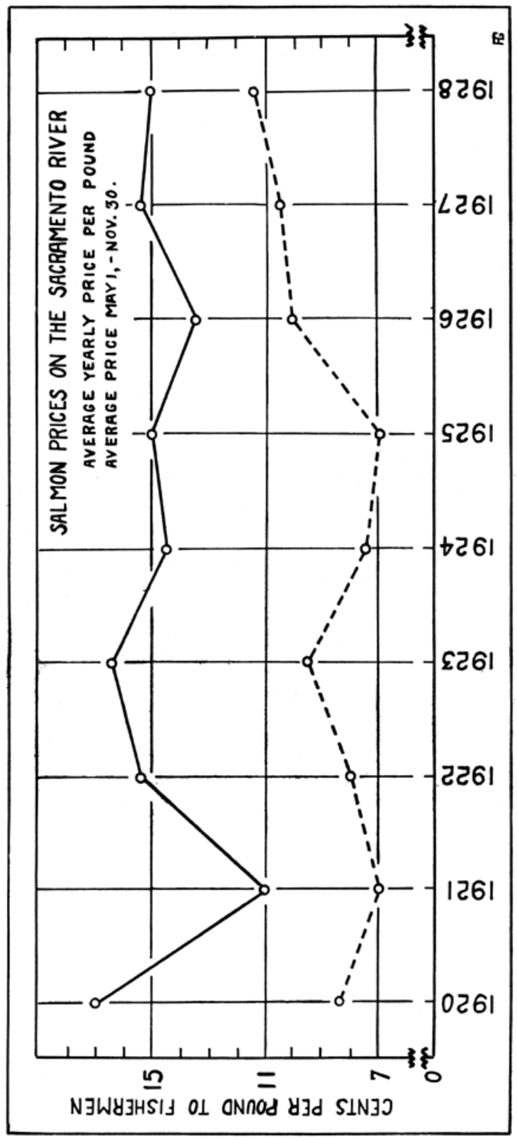

FIG. 11. The solid line indicates average yearly price per pound, and the broken line represents average price during the May 1 to November 30 portion of the fishing season.

FIG. 11. The solid line indicates average yearly price per pound, and the broken line represents average price during the May 1 to November 30 portion of the fishing season

The construction of dams throughout the two river systems has been a contributing factor to depletion. The cutting off of the spawning beds available to salmon has resulted in great losses. How great the damage is, can only be estimated. Part II of this bulletin takes up this subject more fully.

The great overflow basins (also taken up in Part II) that once flooded the Sacramento Valley for miles during the rainy and flood seasons and trapped the young fish, have now been reclaimed and by-passes constructed through them so that they now do very little harm.

The damage done by predatory fishes to the eggs and young of salmon can only be surmised. It is believed that the minnow, the so-called Sacramento Pike (Ptychoheilus grandis) eats young salmon[6] and salmon spawn. Very likely some of the near relatives[6] of Ptychocheilus that live in the same waters also do their share of damage.

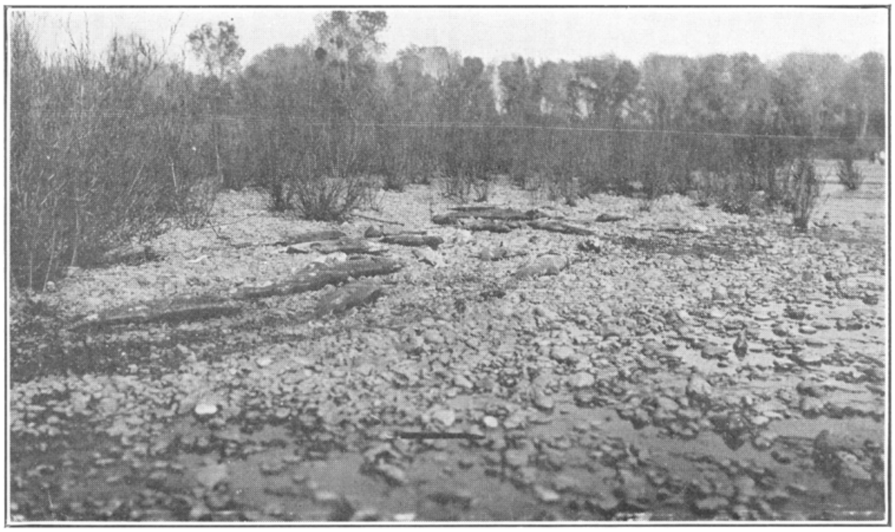

FIG. 12. Salmon left by fishermen who were spearing for food during spawning migration on Ruby Riffle below Sutter-Butte Dam, Feather River. 1925. Photo by A. J. Stanley.

FIG. 12. Salmon left by fishermen who were spearing for food during spawning migration on Ruby Riffle below Sutter-Butte Dam, Feather River. 1925. Photo by A. J. Stanley

There are other factors that have played a part in the depletion of our salmon but the damage done has not been estimated. Pollution of the river from the drainage of rice fields has been known to kill adult salmon. The spearing of spawning fish on the beds has also been a factor in depletion. Now the spawning fish are protected from this latter source of destruction.

There are at times natural conditions, over which we have no control, that will cause a drop in the catch of fish. However, such conditions are only active for one year or perhaps for two consecutive years. A very dry year, a very heavy rainfall, a disease among fish for a year, or any such conditions which would cause the fish to be less numerous, will affect the catch only for a year or two.

[6] Follett, W. I. A Note on the Squawfish and One of Its Relatives. *California Fish and Game*, Vol. 14, No. 4, pp. 282–285, 1928.

There are also artificial causes of an increase or decrease in the catch,[7] such as the price of fish or the general economic conditions. Such conditions boosted the catch of salmon during the war in 1918–19 and lowered the catch somewhat in 1921–22, during the slump after the war. But these things are not permanent and are of little consequence in the long run. Overfishing and more intensive effort in the fishery over a period of years may leave a permanent mark.

Several or all of the various factors enumerated above have been the causes of depletion of the Sacramento salmon fishery. No one factor can be placed as the sole cause. By eliminating the more important causes, the fishery would be materially helped. Overfishing, one of the principal causes, should be curbed and more stringent laws passed to control it, especially outside trolling.

[7] A decrease in catch is not the same as depletion. The catch is subject to extreme fluctuations caused by various agencies, such as price or fishing effort. The catch may decrease or increase and still a fishery may be depleted. It is only when the catch is measured and weighed by the unit of effort put forth for that catch that it will show the true condition of a fishery.

3. PART II
SURVEY OF SALMON SPAWNING GROUNDS OF SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

3.1. Introduction

The available spawning territory of a stream, of course, will control the number of salmon that may spawn in that stream. Assuming that the runs of the Sacramento and San Joaquin rivers are still at their height, the obstructions cut off the salmon from some of their spawning beds and may cause a decrease in the amount of salmon. The dams that have good fishways over them are not a hindrance to the upstream

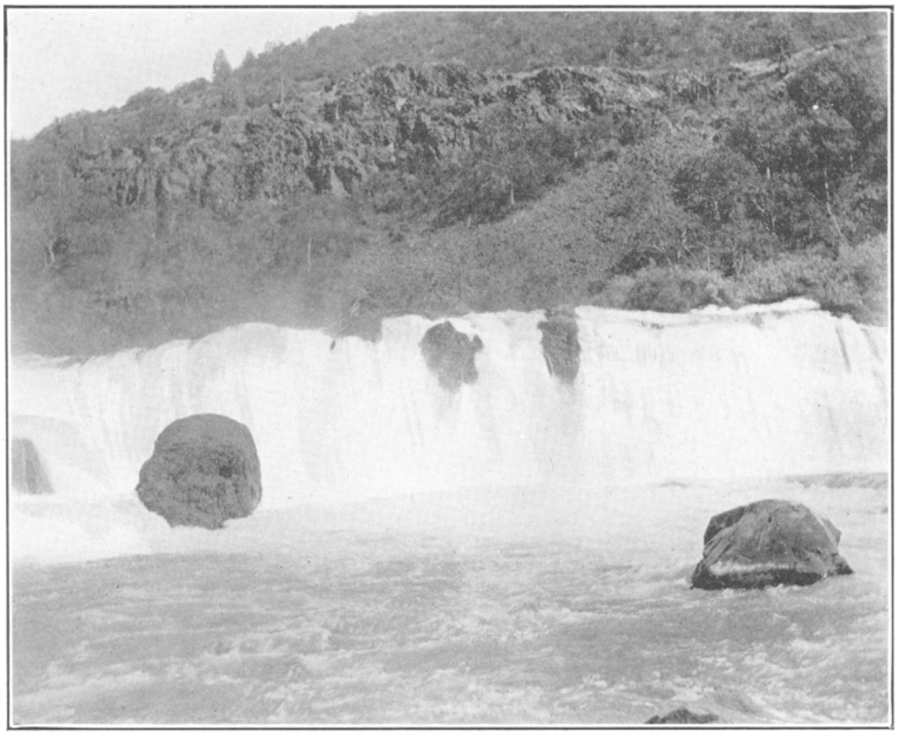

FIG. 13. View of the Pit River Falls. Photo by E. Schaeffle.

FIG. 13. View of the Pit River Falls. Photo by E. Schaeffle

migrations, but when the young salmon come down the next year they would be lost in the intakes of irrigation and power plant ditches, unless these instakes are adequately screened. Likewise the young will be injured or killed in going over a high dam. Some go through the turbines of the power houses and are destroyed.

This investigation conducted by the Division of Fish and Game of California has dealt with the problems concerning spawning grounds; obstructions, with their fish ladders and screens; the time of the salmon runs; and the abundance of salmon in the various salmon streams in the Sacramento and San Joaquin river systems.

3.2. Material

With the above problems in view, work was started in the early spring of 1928 and continued on through the summer and fall. Personal observation of each locality, as well as numerous interviews with the older inhabitants have been necessary in order to get information concerning the salmon runs and abundance. Old records and correspondence have revealed some measure of the abundance of salmon in different streams and of the conditions in the past. The numerous technical journals devoted to power and irrigation have been an aid to finding the history of these projects.

The survey of these two systems has revealed much information. A detailed account of each locality will be related later in this paper.

3.3. Presentation of Data

The Sacramento and San Joaquin valleys cover a large part of the interior of California. Two rivers, by those names, drain the valleys and the surrounding mountains. The west side of both valleys is comparatively arid, while the east side is well supplied with streams, some of which are quite large. It is into these streams on the east side that the salmon run to spawn.

It is estimated that there are (1928) 510 linear miles of stream beds suitable and available for spawning grounds. As nearly as can be estimated, previous to any obstructions in the streams, there were at least 6000 linear miles of stream bed suitable and available to spawning salmon. At least 80 per cent of the spawning grounds has been cut off by obstructions.

There are (1928) eleven dams in the San Joaquin system that are a hindrance to salmon or are a complete barrier. (See Fig. 14.) Six of these dams have fish ladders that are working; one has a ladder that is not in working order; the rest, being too high, are without ladders. At two of these dams the diversion ditches have adequate screens,[8] and at one other dam some of the canals are partly screened.

There are thirty-five dams in the Sacramento system that directly or indirectly affect the salmon migration. (See Fig. 15.) of these, sixteen have working fish ladders, and at eleven of these dams the ditches have adequate screens; four of the ladders in the system are under construction or repair. It has also been determined that the available spawning grounds do not support as large a population of spawning fish each year as they are capable of doing.

The salmon spawning migrations in these two rivers occur about the same time as in the past years. The spring run is on during April, May and June. The fall run is during August, September, and October.

The salmon have decreased tremendously in all the streams except one or two, where they are reported to be holding their own or even increasing. (These streams have very late runs and most of the fish come up after the commercial season on salmon is closed.) The abundance of salmon is taken up more fully in Part I of this paper and also under the detailed account of the streams, which will follow.

[8] The Bureau of Hydraulics of the Division of Fish and Game of California has had great difficulty in enforcing the screen and fish ladder law, and has worked under hardships with a few men to cover the large area of the state. However, under a new direction the work is being taken care of as fast as time permits.

3.4. Obstructions

A word on the history of obstructions seems to have a place in this paper. Information on the early development of power and irrigation projects is hard to obtain, but enough can be had to get a general outlook on the problem. Before power and irrigation dams were so much in evidence, the streams were obstructed with crude barriers thrown up by the early gold seekers. These barriers formed reservoirs to supply water power to the hydraulic mining operations throughout the California gold area. Besides obstructing the streams these mining operations made the rivers boil with mud and silt.[9] . It is a wonder that during this period any salmon got to the spawning beds, much less the eggs being able to hatch in such muddy waters. Some of the dams that are used today are reconstructed on the sites of these gold mining makeshifts. So, really, the days of forty-nine were the beginning of obstructions as far as fish were concerned. In the eighties, water power projects made their first appearance. In 1899 the Colgate and Nevada plants were constructed on the Yuba River. In 1895 the dam and plant at Folsom on the American River was built. The water used for irrigation came from small diversion dams built by the farmers themselves. After 1900 a number of power and irrigation projects were constructed, but the major portion of the large irrigation and power dams have been built since 1910. Such being the case, it coincides closely with the decrease of the salmon from 1910 on to the present (1928). It would seem that, as the dams have increased, the fish have decreased, although, of course, other factors have had a part in this depletion.

3.5. Details of each stream

As a source of information for future workers in the field and for the people who live in the localities discussed, a detailed account of the streams in the two river systems in which salmon run, will be given.

The San Joaquin River originates in the mountains east of Fresno. It drains the San Joaquin Valley and surrounding high country from Fresno north to San Francisco Bay, where it unites with the Sacramento River. The eastern side of the valley is drained by the Merced, Tuolumne and Stanislaus rivers. The west side of the valley is almost arid, having no streams of importance.

San Joaquin River, Fresno County (above the Merced River): The salmon of this river run in the spring[10] (the water is too low for the fall run). The spawning beds extend from the mouth of Fine Gold Creek to Kerchoff Dam and in the small streams of that area. Actual length of beds is about 36 miles. There are a few scattered beds below Friant. Four dams affect the salmon on this river. The lowermost is the Delta weir in a slough on the west side of the river, 14 miles southeast of Los Banos. The weir is about 10 feet high, 30 feet wide; a fishway on one side is in working order but there are no screens on the ditches. Stevenson's weir is on the main river directly east of the Delta weir. The

[9] Water that has a great amount of sediment in it will cause adult salmon to die or turn back because of the mud in the gills stopping respiration. When enough silt collects on eggs in the water, they die for want of oxygen.

[10] The spring run is during the months of April, May and June. The fall run is during September, October and November. The salmon spawn from September to December.

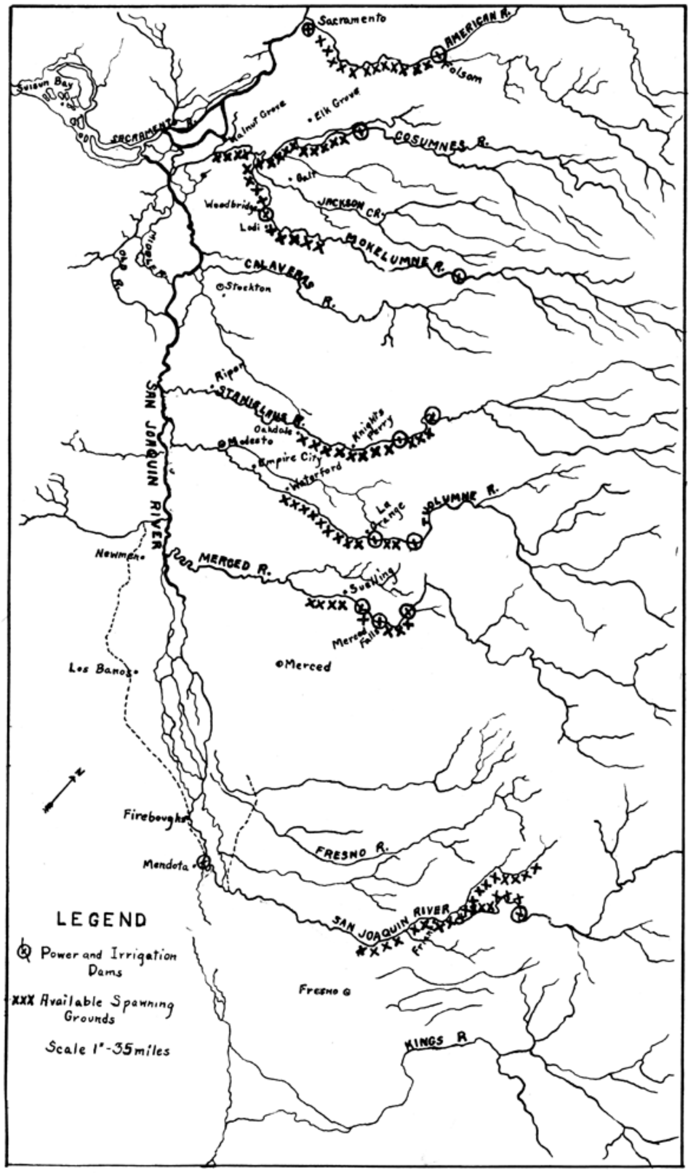

FIG. 14. Map of the San Joaquin River, showing power and irrigation dams and available spawning grounds for salmon.

FIG. 14. Map of the San Joaquin River, showing power and irrigation dams and available spawning grounds for salmon

weir is 110 feet long and 6 feet high and has a good fishway. Both of these dams are irrigation diversion projects. Mendota weir is on the main river a mile and a half from the town of Mendota. It is a large irrigation diversion dam owned by Miller and Lux; it is 30 feet high, 200 feet long and built of concrete. The fishway is in working order during high water. There are several large canals taking water out of this reservoir and only those that have lifts on them are screened. The Kerchoff Dam is in the foothills 35 miles above Friant. It is 180 feet high and impassable to salmon. It was built about 1920 to divert water for power generation. At the town of Friant there is a proposed project to be constructed in 1928–29. This structure is to be 125 feet high and will cut off most of the spawning grounds of this river.

Fifty or sixty years ago, the salmon in the San Joaquin were very numerous and came in great hordes. As the various agencies of depletion such as dams, irrigation ditches and overfishing came into play, the runs fell off. In 1916–17 there was reported a very good run in the river at Mendota. In 1920 it was fairly good. The run has fallen off each year until in 1928 very few salmon were seen in the stream. In 1926 there was a fair run, better than it had been for several years. Contrary to the belief that the San Joaquin River salmon are increasing, it seems that, like the rest of the streams in the state, the run is fast decreasing.

Merced River, in Merced County: The salmon of the Merced River run in the spring and fall. The spawning beds extend from the mouth of the river to the Exchequer Dam on occasional gravel bars that occur along the river. Perhaps the length in linear miles of stream bed available is about 12 miles. There are three obstructions that affect the salmon. The Crocker Huffman irrigation diversion dam near Snelling is the lowermost. This dam, which was built about 1918, is about 15 feet high and has a good working fishway in high water. There are a few screens but not over all the ditches. At Merced Falls there is a natural fall and a 20-foot dam has been constructed to form a millpond and to generate power for a sawmill. The dam was built prior to 1913. There is a fishway, but it has been closed and out of order for a number of years. There are screens over the intakes to the power house. The Exchequer Dam is about 20 miles above the Merced Falls and is impassable to fish. It is a 120-foot power dam.

The abundance of salmon in the Merced River now (1928) as compared to the past years tells the same story of depletion as do the other rivers. The reports of the early residents in that section speak of great quantities of fish coming up the river to spawn in the summer and fall. In 1920, a letter received by the Fish and Game Commission from a resident of the country near the Merced River states that there were fifty salmon in the past for each one now (1920). In the above-mentioned letter the blame for this decrease was attributed to the construction of dams. Residents along the river in 1928 say that the salmon are so scarce that they rarely see any. They remember the fish being so numerous that it looked as if one could walk across the stream on their backs. One report from Merced stated there were no salmon which ran up the river any more, but later the statement was to the effect that a few went up in the fall. Another statement from a deputy of the Division of Fish and Game, dated November 12, 1928, says that there are several hundred salmon in the Merced this fall. The deputy counted 391 in one small stream below a dam. The river was dry for a distance above this creek so the salmon could not continue up the river until the rains came and increased the water supply.

A great deal of the water in the Merced River is used for irrigation during the spring, summer and early fall. The river during this irrigation season is very low, and the salmon find it hard to get up the river until after the rains. This condition has just about killed off the spring and summer runs and now the only fish that come in arrive during the late fall.

Tuolumne River, in Stanislaus and Tuolumne counties: The spawning run of the salmon in the Tuolumne is during the spring and fall. The fall run is the only one of any consequence. The spawning grounds extend from the town of Waterford to La Grange, a distance of twenty miles of good gravel river. The Tuolumne River, like the other rivers of the San Joaquin system, is used for irrigation. Two dams on the river affect the salmon. The lower is the La Grange Dam near the town by that name. It is an irrigation diversion dam which supplies water for the ranches in the lower country. The dam is 120 feet high and has no fish ladder. Thirteen miles above this is the Don Pedro Dam, which is about 300 feet high and was built in 1923. It forms a large storage reservoir for irrigation and also generates some power.

Salmon in the Tuolumne River are scarce. The spring run amounts to almost nothing, but there are some fish that come up the stream in the fall. This river, like the rest in years past, used to abound with salmon. Three years ago (1925) a good run was reported in the stream that surpassed anything that had appeared in several years.

Stanislaus River, in Stanislaus and Calaveras counties: The Stanislaus River has a good spring and fall run of salmon. The spawning grounds extend from the marsh lands above Oakdale to Knight's Ferry, a distance of 10 miles. The Stanislaus, like the other rivers, has dams which hinder and block the salmon. There was a small power dam built in 1910 at Knight's Ferry but it was replaced in 1913 by the Goodwin Dam, situated 18 miles above Oakdale. The dam is 20 feet high and has a fishway so that salmon can spawn between this dam and the Melones Dam, which is a short distance above the old town of Melones in Iron Canyon. It is 210 feet high and was dedicated in 1926. The dam, of course, is an impassable barrier to salmon. It is a combination power and irrigation project.

The abundance of salmon in the Stanislaus is about the same as in the Tuolumne. The rivers are very nearly alike and what is true in one is true in the other.

The San Joaquin River below the mouth of the Merced does not figure as a spawning stream. It only acts as a passageway to the other rivers. The San Joaquin, as has been stated, has known its glory as a salmon stream, but that era is past, and the system has fallen to the development of irrigation and power projects. The salmon have dwindled and will go on to complete extinction unless more stringent measures of protection are soon put into effect. There is a chance to save a fair run of salmon in this system for there are enough good spawning grounds at the present to support quite a large number of

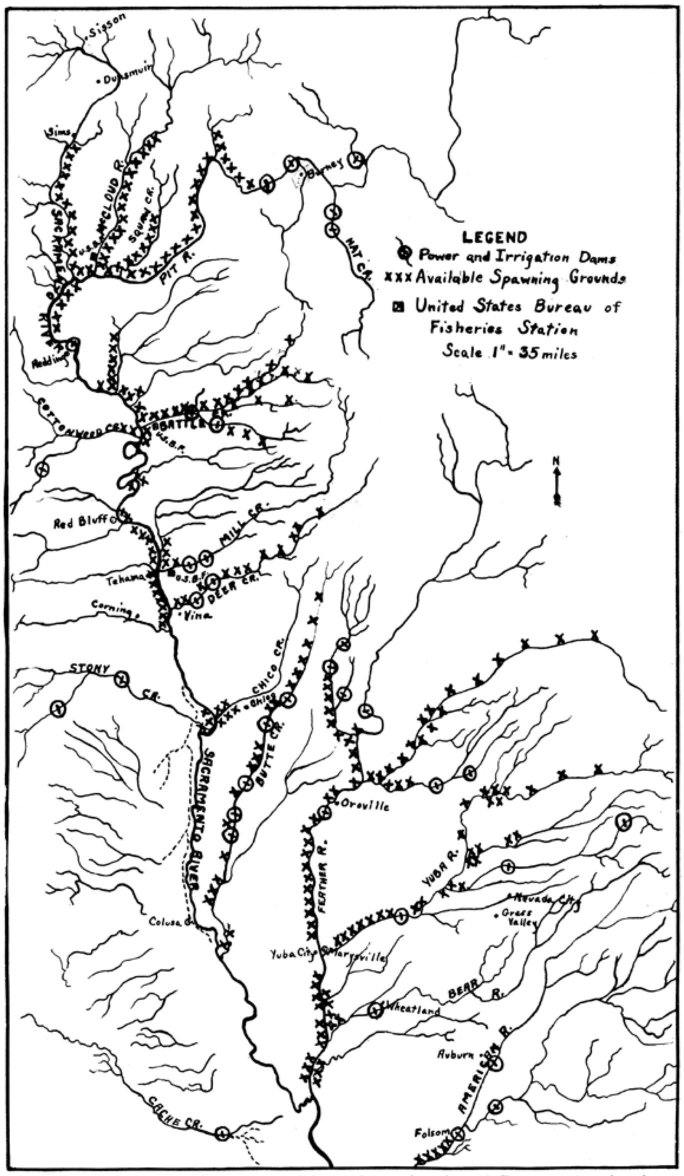

FIG. 15. Map of the Sacramento River above the city of Sacramento, showing power and irrigation dams and available spawning grounds for salmon.

FIG. 15. Map of the Sacramento River above the city of Sacramento, showing power and irrigation dams and available spawning grounds for salmon

salmon. These beds could be restocked and then protected until a good run has been established.

The Sacramento River drains the large Sacramento Valley and the surrounding mountain ranges, and has its source from the Pit River, which rises in the Sierra east of the Modoc lava beds, and from the Little Sacramento and McCloud rivers, which rise in the Siskiyou Mountains. These rivers unite a few miles above Redding to form the main Sacramento River, which is joined on the east side by the Feather, the Yuba, the American, and Mokelumne rivers, as well as numerous other smaller streams on the east side that are important salmon waters. The west side is quite arid and has only two or three small streams that join the river near Red Bluff. The river flows almost due south and empties into Suisun Bay.

Sacramento River, through Solano, Yolo, Sacramento, Sutter, Colusa, Glenn, Butte, Tehama and Shasta counties: The Sacramento, the most

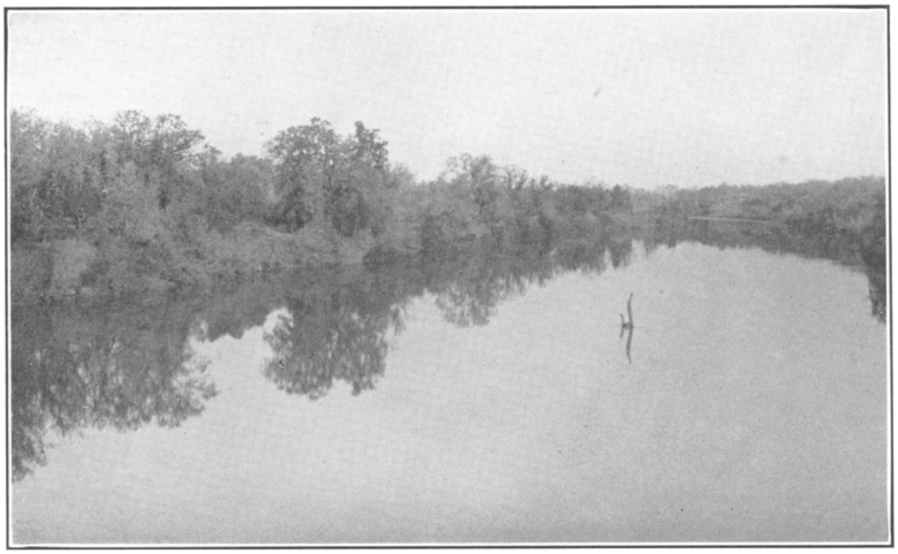

FIG. 16. Sacramento River from bridge near Red Bluff. 1923. Photo by J. O. Snyder.

FIG. 16. Sacramento River from bridge near Red Bluff. 1923. Photo by J. O. Snyder

important salmon stream in the state, has two runs of salmon, one in the spring and the other in the fall. The spawning grounds of the main river extend from below the town of Tehama in Tehama County as far as the railroad station at Sims on the Little Sacramento River in Shasta County. The beds from Tehama to where the Pit joins the main river are limited to occasional gravel bars that occur in the river and at the mouths of the creeks. There is a large bed near the mouth of the Pit River. The entire Little Sacramento River has wonderful spawning beds, but there are falls at Sims which stop most of the salmon, although a few fish are able to get over them.

The Anderson-Cottonwood Dam at Redding is the only dam on the main river. It is an irrigation diversion dam 15 feet high and 440 feet long. The fishway is in good working order and the ditch is screened.

Abundance of salmon in this river has been taken up at length in Part I of this bulletin. It is readily seen that the salmon catch has fallen off to about one-tenth its former level of 1910. (See Fig. 2.) (The catch is a measurement of abundance when fishing effort has remained constant or increased as is the case here.) Until the last few years the Anderson-Cottonwood Dam has been a barrier to salmon as formerly it had no provision for an adequate fish ladder or fishway. Some of the flash boards were removed in two of the sections of the dam near the center for the passage of fish. In 1921 the Fish and Game Commission found after an investigation,[11] that this supposed fishway was not adequate and so the irrigation company was compelled to put in a new fish ladder which works very satisfactorily. For a number of years, the Anderson-Cottonwood Dam was such a barrier that it nearly exterminated the salmon run in that part of the river. Now (1928) there are quite a number of salmon that pass over the dam but nothing to compare with conditions before the dam was constructed. The part of the river known as the Little Sacramento is another problem. As stated above it is an ideal spawning stream. Before the Southern Pacific Railroad was put through the Sacramento Canyon, the salmon were extremely abundant, but about 1884–87 during the construction work the run was almost destroyed. Quantities of rock and dirt naturally rolled into the river, blocking it and making the water muddy. The laborers employed caught fish by blasting the holes. These combined factors very nearly destroyed the run in the Little Sacramento River.

Calaveras River, in Calaveras County: This river is dry most of the summer and fall so it has no run of salmon.

Mokelumne River, in San Joaquin and Amador counties: It has only a fall run of salmon, which is usually quite late. The spawning beds reach from near the mouth above tidewater to Woodbridge Dam and also above the dam where the salmon get over it, on the gravel bars along the river. The Woodbridge Dam, constructed in 1914 and located at the town of Woodbridge near the state highway, is about 15 feet high. The fishway is small, and very little if any water goes through it in the summer and fall. The flashboards are taken out in the late fall (November) to let the salmon through.

The salmon are not as abundant as in former years but a considerable run comes up the river each year.

Cosumnes River, in El Dorado County: It is a branch of the Mokelumne River and has only a fall run. The spawning grounds extend from the mouth of the river above tidewater to a dam near the town of Sloughhouse.

There is an irrigation diversion dam near Sloughhouse which is a barrier to the fish. The screens are in order and there is a fishway now under construction. The abundance of salmon in the river is the same as in the Mokelumne.

The American River, in Sacramento and Placer counties: This river has a fall run of salmon which spawn from the mouth of the river to Folsom, a distance of 30 miles of good gravel river.

[11] McGregor, E. A. Migrating Salmon at the Redding Dam. *California Fish and Game,* Vol. 8, No. 3, p. 141, 1922.

The Folsom Dam a mile or so above the town of Folsom stops the salmon in that stream. The dam is owned jointly by the state and the Pacific Gas and Electric Company. The water is used to generate power for the State Prison there and for the Pacific Gas and Electric Company. The structure is about 50 feet high and was built in the late nineties by the convicts. There are no screens, but there is a fish

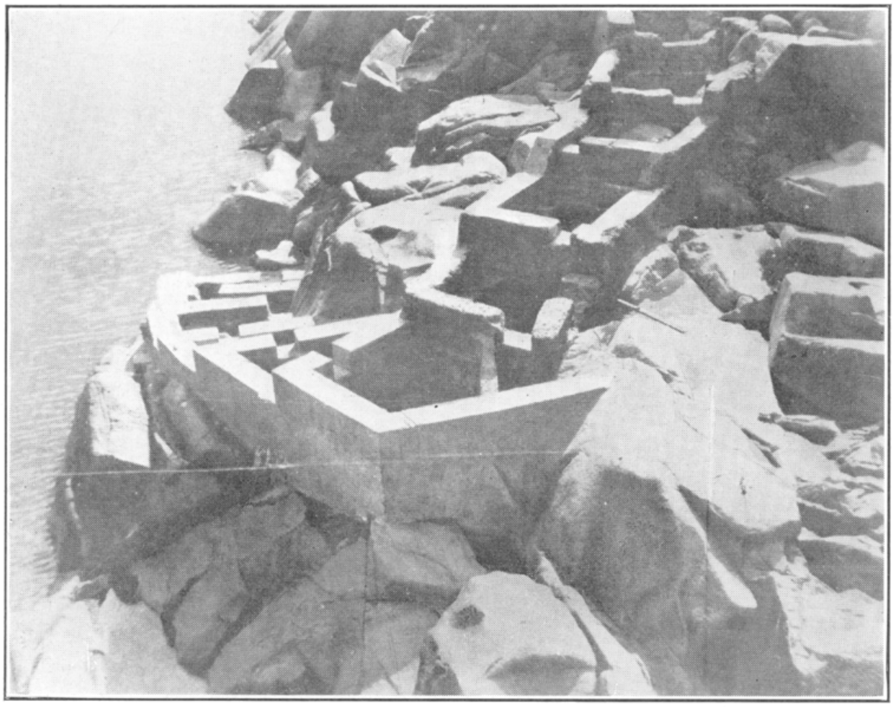

FIG. 17. Fish ladder at Folsom Dam, American River. Oct. 24, 1919. Photo by A. E. Doney.

FIG. 17. Fish ladder at Folsom Dam, American River. Oct. 24, 1919. Photo by A. E. Doney

ladder which has just been repaired this summer (1928). However, while the fishway is all right for trout, salmon have never been known to go over it. There are other dams on the river, but as the Folsom Dam seems to stop all salmon, those need not concern us here.

The run of salmon into the American River has always been a late fall migration and like the other rivers has known great runs. In 1927–28 there was a very good run in the river, which has shown to the inhabitants no noticeable decrease in the last twenty years. It was reported that the run of salmon in this river had been destroyed by the early mining operations. Such may have been the case, but since then the run has returned and has remained fairly constant, according to the observations of local residents.

Bear River, Placer County: It has never been known to be a salmon stream as only occasional salmon have been observed there. The river is dry near its mouth in the summer and fall months, and there is an impassable dam on the river near the town of Lincoln.

Yuba River, in Yuba County: This river has a fall run with a slight spring run occasionally, while the spawning grounds extend from the mouth of the river as far up as the town of Smartsville. Some salmon go up farther, but very few, as the greater run is in the late fall.

There is a dam known as the Government barrier, near the town of Hammond below Smartsville, which is for the purpose of catching the sediment caused by the mining and dredging operations above on the river. There are two fishways around this dam, one for low water and the other for high water. The fishways were destroyed by floods in the winter of 1927–28, but will be repaired. However, it is reported that few salmon go past this point to spawn. On the south fork of the Yuba River directly north of Nevada City is the Excelsior Dam, a power project built in 1912, and has a good fish ladder and screens. The other dams along the river were either washed out or badly damaged during the high water and flood of the winter of 1927–28.

Very little could be learned as to the amount of salmon in the river during past years, but recently the salmon have been holding their own and not decreasing. The river near its mouth is very muddy, being brick red in color and would seem to indicate that fish could not survive, but apparently they do.

Feather River, in Yuba, Butte and Plumas counties: It has a spring and fall run of salmon. The main spawning beds extend from the mouth of the river to Oroville, a distance of 30 miles. The spring run goes up into the four branches until the fish are stopped by dams.

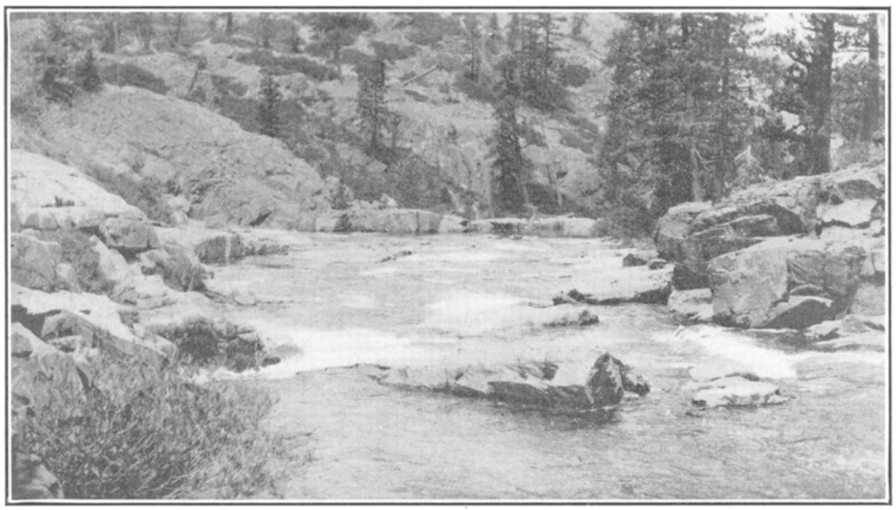

FIG. 18. Yuba River near Donner Pass. June 30, 1924. Photo by J. O. Snyder.

FIG. 18. Yuba River near Donner Pass. June 30, 1924. Photo by J. O. Snyder

Salmon spawn along these streams on the gravel bars. Almost all parts of the river which are not barricaded by dams are suitable for spawning grounds.

The Sutter-Butte Dam (see Fig. 19), the lowermost on the Feather River, is 6 miles below Oroville. It is an irrigation diversion dam about 5 feet high, having a fishway that is reported by the local people to be ineffective, but seems to do the work. There are no proper screens on the intake ditches.

The Miocene Dam is on the west fork of the river near the town of Magalia. The dam is a Pacific Gas and Electric power project 12½ feet high built about 1914, having no fishway or screens.

The Stirling City Dam is on the west fork, near the town of that name. It is an old dam about 8 feet high, that has been patched up to divert water to a power house. There is a fish ladder but it is of no use in low water. Salmon never get this far up the river. The ditch is provided with a revolving screen and sump arrangement.

Another dam of the Great Western Power Company is on the north fork of the Feather River. This dam is on the upper curve of the "Big Bend" where it diverts the water across the hill to the lower end of the bend and the power house at Island Bar. This dries up the river for a number of miles at low water periods, and of course stops the salmon before they get to the fish ladder at the dam.

As far as could be ascertained, the middle fork of the Feather River is without barriers which would hinder salmon.

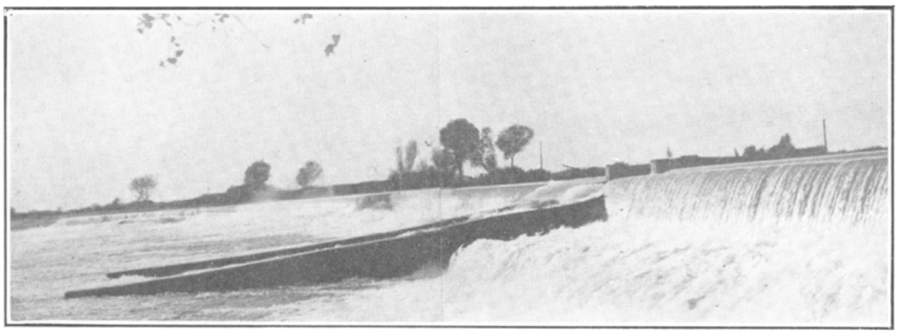

FIG. 19. Sutter-Butte Dam, Feather River, below Oroville. November, 1928. (Notice the fish ladder.)

FIG. 19. Sutter-Butte Dam, Feather River, below Oroville. November, 1928. (Notice the fish ladder.)

On the south fork of the Feather River there are two dams, owned by the Palermo-Wyandotte irrigation district. Dam No. 2 is on the main fork and has no fishway. No. 1 on Lost Creek takes nearly all the water from the south fork during the summer months.

The runs of salmon, both spring and fall, used to be very heavy in the Feather River previous to the building of obstructions. It is true that the mining operations in the early years may have reduced the amount of fish somewhat, but the building of dams has almost destroyed the spring run. The fall run is large, although not extremely abundant, and has fallen off in the last few years. It is possible from what the inhabitants say that there is a three or four year cycle for salmon in the river.

Butte Creek, in Butte County: It is a tributary to the Sacramento River, flowing through a very fertile section of the valley, and has been known as a very fine salmon stream and as a good spawning ground. There is only a fall run in the creek as the water is very low and warm in the summer. The salmon that enter the creek now, spawn in the upper reaches if they can run the gauntlet of irrigation dams and ditches.

There are some few beds lower in the creek but the water is very low most of the summer and fall and so few salmon go up the stream now (1928).

The two duck club weirs and three irrigation dams on the creek are all so low that fish can get over them if there is enough water. The dams are unimportant except for the fact that they divert so much water that fish can not ascend the stream. A drainage canal, known as "833," carries considerable water and the salmon which ascend this towards its blind end, become stranded and die in the mud. As has been stated, the creek was formerly one of the best salmon streams, but because of the irrigation dams and low water the run has been almost destroyed.

Deer Creek, in Tehama County: This creek is a tributary to the Sacramento and joins the river near the town of Vina about 20 miles above Chico. It has a small spring run and quite a large fall run. The spawning beds extend from the mouth of the creek up into the foothills, a distance of about 10 miles.

The Stanford Vina Dam, about 3 miles east of Vina, is an irrigation diversion dam about 5 feet high and was built about 1915. There is a good fish ladder and the screens on the ditches are in place. The Deer Creek Irrigation District Dam, 8 miles east of Vina, is not considered an obstruction so no ladder is needed. Screens will be installed in the near future.

The salmon were very numerous in Deer Creek until dams were built which took most of the water from the creek. The spring run has never been successful as the fish come up in the spring and summer and lay in the holes until fall before spawning. The water becomes too warm for them and they die before they can spawn. The fall runs have been more successful as the stream is a good spawning ground when there is water. There is sometimes enough water in late fall but not in the summer. At the present time (1928) the run is very small because of irrigation projects diverting the water.

Mill Creek, (see Fig. 20) in Tehama County: This is a celebrated salmon stream and has had some very large runs of fish. A. U. S. Bureau of Fisheries' egg station and hatchery has been on the stream since 1901, and is about a mile from the mouth of the creek. Each fall the salmon are trapped and their eggs taken, but eggs are not taken from the spring runs because the fish can not be held. The spring run is very small and is affected by the same conditions and warm weather as affect Deer Creek. The fall run is all taken by the egg station. The existing spawning beds are from the egg station to the Clough Dam, a distance of about 2 miles.

There are three dams on the creek. The first one, which has screens on the diversion ditches, belongs to the Molinas Water Company and is not considered an obstruction. The second is the Clough Dam, 16 feet high, which is an irrigation diversion dam built about 1913. There is a fishway but it is poor, and the water is usually so low that fish seldom get over it. The screens are in place. Another dam above this, which is 7 feet high, also has screens in place on the ditches.

The annual run of salmon into Mill Creek can be best judged by the number of eggs taken each year at the egg station. Figure 6 and Table

VII (in Appendix) will show the increases and decreases of egg takes for the creek. The number of eggs produced by a given number of fish, can be estimated fairly closely. For instance, in 1905 at the peak of

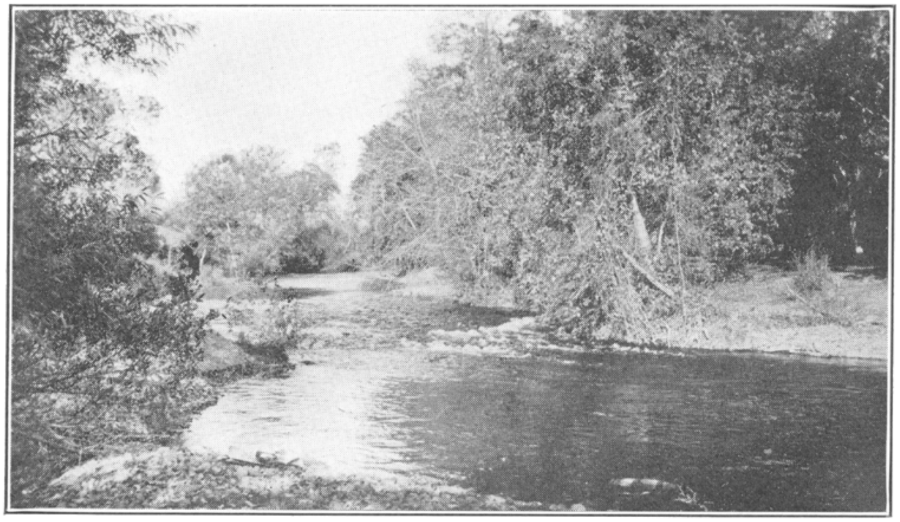

FIG. 20. Mill Creek near the U. S. Bureau of Fisheries Station. 1923. Photo by J. O. Snyder.

FIG. 20. Mill Creek near the U. S. Bureau of Fisheries Station. 1923. Photo by J. O. Snyder

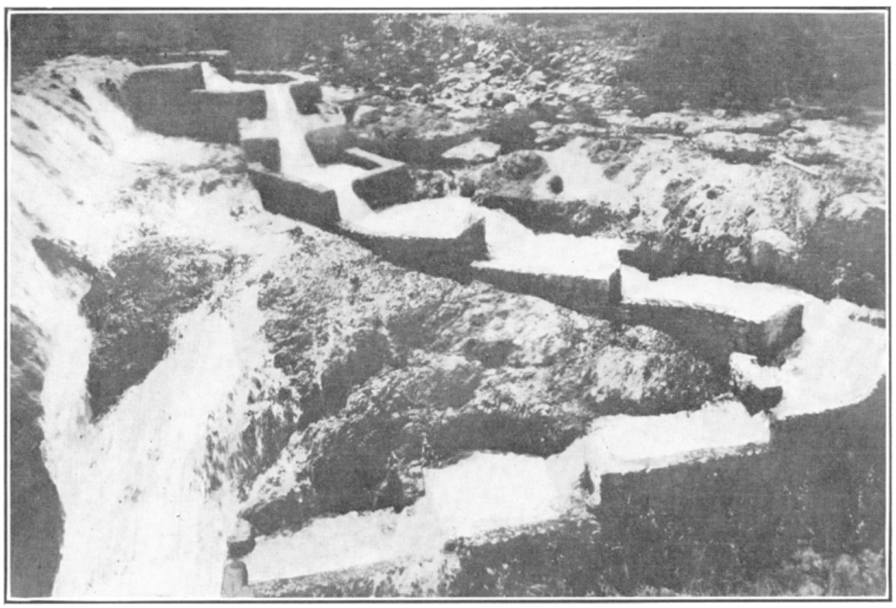

FIG. 21. Fine type of fish ladder. Inskip Dam, South Battle Creek. 1920. Photo by A. E. Culver.

FIG. 21. Fine type of fish ladder. Inskip Dam, South Battle Creek. 1920. Photo by A. E. Culver

Mill Creek's productivity, 30,000,000 eggs were taken. Since a female salmon of this river produces about 5000 eggs, then about 6000 female salmon are required to produce 30,000,000. There are at least half again the number of males, making a total number of 9000 salmon for that year. In 1924 only 2,300,000 eggs were taken from about 450 females, with a total of 675 fish taken, counting the males. The spring or summer run of salmon that go above the station to spawn is very small and decreasing each year.

Battle Creek, in Tehama County: This is another celebrated salmon stream of the state; it is even better known than Mill Creek. A U. S. Bureau of Fisheries' egg station and hatchery is situated about a mile and a half from the mouth of the stream. There is a small spring run of salmon in this creek which is not held by the racks of the station, but is allowed to go up to spawn. These fish, if they can survive the hot weather, spawn between the station and the dams which begin 5 miles above. The fall run is taken by the egg station.

There are three Pacific Gas and Electric dams and plants on Battle Creek. The lowermost, constructed in 1911, is the Coleman plant which is about 5 miles above the station. The fish ladder is in order and the screens on the diversion canals are in place. Another dam built in 1909 to divert water to a power house is on the south fork about 20 miles above the Coleman plant. It is 30 feet high with a good fish ladder and ditch screens. The third dam, the Volta plant, is on the north fork and was built in 1900. While there are fish ladders in these dams the water is often so low that fish are unable to get over them.

The fluctuations of abundance of salmon of Battle Creek like Mill Creek can be seen best from Figure 6 and Table VII (in Appendix). These figures of course only show the fall runs. The spring run is allowed to spawn naturally, and did so until the power dams became more or less barriers. Now the spring runs amount to almost nothing, only six or seven spring fish having been seen in the creek this year (1928).

The egg station was established in 1895, in which year 10,000,000 eggs from about 2,000 females were taken. The peak was reached in 1904 with 50,000,000 eggs or about 10,000 females. In 1924 the station took less than 1,000,000 eggs or about 200 females. The graph (see Fig. 6) shows clearly this rise and decline.

Cow Creek: It is a tributary to Sacramento River a few miles above Battle Creek. A few salmon run in there each year to spawn, but the water is so low most of the time that the stream is of no importance as a salmon spawning ground.

Pit River, in Shasta County: It makes up at least half of the main Sacramento River. The Pit, McCloud, and the Little Sacramento rivers join a few miles above Redding to form the main river. There is a spring and fall run of salmon in the Pit River. The spawning beds extend from the mouth of the river to the base of the dam, Pit 4. Over this part of the river are occasional gravel bars on which salmon may spawn. Squaw Creek, a tributary of the river on the north side, and two or three smaller creeks afford suitable places for salmon to spawn.

There are several dams on the Pit River that are a complete barrier to salmon. It is interesting to give details of each so that the gradual cutting off of beds and rivers can be noted. The lowermost dam, Pit 4, like the rest is the property of the Pacific Gas and Electric Company.

Pit 4 is about 9 miles down the river from Burney and Burney Falls. The dam, 60 feet high, 400 feet long, was completed in May, 1927, and is impassable with no provisions to take care of the fish. The dam known as Pit 3 is 9 miles up the river from Pit 4. It is also a power project, 125 feet long, and was erected in 1923–25. It also is impasable. However, the Pacific Gas and Electric Company has built a hatchery for the Division of Fish and Game on the lake formed by the dam. This hatchery has a capacity for about 1,000,000 fish, but

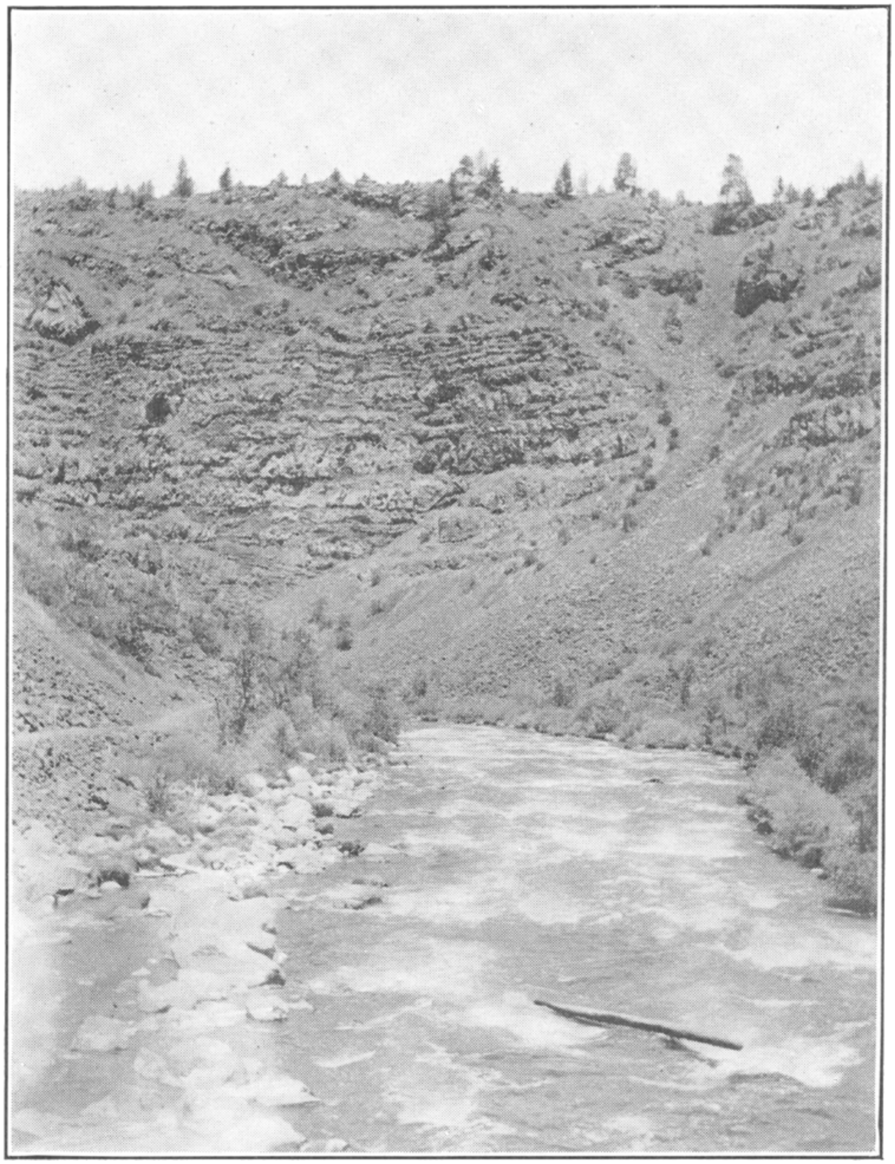

FIG. 22. Pit River Gorge below falls. Photo by E. Schaeffle.

FIG. 22. Pit River Gorge below falls. Photo by E. Schaeffle

no provisions have been made to get eggs, either salmon or trout. The hatchery uses eggs sent in from other collecting stations. Pit 1 is on the Fall River, a main tributary to the Pit River. The dam diverts water from Fall River to the power house on Pit River. (Salmon have never been abundant on the Pit above Fall River because their course was up Fall River.) The dam and plant of Pit 1 is near the town of Fall River Mills. This dam, completed in September, 1922, is also impassable. Hat Creek, a tributary to the Pit River on the south side, is about half way between Pit 3 and Pit 1. (See Fig. 15). The fishways on the two dams are not working, so are impassable. There is a proposed dam to be known as Pit 5 to be constructed about 10 or 15 miles below Pit 4, on what is known as the Big Bend. From information gathered this dam was to be constructed in 1928, but up to this writing has not been built.

There are contrary opinions concerning the merits of the Pit River as a salmon stream, but statements from men born and raised on the stream, who have spent a great number of years as guides to hunters and fishermen, indicate that the stream was one of the best for salmon, but has now decreased considerably. Livingston Stone, who put the first salmon hatchery on the McCloud River, reports in 1872 that the salmon came up the Pit River in great numbers in the spring, but as the weather got warmer the salmon went into the McCloud. Again in the fall the salmon went up the Pit in numbers. In comparison to former years, at the present time (1928) the Pit River salmon population is very small.

On July 10, 1928, the writer stood on the Pit 4 dam and saw perhaps 30 salmon at one time. An estimate of the salmon in the pool below the dam came to about 150 to 200 fish at the most. The whole spring run was probably at the foot of that impassable dam. It was what remained of a large run of fish. For eight years there have been dams on the upper part of the river, and in the last five years there have been two more dams completely blocking the river; so the salmon have gradually lost their native grounds and decreased considerably in numbers.

McCloud River, in Shasta County: This river is one of history in the development of the salmon industry and fish culture on the Pacific coast. Livingston Stone has left us some very good records from his investigations on the river.

There is a spring and fall run of fish in the McCloud River, although the fall run is not as heavy as the spring. Almost all the salmon since 1872 have been taken by the egg station, but the river from its mouth to near its source, where falls act as a barrier, is a good spawning stream. There are no dams in the river except the racks put up at the egg station to stop the salmon.

Stone (1872–73) in his report to the U. S. Fish Commission, says that the Little Sacramento River is, with the exception of the McCloud River, the principal spawning stream for the Sacramento system. He says the salmon came in there in vast numbers. Since 1872 a record of the egg take has been kept and from that an idea of the abundance may be obtained. (See Fig. 6 and Table VII in Appendix.) In 1873, 2,000,000 eggs were taken from about 400 females. In 1878, 12,000,000 eggs were taken from 2400 females, while in 1903, 28,000,000 eggs were taken or about 5600 females. In 1924 there were only about 260 fish at the racks. The salmon of the McCloud River, like those of other rivers, are decreasing.

Cottonwood Creek, in Tehama County: This creek is a west side tributary to the Sacramento River, that joins the main stream between Redding and Red Bluff. The creek had a spring and fall run, while now it only has a very slight fall run. The salmon spawn near the mouth of the creek, because the water is so low they can not go up stream. A dam, 25 miles from the mouth of the creek on the south fork, is used for irrigation and there is no fishway, for salmon rarely get up that far. There are other smaller irrigation ditches which divert water used by the local farmers out of the creek.

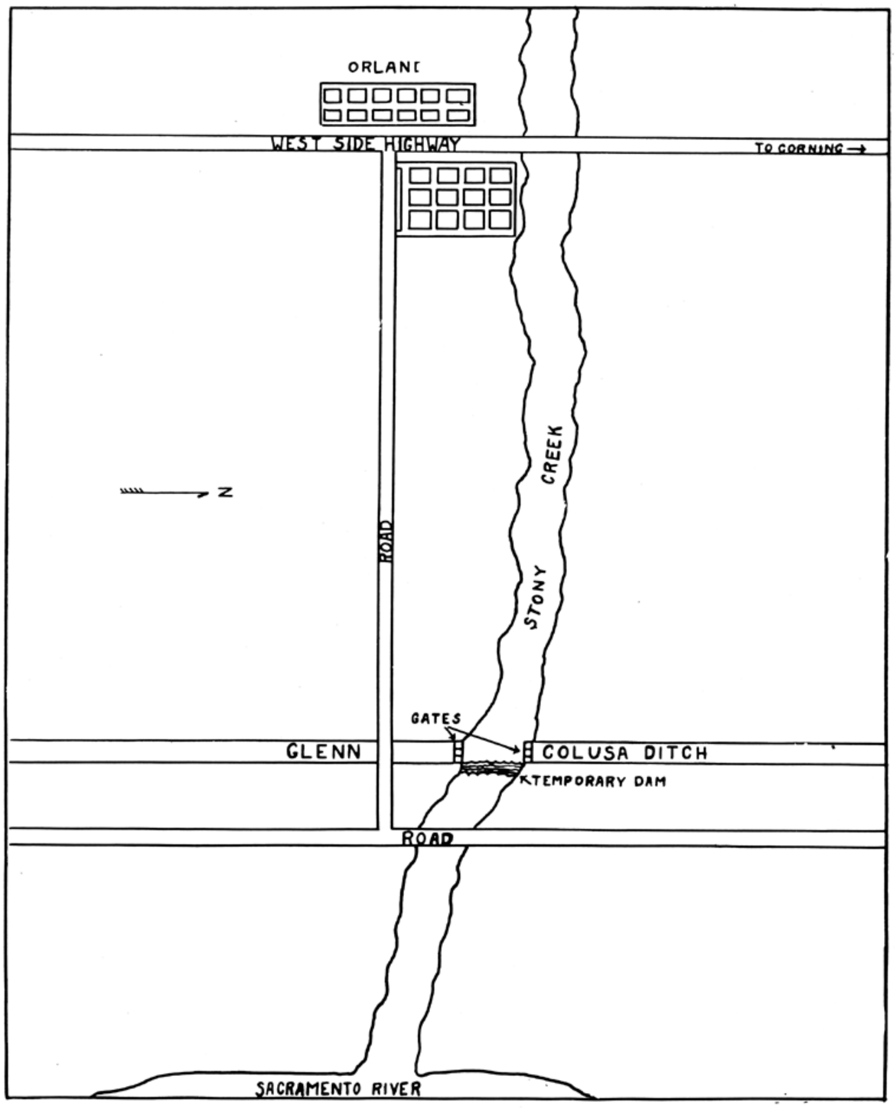

FIG. 23. Showing the crossing of the Glenn-Colusa Ditch over Stony Creek.

FIG. 23. Showing the crossing of the Glenn-Colusa Ditch over Stony Creek

From all reports Cottonwood Creek in past years had a considerable salmon run. Now (1928) it is a rare year if more than 5 or 6 salmon are seen in the stream, which is so low most of the year that salmon can not get up to spawn.

Stony Creek, in Tehama County: This is also a branch on the west side which joins the Sacramento River near the town of Hamilton.

Formerly there was a spring and fall run in this stream, but now there is neither, as the stream is dry except during the rainy season.

There are two dams on this stream. The Orland Project Dam, owned by the U. S. Reclamation Service and located 4 miles west of Stonyford, is 20 feet high and was built about 1914. The water is used for irrigation around Orland. Another dam on Big Stony Creek is 90 feet high, which is too high for a fish ladder.

The Glenn-Colusa Irrigation District pumps water from the Sacramento River above Hamilton. There are no screens on the pumps and small fish are pumped into the large canal, which crosses Stony Creek below Hamilton. The company has thrown up a temporary dam with a solid base across Stony Creek so that the irrigation water can cross the stream. (See Fig. 23.) There are gates on each side of Stony Creek where the canal crosses to control the creek water in flood time. Dredges are kept there to keep the canal clear, across Stony Creek, during the summer and fall. The dam usually is washed out in high

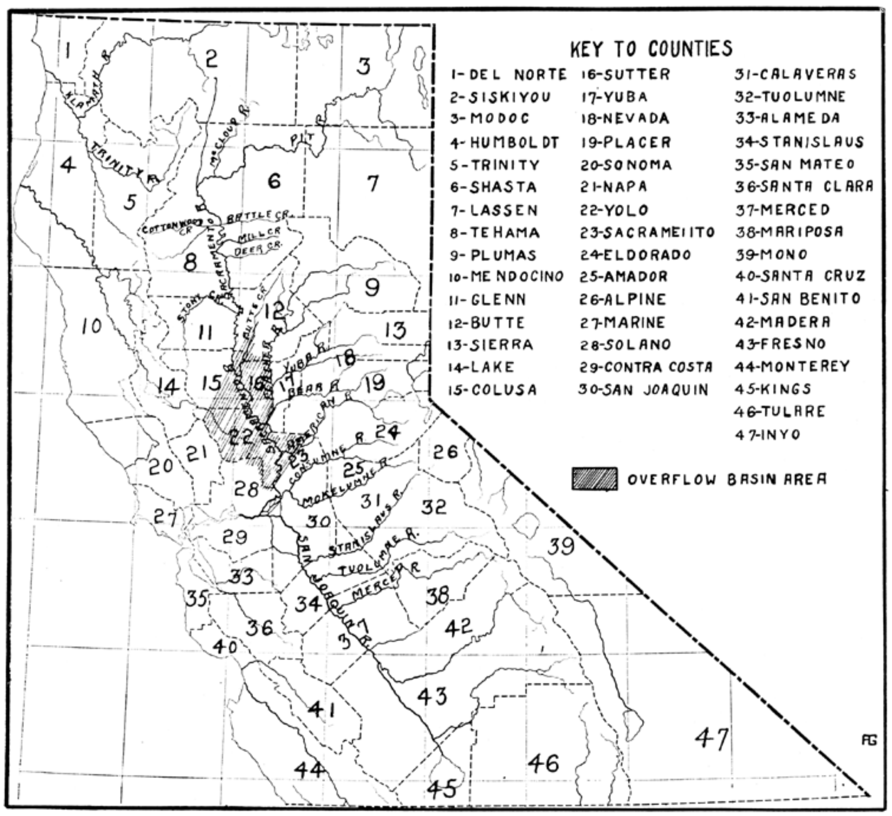

FIG. 24. Map of northern California, showing rivers and counties.

FIG. 24. Map of northern California, showing rivers and counties

water. Any water that may run in Stony Creek during the irrigation season is diverted into the Glenn-Colusa Canal. Salmon have no chance of getting up this stream now, even if there were any water.

From reports, Stony Creek, before irrigation dams were put in, was a very good salmon stream, but now no salmon can go up the creek as there is no water, as explained above.

Cache Creek, in Yolo County: It has its origin in Lake County, near Clear Lake, and flows into the marshy upper end of the Yolo Basin. This stream has never had salmon in it because the fish could not get through the marshland to the main creek, but now since the Yolo Basin has been reclaimed, all the water in Cache Creek is used for irrigation. At the lower end of Yolo Basin there is a slough known as "Cache Slough," into which flows the drainage water from the basin. This blind slough is in tidewater and salmon run into it, where they are sometimes taken illegally by commercial fishermen.

The overflow basins in the Sacramento Valley discussed in Part I of this paper, cover large areas (see Fig. 24) and are named "overflow basins" because each year during the flood water the river overflows its banks into this lower country. At such times (early spring) the breaks or overflows of the river carry great quantities of young salmon into the basins. As the water in the river subsides these basins are left as isolated lakes, sometimes miles in extent, without inlet or outlet. The fish that have been carried into these basins are captives and, as the water warms up, die or are eaten by shore birds. To remedy this condition, and do away with these tracts of water, the river banks have been built up and by-passes have been constructed to run the water from these basins back into the river. The fish are now reasonably safe and can return to the river if they have been washed into the basin. The land in the three main basins, Yolo in Yolo County, American in Sacramento County, Sutter in Sutter County, and Butte Sink in Butte County has been almost entirely reclaimed. While sometimes the water from the rivers breaks through, it is quite readily drained by means of by-passes.

4. PART III
DETERMINATION OF THE AGE OF MATURITY OF THE SACRAMENTO-SAN JOAQUIN RIVER SALMON
(Oncorhynchus tschawytscha)

The life histories of the Pacific coast salmon (Oncorhynchus) are relatively well known now. We are indebted to Scofield (1900, 1913), Rutter (1902) and Chamberlain (1907) for a beginning in the life history study of chinook salmon. The work of Rutter (1902) and Scofield (1900) is of particular value to us in this present study because these men made their investigation on the Sacramento River. The present paper deals principally with the chinook salmon on the Sacramento and San Joaquin rivers; with the interpretation of the age of these fish by means of scale study; with the relative abundance of age classes in the catch; with the early life history of salmon as revealed by the scales; and with the different life histories.

4.1. Previous investigations

Rutter's paper on the "Life History of the Quinnat Salmon" (1902), was the first investigation on the life histories of the various species of Pacific coast salmon. The work was begun by Scofield in 1897, who turned his findings over to Rutter and assisted later. Rutter observed the salmon from the time they entered the bays and lower river until they reached the spawning beds, spawned, and then perished. He definitely determined and established the fact that the salmon die after spawning. Rutter carried on experiments with artificial and natural fertilization, and experiments to find the best time to plant young fish and at what size the young were best prepared to survive. Extensive work was done on the downstream migration of fingerlings. Set nets were placed at various points on the river and the young fish observed. It was discovered that some of the young remained in the stream over the winter to the number of approximately 10,000 to the mile. Rutter states that the salmon spend from two to four years in the ocean. Nothing else was determined in regard to the age of the fish.

Scofield (1913), who worked with Rutter in the above investigation, in a general report of work on the Sacramento beginning in 1911, under the direction of Gilbert, sets forth the course of an investigation which was inaugurated in an effort to discover additional information about the salmon fry and fingerlings and methods of artificial propagation. However, after the discovery that large numbers of fingerlings were being destroyed in the large overflow basins in the valley, the original purpose was abandoned and an investigation of the basins carried on.

Scofield (1913) in the spring of 1912 took chinook salmon and steelhead fry from Sacramento to the sea in an attempt to see if the water in the river and the ensuing strong salinity of the bay would have any deleterious effect on the fingerlings. It had been considered that Sacramento would be a good place to plant the fingerlings to avoid the dangers of the upper river. These fish were marked at liberation but nothing came of the marking because no fish were recovered.

Gilbert (1912) carried on an extensive study of the age of maturity of the five species of the genus Oncorhynchus. This was the beginning of age reading of the Pacific coast salmon, and the paper has since been a manual for other investigations in that field.

Blemer,[12] working under the authority of the California Fish and Game Commission (now the Division of Fish and Game of California), started work to determine the age of the Sacramento salmon in the years 1916–17–18. Due to Blemer's untimely death the work was not finished or published.

Rich (1920) carried on an investigation of the "Early History and Seaward Migration of Chinook Salmon in the Columbia and Sacramento Rivers," by scale study of the fry and fingerlings. Rich's work carried to a further degree the work on the summer resident salmon in the Sacramento, which Rutter first recorded.

Snyder took over the salmon investigation work for the state commission about 1918 and has been carrying on the work since. Snyder (1920) has carried out extensive marking experiments with the salmon fingerlings, cutting off the fins of the salmon and then liberating them. He has had good results from these experiments. Information substantiating the parent stream theory (that salmon return to the streams from which they were hatched), and also a great deal of the range of the salmon in the ocean has been discovered. Also the marked fish returning are of a known age and furnish a check on the age reading carried on from sample scales and data taken along the California coast and in the rivers.

There have been two marking experiments in the Sacramento River. The first fingerlings were marked in 1917, and 18,000 were liberated in March, 1918, into Cold Creek, a tributary of the Sacramento. Three of these salmon were found in 1920, one at Fort Bragg, one at Monterey and one at Pittsburg on the Sacramento River. The next year more were found. A second experiment was started, and in September and October of 1920, 20,000 fingerlings were marked by removing the adipose and posterior half of the dorsal. These were liberated in April of 1921 in Sullaway Creek, a tributary to the Sacramento. A number of returns came from this experiment also. From these two experiments the range of the Sacramento salmon was found to be much wider than was formerly supposed. Sacramento fish were found up the coast as far north as Eureka and south to Monterey. These returns from marked fish, with scales and data, are in the scale collection at Stanford University and can be referred to at any time.

4.2. Procedure

From the Stanford University collection a good series of fry and fingerlings from the Sacramento were obtained. These salmon were collected at various places on the river and at different months of the year. From this collection 125 young were used, their scales mounted and examined in order that a basis could be formed for the future readings of the adult scales.

[12] Blemer's scale material was so badly absorbed on the edges that nothing could be done with it. The same is true for part of all the collections, noticeably in the 1920 and 1924 collections.

Scales have been mounted for two years (1919 and 1921), thirty being mounted from each day's collection. These scales were read and the age recorded on forms for that purpose. The fish are classified as to age and nuclear types.[13] Summaries were made of classes, types, and sex types, also a summary of each year's class in relation to sex, type, and length of fish in centimeters.

4.3. Objectives

There is presented in this paper an attempt (1) to obtain information relating to the early life history of the Sacramento-San Joaquin chinook salmon as revealed by the nuclear types of scales; (2) to ascertain the age at maturity of the salmon of the Sacramento-San Joaquin rivers, and (3) to determine the percentage of age classes which mature in a given year.

4.4. Material

In studies of this nature, it has been found advisable to have a thorough knowledge of the scales of the fry and fingerling fish before attempting any work on the scales of the adult specimens. With this in mind, 125 fry and fingerling chinook salmon from the Stanford University collection, taken at various points along the Sacramento and San Joaquin rivers at different months of the year, were utilized. The material for the study of adult scales was obtained by the California Fish and Game Commission during the years 1919, 1920 and 1921 from the salmon fisheries at Pittsburg at the junction of the Sacramento and San Joaquin rivers. The collections are representative samples of the commercial catch. A number of scales were taken from about a hundred salmon each day during the fishing season, also data as to the length and sex of each fish. Only the data for the years 1919 and 1921 from Pittsburg are extensive enough to be reliable.

4.5. Nuclear Types

The growth of chinook salmon is portrayed by the markings on the scales. Thus by examining the scales of a salmon and noting the increase of circuli, and the annual checks (see Fig. 27) in the growth of the scale, the age and early history of the fish are revealed. The young salmon either migrate to the ocean as soon as they reach the fingerling stage (when the yolk sac is absorbed and the fish can swim freely) or they remain in the stream for about a year before going to sea.

The number of salmon that go from fresh water to the ocean during their first year (as determined from an analysis of adult scales) is 80 to 90 per cent. In the ocean the young fish find an abundant food supply and their growth is rapid as is indicated on the scales by the larger spaces between the circuli, as compared with those which developed while the fish were in the stream. (See Figs. 29 and 30.) During the winter the growth is retarded, possibly because of a scarcity of food, lower temperature, or some other cause, as is shown on the scales by the annuli (see Fig. 27), while in the spring of the year the

[13] See section on nuclear types.

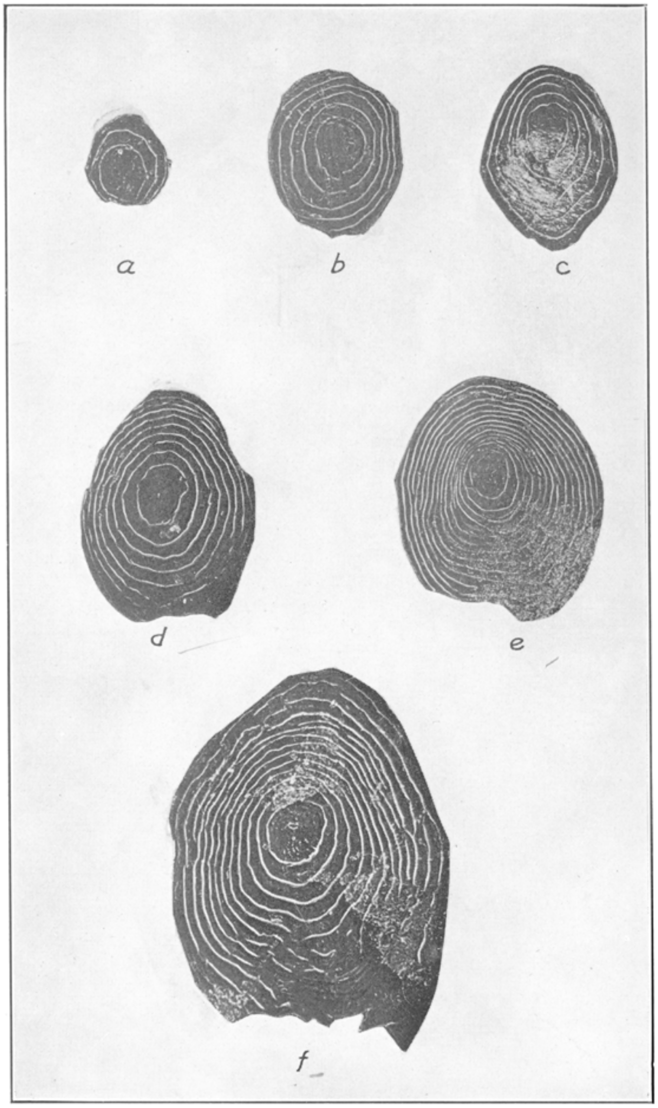

FIG. 25. Photographs of salmon fingerling scales (x 53).
(See explanation on following page.)

FIG. 25. Photographs of salmon fingerling scales (x 53)
(See explanation on following page.)

a. Scale of salmon fry, 46 mm. long, collected by E. C. Scofield at the mouth of San Rafael Creek, San Francisco Bay, March 18, 1926.
b. Scale of salmon fry, 67 mm. long, collected by E. C. Scofield in Montezuma Slough, April 8, 1927.
c. Scale of salmon fry, 57 mm. long, collected by N. B. Scofield at Walnut Grove, Sacramento River, April 9, 1911.
d. Scale of salmon fingerling, 95 mm. long, taken by bait fishermen in Raccoon Straits, June 10, 1914.
e. Scale of salmon fingerling, 75 mm. long. Sample of the marked fish put into the Sacramento River in 1922. The mark used was the adipose and right ventral fins removed.
f. Scale of salmon fingerling, 114 mm. long, taken by bait fishermen at Half Moon Bay, May 21, 1914.
See page 50.

salmon resume growth as is indicated by the wide spaced circuli or rings. The above description is of salmon scales that have ocean type nuclei (the young migrating to the ocean soon after they are able to swim). (See Fig. 29.)

From 10 to 18 per cent of the adult Sacramento-San Joaquin river salmon have a different early history. The fingerlings, instead of going to the ocean as soon as they are able to swim freely, remain in fresh water for approximately a year before they make their way to the sea. When they reach the salt water their growth, as portrayed by the scales, is the same as that of a salmon having scales containing the ocean type nuclei. (See Fig. 28.) The growth in the stream is not rapid because of the more or less limited food supply and possibly other unknown factors. This early slow growth is shown on the scale by the narrow spaces between the circuli, thus forming a compact nucleus of rings from the center to the first check. (See Fig. 30.) This nucleus is known as a stream nucleus and signifies that the fish spent its first year in fresh water before entering the ocean. (See Fig. 30.)

4.6. Fingerlings

As has been stated above, the fry and fingerling specimens and scales had to be studied as a preparation for the reading of adult scales and determining the nuclear types. The chinook fry and fingerlings examined were measured in millimeters from the snout to the middle of caudal fin. The number of rings or circuli on the scales were counted to new growth, if new growth was in evidence, then to the boundary of the scale. (See Fig. 26.) The scales were measured from the center of the innermost circulus to new growth, then to the margin of the embedded area. All measurements were made by aid of a camera lucida with a micrometer, using a magnification of eighty diameters.

The following table presents an analysis of a few typical scales, the data at hand being too extensive to include.

TABLE XI

Table of Chinook Fingerling Measurements

Number	*Length in mm.*	*Number rings, first year growth*	*Number rings, new growth*	*Total rings*
48	112	13	--	13
18	105	16	--	16
21	43	3	--	3
23	46	3	--	3
29	50	5	--	5
2	67	7	--	7
3	56	4	--	4
n. 2	47	4	--	4

TABLE XI
Table of Chinook Fingerling Measurements

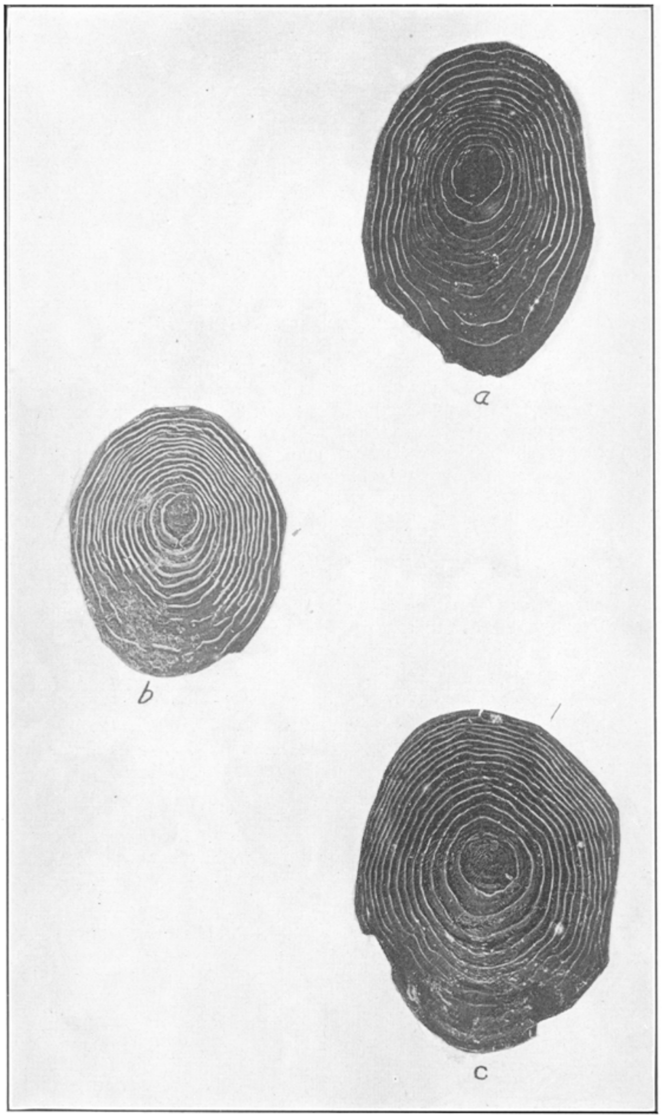

FIG. 26. Photographs of salmon fingerling scales (x 53).

a. Scale of salmon fingerling, 168 mm. long, taken by bait fishermen at Half Moon Bay, June 9, 1914.
b. Scale of salmon fingerling, 100 mm. long, collected at Baird, McCloud River, September 24, 1909.
c. Scale of salmon fingerling, 108 mm. long, collected at Baird, McCloud River, October 18, 1911.

FIG. 26. Photographs of salmon fingerling scales (x 53)

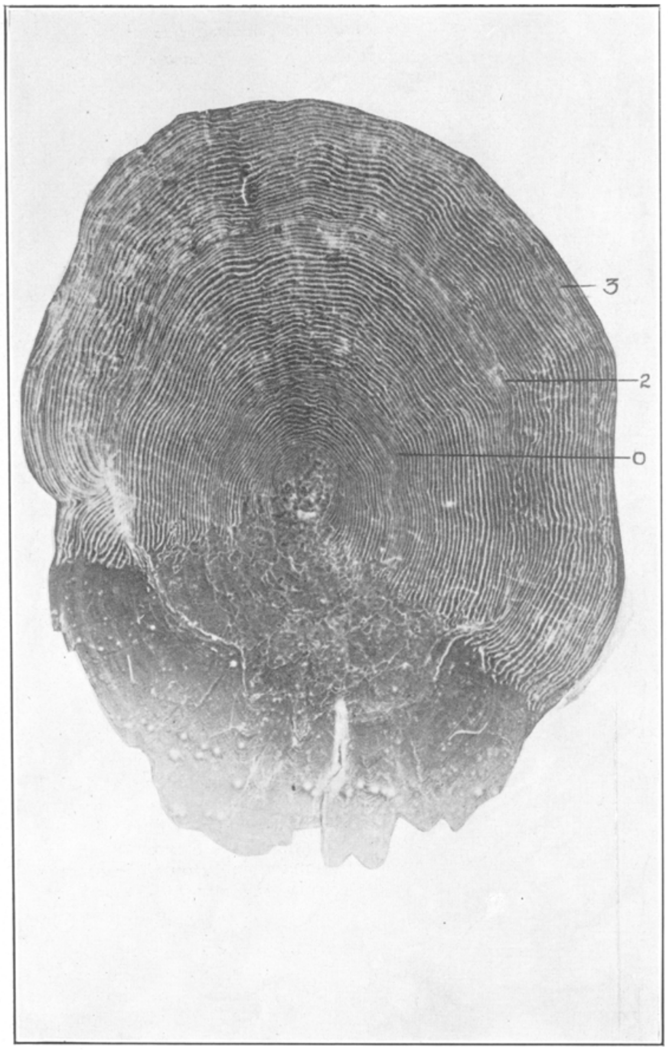

FIG. 27. Photograph (x 9) of a scale (sample 6721) of a female chinook salmon, 86 cm. long, taken at Pittsburg, California, May 9, 1919. The fish is in its fourth year and has an ocean type nucleus, shown by "o" on the figure.

FIG. 27. Photograph (x 9) of a scale (sample 6721) of a female chinook salmon, 86 cm. long, taken at Pittsburg, California, May 9, 1919. The fish is in its fourth year and has an ocean type nucleus, shown by "o" on the figure

TABLE XI—Continued

Table of Chinook Fingerling Measurements

Number	*Length in mm.*	*Number rings, first year growth*	*Number rings, new growth*	*Total rings*
n. 6	65	5	--	5
39	147	10	5	15
5	60	6	--	6
14	63	5	--	5
52	168	9	8	17
55	92	12	--	12
58	103	13	--	13
34	86	7	3	10
30	96	10	--	10
44	75	10	--	10
46	79	10	--	10
2307	89	12	--	12
17	100	16	--	16
13	109	13	--	13
60	101	15	--	15

Number	*Length scale to new growth in mm.*	*Mm. length to edge*	*Locality and date*
48	--	26	McCloud River, Baird, January 22, 1922
18	--	34	McCloud River, Baird, January 22, 1922
21	--	10	Mouth, San Rafael Creek, S. F. Bay, March 18, 1926
23	--	13	Mouth, San Rafael Creek, S. F. Bay, March 18, 1926
29	--	16	Mouth, San Rafael Creek, S. F. Bay, March 18, 1926
2	--	20	Montezuma Slough, S. F. Bay, April 8, 1927
3	--	14	Montezuma Slough, S. F. Bay, April 8, 1927
n. 2	--	13	Walnut Grove, Sacramento River, April 9, 1911
n. 6	--	18	Walnut Grove, Sacramento River, April 9, 1911
39	30	43	Half Moon Bay, May 21, 1914
5	--	17	San Joaquin River, Mendota, May 24, 1919
14	--	16	San Joaquin River, Mendota, May 24, 1919
52	23	44	Half Moon Bay, June 9, 1914
55	--	31	Raccoon Straits, S. F. Bay, June 10, 1914
58	--	30	Raccoon Straits, S. F. Bay, June 10, 1914
34	20	26	Overflow basin, Sacramento River, Collinsville, June 22, 1922
30	--	26	Overflow basin, Sacramento River, Collinsville, June 22, 1922
44	--	30	Off shore, June 29, 1922
46	--	29	Off shore, June 29, 1922
2307	--	23	McCloud River, Baird, September 24, 1909
17	--	30	McCloud River, Baird, September 24, 1909
13	--	27	McCloud River, Baird, October 18, 1911
60	--	40	McCloud River, Baird, October 18, 1911

TABLE XI

Table of Chinook Fingerling Measurements

It will be noticed from Table XI that there is a distinction in the scales of the fingerlings of the two nuclear types. Numbers 48 and 18 are large fish with many circuli. These fish were taken at Baird on the McCloud River in January, and are fish whose scales show a perfect stream type nucleus. (See Fig. 26c.) The same is true of numbers 2307, 17, 13, and 60. (See Fig. 26, b and c.) However, numbers 21, 23, 29, 2, 3, n. 2, and n. 6, are all fish presumably on their oceanward migration. These fish might remain in the stream or estuary for the rest of the year, but it is very probable that they will continue on to the sea. Numbers 39 and 52 are large fish whose scales show new growth. (See Figs. 25f and 26a.) These fish were collected in Half Moon Bay and are less than a year of age, with the characteristic new ocean growth on the scales that is typical of a salmon having scales with ocean type nuclei. (See Fig. 29.) Number 34 is a sample of a fish which has been retained under abnormal conditions and therefore the scales do not show a normal growth. The fish taken in January have undoubtedly spent a year in the stream and are prepared to migrate at any time. (See Fig. 26c.) The young salmon collected in March, April and June are of the year and are on their way to the sea as can be seen from the successive collecting stations along the river and into the bay.

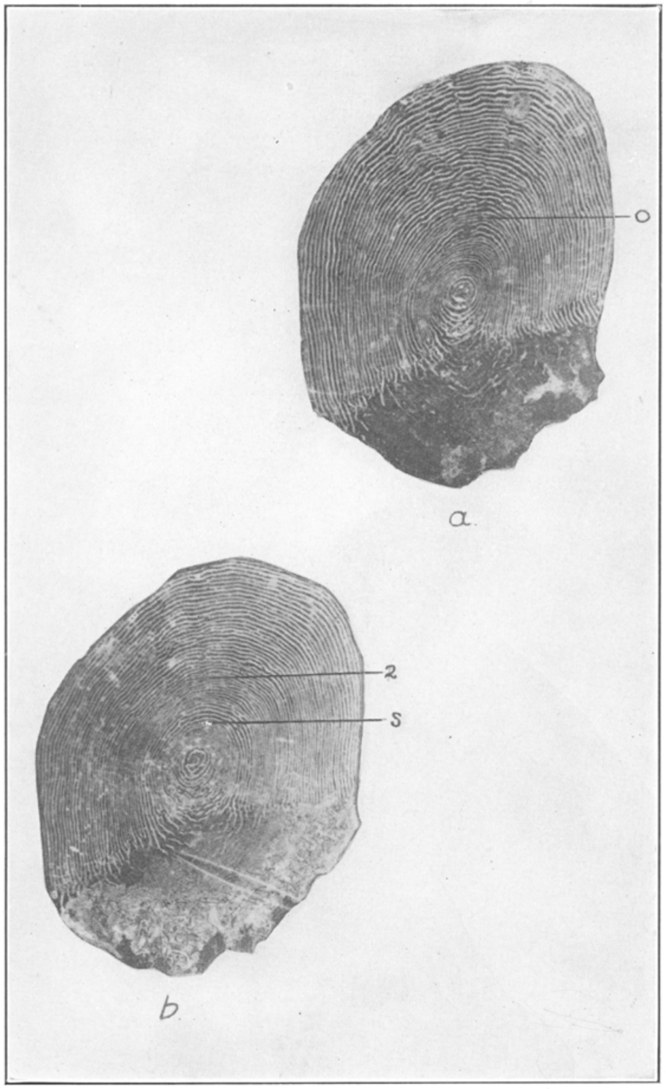

FIG. 28. Photographs of adult chinook salmon scales (x 9).
a. Scale (sample 35776) of a male chinook salmon, 54 cm. long, taken at Pittsburg, California, August 1, 1921. The fish is in its second year and has an ocean type nucleus, shown by "o" on the figure.
b. Scale (sample 7936) of a male chinook salmon, 49 cm. long, taken by J. O. Snyder at the Mendota Wier, San Joaquin River, May 24, 1919. The fish is in its third year, and has a stream type nucleus, shown by "s" on the figure.

FIG. 28. Photographs of adult chinook salmon scales (x 9)

There were no samples of young fish taken in July or August. (See Table XI.) It is the opinion of some observers that there is no oceanward migration of chinook fingerlings during the summer months in the Sacramento and San Joaquin rivers. The samples of September and October were obtained from the upper river (see Table XI); consequently the fingerlings from both of these months are summer residents having stream type nuclei. (See Fig. 26, b and c.)

The following table of measurements of fingerlings from Half Moon Bay indicates a sample of much larger fish. In this group the scales appear to have the beginning of a new growth[14] on the outer edge, formed by three or four rings and could not be definitely classed as fish of the year. (It is not known if these fish come from the Sacramento or San Joaquin rivers, but it is very probable that they are from either of these regions.) There is no distinct check shown on the scales, and they do not resemble scales taken in the upper river during the winter months. (See Figs. 25f and 26a.) The growth of the scales and fish seems to be greater than others for that time of the year and yet smaller than that of fish of two years of age (see Fig. 28) taken elsewhere in the ocean. The only possible interpretation of the early history of these fingerlings is that the fish migrated very early in the spring to the estuary and ocean where fast growth took place. The scales, therefore, have the ocean type of nuclei. The new growth, or what appears to be new growth, is very likely the result of the change from fresh to brackish and salt water with better feeding grounds.

TABLE XII

Half Moon Bay, May 21, 1914

	Lengths in mm.	*No. rings in first growth*	*No. rings in new growth*	*Total*
	147	10	5	15
	112	8	3	11
	114	10	4	14
	114	10	7	17
Average	121.7	9.5	4.75	14.2

Half Moon Bay, June 9, 1914

	Lengths in mm.	*No. rings in first growth*	*No. rings in new growth*	*Total*
	168	9	8	17
	152	12	6	18
Average	160.0	10.5	7.0	17.5

TABLE XII

4.7. Adults

After the preliminary analysis of the fingerling scales to determine the nuclear types had been completed, an attempt was made to age the adults by means of the markings on the scales. In the large collection examined, there were found many variations in the nuclei. The nuclei intergrade from the purely stream type to the typical ocean type with all the gradations between these categories. The scales showing both stream and ocean growth for the first year are termed "composite" by Rich and Holmes (1927). However, in the present analysis the scales that have a complete or almost a full first year of stream history are classed as having a stream type nucleus. The

[14] Specimens found in 1924 were examined by Snyder and some were found to be in the first year, others in the second with stream nuclei. These fish were much smaller in length than those given in Table XII. (Young Salmon Taken at Sea. *California Fish and Game*, Vol. 10, No. 2, April, 1924, p. 62.)

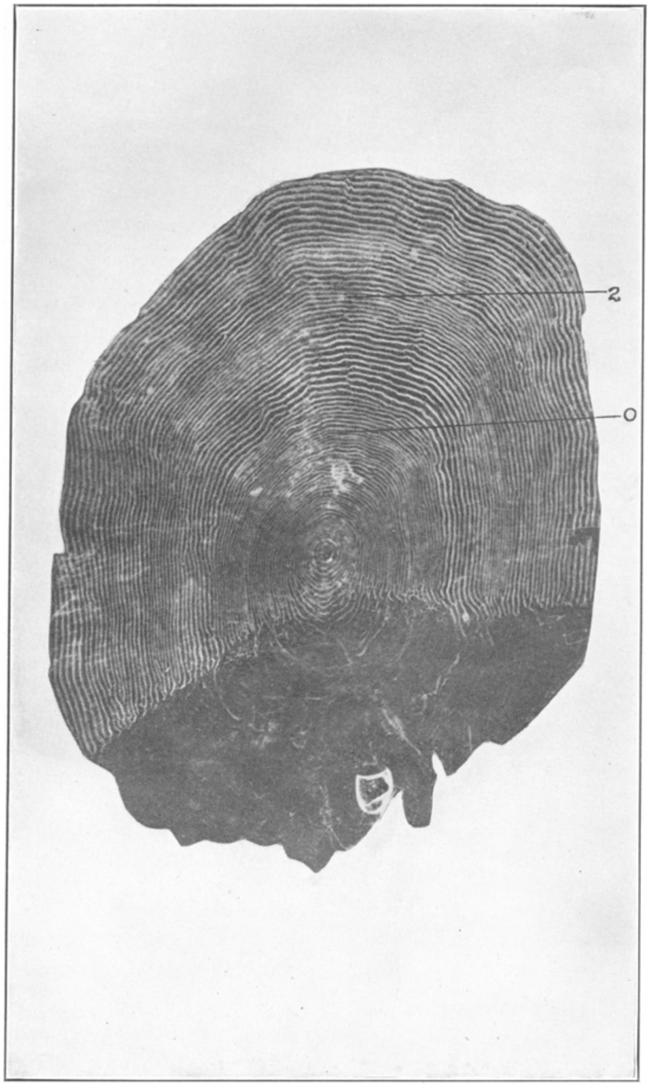

FIG. 29. Photograph (x 9) of a scale (sample 6817) of an adult made chinook salmon, 70 cm. long, taken at Pittsburg, California, May 16, 1919. The fish is in its third year and has an ocean type nucleus, shown by "o" on the figure.

FIG. 29. Photograph (x 9) of a scale (sample 6817) of an adult made chinook salmon, 70 cm. long, taken at Pittsburg, California, May 16, 1919. The fish is in its third year and has an ocean type nucleus, shown by "o" on the figure

scales which are classed as having an ocean type nucleus include scales having estuary and ocean growth and also those scales which have a "composite" growth for the first year.

The scales of the salmon of the Sacramento-San Joaquin rivers begin to show absorption along the outer edge of the embedded area soon after the fish enter fresh water on their spawning migration. This absorption in many cases makes it difficult to determine the exact age of the fish; consequently when it was thought an annulus had been thus obscured the scale of the salmon was discarded.

The percentage of nuclear types as revealed by a study of the scales of the adults may be regarded as an insight into the early history of the fish. How great a proportion of the young salmon population in the streams goes to the ocean during its first year and what percentage remains in fresh water have not been determined. However, it is thought that a much greater number go to the sea in their first year, probably 70 to 90 per cent. The young salmon that remain in the stream approximately their first year are supposedly better fitted for survival in the ocean than the fish that go earlier to sea. Information as to the truth of this statement can only be gathered from experiments with artificially reared fish. The only reliable data at hand as to the early history of the salmon population may be gathered from an interpretation of the nuclear types of the adult scales. A comparison of the males and females and nuclear types will be found in the following table (XIII), expressed in percentage of fish examined from the Sacramento and San Joaquin rivers.

TABLE XIII

Year	*Male*	*Female*	*Ocean type*	*Stream type*	*Ocean type, male*	*Ocean type, female*	*Stream type, male*	*Stream type, female*
1919	32.0	68.0	89.0	13.0	29.0	58.0	3.0	10.0
1921	30.0	70.0	91.0	9.0	28.0	63.0	2.0	7.0

TABLE XIII

It will be noted in Table XIII that there are only minor differences between the two years of 1919 and 1921. The percentage of the nuclear types are very nearly alike throughout the whole comparison. Attention is directed to the low percentage of male specimens for both years as compared to the high proportion of females. This predominance of females in the Sacramento-San Joaquin River catch as shown by the analysis of the samples is probably due to the shortening of the latter part of the season by legal restrictions. The females may be more abundant in the early part of the run, while the males increase as the season advances. (See Figs. 31 and 32 in Appendix.) Consequently, if the latter end of the run is not taken by the fishermen the females will be more numerous in the catch.

The wide range of salmon[15] in the ocean tends to make the percentage of fish having a certain type of nucleus more or less uniform along the Pacific coast. The river catches of California show a decided lower percentage of fish with stream nuclei than the ocean catch of the Columbia and Straits of Georgia. (See Figs. 31 and 32 in Appendix.)

[15] Tagging experiments carried out by the U. S. Bureau of Fisheries in cooperation with the Pacific coast states and Canada have obtained more information on the range of the salmon in the sea. The experiments were not entirely successful in all cases, but enough was done so that the evidence would point to a very wide range of chinook in the sea.

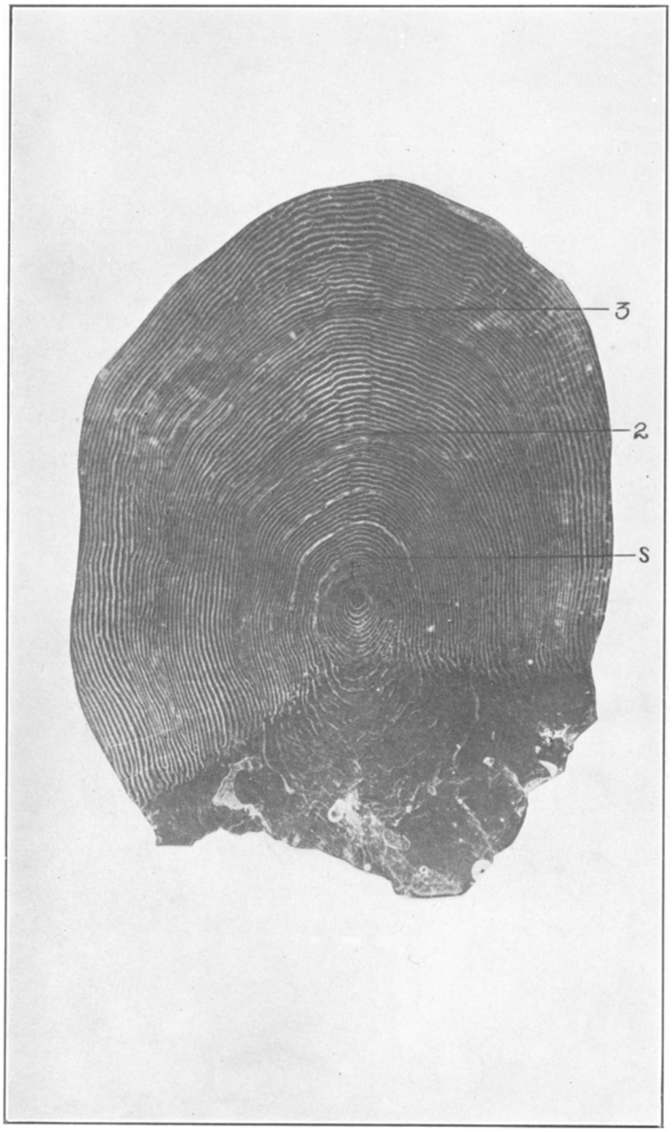

FIG. 30. Photograph (x 9) of a scale (sample 7111) of an adult male chinook salmon, 73 cm. long, weight 11 lbs., taken at Pittsburg, California, September 5, 1919. The fish is in its fourth year and has a stream type nucleus, shown by "s" on the figure.

FIG. 30. Photograph (x 9) of a scale (sample 7111) of an adult male chinook salmon, 73 cm. long, weight 11 lbs., taken at Pittsburg, California, September 5, 1919. The fish is in its fourth year and has a stream type nucleus, shown by "s" on the figure

This substantiates the evidence put forth by Rich (1925) that the higher latitudes and altitudes tend to increase the percentage of chinook salmon that spend a year in the stream before going to sea.

A salmon is mature at the time it returns from the ocean to fresh water to spawn, and the age at which the greatest per cent of salmon reach maturity in the Sacramento-San Joaquin rivers is at four years. (See Figs. 31 and 32 in Appendix.) From the representative sample for 1919, it was found that 49 per cent of the fish matured in their fourth year. In 1921,[16] from a like representative sample, 44 per cent matured in the fourth year.

The following table of age classes maturing in 1919 as compared to 1921, is expressed in percentages of the total fish examined for each year from the Sacramento and San Joaquin rivers.

TABLE XIV

Year	2 year fish	3 year fish	4 year fish	5 year fish	6 year fish	Total number of fish
1919	0.2	22.0	49.0	24.0	4.0	456
1921	2.0	12.0	44.0	41.0	0.7	1291

TABLE XIV

There is presented in Table XV a comparison between 1919 and 1921 of the average lengths of each year class. The figures below will give in a very superficial manner an idea of the rate of growth of the salmon of the Sacramento-San Joaquin rivers.

TABLE XV

Year	2 year fish	No. of fish	3 year fish	No. of fish	4 year fish	No. of fish	5 year fish	No. of fish	6 year fish	No. of fish
1919	---	--	66.1	99	90.4	226	101.4	112	102.8	18
1921	54.9	28	73.1	148	94.5	572	103.6	534	106.7	6

TABLE XV

There is, as shown by Table XV, a considerable difference between the two years. The average lengths for 1921 are larger in all classes except the two-year fish. However, the sample for 1921 is made up of more individuals, and consequently it may be regarded as the more reliable. Also there is to be considered the selection of large fish in 1921 by the use of a larger mesh net during one month of fishing as is described in footnote 16.

4.8. Summary

From this analysis of the Sacramento River catch, we are able to arrive at the following conclusions:

(1) Ninety per cent of the Sacramento-San Joaquin River salmon have scales of the ocean nuclear type.
(2) The percentage of salmon having stream nuclei in California is lower than that of the fish off the Columbia River and Straits of Georgia.
(3) About two-thirds of the fish from the samples from the Sacramento-San Joaquin rivers are females. (See explanation.)
(4) About fifty per cent of the catch of the Sacramento-San Joaquin salmon mature at four years of age.
(5) The ages of the mature salmon of the catch are in decreasing order of abundance: Four years, five years, three years, six years, and two years.
(6) The average lengths of the year classes from the samples from the Sacramento-San Joaquin rivers for 1919 and 1921 are comparable and show steady growth.
(7) On the whole the results from the Sacramento-San Joaquin rivers are in agreement with those obtained by investigators who have worked on the salmon of other localities.

4.9. General Conclusions

Depletion of the Sacramento-San Joaquin salmon is evident. It is conclusively shown by the drop in total catch despite the effort put forth; it is shown by the decrease in the egg take; it is portrayed by the change in legislation, the gradual tightening stringency of laws; and it is demonstrated by the increase in price of the fish in spite of constant effort to catch salmon.

This investigation points to the following causes of depletion:

Overfishing. 1.
Dams obstructing streams and cutting off spawning grounds. 2.
Overflow basins. 3.
Predatory fishes. 4.
Pollution. 5.
Spearing salmon on spawning beds. 6.

The available spawning grounds of salmon in the Sacramento-San Joaquin river systems are about 500 linear miles of stream. Obstructions have cut off 5500 miles of suitable and available spawning grounds, reducing the spawning area 80 per cent. It has also been ascertained that the available beds now (1928) do not support as many salmon as they are capable of doing. An attempt to build up the runs in the various rivers where the depletion factors are not so abundant should be undertaken, such as the Little Sacramento, McCloud and American rivers.

Little hope remains for those streams already blocked by high dams. Fish ladders and lifts are not successful and

[16] It must be remembered that the data are representative of the the catch and not the run, although the runs are more or less portrayed by the catch. It will be noticed that the fifth year group in 1921 is 20 per cent higher than in 1919, which is perhaps due to the fact that in 1919 the mesh limit on nets was 5 ½ inches and the season was closed from June first to July first. In 1921 the season was opened from June first to July first for 7 ½-inch mesh nets. This may account for the increase of the five-year class in 1921 over 1919.

in no case has a means been devised to get young fish safely down over high dams. In low dams the fish ladders serve the purpose but the intakes to turbines and irrigation ditches must be screened to save the young fish. However, in some of the streams blocked by dams there are good spawning grounds below these dams, *i. e.*, American, Feather, Pit, Tuolumne, Stanislaus, and San Joaquin rivers. If the salmon in these rivers are protected and the commercial closed season lengthened, the runs very likely would build themselves up again.

About 50 per cent of the Sacramento salmon mature at four years of age. The five-year mature fish come next in percentage of total, followed by the three-year, the six and then the two-year fish. About 90 per cent of the fish have the ocean type nuclei, with 10 per cent having the stream type nuclei. The percentage of the stream type fish in California is lower than the percentage of the Columbia River and Straits of Georgia.

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6. APPENDIX

APPENDIX

TABLE I

Pack * of Canned Salmon from 1864 to 1919 on the Sacramento River †

Year	*Cases packed‡*	*Canneries operating*
1864	2,000	1
1865	2,000	1
1874	2,500	
1875	3,000	
1876	10,000	2
1877	21,500	
1878	34,017	6
1879	13,855	4
1880	62,000	9
1881	181,200	20
1882	200,000	19
1883	123,000	21
1884	81,450	
1885	90,000	6
1886	39,300	9
1887	36,500	
1888	68,075	6
1889	57,300	3
1890	25,065	
1891	10,353	
1892	2,281	
1893	23,336	3
1894	28,463	2
1895	25,185	3
1896	13,387	
1897	38,543	
1898	29,731	
1899	52,580	
1900	39,304	
1901	50,304	
1902	48,172	
1903	64,430	
1904	54,710	2
1905	51,510	1
1906	53,874	
1913	950	1
1914	17,315	2
1915	5,229	3
1916	6,636	1
1917	9,443	3
1918	7,607	3
1919	3,125	2

*Cobb, John N. Pacific Salmon Fisheries. Appendix I to Report of U. S. Commissioner of Fisheries for 1921, U. S. Bureau of Fisheries Document No. 902. Also Biennial Reports of California Fish and Game Commission.

†Includes San Joaquin River, Sacramento River and Suisun Bay.

‡Reduced to a common basis of 48 one-pound cans to the case.

TABLE I
Pack of Canned Salmon from 1864 to 1919 on the Sacramento River

TABLE II

Commercial Salmon Catch, Sacramento and San Joaquin Rivers

Year	*Catch**	*Year*	*Catch**
1874	4,079,025	1901	--------
1875	5,095,781	1902	--------
1876	5,311,423	1903	--------
1877	6,493,563	1904	8,233,148
1878	6,520,768	1905	--------
1879	4,432,250	1906	--------
1880	10,837,400	1907	9,111,200
1881	9,605,000	1908	7,292,000
1882	9,605,280	1909	8,796,828
1883	9,000,000	1910	10,256,000
1884	--------	1911	--------
1885	--------	1912	--------
1886	--------	1913	--------
1887	--------	1914	--------
1888	6,622,978	1915	3,471,624
1889	6,471,095	1916	3,450,786
1890	2,970,111	1917	3,975,486
1891	1,957,354	1918	5,938,029
1892	3,435,710	1919	4,529,222
1893	3,950,373	1920	3,860,312
1894	4,494,618	1921	2,511,127
1895	3,581,244	1922	1,765,066
1896	3,276,587	1923	2,243,945
1897	3,979,397	1924	2,640,110
1898	4,079,397	1925	2,778,846
1899	6,458,959	1926	1,261,776
1900	--------	1927	917,525

*Catch in pounds live weight.

TABLE II
Commercial Salmon Catch, Sacramento and San Joaquin Rivers

TABLE V.

Output for Distribution of Chinook Salmon from Baird and Substations

Calendar years	*Baird*	*Battle Creek*	*Mill Creek*	*Totals*
1872—				
Eggs	50,000	--------	--------	50,000
1873—				
Eggs	2,000,000	--------	--------	2,000,000
1874—				
Eggs	5,005,000	--------	--------	5,005,000
1875—				
Eggs	8,629,300	--------	--------	8,629,300
1876—				
Eggs	7,498,500	--------	--------	7,498,500
1877—				
Eggs	7,053,000	--------	--------	7,053,000
1878—				
Eggs	12,246,000	--------	--------	12,246,000
1879—				
Eggs	6,889,350	--------	--------	6,889,350
1880—				
Eggs	7,396,800	--------	--------	7,396,800
1881—				
Eggs	7,270,000	--------	--------	7,270,000
1882—				
Eggs	3,991,750	--------	--------	3,991,750
1883—				
Eggs	1,034,825	--------	--------	1,034,825
1884–1887—Operations suspended.				
1888—				
Eggs	5,500,000	--------	--------	5,500,000
1889—				
Eggs	1,705,000	--------	--------	1,705,000
1890—				
Eggs	3,915,000	--------	--------	3,915,000
1891—				
Eggs	3,376,000	--------	--------	3,376,000
1892—				
Eggs	3,530,000	--------	--------	3,530,000
1893—				
Eggs	8,088,350	--------	--------	8,088,350
1894—				
Eggs	4,393,100	--------	--------	4,393,100
1895—				
Eggs	9,663,000	10,000,000[a]	--------	19,663,000
1896—				
Eggs	5,196,700	25,852,880[b]	--------	31,049,580
1897—				
Eggs	9,194,400	48,527,000[c]	--------	57,721,400
1898—				
Eggs	16,567,700	19,429,000	--------	35,996,700
1899—				
Eggs	6,415,140	1,420,500[d]	--------	7,835,640
1900—				
Eggs	2,139,500	3,520,100[e]	--------	5,659,600
1901—				
Eggs	8,933,290	10,059,000	2,561,000	21,533,290
1902—				
Eggs	1,070,000	5,705,600	3,880,000[f]	10,655,000
1903—				
Eggs	27,352,850	21,354,255	15,891,249	64,598,354
Fry	2,350,130	--------	--------	2,350,130
1904—				
Eggs	8,661,510	50,644,800[g]	36,719,465	96,025,775
Fry	7,561,380	--------	--------	7,561,380
1905—				
Eggs	25,743,770	49,032,376	33,110,330	107,886,445
Fry	3,488,552	--------	--------	3,488,552
1906—				
Eggs	2,984,015	32.640,300	37,752,000	73.376.315
Fry	2,512,250	--------	--------	2,512,250
1907—				
Eggs	10,442,950[h]	36,379,700	18,132,900[i]	64,955,550
Fry	4,780,855	--------	--------	4,780,855

[a] Operated by California Commission for that year.
[b] 2,000,000 eggs transferred to Baird.
[c] 4,247,000 eggs transferred to Baird.
[d] 1,224,000 eggs transferred to Baird.
[e] 1,000,000 eggs transferred to Baird.
[f] 600,000 eggs transferred to Baird.
[g] 5,993,900 eggs transferred to Baird.
[h] 35,000 eggs transferred to Central Station.
[i] 1,285,000 eggs transferred to Baird.

TABLE V
Output for Distribution of Chinook Salmon from Baird and Substations

TABLE V—Continued

Output for Distribution of Chinook Salmon from Baird and Substations

Calendar years	*Baird*	*Battle Creek*	*Mill Creek*	*Totals*
1908—				
Eggs	5,078,065[j]	14,006,550	13,193,650	32,278,265
Fry	3,590,078	--------	--------	3,590,078
1909—				
Eggs	7,331,317[k]	7,358,800	15,849,450	30,539.467
Fry	2,286,257	--------	--------	2,286,257
1910—				
Eggs	--------	--------	--------	35,539,368
1911—				
Eggs	60,000[l]	11,090,000	9,547,550[m]	20,697,550
Fry	7,243,325	--------	--------	7,243,325
1912—				
Eggs	495,275[n]	6,270,540	10,327,058[o]	17,092,873
Fry	2,195,100	--------	--------	2,195,100
1913—				
Eggs	2,900	9,600,365	14,782,800[p]	24,386,065
Fry	--------	4,793,249	--------	4.793,249
Fingerlings	13,011,085	838,906	--------	13,849,991
1914—				
Eggs	--------	14,968,398[q]	16,654,400	31,622,798
Fry	--------	--------	5,015,400	5,015,400
Fingerlings	2,875,544	5,001,345	--------	7,876,889
1915—				
Eggs	--------	750,000	3,000,000[r]	3,750,000
Fry	435,000	6,155,950	3,250,000	9,840,950
Fingerlings	2,029,254	3,508,070	6,400,000	11,937,424
1916—				
Eggs	--------	5,000,000[s]	1,027,300[t]	6,027,300
Fingerlings	3,702,000	5,695,300	4,863,000	14,260,300
1917—				
Eggs	--------	760,000	13,386,000	14,146,000
Fingerlings	2,760,000	4,050,500	3,878,900	10,689,400
1918—				
Eggs	--------	638,000	11,164,500	11,802,500
Fingerlings	2,280,000	4,509,000	3,498,800	10,287,800
1919—				
Eggs	--------	4,078,000	6,358,000	10,436,000
1920—				
Eggs	--------	--------	3,000,000	3,000,000
Fingerlings	1,465,000	1,781,000[u]	1,347,400	4,593,400
1921—				
Eggs	--------	--------	6,363,000	6,363,000
Fingerlings	1,500,000	2,386,000	1,986,200	5,872,200
1922—				
Eggs	1,521,000	1,587,500	791,000	3,899,000
1923—				
Eggs	1,000,000	2,066,000	3,012,000[v]	6,078,000
1924—				
Eggs	1,200,000	887,500	2,300,000[w]	4,387,500

[j] 14,000 eggs transferred to Central Station.
[k] 100,000 eggs transferred to Nashua.
[l] 20,000 eggs transferred to Central Station.
[m] 100,000 eggs transferred to Nashua.
[n] 20,000 eggs transferred to Central Station.
[o] 2,000,000 eggs transferred to Baird.
[p] 1,360,000 eggs transferred to Baird.
[q] 781,632 eggs transferred to Baird.
[r] 2,500,000 eggs transferred to Baird.
[s] 2,598,500 eggs transferred to Baird.
[t] 413,300 eggs transferred to Baird.
[u] 20,000 eggs transferred to Central Station.
[v] 1,160,000 eggs transferred to Baird.
[w] 500,000 eggs transferred to Battle Creek.

TABLE V
Output for Distribution of Chinook Salmon from Baird and Substations

TABLE VI

Distribution of Chinook Salmon from Baird and Substations

Calendar Years	*Eggs*	*Fry*	*Finger-lings*
1872—			
Eastern States and Foreign Countries	--------	30,000	--------
1873—			
California Commission for Sacramento River	500,000	--------	--------
McCloud River, Baird	20,000	--------	--------
Eastern States and Foreign Countries	1,400,000	--------	--------
1874—			
California Commission for Sacramento River	850,000	--------	--------
Eastern States and Foreign Countries	4,155,000	--------	--------
1875—			
California Commission for Sacramento River	500,000	--------	--------
McCloud River, Baird	1,750,000	--------	--------
Eastern States and Foreign Countries	5,750,000	--------	--------
1876—			
California Commission for Sacramento River	1,500,000	--------	--------
San Francisco Sport Club	300,000	--------	--------
Eastern States and Foreign Countries	4,765,000	--------	--------
1877—			
California Commission for Sacramento River	2,200,000	--------	--------
San Francisco Sport Club	250,000	--------	--------
Eastern States and Foreign Countries	4,533,000	--------	--------
1878—			
California Commission for Sacramento River	2,500,000	--------	--------
Eastern States and Foreign Countries	7,810,000	--------	--------
1879—			
California Commission for Sacramento River	2,300,000	--------	--------
Eastern States and Foreign Countries	4,650,000	--------	--------
1880—			
California Commission for Sacramento River	2,000,000	--------	--------
Eastern States and Foreign Countries	3,800,000	--------	--------
1881—			
California Commission for Sacramento River	700,000	--------	--------
McCloud River, Baird	3,720,000	--------	--------
Eastern States and Foreign Countries	2,950,000	--------	--------
1882—			
California Commission for Sacramento River	3,991,750	--------	--------
1883—			
McCloud River, Baird	7,034,825[a]	--------	--------
1884-1887—Operations suspended.			
1888—			
California Commission for Sacramento River at Sisson	3,300,000	--------	--------
McCloud River, Baird	--------	1,500,000	--------
Eastern States and Foreign Countries	150,000	--------	--------
1889—			
California Commission for Sacramento River at Sisson	1,329,000	--------	--------
McCloud River, Baird	--------	84,000	--------
Fort Gaston on Trinity River	100,000	--------	--------
Eastern States and Foreign Countries	125,000	--------	--------
1890—			
California Commission for Sacramento River at Sisson	2,838,000	--------	--------
McCloud River, Baird	--------	722,000	--------
Eastern States and Foreign Countries	150,000	--------	--------
1891—			
California Commission for Sacramento River at Sisson	2,852,250	--------	--------
McCloud River, Baird	--------	25,500	--------
Eastern States and Foreign Countries	50,000	--------	--------
1892—			
California Commission for Sacramento River at Sisson	2,080,500	--------	--------
McCloud River, Baird	--------	533,100	--------
1893—			
California Commission for Sacramento River at Sisson	7,500,000	--------	--------
McCloud River, Baird	--------	500,000	--------
Eastern States and Foreign Countries	50,000	--------	--------
1894—			
California Commission for Sacramento River at Sisson	3,526,300	--------	--------
McCloud River, Baird	--------	500,000	--------
Eastern States and Foreign Countries	150,000	--------	--------

[a] 25 per cent lost because of damage to water supply.

TABLE VI
Distribution of Chinook Salmon from Baird and Substations

TABLE VI—Continued

Distribution of Chinook Salmon from Baird and Substations

Calendar Years	*Eggs*	*Fry*	*Finger-lings*
1895—			
California Commission for Sisson Hatchery	6,076,000	9,000,000[b]	--------
McCloud River, Battle Creek and Mill Creek	--------	650,000	--------
Eastern States and Foreign Countries	2,819,000	1,000,000[c]	--------
1896—			
California Commission for Sisson Hatchery	18,841,700	--------	--------
Olema, California	750,500	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	1,900,000	--------
Eastern States and Foreign Countries	8,150,000	--------	--------
1897—			
California Commission for Sisson Hatchery	22,255,000	--------	--------
Eel River, California	8,000,000	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	12,447,300	--------
Eastern States and Foreign Countries	11,270,000	--------	--------
1898—			
California Commission for Sisson Hatchery	14,842,000	--------	--------
Eel River, California	10,042,300	--------	--------
McCloud River, Battle Creek and Mill Creek	85,200	3,263,560	--------
Bear Valley, California	1,000,000	--------	--------
Eastern States and Foreign Countries	185,000	--------	--------
1899—			
California Commission for Sisson Hatchery	1,905,000	--------	--------
Eel River, California	1,000,000	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	4,511,733	--------
Eastern States and Foreign Countries	20,000	--------	--------
1900—			
California Commission for Sisson Hatchery	4,100,660	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	889,570	--------
Stanford University	1,000	--------	--------
Eastern States and Foreign Countries	75,000	--------	--------
1901—			
California Commission for Sisson Hatchery	14,613,380	--------	--------
Eel River, California	2,008,030	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	2,115,560	--------
Price Creek Hatchery	1,000,000	--------	--------
Eastern States and Foreign Countries	50,000	--------	--------
1902—			
California Commission for Sisson Hatchery	7,455,477	--------	--------
Eel River, California	2,080,300	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	1,918,066	--------
Price Creek Hatchery	1,378,000	--------	--------
1903—			
California Commission for Sisson Hatchery	58,624,371	--------	--------
Eel River, California	5,522,983	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	2,350,130	--------
1904—			
California Commission for Sisson Hatchery	87,170,824	--------	--------
Eel River, California	8,414,950	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	7,561,380	--------
Eastern States and Foreign Countries	400,000	--------	--------
1905—			
Sacramento River, Mt. Shasta Hatchery[d]	96,190,685	--------	--------
California Commission for Eel River	9,943,320	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	3,488,552	--------
Brookdale Hatchery	932,440	--------	--------
Eastern States and Foreign Countries	800,000	--------	--------
1906—			
Sacramento River, Mt. Shasta Hatchery	63,671,415	--------	--------
California Commission at Alton	7,768,900	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	2,512,250	--------
Brookdale Hatchery	1,400,000	--------	--------
Eastern States and Foreign Countries	500,000	--------	--------
1907—			
Sacramento River, Mt. Shasta Hatchery	56,493,350	--------	--------
California Commission for Eel River	7,154,200	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	4,780,855	--------
Brookdale Hatchery	1,000,000	--------	--------
Eastern States and Foreign Countries	--------	250,000	--------
1908—			
Sacramento River, Mt. Shasta Hatchery	26,599,265	--------	--------
California Commission for Eel River	--------	5,440,000	--------
McCloud River, Battle Creek and Mill Creek	--------	3,590,078	--------
Eastern States and Foreign Countries	200,000	--------	--------

[b] Eggs from Battle Creek (Station operated by California Commission in 1895).
[c] Eggs from Battle Creek to Oregon.
[d] Sisson Hatchery and Mt. Shasta Hatchery are the same.

TABLE VI
Distribution of Chinook Salmon from Baird and Substations

TABLE VI—Continued

Distribution of Chinook Salmon from Baird and Substations

Calendar Years	*Eggs*	*Fry*	*Finger-lings*
1909[e]—			
Sacramento River, Mt. Shasta Hatchery	27,214,967	--------	--------
California Commission for Eel River	1,549,500	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	2,286,257	--------
Brookdale Hatchery	1,000,000	--------	--------
Eastern States and Foreign Countries	200,000	--------	--------
1910—			
Sacramento River, Mt. Shasta Hatchery	32,952,514	--------	--------
1911—			
Sacramento River, Mt. Shasta Hatchery	16,254,550	--------	--------
California Commission for City of Sacramento	71,000	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	7,243,325	--------
Brookdale Hatchery	960,000	--------	--------
California Commission at San Francisco	3,240,000	--------	--------
1912[f]—			
Sacramento River, Mt. Shasta Hatchery	14,522,873	--------	--------
California Commission for City of Sacramento	600,000	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	2,195,100	--------
Brookdale Hatchery	300,000	--------	--------
California Commission at San Francisco	1,500,000	--------	--------
1913—			
Sacramento River, Mt. Shasta Hatchery	22,796,645	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	4,793,249	3,848,991
California Commission at San Francisco	2,527,000	--------	--------
1914—			
Sacramento River, Mt. Shasta Hatchery	34,301,073	--------	--------
Into Sacramento River at Tehama	--------	1,275,000	--------
McCloud River, Battle Creek and Mill Creek	--------	3,740,400	7,876,889
1915—			
Sacramento River, Mt. Shasta Hatchery	3,000,000	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	16,300,950	5,538,224
California Commission at San Francisco	750,000	--------	--------
1916—			
Sacramento River, Mt. Shasta Hatchery	7,027,300	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	--------	14,260,300
1917—			
Sacramento River, Mt. Shasta Hatchery	14,321,900	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	--------	10,689,400
1918—			
Sacramento River, Mt. Shasta Hatchery	11,802,500	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	--------	10,287,800
1919—			
Sacramento River, Mt. Shasta Hatchery	4,235,000	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	--------	5,741,000
1920—			
Sacramento River, Mt. Shasta Hatchery	3,000,000	--------	--------
McCloud River, Battle Creek and Mill Creek	--------	--------	13,593,400
1921—			
McCloud River, Battle Creek and Mill Creek	--------	--------	5,872,200
1922—			
McCloud River, Battle Creek and Mill Creek	--------	--------	3,803,500
1923—			
McCloud River, Battle Creek and Mill Creek	--------	1,050,000	1,486,000
1924—			
McCloud River, Battle Creek and Mill Creek	--------	2,148,800	1,892,500

[e] Also 300,000 eggs to Point Reyes, California.
[f] Also 20,000 eggs to Truckee, California.

TABLE VI
Distribution of Chinook Salmon from Baird and Substations

TABLE VII

Total Egg Take of Salmon by Stations on Sacramento River

(Fry and Fingerlings Reduced to Eggs)

Calendar Years	*Baird*	*Battle Creek*	*Mill Creek*
1872	50,000		
1873	2,000,000		
1874	5,005,000		
1875	8,629,300		
1876	7,498,500		
1877	7,053,000		
1878	12,246,000		
1879	6,889,350		
1880	7,396,800		
1881	7,270,000		
1882	3,991,750		
1883	1,034,825		
1884-1887	Operations suspended		
1888	5,500,000		
1889	1,705,000		
1890	3,915,000		
1891	3,376,000		
1892	3,530,000		
1893	8,088,350		
1894	4,393,100		
1895	9,663,000	10,000,000**	
1896	5,196,700	25,852,880	
1897	9,194,400	48,527,000	
1898	16,567,700	19,429,000	
1899	6,415,140	1,420,500	
1900	2,139,500	3,520,100	
1901	8,933,290	10,059,000	2,561,000
1902	1,070,000	5,705,000	3,880,000
1903	29,937,993	21.354,255	15,891,249
1904	16,979,028	50,644,800	36,719,465
1905	29,581,177	49,032,375	33,110,330
1906	5,747,490	32,640,300	37,752,000
1907	15,701,890	36,379,700	18,132,900
1908	9,027,150	14,006,550	13,193,650
1909	9,846,099	7,358,800	15,849,450
1910	6,851,028*	10,000,000*	18,857,028***
1911	8,027,657	11,090,000	9,547,550
1912	2,909,885	6,270,540	10,327,058
1913	3,315,093	15,795,734	14,782,800
1914	3,163,098	20,469,877	22,171,340
1915	2,711,789	11,380,422	14,725,000
1916	4,072,200	11,264,830	6,376,600
1917	3,036,000	5,215,550	17,652,790
1918	2,508,000	5,597,900	15,814,180
1919	--------	4,078,000	6,358,000
1920	1,611,500	1,959,100	4,482,140
1921	1,650,000	2,624,600	2,184,820
1922	1,521,000	1,587,500	791,000
1923	1,000,000	2,066,000	3,012,000
1924	1,200,000	887,500	2,300,000

*Total for 1910 is 35,539,468 eggs; 18,000,000 of these were taken at Mill Creek, while the remainder was arbitrarily portioned out to the other two stations.

**Battle Creek station operated by California Commission in 1895.

***Mill Creek Station operated by California Commission in 1910.

TABLE VII
Total Egg Take of Salmon by Stations on Sacramento River

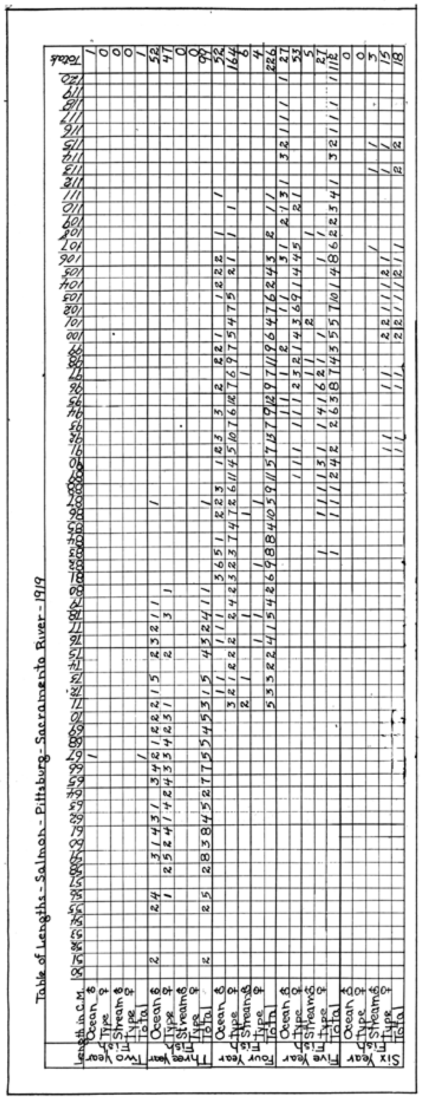

Table of Lengths - Salmon - Pittsburg - Sacramento River - 1919

		Totals
Two Year Fish	Ocean Type ♂	1
	Ocean Type ♀	0
	Stream Type ♂	0
	Stream Type ♀	0
	Total	1
Three Year Fish	Ocean Type ♂	52
	Ocean Type ♀	47
	Stream Type ♂	0
	Stream Type ♀	0
	Total	99
Four Year Fish	Ocean Type ♂	52
	Ocean Type ♀	164
	Stream Type ♂	6
	Stream Type ♀	4
	Total	226
Five Year Fish	Ocean Type ♂	27
	Ocean Type ♀	53
	Stream Type ♂	5
	Stream Type ♀	27
	Total	112
Six Year Fish	Ocean Type ♂	0
	Ocean Type ♀	0
	Stream Type ♂	3
	Stream Type ♀	15
	Total	18

Summary - Salmon - Pittsburg - Sacramento R. 1919

Classes	2 Yr.	3 Yr.	4 Yr.	5 Yr.	6 Yr.	Total	%
Males	1	52	58	32	3	146	32.0
Females	0	47	168	80	15	310	68.0
Ocean type	1	99	216	80	0	396	87.0
Stream type	0	0	10	32	18	60	13.0
Ocean type ♂	1	52	52	27	0	132	29.0
Ocean type ♀	0	47	164	53	0	264	58.0
Stream type ♂	0	0	6	5	3	14	3.0
Stream type ♀	0	0	4	27	15	46	10.0
Totals	1	99	226	112	18	456	
Percentage	.2	21.7	49.5	24.5	4.0		
Av. len. in c.m.	67.0	66.1	90.4	101.4	102.8		

Fig. 31.

Fig. 31

Table of Lengths, Salmon - Pittsburg - Sacramento River - 1921

Length in C.M.	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
Two year Fish, Ocean Type ♂	1				2	2	6	8	4	1	1	2	1							
Two year Fish, Ocean Type ♀																				
Two year Fish, Stream Type ♂																				
Two year Fish, Stream Type ♀																				
Two year Fish, Total	1				2	2	6	8	4	1	1	2	1							
Three year Fish, Ocean Type ♂			1		1				1	2	3	2	6	3	3		3	6	2	3
Three year Fish, Ocean Type ♀																				
Three year Fish, Stream Type ♂						1											1			1
Three year Fish, Stream Type ♀																				
Three year Fish, Total			1		1	1			1	2	3	2	6	3	3		4	6	2	4
Four year Fish, Ocean Type ♂																				1
Four year Fish, Ocean Type ♀																				
Four year Fish, Stream Type ♂																				
Four year Fish, Stream Type ♀																				
Four year Fish, Total																				1
Five year Fish, Ocean Type ♂																				
Five year Fish, Ocean Type ♀																				
Five year Fish, Stream Type ♂																				
Five year Fish, Stream Type ♀																				
Five year Fish, Total																				
Six year Fish, Ocean Type ♂																				
Six year Fish, Ocean Type ♀																				
Six year Fish, Stream Type ♂																				
Six year Fish, Stream Type ♀																				
Six year Fish, Total																				

Length in C.M.	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Two year Fish, Ocean Type ♂																				
Two year Fish, Ocean Type ♀																				
Two year Fish, Stream Type ♂																				
Two year Fish, Stream Type ♀																				
Two year Fish, Total																				
Three year Fish, Ocean Type ♂	4	6	4	8	2	8	5	7	5	2	5	4	2	1	2	2	1	1		
Three year Fish, Ocean Type ♀	1	2			1			2		2	4	2	3	2	2	8	1	3	3	1
Three year Fish, Stream Type ♂	1																			
Three year Fish, Stream Type ♀																				
Three year Fish, Total	6	8	4	8	3	8	5	9	5	4	9	6	5	3	4	10	2	4	3	1
Four year Fish, Ocean Type ♂		1		1			1	1	3		2	3	3	5	3	4	1	6	7	3
Four year Fish, Ocean Type ♀						1					3	3	3	3	6	6	6	7	8	9
Four year Fish, Stream Type ♂						1		1								2		1		
Four year Fish, Stream Type ♀													2			3		2		2
Four year Fish, Total		1		1		2	1	2	3		5	6	8	8	9	15	7	16	15	14
Five year Fish, Ocean Type ♂																1		1		
Five year Fish, Ocean Type ♀														1						
Five year Fish, Stream Type ♂																		1		
Five year Fish, Stream Type ♀														1		1			2	
Five year Fish, Total														2		2		2	2	
Six year Fish, Ocean Type ♂																				
Six year Fish, Ocean Type ♀																				
Six year Fish, Stream Type ♂																				
Six year Fish, Stream Type ♀																				
Six year Fish, Total																				

Length in C.M.	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107
Two year Fish, Ocean Type ♂																				
Two year Fish, Ocean Type ♀																				
Two year Fish, Stream Type ♂																				
Two year Fish, Stream Type ♀																				
Two year Fish, Total																				
Three year Fish, Ocean Type ♂		1																		
Three year Fish, Ocean Type ♀		1																		
Three year Fish, Stream Type ♂																				
Three year Fish, Stream Type ♀																				
Three year Fish, Total		2																		
Four year Fish, Ocean Type ♂	6	4	2	5	5	1	6	4	4	4	3	6		2	3	1	5	1	4	2
Four year Fish, Ocean Type ♀	11	15	11	22	22	24	25	21	31	20	20	22	27	9	9	15	15	9	7	4
Four year Fish, Stream Type ♂					1			2				1								
Four year Fish, Stream Type ♀	2		2	1	4	1	3		1	1	2	2		1						
Four year Fish, Total	19	17	15	28	32	26	32	27	36	25	25	31	27	12	12	14	18	10	11	6
Five year Fish, Ocean Type ♂	1	2	2	2	1	2	1	1		1	2		1	2	3	1	4	1	4	3
Five year Fish, Ocean Type ♀			2	4	1	3	9	12	11	11	22	18	21	21	33	18	45	29	26	26
Five year Fish, Stream Type ♂					1					1					1	1				1
Five year Fish, Stream Type ♀	1		1			4	2	2	6	3	6	3	2	4	3	2	3		3	4
Five year Fish, Total	2	2	5	6	3	9	12	15	17	16	30	21	24	27	40	22	50	30	35	34
Six year Fish, Ocean Type ♂																				
Six year Fish, Ocean Type ♀																1		1		
Six year Fish, Stream Type ♂																				
Six year Fish, Stream Type ♀														1		1	1			
Six year Fish, Total														1		2	1	1		

Length in C.M.	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	Totals
Two year Fish, Ocean Type ♂																			28
Two year Fish, Ocean Type ♀																			0
Two year Fish, Stream Type ♂																			0
Two year Fish, Stream Type ♀																			0
Two year Fish, Total																			28
Three year Fish, Ocean Type ♂																			106
Three year Fish, Ocean Type ♀																			38
Three year Fish, Stream Type ♂																			4
Three year Fish, Stream Type ♀																			0
Three year Fish, Total																			148
Four year Fish, Ocean Type ♂	2	2	3	3	3	1	1	1		1			1						129
Four year Fish, Ocean Type ♀	4	5	2	3	2				1										405
Four year Fish, Stream Type ♂																			9
Four year Fish, Stream Type ♀																			29
Four year Fish, Total	6	7	5	6	5	1	1	1	1	1			1						572
Five year Fish, Ocean Type ♂	1	2	1	4	4	3	8	4	3	8	6	4	4	3	5	3	2		101
Five year Fish, Ocean Type ♀	18	11	7	9	4	4	4												368
Five year Fish, Stream Type ♂	1	1				1													9
Five year Fish, Stream Type ♀	1		2																56
Five year Fish, Total	21	14	10	13	8	8	12	4	3	8	6	4	4	3	5	3	2		534
Six year Fish, Ocean Type ♂																			0
Six year Fish, Ocean Type ♀		1																	3
Six year Fish, Stream Type ♂			1							1									2
Six year Fish, Stream Type ♀		1																	4
Six year Fish, Total		2	1							1									9

Summary Salmon Pittsburg Sacramento R. 1921

Classes	2 Yr.	3 Yr.	4 Yr.	5 Yr.	6 Yr.	Total	%
Males	28	110	138	110	2	388	30.0
Females	0	38	434	424	7	903	70.0
Ocean type	28	144	534	469	3	1178	91.0
Stream type	0	4	38	65	6	113	9.0
Ocean type ♂	28	106	129	101	0	364	28.0
Ocean type ♀	0	38	405	368	3	814	63.0
Stream type ♂	0	4	9	9	2	24	2.0
Stream type ♀	0	0	29	56	4	89	7.0
Totals	28	148	572	534	9	1291	
Per centage	2.0	12.0	44.0	41.0	.7		
Av. len. in c.m.	54.9	73.1	94.5	103.6	106.7		

Fig. 32.

Fig. 32