NATURAL HISTORY OF THE QUINNAT SALMON.

A REPORT OF INVESTIGATIONS IN THE SACRAMENTO RIVER, 1896–1901.

By CLOUDSLEY RUTTER,

Naturalist, United States Fish Commission Steamer Albatross.

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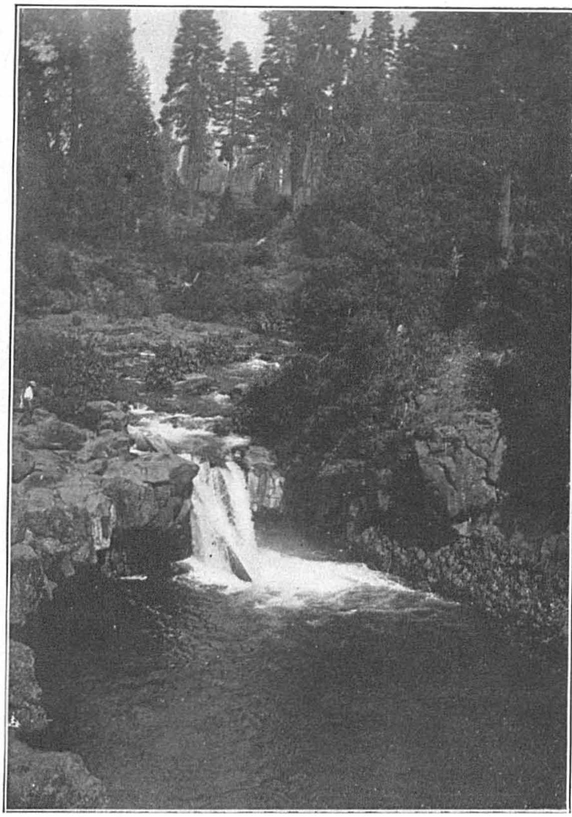

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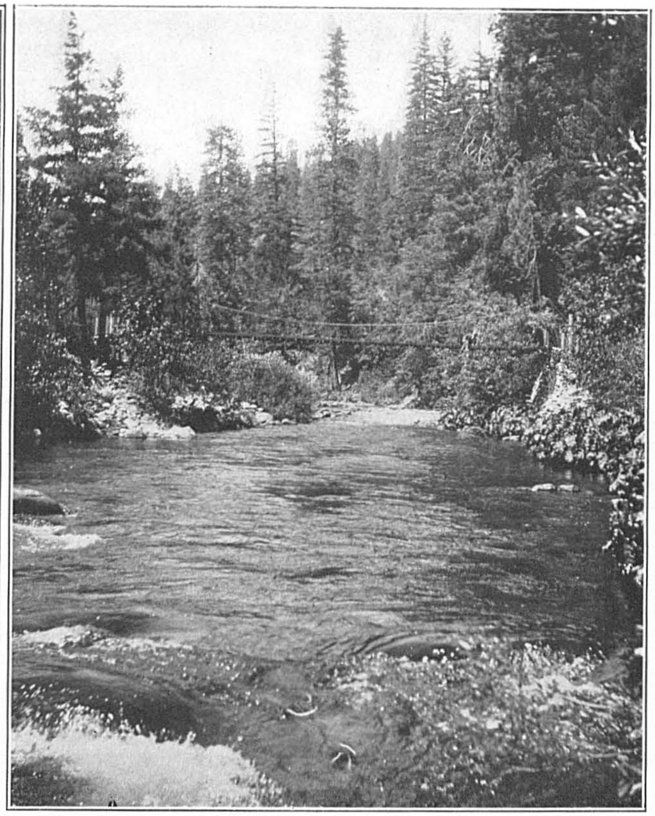

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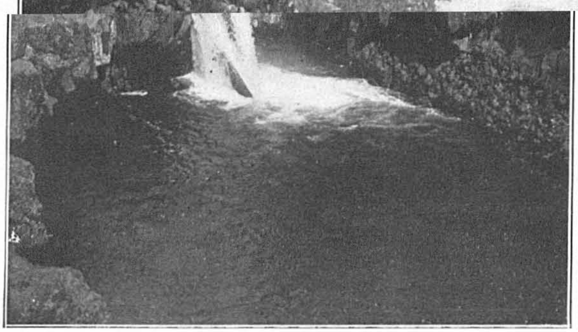

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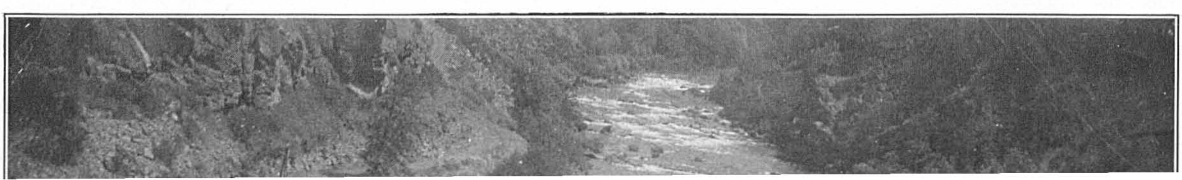

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ORIGIN AND METHOD OF THE INVESTIGATIONS.

The superlative value of the quinnat salmon as a food-fish has long been recognized, and the great market demand for it was, until recently, rapidly leading to its extermination. Within the last few years, however, artificial propagation has reached such efficiency that the species is again increasing, especially in the Sacramento River, California. Two divisions of the work of artificial propagation—spawning and hatching—have received much attention and are especially well understood. The first includes securing the spawning fishes and taking and fertilizing the ova; the second includes the care of the eggs from the time they are fertilized until they are hatched.

At Battle Creek hatchery in 1897 nearly 50,000,000 eggs were taken, which hatched over 40,000,000 alevins. With such an enormous output of young salmon the question of the best method of planting them became of vital importance. It had usually been the custom to plant the alevins within a few days after they were hatched, and with such large numbers as were produced in 1897 this was an absolute necessity, owing to lack of space in which to care for them. But there was evidently a great risk in planting so many helpless young fishes when the knowledge of their habits and enemies in the streams was so limited. It was for the purpose of supplying such knowledge that these investigations were undertaken. Begun originally with the one purpose in view, the investigation has grown till many other questions have been involved. In order to determine the best method of planting it was necessary to study the habits of the young salmon under natural conditions. This led to a study of the spawning habits and finally the general life-history. In studying the natural propagation it seemed advisable to compare it with artificial propagation, which led to various experiments bearing on the latter subject. Most of the work was carried on in the Sacramento basin. Every mile of the Sacramento River from source to mouth has been visited, except 5 or 6 miles below the head of Box Canyon near Sisson. Nearly 1,000 miles have been traveled in skiffs, and twice the entire distance from Redding to Sacramento has been thus covered, seining stations being established every 17 miles on an average. In exploring Pit basin and the sources of Feather River about 500 miles were traveled by wagon and about 30 seining stations were made. (See chart of explorations, plate 18.)

Daily observations of the migrations of the young salmon in the main river were made at two stations, about 325 miles apart, from January to May, 1899. The hatchery experiments were carried on during two seasons, 1897 and 1898, at Battle Creek hatchery. Twenty-five thousand eggs were hatched at the Hopkins Seaside Laboratory at Pacific Grove during the winter of 1898-99, and the young were used in experiments testing the effect of sea water on alevins and fry. Experiments in planting alevins and fry were made at Olema, Marin County, and at Sisson, Siskiyou County, in 1897 and 1898. The investigations in 1900 and 1901 consisted of observations on adult salmon at Pacific Grove and at various points on the Sacramento, especially at Black Diamond, Rio Vista, and Mill Creek and Battle Creek fisheries.

Observations of the habits of the young were made first by watching them in the water. This, of course, could be done only in the small streams, but was very successful in the work the first year at Olema. Specimens were secured by means of the ordinary Baird seine; the one most used in this investigation was 50 feet long and 7 feet deep; smaller seines, 20 and 15 feet long, were used in small streams; in some of the work in San Pablo Bay a net 150 feet long was used. Traps constructed to suit particular purposes were employed where occasion required.

The work was carried on under the direction of the United States Fish Commission, with the cooperation of the California Fish Commission, through Mr. N. B. Scofield, during the first two years. Mr. F. M. Chamberlain, of the United States Fish Commission steamer *Albatross*, assisted in the work from May, 1898, to April, 1899. Mr. A. B. Alexander, also of the steamer *Albatross*, began the work at Olema in 1897. Much of the success of the investigation is due to the interest and counsel of Mr. J. P. Babcock, of the California Fish Commission; and Prof. Charles H. Gilbert, of Stanford University, has aided much in planning the work and in affording facilities for studying the collections.

The author is under obligations to the agents of the Southern Pacific Company at the shipping-points along the Sacramento River, to the various fish-dealers in Sacramento, and to the salmon-packing associations at Benicia and Black Diamond for statements of the catch of salmon at various places along the river and bays and for other courtesies; also to the officials of the United States Weather Bureau at San Francisco and Red Bluff and to the agent of the Southern Pacific Company at Sacramento Bridge for river statistics. The directors of the Hopkins Seaside Laboratory at Pacific Grove gave the free use of laboratory facilities for carrying on the experiments at that place.

GENERAL RESULTS OF THE INVESTIGATIONS.

A great many points of more or less interest have been considered in this series of investigations, of which the following have the most practical value and deserve special mention:

1. The original object of the investigation has been carried out in determining that young salmon should be released from the hatcheries soon after the yolk has been entirely absorbed and that they should not be released in the headwaters late in the spring.

2. A method has been found for removing and fertilizing the eggs left in the fish after artificial spawning, thus increasing the take of eggs from a given number of fishes by about one-fifth.

3. The site for a new hatchery, Mill Creek station, has been discovered.

Other points of interest determined are:

a. The spermatozoa of the milt are active for only 3 to 5 minutes after the milt is mixed with water.

b. Ova become incapable of fertilization after 5 minutes' immersion in water, and good results can not be obtained after 1 minute.

c. Ova can be exposed to air for half an hour provided they are kept moist by the ovarian fluid.

d. Ova may be fertilized while immersed in the ovarian fluid, or in the slime from the skin, or in unclotted blood.

e. Ova are not affected by immersion in normal salt solution for half an hour, and are capable of fertilization thereafter.

f. Between the ages of 6 and 16 days, when the water temperature is about 50°, the embryo is especially sensitive and liable to injury. During this period the eggs should be handled with the greatest care.

g. Fungus is not a great pest at Battle Creek hatchery, probably owing to the considerable amount of silt carried in the water and deposited on the mat of filaments.

h. Alevins have many enemies in the streams; fry but few.

i. The fry begin feeding and commence their downstream migration as soon as the yolk is absorbed and they are able to swim.

j. The fry drift downstream tail first, traveling mostly at night and averaging about 10 miles a day. They are 4 or 5 months old when they reach the ocean.

k. A few of the later winter fry, about 10,000 to the mile in the Upper Sacramento, remain in the headwaters all summer, which is deleterious on account of slow growth.

l. The food of young salmon at all places and seasons is insects, larval or adult.

m. Salmon spend from 2 to 4 years in the ocean.

n. They usually return to the river through which they reached the ocean, because during their ocean life they do not get far away from its mouth.

o. The later fall salmon ascend the Sacramento River at the rate of 4 or 5 miles a day, being about 65 days reaching Tehama from Rio Vista. The spring salmon, without doubt, travel faster.

p. Salmon do not eat after leaving the ocean, and the stomach shrivels up to about a tenth of its normal size.

q. Salmon lose from 15 to 20 per cent of their weight in migrating, and from 10 to 15 per cent more in spawning.

r. The sexes can not be distinguished in salt water, but they differ greatly in fresh water. The males develop the long hooked jaw, the large canine teeth, the deep slab-sided body, and the color usually becomes more or less reddish. The females do not change in appearance except as is due to the loss of flesh, the development of the ova, and to the change in color from silvery to olive.

s. The males vary more in size than the females and are of two forms, adult and grilse; the grilse resemble the females, but are much smaller.

t. The percentage of fertilization in natural propagation is high, probably about 85 per cent.

u. The injuries received in fresh water are mostly due to exertions in spawning the last few ova.

v. It is well known that all Pacific salmons die immediately after spawning once, and this investigation simply bears out the fact.

THE SACRAMENTO RIVER AS A SALMON STREAM.

The Sacramento is a large river, navigable for boats as far as Red Bluff, which is 225 miles by rail from San Francisco. It is quite crooked, and the distance by water from Red Bluff to the Golden Gate is about 375 miles. The river rises in several small lakes in the mountains about 20 miles west of Sisson, in Siskiyou County, California, and for nearly half its length flows through a narrow canyon. The upper portion is a typical mountain stream, with innumerable pools and rapids and gravel beds, forming ideal spawning-places for the salmon, though it has not been visited by many of them during the past few years. Near the lower end of the canyon it receives Pit River from the east.

Pit River is a much larger stream than the Sacramento above their union. Its lower portion lies in a canyon and except in size is similar to the Upper Sacramento. About 75 miles above its mouth are the Pit River Falls, which, until a fishway was blasted out, were impassable for salmon. The upper portion of Pit River lies on a plateau and during the summer is a very unimportant stream.

The salmon that pass Pit River Falls spawn in Fall River, which enters Pit River a few miles above the falls. When seen in August, 1898, Fall River flowed several times as much water as Upper Pit River, though it is only 12 or 15 miles in a direct line from its mouth to its source. It is about 100 feet wide and 3 to 4 feet deep, flowing through a level plain and taking its rise in several large springs.

Hat Creek, draining Mount Lassen on the north, empties into Pit River a few miles below the falls. It is a considerable stream, but its ascent is difficult for salmon on account of very steep rapids.

McCloud River, draining Mount Shasta on the south, empties into Pit River near its mouth. It is two or three times the size of the Sacramento River above the mouth of Pit River and is an important salmon stream. Baird hatchery is located near its mouth.

The most important salmon stream of the basin, excepting the main river as noted below, is Battle Creek, which drains Mount Lassen on the west and empties into the Sacramento between Redding and Red Bluff. Battle Creek hatchery is located at the mouth of this stream.

A few miles below the mouth of Pit River, and just above Redding, the Sacramento emerges from the canyon through which it runs from its source and widens into a broad, shallow stream, though the current continues swift. Below Redding, for perhaps 100 or 150 miles as the river winds, it continues broad and shallow, with many short riffles and usually a gravel bank along one side. In ordinary years when the river is in its normal low-water condition the principal spawning-beds of the fall salmon are in this portion of the main river, notably in the vicinity of Red Bluff and Tehama. In November, 1900, the river was examined carefully between the mouth of Battle Creek and Tehama. Few salmon were seen until within a few miles of Red Bluff, but from that point on every riffle was covered with spawning-beds and dead salmon were everywhere abundant in their vicinity. Seventy-five dead fishes were counted at one time in the lower 100 yards of Mill Creek and in the river within 50 yards of its mouth.

A few miles above Red Bluff the river cuts through a range of hills, and for 2 or 3 miles consists of a series of rapids, the longest of which is known as Iron Canyon. After passing Iron Canyon the river again assumes the character found at and below Redding. Farther downstream the channel becomes deeper, gravel banks disappear, sand banks become less frequent, and rapids are wanting. Such is the character from Colusa to Sacramento. Below Sacramento it runs through a level country and for most of the distance is affected by tides. There are many sloughs, some connecting it with the San Joaquin. The Sacramento and San Joaquin rivers join as they empty into Suisun Bay.

The water of the upper part of Sacramento River and the upper tributaries is quite clear, and continues so until the mouth of Feather River is reached, from which point to the mouth it is very muddy. It is in the muddy water between the mouth of Feather River and Vallejo that the salmon for the markets are taken.

The only species of salmon regularly frequenting the Sacramento River is the quinnat. The dog salmon is found occasionally, four specimens having been seen during this investigation. Mr. Chamberlain reports finding single specimens of the blueback and humpback at Baird in 1899. The humpback has also been reported by others. The only record of the silver salmon from the Sacramento River is that given by Jordan & Jouy (Proc. U. S. National Museum 1881).

THE GENERAL LIFE-HISTORY OF THE PACIFIC SALMONS.

The salmon under consideration in this report is the Sacramento or quinnat salmon (*Oncorhynchus tschawytscha*), also known as Columbia River salmon, king salmon, and chinook salmon, and is the largest and most important of the five species of Pacific salmons. The others, in the order of their importance, are (1) blueback (*O. nerka*), also called red salmon, redfish, and sockeye; (2) silver salmon (*O. kisutch*); (3) humpback salmon (*O. gorbuscha*), and (4) dog salmon (*O. keta*).

The Pacific salmons, as above named, are different from the Atlantic salmon, which is related to the steelhead or salmon trout of the Pacific coast. One of the important characters that separate the Pacific salmons from the steelhead and its relatives, the Atlantic salmon and the rainbow and cut-throat trouts, is the larger number of rays in the anal fin—the unpaired fin on the under side of the tail. The steelhead and its allies have fewer than 13 rays (usually 11) in this fin, while the Pacific salmons have more than 13, the number for the quinnat being 16.[a]

An equally fundamental, though physiological, difference lies in the fact that the Atlantic salmon and steelhead trout spawn several times while the Pacific salmon, of whatever species, dies as soon as it spawns once. This is a very striking difference and its importance can hardly be overestimated. A further difference lies in the habits of the young. The young of the Pacific salmon seek the ocean as soon as they are able to swim; their migration is accelerated by high water and retarded by low water, and they do not return to fresh water till mature. On the contrary, young trout do not seek the ocean for several months after they are able to swim, low water is an incentive to migration, and they run back and forth between fresh and salt water seeking food.

The quinnat salmon is found throughout the Pacific coast from Monterey Bay northward, but is less abundant north of Puget Sound. At spawning time it frequents the larger streams, especially those with estuaries. The blueback salmon is the most abundant of the Pacific salmons, and is most numerous in Alaska. Its favorite spawning streams are those tributary to lakes. The silver salmon prefers

[a] For other anatomical characters, see Jordan & Evermann, Fishes of North and Middle America, Bulletin 47, United States National Museum.

the larger streams, though not necessarily those emptying through estuaries. The other two species are of little importance. They spawn in any kind of stream, frequently in mere brooks that empty directly into the ocean.

The Pacific salmon, of whatever species, passes most of its life in the ocean, and upon arriving at maturity ascends the rivers to spawn. Sometimes enormous numbers pass upstream together; stories of their being "thick enough to walk across on" are often told, but I have never seen them quite so numerous as that.

The upstream migration occurs sometime during the warmer half of the year, the earlier fish going farther upstream. Spawning occurs late in the summer or during the fall, and as soon as it is completed the salmon dies.

Most of the eggs deposited are eaten by other fishes, or are killed by being covered with sand and gravel. Those not destroyed hatch in from seven to ten weeks, according to the temperature of the water. In the cold waters of Alaska they are four or five months in hatching. It requires about six weeks more for the yolk-sac to be absorbed, when the fry are able to swim and are ready for their seaward migration. Most of the alevins, however, are devoured by other fishes before they are able to swim. It is to prevent this great mortality among eggs and alevins that artificial propagation has been employed.

The young salmon start downstream as soon as they are able to swim, and reach brackish water when three to five months old, according to the distance they have to go. Those from the vicinity of Battle Creek hatchery reach Benicia in about seven weeks. It is not known when they reach the ocean, but probably soon after. The variation in the time of spawning and hatching makes the period of migration very long. The fry from the summer run begin passing Battle Creek in September, and from that time until April following there is a continuous stream of young salmon, about 1½ inches long, passing that point.

Although a large majority go downstream as soon as they can swim, many, especially those hatched in the spring, remain in the pools in the headwaters all summer and fall. There were estimated to be from 700 to 1,000 in each of several pools in the vicinity of Sims during the summer of 1898, and there were probably as many as 10,000 to the mile in that portion of the river. These remained in the headwaters until the first of December, when rains caused a rise in the river.

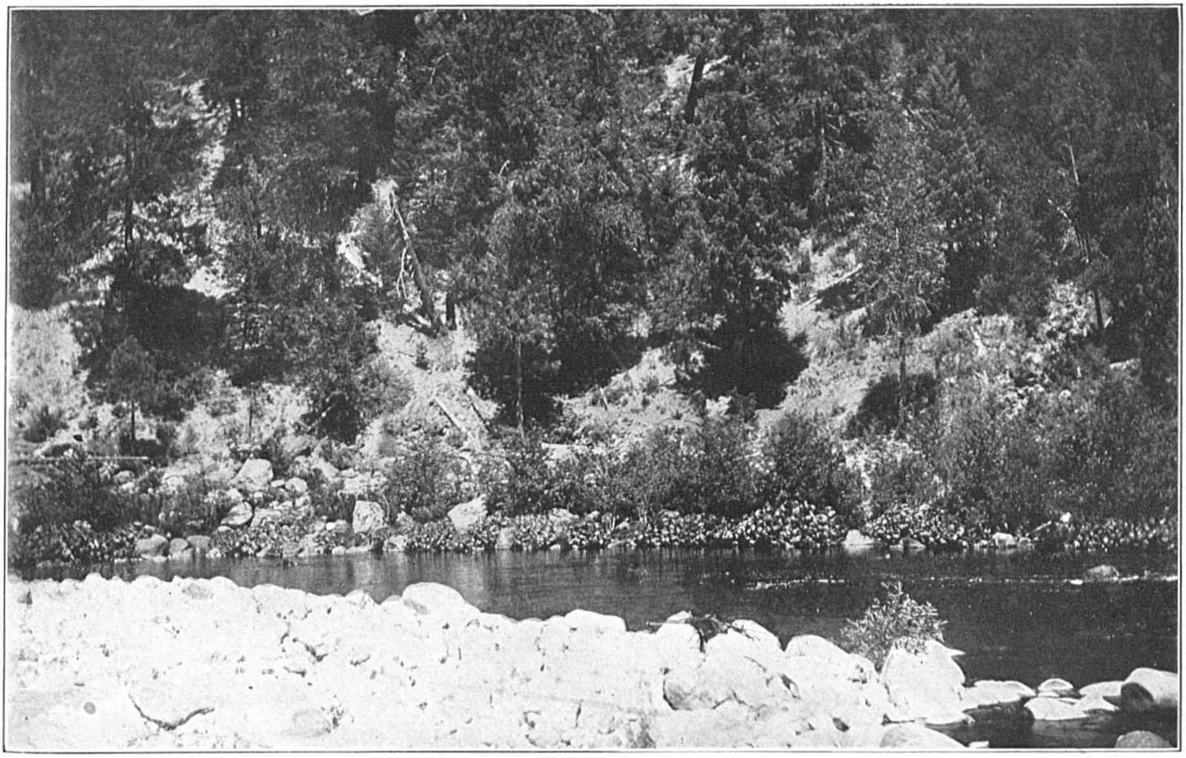
The food of young salmon in fresh water, at all times, places, and ages, consists of insects, either larval or adult.

SALMON EGGS AND MILT.

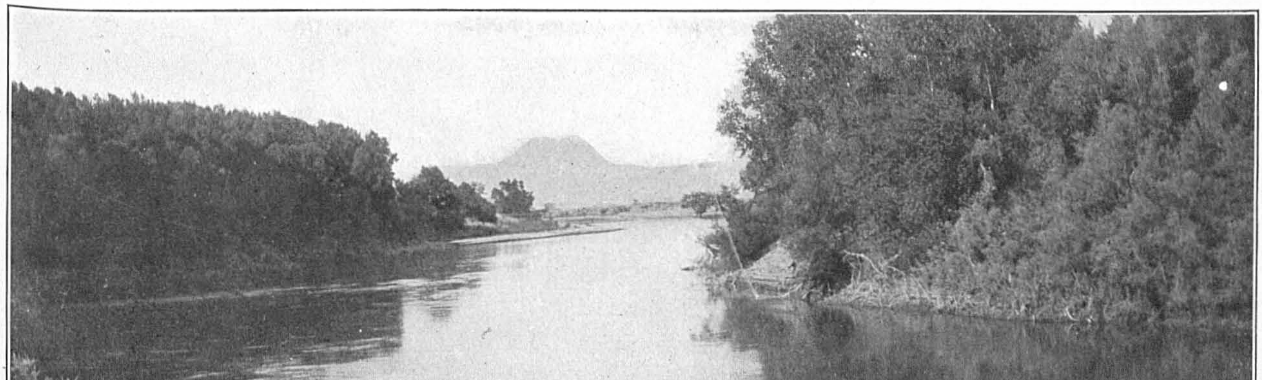
The following notes embody observations and experiments made at Battle Creek hatchery in 1897 and 1898. Although dealing largely with artificial propagation, they are not intended to give even a general account of the methods of fish-culture as applied to the Pacific salmon. For such an account reference is made to the Manual of Fish-culture issued by the United States Fish Commission.[a]

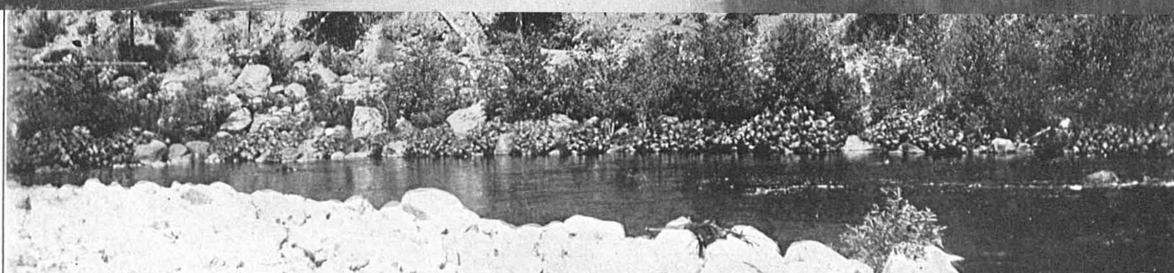
For facilities placed at my disposal I am under obligations to Mr. G. H. Lambson, superintendent of the station. Special acknowledgments are due to Mr. William Shebley, superintendent of Sisson hatchery, and to Mr. Robert Radcliff, of Baird, who had charge of the spawn-taking operations in 1897 and 1898, respectively, and heartily cooperated in the experimental work.

[a] Report United States Fish Commission 1897, pages 1-340.



SACRAMENTO RIVER NEAR SIMS, "POOL B," REFERRED TO ON PAGE 102.





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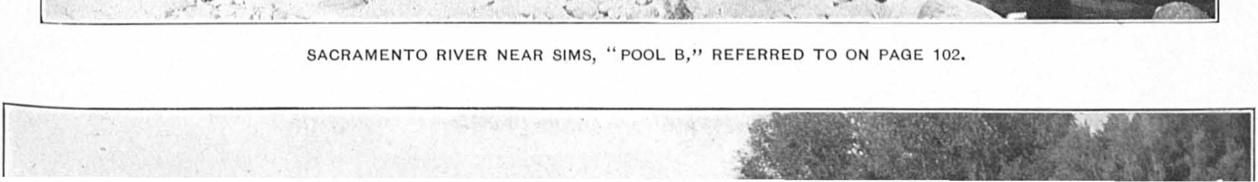


EXPERIMENTS ON THE VITALITY OF SPERMATOZOA.

Vitality in water. Experiment No. 1.—Milt was mixed with water until the mixture became of a milky appearance, which was the condition desired for fertilizing the ova at the spawning platform. Small quantities of the mixture were taken from time to time and examined under a compound microscope. After several repetitions of the experiment it was found that the spermatozoa remained active in the water from 3 to 5 minutes, the length of time varying slightly in each experiment. Each time the spermatozoa were placed on the slide they were very active for about 30 seconds, after which time nearly all became attached by the tail to the slide or cover. The head continued to move for a few seconds longer, but all motion ceased after 65 seconds from the time the milt was placed on the slide.

Experiment No. 2.—Water was mixed with milt as in the above experiment and a small quantity used to fertilize eggs every half minute for 8½ minutes, with the following results, the eggs being freshly spawned in each case:

Time milt had been in the water.	Percentage of fertilization.	Time milt had been in the water.	Percentage of fertilization.
0.25 minute	98	4.5 minutes	7
0.5 minute	88	5 minutes	0
1 minute	38	5.5 minutes	0
1.5 minutes	4	6 minutes	0
2 minutes	8	6.5 minutes	0
2.5 minutes	2	7 minutes	2
3 minutes	8	7.5 minutes	0
3.5 minutes	1	8 minutes	0
4 minutes	0	8.5 minutes	0

The experiment was tried three times, but the results were practically the same. At one time a number of eggs were immersed in water taken from the top of the can in which the spawn was taken from the spawning platform to the hatchery. This water was white from the superfluous milt which had been spawned from 3 to 10 minutes. None of the eggs so treated were fertilized.

From these experiments it will be seen that the milt and eggs should be thoroughly mixed while in the spawning pan and within 30 seconds from the time the milt is mixed with water.

Activity in normal salt solution.[a]—Milt was mixed with normal salt solution until the liquid was distinctly whitish, and a portion of it was at intervals poured over freshly spawned eggs. After a short time the eggs were washed with fresh water. The per cent fertilized in each case is given in the following table:

Time solution had been spermatized.	Percentage of fertilization.	
	First attempt.	Second attempt.
1 minute	74	98
2 minutes	83	
4 minutes	55	
5 minutes		79
6 minutes	70	
8 minutes	34	15

[a] Normal salt solution, 0.75 per cent common salt in water.

The results of this experiment are too varying to be of any practical value. It seems probable that both spermatozoa and ova remain passive in the salt solution and that fertilization takes place only after the addition of fresh water in washing. Where a considerable quantity of fresh water was added and the ova mixed well with it before it was poured off the percentage of fertilization was high. When the water was poured off immediately and without mixing the ova well the fertilization was incomplete. Normal salt solution apparently preserves the vitality of the spermatozoa longer than fresh water.

Vitality in air.—It was found that milt kept in an open, large-mouth bottle for 24 hours fertilized 74 per cent of the eggs it was mixed with. Milt that had been so exposed 48 hours did not fertilize any eggs, nor did that kept in a tightly corked vial for 24 hours.

"*Watery*" *milt.*—Milt when taken from the fish varies greatly in consistency. That from some fishes is very thin and is known as watery milt. Experiment proves that it fertilizes eggs as well as any and that no larger quantity is needed.

Amount of milt required in artificial fertilization.—In taking spawn it was the custom at Battle Creek to express the eggs from one female into a pan containing about a pint of water and add enough milt to make the water distinctly whitish. The amount of milt necessary for this varies, depending on the amount of abdominal fluid mixed with it, but is never less than 3 or 4 fluid ounces. This method gives good results and should be followed when there is an abundance of males, which is always true at Battle Creek after the first few days of the season. A smaller amount of milt, however, will suffice. Ninety-six per cent of the eggs from one female were fertilized by a tablespoonful of milt; 85 per cent were fertilized by a teaspoonful; 35 and 57 per cent were fertilized by spawning fishes in the creek and letting the milt float over the eggs, which had been caught on a screen.

Of course, all that is necessary is to bring a very minute quantity of milt in contact with each egg. A single drop of milt if thoroughly disseminated through the water would be sufficient to fertilize all the eggs from one female. In the experiments above noted the milt could not have been thoroughly mixed until after it had become inactive. It is not advisable to use less than a fifth of an ounce of milt to fertilize 1,000 eggs. More water is necessary where a small amount of milt is used in order to facilitate thorough mixing.

EXPERIMENTS WITH OVA.

How to test fertilization.—The quickest and surest way to determine whether ova have been fertilized is to put them into a dilute (5 to 10 per cent) acetic acid. This can be made from commercial acetic by adding from two to five parts of water. A few minutes after the ova have been placed in the acid the embryos turn white, while the yolk remains clear. The embryo can be distinguished in this manner within 15 hours after the ovum has been fertilized. In making this test for the first time it is best to make a comparative test with unfertilized ova that have been kept in water during the same period.

Short exposure to water detrimental.—A quantity of eggs were spawned into a pan of water and some were removed and spermatized every half minute for several minutes, and for various periods up to several hours. The milt was, of course, taken fresh each time.

The results were as follows:

Time eggs had been in water.	Percentage of fertilization.	Time eggs had been in water.	Percentage of fertilization.
0.25 minute	98	4 minutes	4
0.50 minute	96	4.5 minutes	5
1 minute	95	5 minutes	4
1.5 minutes	68	5.5 minutes	1
2 minutes	57	6 minutes	0
2.5 minutes	33	6.5 minutes	0
3 minutes	17	7 minutes	1
3.5 minutes	17	7+	0

The susceptibility of ova to fertilization decreases rapidly after they are placed in fresh water, and the milt can not be added too quickly. Fifteen seconds is as long as they should be in the water before the milt is added, and it is preferable to add the milt at the same time that the ova are spawned.

On one occasion the eggs remaining in the body cavity after artificial spawning were removed by cutting the fish open, which mixed them with much blood. They were washed as quickly at possible and then spermatized. Only 11 per cent of the eggs were fertilized. In another experiment 85 per cent were fertilized in the blood without washing it off.

Effect of exposure to air.—A number of eggs were spermatized after having been exposed to the air, temperature 76°, for various periods with the following results, the ordinary method giving fertilization of 99 per cent:

Time ova were exposed to air.	Percentage of fertilization.
12 minutes	100
30 minutes	99
50 minutes	76

Apparently there is no injury to eggs by an exposure to the air for half an hour. It must be noted that although the eggs were in an open pan they were practically immersed in the liquid from the body cavity.

Fish slime not deleterious.—It is sometimes said that the slime on the fishes is fatal to the spermatozoa, and at some stations much care is taken to wipe the fish dry before spawning. To test the truth of the supposition, a pan of eggs were covered with slime scraped from several fishes, and then spermatized without the use of water. Out of 174 eggs examined only two were unfertilized, which is as good as is obtained by the ordinary process.

Fertilization in body fluid.—At another time, 392 eggs were spermatized "dry," and the milt entirely washed off with normal salt solution before water was added. All but six, or 98.5 per cent, were fertilized. This proves that water is not necessary to excite the activity of the spermatozoa, and that fertilization may be effected in the abdominal fluid alone.

Immersion in normal salt solution.—A quantity of eggs were immersed in normal salt solution and at the end of certain periods were taken out and fertilized in the usual manner. The results as shown in the table, while as good as could be desired, are scarcely better than are obtained by the ordinary method, which gives a fertilization of 99 per cent. The value of the experiment lies in the fact that it gives us a method of washing bloody eggs without preventing their fertilization, as will be noted below. By making a chemical analysis of the fluid of the body cavity, a liquid could probably be prepared that would be entirely passive and in which the ova could be kept for days. This, however, is unnecessary, as a saltness of three-fourths of 1 per cent gives a liquid sufficiently passive for washing out bloody eggs.

Time eggs were in salt solution.	Percentage of fertilization.
2 minutes	99
4 minutes	100
6 minutes	100
8 minutes	99
15 minutes	97
25 minutes	86

To make artificial spawning complete.—Even the best spawn-takers can not get all the eggs from the fish. Often the fish is not entirely ripe; but whatever the condition may be many of the eggs are entangled in the folds of the ovary and viscera and are not spawned. Under natural conditions the ovary shrivels up and does not obstruct the outward passage of the eggs. The number of eggs remaining in the fish after the artificial spawning varies from 200 to 1,500, depending upon the size and condition of the fish. I have found an average of 900 eggs remaining in 55 fishes after artificial spawning. The spawning was done by experienced men and could not well be improved upon.

The average number of eggs taken from a fish in ordinary spawning is 5,000. This was the average during the season of 1897. By removing the remaining 900 eggs the yield can be increased about 18 per cent. They can all be removed only by slitting the abdomen from the pectoral fins backward, but this allows a large quantity of blood to mix with them. It is possible to fertilize 85 per cent of these eggs in the blood, but in this case the unfertilized 15 per cent have to be picked out of the hatching baskets, which would be a considerable expense if the plan were followed. But the blood can be removed from the eggs without any detriment to fertilization by washing them in normal salt solution (one ounce of common salt to one gallon of water). They can then be fertilized in the ordinary manner.

This method has been used at Battle Creek hatchery since 1900 with satisfactory results, the loss with the "remnant" eggs being but little greater than with the ordinary take. By care in handling the loss need not be any greater. By such means the take of eggs can be increased from 10 to 20 per cent without increasing the cost appreciably.[a]

An aid to spawn-taking.—It was found that fishes were much more easily and rapidly spawned after cutting the body walls across the opening of the oviduct. Unless the cut was made considerably in advance of the vent no perceptible amount of blood issued. A greater percentage of the ova were spawned than if the gash had not been made, and no eggs were broken in spawning, which is an important point. The shells or "shucks" from eggs broken in spawning are a great nuisance in the hatching basket, being difficult to pick out and forming a basis for the growth

[a] From his study of the physiology of the Sacramento salmon in 1902, Prof. C. W. Greene, of the University of Missouri, has determined the amount of salt in the ovarian fluid to be 0.94 per cent, which, therefore, is the density of the solution that is normal for salmon ova, and should be used in washing the blood from eggs, rather than 0.75 per cent as used in the experiments here noted. A solution of 0.94 per cent can be made by adding 1¼ ounces of pure dry salt to 1 gallon of water.

of fungus if they are not removed. It was found by counting the number of broken eggs in several lots spawned in the ordinary manner that they averaged nearly 1 per cent of the entire take.

In the ordinary method of expressing the eggs they leave the oviduct under considerable pressure and strike the spawning pan with as much force as if they had fallen several feet. This manner of spawning, as already seen, breaks nearly 1 per cent of the eggs, and there may be many among those not broken that are injured; this may account for the heavy loss of the first day in the hatching-house.

Dry process of fertilization.—The method of fertilization used at Battle Creek in 1897 and 1898 was to spawn the eggs into a pan containing a little less than a pint of water, spermatizing them at the same time. They were then allowed to stand about 2½ minutes, when they were poured into a large bucket and gradually washed by adding fresh water. Basket No. 6 of the table given in the notes below on the critical period experiment was treated in this manner. The eggs of basket No. 5 were fertilized without any water, but otherwise were treated the same as No. 6. There was a difference of only 0.3 per cent in fertilization. There was a difference of 0.2 per cent between baskets No. 6 and No. 7, and they were from the same fishes and treated in the same way, so far as fertilization was concerned.

The method used at Battle Creek seems the better, as the eggs can be mixed with the milt more easily. A half minute, or just long enough to mix the eggs thoroughly, is an abundance of time for them to remain in the spawning-pan.

Killing the female before spawning.—It has been claimed by some fish-culturists that killing the female before spawning causes deformed fry. Basket No. 1 (see table on p. 79) contained eggs from fishes killed by a blow on the head. There were not even so many deformities in it as in others. This method of procedure is not recommended, however, as green fishes would sometimes be killed, and their eggs therefore lost.

Quality of bloody eggs.—Occasionally a female has been injured before spawning, and the eggs when pressed from the body were mixed with blood. Eggs from three such fishes were kept separate; 7.7 per cent of the eggs died within five days; of the remainder, 2 per cent (3 out of 154) were unfertilized. The fertilization was about as good as the average, and a small amount of blood seems not to be detrimental to fertilization. Several females were opened after spawning, and the eggs remaining were removed. The eggs were mixed with a great deal of blood, and only 85 per cent could be fertilized, so that a large amount of blood is detrimental to fertilization, probably because clots of blood prevent thorough mixing with the milt rather than from any injurious effect upon the ova or spermatozoa.

Foamy eggs.—Often the ovarian liquid becomes foamy as the eggs are spawned. It was not known whether such eggs were fertilizable. In the foamy eggs experimented with 99 per cent were fertilized.

Granular eggs.—The eggs from a certain small salmon, owing to the arrangement or superabundance of oil globules, had a peculiar granular appearance. Fertilization by ordinary process was 99 per cent; apparently healthy when 26 days old.

Eggs dead when spawned.—Occasionally eggs at the time of spawning have a dull, yellowish appearance, and are evidently not healthy. They are always thrown away. Eggs of this kind from one fish were kept. Seventeen days after spawning 30 per cent had died, and of the remainder 23 per cent were unfertilized. They were not kept for further observations. Such eggs were not found in 1898.

Eggs from dead fish.—On two occasions a ripe female was removed from the water, and after it had been dead 2 hours a few eggs were spawned and fertilized in the usual manner. A few eggs were spawned from time to time until the fish had been dead 34 hours. The following table gives the results:

Number of hours fish had been dead.	Percentage of fertilization. First fish.	Percentage of fertilization. Second fish.	Percentage of eggs that died within 10 days.
2 hours	99		
4 hours	98		
6 hours	92	94	
8 hours	92	89	
10 hours		27	10
12 hours		62	31
16 hours		21	68
24 hours	0		100
34 hours		0	100

The first four lots of eggs of 2, 4, 6, and 8 hours were kept 26 days and were apparently entirely healthy at the end of that time.

At another time eggs were taken from two fishes that had died in the water. One had been dead 1 hour, the other over 6 hours. Of the first, over 97 per cent hatched and were healthy fry; of the other, 85 per cent.

From the above it is evidently safe to take the eggs from fishes that have been dead less than 5 hours, and fairly good results can be obtained up to 8 hours.

Spotted eggs.—Sometimes a considerable number of eggs, a few weeks after fertilization, have a small, irregular white spot about the size of the head of a pin in the yolk near the surface. This does not mean that the egg is about to die. Fifteen such eggs were put into a separate basket, and all hatched as perfectly healthy fry excepting one, which died in breaking through the shell. The spot did not appear on the yolk-sac.

Yellow eggs.—When eggs are nearly ready to hatch a yellowish fluid sometimes collects around the embryo. This does not affect them very seriously, as most of them hatch into healthy alevins.

The critical period for eggs.—It is a well-known fact that at a certain stage in development, from about the sixth to the sixteenth day, eggs are much more liable to injury than at other stages. When first taken they can be handled with comparative roughness with impunity. At Battle Creek in 1897 the spawning platform was about half a mile from the hatchery. The eggs were hauled this distance over a road that lacked much of being smooth, yet the loss traceable to such handling was slight. Of nearly 700,000 eyed eggs sent from Battle Creek to Olema at one time, less than 300 were killed in shipping. They were hauled about 10 miles in a heavy wagon, were on the train some 15 hours, and out of the water 48 hours. At the time of shipment the eggs were 43 days old. But at an earlier date, when 6 to 16 days old, such treatment would have killed every egg.

For purposes of comparison 60,000 eggs from several fishes, fertilized in the ordinary manner, were mixed in a can at the spawning platform, and at the hatchery were equally divided between two baskets. The eggs of one of the baskets were picked over daily regardless of results in order to remove the dead or addled eggs. The eggs in the other were picked over in the same manner on the first, third, twenty-second, twenty-fourth, and forty-first days, and occasionally after that date. The former of these experiments was called No. 7, the latter No. 6. As a further test another basket, No. 1, of 30,000 eggs was picked daily. The loss of the baskets picked daily was from three to seven times greater than that of baskets not so treated.

The following table indicates the comparative loss in baskets No. 6 and No. 7, and shows that eggs are very sensitive between the sixth and sixteenth days, and that they should be disturbed as little as possible during that period. Basket No. 6 lost but 785 eggs from the fourth to the twenty-second day, while basket No. 7, which was picked daily, lost over 8,000. After the twenty-second day the loss in this basket, No. 7, was only 613, while it was 1,369 in No. 6, the one not picked daily. The loss on the forty-third day was the result of being shipped from Battle Creek to Olema, in which case the loss in No. 6 was nearly eight times that of No. 7. It is evident, therefore, that daily picking takes out nearly all the weak eggs, but it is also strikingly evident that it takes out a very great many that are not weak.

Table showing loss of eggs in baskets No. 6 and No. 7, taken November 15, 1897.

Age, days.	Temperature of water.	Loss.		Age, days.	Temperature of water.	Loss.	
		No. 6.	No. 7.			No. 6.	No. 7.
	° *F.*				° *F.*		
1	49	803	306	35	47	-------	16
2	49	-------	54	43	-------	665	84
3	52	56	114	46	-------	-------	18
4	52	-------	60	47	-------	-------	5
5	53	-------	131	48	-------	-------	2
6	51	-------	203	49	-------	64	3
7	50	-------	[a]267	50	-------	-------	5
8	51	-------	[a]225	51	-------	-------	3
9	50	-------	[a]420	52	-------	-------	4
10	49	-------	[b]1,240	53	-------	-------	9
11	47	-------	[b]1,000	54	-------	-------	11
12	48	-------	[c]797	56	-------	-------	2
13	48	-------	1,200	57	-------	-------	2
14	49	-------	1,582	58	-------	62	-------
15	52	-------	469	60	-------	-------	14
16	51	-------	331	61	-------	23	-------
17	48	-------	182	62	-------	-------	20
18	46	-------	47	63	-------	25	-------
19	46	-------	100	64	-------	-------	16
20	48	-------	54	65	-------	-------	17
21	51	-------	28	68	-------	21	13
22	50	785	31	69	-------	15	9
23	50	-------	18	72	-------	32	24
24	48	430	24	74	-------	11	15
25	50	-------	31	75	-------	5	14
26	51	-------	28	77	-------	5	9
27	51	-------	24	78	-------	4	-------
28	49	-------	12	79	-------	3	-------
29	49	-------	44	80	-------	2	-------
30	47	-------	28	83	-------	-------	8
31	46	-------	23	84	-------	2	5
32	45	-------	23				
33	46	-------	16	Total	-------	2,497	9,404
34	44	-------	14				

[a] Many killed while picking (went over basket but once). [b] Not so many killed while picking.
[c] Died almost as fast as one person could pick them out.

The table below gives a summary of the loss in four baskets; two, No. 1 and No. 7, picked daily, and two, No. 5 and No. 6, picked so as to avoid the critical period:

	Picked daily.		No. 5.	No. 6.
	No. 1.	No. 7.		
Loss of eggs	16,889	9,404	3,292	2,497
Loss of alevins	7	14	21	[a]112
Deformed fry	35	4	38	56
Total loss	16,931	9,422	3,351	2,665
Percentage of loss	56	32	11	9
Percentage unfertilized	0.3	0.6	0.7	0.4

[a] The large loss of alevins of No. 6 was caused by accidental smothering.

There were 30,000 eggs in each basket at first. The eggs of basket No. 1 were from fish that were killed before spawning. Those of No. 5 were fertilized according to the dry process. Those of No. 6 and No. 7 were fertilized by the ordinary process used at Battle Creek. Nos. 1 and 7 were picked daily. Nos. 5 and 6 were not disturbed during the critical period. The number unfertilized among the dead eggs was not determined before the twenty-eighth day; therefore the last item of the table is only relative. To get the true percentage of unfertilized eggs it would probably be about right to double that given. (It can be determined whether addled eggs are fertilized by putting them in about 8 per cent acetic acid. The yolk of the egg becomes clear, and the embryo, if there be one, turns white. A strong solution of common salt will clear addled eggs, but it also disintegrates very young embryos.)

Even after the critical period has passed, the most careful handling kills some fertilized eggs. Several tests show that from 10 to 20 per cent of the loss after the critical period is in fertilized eggs that have been killed in handling. They should therefore be disturbed as little as possible.

Fungus in the hatchery.—Fungus is a considerable pest in a hatchery, but the loss of eggs at Battle Creek traceable to this cause is very small. Numerous experiments were made in order to determine if the fungus would attack and destroy living eggs. Only on one occasion have I found a live egg attacked by fungus. This one had a few filaments of fungus growing on one side, and the egg had begun to die where the fungus was attached. Whether the egg had started to die before the fungus attacked it or whether it was attacked first I can not say, but all other observations and experiments indicate that the fungus attacks only the dead eggs.

Fungus grows rapidly on dead eggs, and the filaments extend in all directions and entwine the adjacent eggs in a thick mat. This interrupts the circulation of the water and often smothers the eggs so matted. When eggs are smothered the embryo turns white before the yolk becomes addled, so that death from that cause can be distinguished.

At Battle Creek, in 1897 and 1898, the baskets of eggs were gone over on the second and third days after spawning and all of the dead eggs picked out. They were not disturbed again until after the critical period, or about the twentieth day. This method was followed even where baskets (size, 23 by 15½ by 6 inches) contained 40,000 eggs each. The number of eggs that died after the third day was small, and at the "breaking out," that is, the first picking after the critical period at about the twentieth day, the few dead eggs were found scattered here and there through the baskets. Each dead egg was covered with fungus, the filaments of which had entangled the live eggs lying in its immediate neighborhood, holding them together in a bunch. It was seldom that more than fifteen eggs were held together in such a bunch, and the dead eggs never exceeded three or four.

Such treatment is not recommended for other stations, as the difference in the character of the water supply makes it necessary to carry on separate investigations for each station in order to determine methods of treatment.

The reason Battle Creek is so free from fungus is that the water contains a considerable quantity of silt or dirt, and if the eggs are left undisturbed a couple of days they become covered with a fine sediment. This collects on the fungus, which acts as a kind of filter, making of it a black muddy mass and impeding its growth. Clay or other dirt free from organic matter is often mixed in the water to destroy a growth of fungus on fry.

While carrying on the experiments at Pacific Grove in January, 1899, when they were 38 days old the fry were attacked by a very serious growth of slime, sometimes called gill-fungus by fish-culturists. This slime was composed mostly of a microscopic unicellular animal with a silicious shell, belonging to the order *Flagellatæ*. Some other microscopic animals and unicellular plants, such as diatoms, were present. The slime collected on the gills of the fish and killed about two-thirds of them. They were treated with a 25 per cent mixture of sea water, which was very effective. Those which had been removed to a mixture of sea water before the appearance of the slime were not affected at all.

It must not be supposed from the statements given above that hatching troughs and baskets must never be touched during the critical period, nor that fungus is the only disease to which salmon ova and the alevins are liable. As has been stated above, I am not giving a general method of fish-culture, but an account of certain investigations. If the deposits of sediment on the eggs and troughs show traces of decaying organic matter, especially if there is a growth of slime on the sides of the trough, everything must be cleaned immediately. There is no doubt that microscopic plants and animals, such as bacteria and those mentioned above as having injured the fry at Pacific Grove, are very injurious to the eggs, alevins, and fry and must be scrupulously guarded against.

THE ALEVIN.

UNDER NATURAL CONDITIONS.

The eggs that are not destroyed in one way or another when deposited by the spawning fishes lie among the rocks, where they lodge and hatch in from 6 to 9 weeks, the time depending on the temperature of the water. The alevins also remain among the rocks at the bottom for a few weeks, and their movements, slight though they are, expose them greatly to such fishes as the sculpin and trout. During this time the yolk supplies them with what nourishment they need, but about four weeks after hatching the quantity of yolk has become so small that it is not absorbed rapidly enough by the blood to meet the needs of growth. At this time also the alevin is able to swim a little, and it frequently leaves the bottom to snap at some floating object. Its movements are necessarily awkward on account of the unabsorbed yolk, and it therefore attracts predaceous fishes. This is the most critical period in the life of the salmon after hatching. The yolk-sac disappears entirely at the age of 5 or 6 weeks, when the young are known as fry. This is the age at which they begin feeding.

OBSERVATIONS ON ALEVINS ARTIFICIALLY REARED.

General account.—In December, 1896, 855,000 eyed eggs were shipped from Battle Creek hatchery to Bear Valley hatchery in Marin County. Here they were hatched early in February, 1897, under the care of Mr. Frank Shebley, of the California Fish Commission. After the yolk-sac was absorbed, which was about 35 days later, they were fed for a few days on curds of milk, and then, in the second week of March, were turned into Paper-mill Creek and its tributaries, Nicasio, Olema, and Hatchery creeks. The fry were strong and healthy, and were turned into the streams in the best of condition. The young salmon were watched day after day, and systematic observations were made of their movements, habits, enemies, and rate of growth. The work was first begun by the United States Fish Commission and carried on until the middle of May. After a break here of three weeks the California State Commission carried it to completion.

In the winter of 1897–98 eggs were again shipped from Battle Creek to Bear Valley. This time the number was increased to 2,000,000, necessitating the planting of the alevins as soon as they began to hatch. All were planted before the yolk-sac was absorbed. This, when taken in connection with the previous year's work, gave an opportunity to study the comparative effectiveness of planting alevins and fry. The alevins were transported from the hatchery to the planting-grounds in 20-gallon cans. It was possible to carry 40,000 alevins in such a can for two hours at a temperature of 40° without loss, though 20,000 or 30,000 to the can was the usual number carried. They were carried by wagon or rail as the case required. A wagon was found to be preferable, the jolting being an advantage, as the splashing in the cans kept the water well aerated. If the road was smooth or if carried by rail, the water had to be aerated frequently, and it was necessary to put fewer in the can. Although alevins appear to be very delicate, they stand transportation much better than fry, and a much larger number can be safely carried in each can.

Paper-mill Creek and its tributaries, where the young salmon were planted, were never visited by the quinnat salmon. This was one reason that they were selected for the experiment, as any young of that species that we might find would be known to have been planted there. The streams are rich in aquatic insect life, affording an abundance of food for the salmon fry. Trout and sculpins (*Cottus*) are the only predaceous fishes. The streams do not flow directly into the ocean but through several miles of brackish tidewater into Tomales Bay, and the transition from fresh to salt water is very gradual, removing the danger of the fry being rushed too quickly from river to ocean water. It was thought that if the fry could thrive in these streams and pass successfully into salt water it would be of advantage to utilize coast hatcheries and plant in the smaller streams, where the young salmon would not be subjected to their supposed enemies during the long journey from the Upper Sacramento to the sea. The thing feared in the experiment was that the streams would prove too short and that the young salmon would arrive at salt water before they were ready to conform to the conditions of life they would have to encounter there.

Observations indicate that fry can be as safely planted in Paper-mill Creek and its tributaries as in the Sacramento River, and they reach the ocean six weeks earlier. If it is true, as the experiments made at the Clackamas hatchery in Oregon indicate, that most of the salmon return to fresh water to spawn after being in the ocean two years, a difference of one or two months in the time of reaching the ocean is worth considering. If the full growth is attained in 24 to 36 months, the average gain in weight is from 12 to 16 ounces a month. As the gain is necessarily slight at first, it must be much more than a pound a month later. Any extension of time for living in salt water is an increase of the rapid-growing period, as the early period of slight increase in weight must be passed through in any case. This argument holds good only on the supposition that the individual would leave the ocean in a particular month. But the great variation in the time in which the Sacramento salmon leaves tne ocean makes it quite certain that the time is determined by other influences than the season. If so, it is doubtful whether those planted in Paper-mill Creek would have any advantage over those planted in the Sacramento River.

Planting alevins.—Alevins on being liberated in swift water swim frantically and scatter in all directions as they are swept downsteam. Most of them seek the bottom and crowd into crevices between the pebbles or get into quiet places under or behind large bowlders. Others find their way into still water along the edge of the stream, where they remain exposed to view. In moderately swift water some find a lodging-place on the bottom or near the shore before they have been carried a hundred feet downstream, and it has to be very swift water that will carry them a hundred yards. For several hours after being planted in swift water many of them keep moving about. Often the place where they first lodge is too much exposed to the current, and they are repeatedly swept downstream, lodging here and there for a few moments, until they finally reach a quiet place where they can stay. After a few hours this moving about ceases and they remain quiet, retaining their places for at least several days. In one instance 60,000 alevins were liberated on a very swift riffle in Sacramento River 200 yards above a quiet pool. The riffle was shallow, at no place over a foot deep, but so swift as to make it almost impossible for a person to stand. The alevins all found shelter before they were carried a third of the distance to the pool. On visiting the riffle a day later none could be found much over a hundred yards below the place of planting and none was found in the pool below, which was seined thoroughly. All had found sheltered places and had ceased to move down with the current. When alevins are planted only a few yards above a pool, even in moderately quiet water, large numbers will drift into it, where they remain if they are not eaten by trout or other fishes.

When alevins are liberated in a pool or pond they at first scatter out near the surface, but soon settle to the bottom, where they keep up a constant wriggling of the tail and pectoral fins. Within a day or so they collect in bunches, appearing as brilliant salmon-colored blotches over the bottom of the pond. The constant motion of the individuals stirs up the silt until it is washed away from them and each bunch rests on the solid bottom. Alevins in a hatchery, by this constant motion, keep the hatching-trough free from sediment.

During a freshet at the California State hatchery at Eel River a thick sediment of sand was washed into the hatching-troughs and came so fast that the alevins, just hatched, were unable to keep it from settling. It covered the bottom of the troughs to a depth of 2 inches, becoming hard and compact. The alevins, instead of being covered, were found above the cement-like deposit, and none of them had been lost. This interesting incident demonstrates their ability to keep from being covered by sediment during a freshet, whether they be in pools, ponds, or troughs.

Alevins in the pond at the Bear Valley hatchery began swimming about in schools before the yolk-sac was entirely absorbed. The presence of predaceous fishes might have caused them to do otherwise.

Enemies.—When alevins are planted on riffles they are inclined to congregate in eddies and sheltered places behind bowlders. In these places several thousand of them may be found huddled together in a bunch plainly exposed to view. They are not very shy at this age and do not appear to try so much to get out of sight as to get out of swift water. The brilliant salmon color of the yolk makes them very conspicuous, especially when they collect in bunches. One such bunch in Olema Creek, in which there were four or five thousand, could be plainly seen from a point 50 yards distant. In such instances they are very much exposed to the ravages of ducks and geese—both tame and wild—herons, cranes, and other wading birds, and even of hogs, to say nothing of the fish in the stream. Alevins are very tempting morsels, and there is scarcely an animal that will not eat them when given a chance. However, most of the alevins can get into crevices between and under the pebbles and bowlders, where they are much safer from the attacks of the fish that may be in the stream than they would be if they were in the pools or quiet places.

Observations were also made on planting alevins in Sullaway Creek near Sisson. This is a very favorable stream in which to release young salmon, so far as predaceous fishes are concerned. The only fishes of the stream are rainbow trout, sculpins, and quinnat salmon parrs remaining from the season before. The plants were made on the riffles, but as these were all rather short, many of the alevins drifted into the pools. They were liberated in the morning, and in the afternoon the pools were seined with a small-meshed net. The fish caught were examined to find to what extent they had eaten the alevins. The result is shown by the following table, which gives the length of each fish examined and the contents of its stomach:

Species examined.	Size, in inches.	Number alevins eaten.	Other material in stomach.	Species examined.	Size, in inches.	Number alevins eaten.	Other material in stomach.
Trout	6	17	1 small pebble.	Sculpins	3.5	3	
	5.5	9	6 insect larvæ.		3.5	4	
	5	7	1 caddis larva.		3.3	2	
	4.5	6			3.3	2	3 insect larvæ.
	2.5	0	Insect larvæ.		3.3	3	
	2.5	0	Do.		3	2	
Salmon parrs.	3.8	1			3	2	1 insect larva.
	3.5	1			2.8	2	
	3.5	1			2.8	2	
	3.5	2			2.8	2	
	3.5	2			2.7	1	
	3.5	2			2.4	0	
	3.5	2	1 insect larva; 1 water bug.		2.4	1	
					2.4	1	
	3.4	1			2	0	
	3.4	1			2	0	
	3.4	2					
	3	1	2 winged insects.	Species and size unknown		3	

In the case of the largest trout, 6 inches long, 7 of the 17 alevins were in its throat and mouth. It had evidently gorged itself to the limit.

In all cases where salmon parrs had eaten two alevins, the tail of the second remained sticking out of the mouth, their stomachs being large enough to accommodate only one. The sculpins also had gorged themselves in the same manner. All of the fish caught were examined and only three had not eaten alevins, being too small. Three alevins had been disgorged by some of the fish. Evidently alevins are a favorite food for trout, sculpins, and salmon parrs; and when they remain exposed to such enemies from 2 to 4 weeks, it is a wonder that any escape.

Alevins planted in the Marin County streams in 1898 met even a worse fate. Here the trout are more numerous and larger. The sculpins are also larger and more abundant. There were no salmon parrs to feed on alevins, but there were myriads of sticklebacks, which, though unable to swallow an alevin, killed many by nibbling at the yolk. The only other fish in these streams was the roach (*Rutilus symmetricus*), which as far as could be learned did not feed on the alevins. Four is a moderate estimate of the average number of alevins that a trout will eat in a day, at which rate each trout would destroy about 150 before the absorption of the yolk-sac; and 1,000 trout would destroy 150,000 alevins. The lesson is obvious.

Just here it may be well to state that in 1897, although only 150,000 fry—not alevins—were planted in Olema Creek, large numbers of them were yet to be found in June following, and quite a number in August. In 1898, 850,000 alevins were planted in Olema Creek, and in June following there was a smaller number left in the stream than was found in August the year before. There are two ways to account for this. One is that the alevins were washed out to sea before they began swimming; but it is more probable that they were eaten by trout and sculpins.

In the spring of 1898, 7,000,000 salmon were planted at the hatchery on Battle Creek about two weeks before the yolk-sac was absorbed. Although trout are not numerous there, the stream swarms with sculpins (*Cottus gulosus*), salmon fry remaining from the season before, Sacramento pike (*Ptychocheilus grandis*), black pike (*Orthodon microlepidotus*), hitch (*Lavinia exilicauda*), split-tail (*Pogonichthys macrolepidotus*), and suckers (*Catostomus occidentalis*). All of these, though they do not feed exclusively on animal matter, take salmon eggs and alevins when they can get them. The Sacramento pike is very destructive to young fish. The split-tail is the most numerous species, and lives on salmon eggs during the spawning season.

Each day while the hatchery was in operation the bad or addled eggs picked from the hatching baskets were thrown into the stream. Usually they were thrown into a small brook near its entrance to the creek. In a very short time after emptying a can of eggs the split-tails always began to appear, running in from the creek. In a few minutes the water would be alive with them, almost a solid mass tumbling one over the other, splashing the water and crowding each other in their frantic efforts to get the eggs, until some were forced into the mud at the edge, while others were lifted upward till their backs or bellies were out of water, or one might get into a vertical position with its head or tail out of water. Frequently one would gorge itself till throat and mouth were so full that the passage of the water over the gills was shut off and it suffocated. It usually required about 5 minutes to consume 5 gallons of eggs.

Alevins are almost as helpless as eggs and fully as palatable, and there can be little doubt of their fate when planted in such an environment.

Results of observations.—The egg and alevin stages are the periods in the life of the salmon when the care of the fish-culturist is most needed. The art of taking and caring for the spawn has been so perfected that the loss in hatching need not be over 10 per cent, and is often less. The loss of alevins, if they are retained in the hatching-troughs or nursery ponds, need not be over 2 per cent. If the young are planted during the alevin stage, the loss is very great. If large numbers of alevins are released in unsuitable places, where the bottom is comparatively free from stones, and where such predaceous fishes as the split-tail and trout abound, the loss may even be greater than if the parent salmon had been allowed to take their natural course in spawning.

Young salmon should never be planted until the yolk-sac has entirely disappeared and their swimming power has fully developed, even though they have to be fed a few days. There is no advantage in holding them after this time.

THE FRY.

NOTES ON YOUNGER FRY.

Planting fry from the hatchery.—Fry are transported from the hatchery to the streams in the same manner as already described for alevins, but it is not practicable to carry over 10,000 in a can, even for a short distance. They require more care than alevins, it being necessary to aerate the water constantly.

When fry are liberated in running water, they immediately head upstream and try to stem the current. Owing to their being more or less faint from confinement in the can the current nearly always carries them downstream a short distance, but they soon find their way into the more quiet water along the edge of the stream, in the eddies or quiet pools, or among the stones at the bottom. Some even move a few yards above the place of planting before they come to rest. On gaining quieter water they rest themselves, moving only enough to keep from drifting downstream. When in such position they begin feeding on any particles of food that float within their vision, often snapping viciously at insects half as large as themselves.

In a small stream there is no marked tendency of the fry to form schools, each appearing to act independently; but in a larger stream, and especially in the large pools, they often swim about in schools. It appears, too, from our observations in the Sacramento, that they run in schools after gaining the main river in their migration to the sea.

After planting, the fry soon begin to drift downstream from one resting-place to another. This movement in small streams is not in schools. If many are planted at one place the movement downstream is quite rapid, and within 24 hours they will be scattered evenly along the stream for over a mile below the place of planting. The movement, though marked in the daytime, is more general at night. In one instance a screen was placed across a small stream a quarter of a mile below where 50,000 fry were released. Although but few reached the screen that day, the following morning apparently every one had reached it. Other observations have shown the same thing. Muddy water hastens the movement downstream, as does also high water, which is usually muddy.

In Hatchery Creek, in Marin County, 150,000 fry 10 weeks old were released. They gradually scattered downstream, floating tail first. In four or five days they were about evenly distributed along the creek for 1½ miles below the hatchery. At the end of this time a net with a 10-inch circular mouth was placed in the current in the daytime with mouth upstream. In one hour 30 or 40 fry were caught. This illustrates well the decided movement downstream after planting.

When released in a large pool or pond the fry collect in schools immediately and travel toward the inlet.

In 1898, 150,000 alevins were placed in a pond at the Bear Valley hatchery. These remained in the pond without being fed until four weeks after the absorption of the yolk-sac. As it had but 600 square feet of surface and was only 2 or 3 feet deep, there were obviously too many in the pond to do well without being fed. As would be expected, they grew but little, though few, if any, died. At the end of four weeks all were very nearly of one size—1.4 inches long. Those of the same age in the creek a mile below the pond varied from 1.5 to 1.9 inches; specimens from Olema Creek only two weeks older were from 2 to 2.4 inches long.

At any time during the four weeks that the fry were so crowded in the pond they could have gone out, as the overflow trough was unobstructed. Very few if any of them did so, however. Indeed, it was difficult to get them to go out at all, very few escaping till nearly all the water was drawn off. As soon as they came near enough to the overflow to feel the course of the current they would dart back into the pool again. It has often been noticed that fry have an aversion to going over a waterfall or swift rapid. The observations at Sims during the summer of 1898 indicate the same thing. On account of this, fry should not be planted above falls or swift rapids, especially in small streams, as it is desirable that they should move downstream as soon as possible.

Observations of a particular fry.—Fry were observed daily from September 18 to October 3, 1900, in a pool between a rock and the shore in Battle Creek. The pool was about 18 inches across, 4 feet long, and 2 or 3 feet deep. There was but one fry until the 25th, when another appeared. It is probable that only two individuals were seen during the observations, though we can not be sure that such was the case.

When first seen the fry swam near the surface, but after a few days it remained a few inches below. It stayed most of the time in the rather strong current, and was continually snapping at minute floating objects. When swimming near the surface it made from two to ten strikes a minute. Observations could not be made so easily after it began swimming deeper. It was seen to make at least 150 strikes, but each time whatever was caught was immediately ejected. Apparently it had to make a great many efforts before finding anything edible.

One of the fry was seen to leave the pool and resume its migration. It had been in the lower portion of the pool all day, and as evening approached allowed itself to be carried down into the shallow and swift water of the outlet, always keeping its head upstream. Several times it was carried halfway through the outlet, but darted back into the pool. Once it got entirely through the outlet and into the deep water below the rock and then darted back, but finally it was carried out into the main current, tail first, and was lost sight of.

Enemies.—As already stated, 855,000 young salmon were planted in the streams of Marin County, Cal., in 1897, after having been kept in the hatchery until the yolk-sac was absorbed and they had begun to feed. In order to determine to what extent they were preyed upon by the other fishes of the stream, large numbers of trout and a few sculpins were caught and examined, being the only fishes in the stream that could be suspected of eating salmon fry. Beginning at the time the plants were made and continuing for three weeks, 30 or 40 trout, ranging from 6 to 10 inches in length, were daily caught and examined. In not one instance had a salmon been eaten. The only fish eaten by them was the small minnow (*Rutilus symmetricus*), and no more than 10 of these were found in about 700 trout examined. Of the sculpins (*Cottus gulosus*), only 25 of size large enough to eat a salmon fry were caught. None of these had eaten fish of any kind.

In 1898, after the young salmon planted that year had absorbed the yolk-sac, a number of trout were examined. None were found to have eaten salmon fry.

On one occasion a small pool 8 feet across and about 18 inches deep was seined. Over 100 young salmon were caught, averaging 2.1 inches in length. Along with them about a dozen trout from 6 to 8 inches long were taken. It would seem that if ever trout ate young salmon it would be here. These trout were examined, and it was found they had eaten only caddis larvæ and periwinkles. On the Upper Sacramento River I have examined many trout taken while the stream was full of the small salmon fry, but have never found that they had eaten young salmon. The same is the case with the sculpin, and these are the only fishes to be feared in the Upper Sacramento. Farther down stream many of the smaller Sacramento pike have been examined; but none of them were guilty of eating young salmon.

In the spring of 1899, while observing the migration of the salmon fry on the lower Sacramento River by means of a fyke-net trap, we occasionally caught cat-fish along with the young salmon. In every case it was found that the cat-fish had eaten salmon fry. Their capacity for young salmon was greater even than that of the trout for alevins. Several cat-fish 9 inches in length were found with over 60 salmon fry in their stomachs, and one of this same size had eaten 86 of the fry which averaged a little over 1½ inches long. To determine whether the cat-fish captured the fry only while in the bag of the net we caught nearly 50 with hook and line. The stomach of none of them contained a young salmon. Thus it is evident that the cat-fish likes salmon fry and would catch them regularly if it could. It is too sluggish a fish, however, to catch salmon fry under ordinary circumstances.

The only other fish at all likely to prey upon the young salmon in fresh water is the striped bass (*Roccus lineatus*), which is found in the lower river and in large numbers in the brackish water of Suisun Bay. It is also found in San Pablo and in San Francisco bays. I have no information on the subject, except that the striped bass preys to a large extent on the carp in the sloughs of the lower rivers and in the salt or brackish water feeds almost exclusively on small crabs. It is significant, however, that both striped bass and salmon are increasing in numbers in California waters, the former enormously, and it can not, therefore, be very detrimental to salmon. Young pike, suckers, and split-tails are abundant in the waters inhabited by the bass, and all are sluggish in comparison with the salmon. It would seem that young salmon would be the last fish upon which they would prey. A young salmon is very active and strong and much more shy than even a trout of same size; after it has begun to swim about and feed it is perfectly able to take care of itself, and the number killed by enemies in the Sacramento is very small.

MIGRATION OF FRY.

In Olema Creek.—The first year at Olema 150,000 fry, and the second year 850,000 alevins, were released in Olema Creek. The stream was seined about a month after the fry were planted in 1897, and in 1898 about a month after the time when the fry should have begun swimming. Very few young salmon were taken in either year, and the results show that over 95 per cent had left the stream within the month.

Battle Creek station.—The observations in Battle Creek were made while we were engaged with the hatchery experiments during October and November, 1898. In obtaining data concerning the young salmon we used a 50-foot seine such as was employed in nearly all of the investigations; but the most important device for this work was a trap which caught the young salmon as they were going downstream. The trap was made by sewing a piece of fine-meshed webbing across the mouth of the bag of a 30-foot seine and fixing a funnel to extend back into the bag from the middle of the webbing. It was set in a strong current just below the upper rack at the Battle Creek fishery, with the wings extending obliquely upstream, their ends being about 10 feet apart. The fish were deflected by the wings to the middle portion of the net, and found their way through the funnel into the bag. No effective means could be devised to prevent the funnel from becoming choked with leaves or other trash, which often happened within an hour or two after the net was set. There were many adult salmon below the rack, and they often tore the net with their teeth and frequently got fast in the funnel. Part of the time the net was set during the day, more often during the night. Sometimes it was set for only an hour or two during the night. The following is a record of the catch, showing the date, the time of day, and the number and size of the fry taken:

Record of salmon fry taken in trap at Battle Creek fishery, Oct. 7 to Nov. 30, 1898.

Date.	Time.	No.	Size.												
			1.4	1.5	1.5±	1.6	1.7	1.8	4.0	4.3	4.6	4.7	4.8	5.±	5.2
Oct. 7	Day	0													
8	Night	5		5											
9	do	1		1											
11	do	3		2								1			
12	do	17	3	8		5							1		
13	Day	0													
	Night	7		5						2					
14	Day	0													
	Night	10	2	6								2			
16	Day	0													
	Night	8	2	3							1	1			1
17	Day	0													
	Night	6		2										4	
21	do	11		8		2								1	
24	Day	0													
	Night	2		2											
25	5–9 p.m.	4		1		1			1		1				
	Night	6		2		4									
Nov. 12	do	6		2		4									
13	Day	0													
	Night	26	2	10	8	5		1							
14	do	27			26						1				
17	8–9 p.m.	17			17										
21	3–4 a.m.	83	12	37	6	27	1								
22	4–5 a.m.	6			6										
24	12–1 a.m.	1													
25	do	5	2	6	8	5									
26	1–2 a.m.	15													
27	2–3 a.m.	0													
28	do	0													
30	1–2 a.m.	49			49										
	8–9 a.m.	24			24										
	Total		23	100	144	53	1	1							

NOTE.—The numbers in the column headed 1.5± and 5.± indicate the number taken that were about 1.5 inches long, or about 5 inches long, as the case may be, but were released without measuring.

From the preceding record it will be seen that all of the fry (not including the parrs) were practically of the same size, 1.5 inches long. Of the 322 fry examined, only two were over 1.6 inches long, one being 1.7, the other 1.8. The 1.5-inch specimens had just absorbed the yolk-sac. Indeed, there was often a small amount of yolk remaining in the body, although the sac had disappeared. The size of these specimens shows that they begin their downstream migration as soon as they begin swimming, or at the age of six weeks; their continuing the same size during the two months shows that practically all start downstream at the same age. If part of them had held back for two or three weeks, this would have been indicated by a greater variation in size.

The record also shows that ordinarily the young salmon travel at night. The trap was so set that they could not have avoided it had they traveled during the day. That they can be caught during the day is proved by their being taken in the open tow net set in Hatchery Creek, as noted above, under "Planting fry from the hatchery." Fry were seen quite often lying in a pool near the shore during the day, and were seen to rise to small insects that lighted on the water. They probably feed more during the day, which makes their migration slower, or stops it altogether.

On November 30 there was a rise in the creek and the water was muddy. The catch from 8 to 9 a. m. was larger than the average night catch at other times, showing that high and muddy water induces salmon fry to travel during the day. This fact is borne out also by the work at Walnut Grove, an account of which is given below.

The great variation of the catch when the net was set for an hour or two during the night indicates that they travel in schools.

A trap similar to that used in 1898 was set in Battle Creek in 1900 from September 13 to October 4. Salmon fry 1.5 inches long were taken, two or three at a time, from September 18 on. The downstream migration, therefore, begins at least as early as the middle of September.

Adult salmon can be found in some part of the river throughout the year, and the spawning season is therefore very long. It is probable that there are salmon spawning at some place in the river or its tributaries in every month of the year. They are spawning in considerable numbers from July till January, inclusive. With such an extensive spawning period, it is obviously difficult to separate the young according to size, and say that those of a certain size belong to the spring or fall run of a certain year. A variation in rate of growth, noted elsewhere, adds to the difficulty. However, in the following table of measurements of specimens taken with the seine at Battle Creek fishery during October and November, 1898, three sizes may be distinguished, which doubtless represent three runs of adults. Those from 1.4 to 2.2 inches in length were from the summer run of 1898; the 3.7 to 4.7 inch specimens from the fall of 1897 (and they doubtless were among the last to hatch); and the 6.2-inch specimens an earlier run, probably the summer run of 1897.

Measurements of young salmon taken with the seine, Battle Creek, October 18 to December 1, 1898.

Size.	No.	Size.	No.
1.4 inches	1	3.9 inches	....
1.5 inches	13	4 inches	1
1.6 inches	1	4.1 inches	....
1.7 inches	1	4.2 inches	....
1.8 inches	1	4.3 inches	2
1.9 inches	....	4.4 inches	1
2 inches	....	4.5 inches	2
2.1 inches	2	4.6 inches	1
2.2 inches	1	4.7 inches	2
2.3 to 3.6 inches	None.	4.8 to 6.1 inches	None.
3.7 inches	1	6.2 inches	2
3.8 inches	....		

Balls Ferry station.—An observation station equipped with a trap similar to that used at Battle Creek fishery was established on the river at Balls Ferry, about 3 miles above the mouth of Battle Creek. Observations were made by Mr. Chamberlain, beginning January 6 and closing April 25, 1899. The following table gives the data obtained at this station.

Record of salmon fry taken in trap at Balls Ferry, January 6 to April 25, 1899.

Date.	Catch. A. M.	Catch. M.	Catch. P. M.	Size, inches. 1.4	1.5	1.6	1.7	1.8	1.9	2.0	2,1	3.1	Average size.
Jan. 6	24			4	18	2							1.49
7	37	2	0										
8	14	11											
9	33		1										
10	39												
13	25	3	10	7	24	5	1	1					1.51
14	9												
21		35	15	9	25	14	1			1	1		1.53
22	19	44	29										
23	250	22	15										
24	158	13	2										
25	104	1	6										
26	39	6	4										
27	56	12	6										
28	42	13	11										
29	87	15	5										
30	183	18	3	30	89	30	2						1.51
31	173	5	3										
Feb. 1	192	5	2										
2	322	15	4										
3	326	5	2										
4	241	6	0									1	
5	239	0											
6	131	1	2										
7	70												
9	100	7											
10	117												
11	213												
12	157												
13	217	0	2										
14	237		1										
15	143	2	1										
16	163	4	0										
17	100	2	0										
18	137		10										
19	100	9		}25	41	4	2						1.48
20	59												
23	77	0	36										
24	128	82	24										
25	227	70	14										
26	137	61											
27	45	61	5										
28	166	45	15										
Mar. 1	70	41	20										
2	58	12	55										
3	95	28	14										
4	35	5	25										
5	60	14	5										
6	27	14	7										
7	86	29	20	29	78	23	3	1	1				1.51
8	109	30	26										
9	121	31	24										
10	180	28											
11	65	15	7										
12	114	10											
13	45	13	0										
14	76	2	0										
15	254			34	101	88	18						1.52
21		1	5										
22	8												
31		2											
Apr. 1		3	1										
2	4	0	1	}8	2	6	7	1	1				1.58
3	1	0	1										
4	1	1	0										
5	1	1	0										
6	3	0	5										
7	3	0											
8													
9	5												
10		2											
11	7	1	0										
12	5	0	0										
13	0	0	0										
14	2	0	0										
15	1	0	0										
16	1		0										
17	0		0										
18	2		0										
19	2		0										
20	2		0										
21	1		0										
22	0		0										
23	0		0										
24			0										
25	0		0										

The preceding table needs but little explanation. It indicates that the greater part of the young salmon from the fall run passed Balls Ferry between the middle of January and the middle of March. Practically all had passed by March 20. Measurements taken January 6, 13, 21, and 30, February 19, March 7, 15, and 31, and April 1, 2, 3, and 4 show that the average size of those taken on the dates specified, during a period of 3½ months, varied but one-tenth of an inch. The average of all measurements is 1.53 inches. No satisfactory estimate of the number passing could be made, except that there were probably many millions. This record also proves that salmon fry begin migrating as soon as they are able to swim, and that practically all start downstream at that age, otherwise the later ones would have been larger.

It was also ascertained that a large migration was not coincident with remarkably high water. It is probable that when the fry once enter the main river their migration is not impeded by low water; but it seems probable, from observations noted in another place (see "Summer residents") that many of the late fry that hatch in the headwaters are detained there during the summer by low water.

Walnut Grove station.—Our knowledge of migrations through the lower part of the river was gained from the general investigation of 1898, and especially from observations made by means of a trap established at Walnut Grove from January to May, 1899. This trap was constructed especially for the work, but was hardly more efficient than traps made from seines and used at Battle Creek and Balls Ferry. It consisted of a bag with a short funnel hung to a 4-foot hoop, with wings 20 feet long. At Walnut Grove the Sacramento makes a sharp bend, changing its direction from southeast to southwest. At this bend Georgeanna Slough breaks off and continues the southeasterly direction of the river above. It thus gets a large amount of water, probably half as much as the river below, and is in the direct path of the migrating fry. The trap was set about 150 yards from the head of the slough, which at that place is about 75 feet wide and 15 to 20 feet deep. The banks are abrupt and covered with bushes. One end of the trap was fastened by a long rope to a tree on the bank, the other to a buoy anchored about the middle of the stream. It was sometimes set in other positions in the slough or in the river, but without results of particular value. During a sudden rise in the river it could not be set on account of the great amount of trash in the water.

The following gives the record of the catch. In the column headed "A. M." is given the number of fry found in the trap at 8 a. m., and in the "P. M." column the number caught between noon and 5 p. m.

Record of salmon fry taken in the trap at Walnut Grove, January 7 to May 8, 1899.

Date.	Catch.			Size, inches.																								Average size.
	A. M.	M.	P. M.	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.9	4.1	
Jan. 7-13			0																									
20			22	1	7	11		1	1																			1.57
21			8	1	1	5	1																					1.58
23		7	7	1	5	5	3																					1.57
25			25																									
26			28																									
27			14																									
28			12	4	5	3																						1.58
29			18																									
30			28	1	6	12	8											1										1.65
Feb. 1			6																									
2			9																									
3			13																									
4			3																									
5			4																									
6																												

Record of salmon fry taken in the trap at Walnut Grove, January 7 to May 8, 1899—Continued.

Date.	Catch.			Size, inches.																								Average size.
	A.M.	M.	P.M.	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.9	4.1	
Feb. 7		3																										
10			1																									
11			0				4	2	3																			1.79
12	1	5	2																									
13	5		3																									
14	5	3	0																									
15																												
16	0	0	4		1		5	4	3	3																		1.81
17	6	4	1																									
18	2	0	5				2	3	1	1																		1.81
19	1		4																									
20	3		0			1	2	1	1	1	1																	1.82
21	2	2	5																									
22	2	2	0				1			1	1	1																2.00
23	1	5	1						1	1	1	2																
24	1	3								1	1	1																2.11
25	1																											
Mar. 1		8	5		1	3	3			1			2	2	1													1.85
2	5	2	13		1	6	5	3		1	2		1															1.75
3	17	14	30		5	14	17	9	3	1	3	3	3	1	1	1												1.81
4	89	19	128	1	1	12	27	24	8		1				1													1.73
5	44	29	4			6	16	13	5				1															1.74
6			45																									1.79
7	81					2	7	7	4	2																		1.79
8	246	300	138	1	3	2	10	10	8	1					1													1.75
9	36	200	168																									
10	39		51																									
11	175	225	43		2	3	12	6																				1.70
12	183		48		1	6	10	4																				1.68
13	101		92																									
14	12	64	67																									
15	17	36	33																									
16	80	21	25																									
17	19	4																										
19		7	12			1	3	2	1																			1.77
20	16	316	376		1	3	8	3	1																			1.70
21	278	153	263																									
22		64	48																									
27		2																										
28																												
30		11			1	4	2	2			2																	1.70
31		10			1	1	2	1	1	2	1	1			1													1.85
Apr. 1		8																										
2		12				1	1	3	5			1			1													1.94
3		10			1	2	1	1		3	1			1														1.87
4		14				3	3	1	4	1	1				1													1.85
5		25		1		2	3	3	4	4	3		2			1			1			1						1.97
6		18					2	2	2	5	4	2	1															1.99
7		13						1	2	5	3	1		1														2.03
8		17				1	1	1	2	5	2	2		1		2												2.07
9		48					4	10	5	7	8	3	3	2	2		1	2	1									2.03
10		24					3	1	4	7	3	2		1		1	2											2.07
11		14							2	4	2	2			2	1	1											2.19
12		19						3	2	4	4	2	2	1							1							2.11
13		15				1				3	1	4	2			2	1	1										2.27
14		7					1				1	1		1	1		2											2.33
15		8								1		3	1		1	1	1											2.34
16		22								1	5	1	1	3	2	2	2	2	2				1					2.48
17		7					1		1			1	1	1	1			1										2.26
18		8								1		1			3		2		1									2.50
19		7										1		1	2			1										2.48
20		5																										
21		2													2													2.50
22		25					1				1	2		1	2	6		3	1	3	3	1	1					2.69
23		10											3		1	1	2	1		1	1							2.63
24		5			1											1								1	1		1	3.03
25		3						1											1	2								2.68
26		2																	1		1							3.00
27		5																	2		1	1	1					3.08
28		7															2		1	1		2	1					3.00
30		5										1						3			1							2.74
May 1		4														1	1				1				1			3.00
3		4						1			1					1										1		2.60
4		5					1								1		1	1					1					2.60
5		4													1		1	1			1							2.78
6		3																		1		1	1					3.17
7		1																		1								3.00
8		3												1				1			1							2.77

From the data above given it will be seen that—

1. From the middle of January to the middle of May there were salmon fry in various numbers passing Walnut Grove.

2. The height of migration was from March 4 to about the 24th, about 20 days.
3. On March 8 and 20 there were two large runs of fry.
4. Practically all had passed by the 22d of April.
5. The average size of those taken during January was 1.6 inches, during February 1.8 inches, during March 1.7 inches. From the 30th of March till May 7 the size gradually increased from 1.7 inches to 3 inches.
6. No fry were taken during the first 9 days in January.
7. Young salmon traveled as much during the day as during the night.

Comparing the information for Walnut Grove with that for Balls Ferry, as shown in the accompanying diagrams, plate 12, it appears that—

(*a*) The Balls Ferry run of February 2 reached Walnut Grove March 8 and was 34 days making the distance. The fry increased in size 0.3 inch.

(*b*) The Balls Ferry run of February 14 reached Walnut Grove March 20, and was 34 days making the distance. The fry increased in size 0.3 inch.

(*c*) The runs that passed Balls Ferry February 25, and later, were caught by high water the latter part of March, which probably carried them down faster. The runs were not noticed at Walnut Grove; the net could not be worked during the beginning of high water, March 23 to 29, during which time they may have passed.

(*d*) The fry taken at Walnut Grove after April 1 had grown more than 0.3 inch since starting downstream, and were therefore the stragglers from the regular migration. Those taken during May had probably been three months on the way.

It is evident, therefore, that the fry of the regular migration require about 34 days to pass from Balls Ferry to Walnut Grove.

The distance between the two stations is about 350 miles. An object floating as fast as the current would make the distance in about 9 days. It requires 8 days for a rise in the river to travel from Red Bluff to Sacramento. If the fry traveled only at night, and simply kept with the current, they would make the distance in 18 days. There is no doubt that in migrating the fry drift downstream tail first, keeping the head upstream for ease in breathing as well as for convenience in catching food floating in the water. In this way they would drift much more slowly than the current. At Battle Creek hatchery fry have been observed traveling with the current, and always with the head upstream unless frightened.

The later and larger specimens found had simply been longer on the way. The larger they became the more slowly they drifted, as they swam against the current more strongly. Those taken at Walnut Grove in January were but 1.6 inches long, being brought down by the high water in January, the short time they had traveled being indicated by their smaller size.

The failure to catch any fry during the first 9 days in January indicates that the fry from the summer run had all passed and that those from the fall run had not yet reached Walnut Grove. Without doubt there were a few passing at that time, for there were some passing Battle Creek as late as December 6, but they were so few that none were taken in the trap. It is possible that there are a few passing down the river all summer, though we have been unable to find any after June.

Observations at Benicia.—February 21 and 24 and March 3, 1899, five specimens 1.8 to 1.9 inches long were taken in Carquinez Straits at Benicia. The average size at Walnut Grove after February 10 was 1.8 inches and the size of the Benicia specimens indicates a short passage between the two places, probably not over a week. This would make the time from Battle Creek hatchery to brackish water 6 weeks.

A

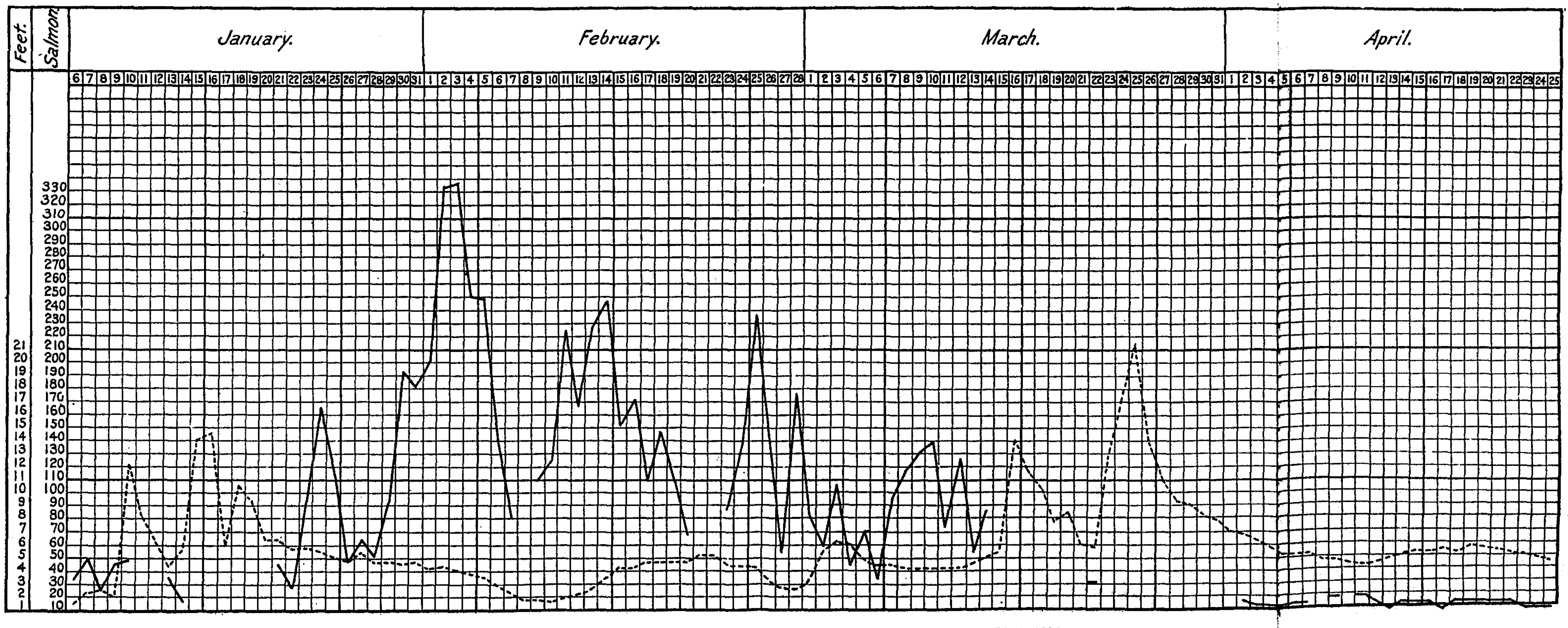


DIAGRAM SHOWING NUMBER OF YOUNG SALMON TAKEN AT BALLS FERRY, 1899.

B

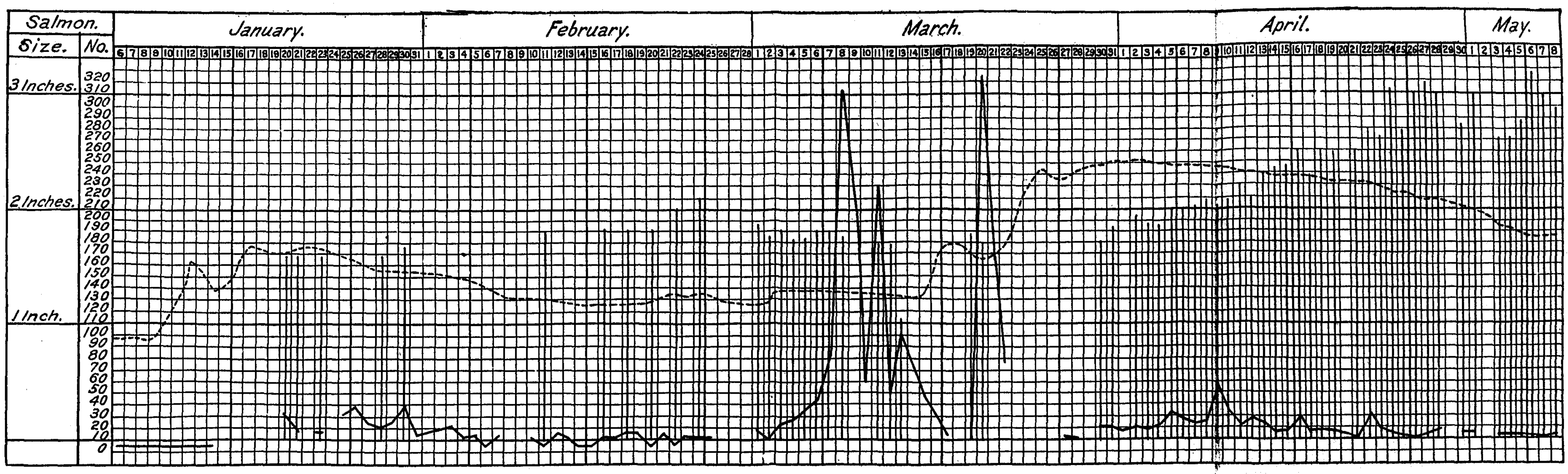


DIAGRAM SHOWING NUMBER AND SIZE OF YOUNG SALMON TAKEN AT WALNUT GROVE, 1899.

Heavy lines indicate number of fry; dotted lines indicate height of river; vertical spaces indicate 10 fry each, or one foot for height of water, or tenths of inch for length of fry; the vertical lines of diagram *B* represent the exact average length of the fry taken.

General investigation during 1898.—The following notes give the data obtained by the general investigation in 1898.

Table showing greatest number of fry taken at one haul of the seine.

Station.	Apr. 28 to May 4.	May 18 to 30.	July 8 to 27.	Station.	Apr. 28 to May 4.	May 18 to 30.	July 8 to 27.
Redding	50	66	8	Princeton		15	0
River at mouth of Battle Creek	60		2	Colusa		6	0
Red Bluff	150	1	0	Grimes		4	0
Six miles below Red Bluff		6	0	Wilson's farm		4	0
Tehama	100	31	0	Twenty miles below Grimes		0	0
River at mouth of Thomas Creek		1	0	Knights Landing		2	0
River at mouth of Deer Creek		8	0	Mouth of Feather River		0	0
Chico bridge		28	0	Sacramento	10	6	0
Jacinto		10	0	Ryde		0	0
Butte City		10	0	Rio Vista		2	0
				Collinsville		0	0
				Benicia		2	0
				San Pablo Bay		4	0

Table showing size of young salmon taken in the Sacramento River in May, 1898.

Dates and localities.	Size in inches.																											Average size.
	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.5	
Sisson, May 15			2	2	5	2	2	1	2	4	2	1	3	3		1								2		1	1	2.4
Sims, May 17		2	3				2	1	2	5	1	2	3	1		2			3	2		3	1	2				2.6
Hazel Creek, May 17		2	5	3	1									4	2													2.0
Redding, May 4 and 18			1	1	3	3	4	2	2	3	1	3	2			2	1	2	1	1				1				2.4
River at Battle Creek, April 30	1	1	3	4	5	3	4	4	4	2	1	2	2		1	2	1				1							2.1
Red Bluff, April 28, May 20		2	1	1	1	4	4	4	1	1	1	1	2			1	2											2.1
Tehama, May 5 and 21		1	3	4	1	1	1	2	1	1	1	2		1				1			1							2.1
River at Thomas Creek, May 22								1			4	1		2		1												2.5
River at Deer Creek, May 22		1				1	1			1	1	2										1						2.2
Chico Bridge, May 23					1	1							1	1	1			1						1				2.7
Jacinto, May 24					1	1				1	1					1					1							2.4
Butte City, May 25						1		1			1																	2.1
Princeton, May 25											2	3	1					1										2.6
Colusa, May 26								1			1			1														2.4
Grimes, May 27									1		1																	2.3
Wilson farm, May 27							1			1		1																2.3
Knights, May 29						1					3	2																2.3
Sacramento, Apr. 23		2	1	1			1	3	2																			1.9
Rio Vista, May 11 and 30									2	2																		2.3
Benicia, May 13 and 23							1	1		1	1		1	1					1									2.6
San Pablo Bay, May 18, June 17											2	2	1	1			1				1							2.7

From the tables given it will be seen that—

1. Young salmon were abundant in the river the first of May, at least between Redding and Tehama. As a few were taken at Sacramento April 23, it is probable that they were distributed throughout the river.
2. The last of May they were nowhere so abundant as they had been at Red Bluff and Tehama three weeks previously.
3. A few were found throughout the river May 18 to 30.
4. The fry found in the river in May had an average size of about 2.2 inches.
5. In July there were no fry found except a few at Redding and Battle Creek.

It is known from the work at Balls Ferry in 1899 that practically all the fry leave the river before March 20. It is evident, therefore, that the fry found between Redding and Tehama in May, 1898, were the stragglers left from the regular migration. Their size, 2.2 inches, precludes their belonging to the regular run. They had collected in the pools where we did our seining, as they do in the headwaters during the summer (see notes on "Summer residents"), which made them appear to be more abundant than they probably were. The rise in the river, which occurred from May 15 to 25, and the accompanying muddy water caused them to pass downstream. This is indicated by finding fewer in the pools in the latter part of May (when migrating they would not be collected in the pools) and by finding none at all in July.

The conditions in 1898 were exceptional on account of the early occurrence of low water—from the middle of March till the middle of May—though doubtless there are always a few stragglers from the regular migrations. These decrease in number and increase in size (slightly) till the rains of the following winter, when all leave the river.

In the mountain streams the young salmon prefer the pools, where they are often abundant. Nearly 500 were taken at one haul of the seine in a pool at the head of Box Canyon, near Sisson, in August, 1897, and it was not at all uncommon to catch over a hundred at a time in many of the pools of the headwaters. The rapids have been fished a number of times, but young salmon were scarcely ever caught unless the water was at least 2 feet deep.

Below Redding more salmon were found in the water with moderate current, gravelly bottom, and a depth of over 2½ feet, but none was found in absolutely still water, and none over a soft mud bottom. Not much seining was done over rocky bottom, on account of the strong current and the injury to the seine by its picking up cobblestones. A few salmon were caught by putting enough floats on the seine to keep it at the surface and then hauling in water 15 feet deep.

The following table indicates the various characters of stream in which young salmon were found in the main river, with the number taken in one haul of the seine under the various conditions.

Table showing number of young salmon taken in various stream conditions.

Localities.	Month.	Current.			Bottom.					2½-feet depth.	
		Slight.	Medium.	Strong.	Mud.	Clay.	Sand.	Gravel.	Rocks.	Under.	Over.
Redding	May			116			116				116
Mouth of Battle Creek	do		60	60				60	60	60	60
Red Bluff	do		36	178		36		178			214
Tehama	do		31	100				31	100	100	31
Vina	do		13					13			13
Chico	do		24	54			32	46		18	60
Jacinto	do		22	2			10	13	1	13	11
Butte City	do	1		22			16	7		8	15
Ten miles below Princeton	do			48			40	8			48
Colusa	do		17					17			17
Grimes	do		8				8				8
Wilsons	do		4			4					4
Knights	do		5			2	1	2			5
Sacramento	April	10					10			10	
Rio Vista	May		4			4					4
Total		11	224	580		46	233	375	161	209	606

Movements in estuary and bay.—Much seining was done both years at Olema in trying to learn something of the movements of young salmon in brackish water. None was found in 1898. A few were caught near the mouth of Paper-mill Creek in 1897, and one was taken 2 or 3 miles from the mouth of the creek, across the head of the bay. The net was stretched across the mouth of the creek for 15 minutes during the flood-tide, and two salmon fry were taken, indicating that they run back and forth with the tide.

The fishermen at Marshall, on Tomales Bay, about 20 miles from the mouth of Paper-mill Creek, reported having taken young salmon in considerable numbers the last of April, 1897, about 50 days after they were liberated in the streams near Olema. At that time the salmon were about 100 days old and were large enough to be taken in the seines used by the fishermen. They caught as many as 15 or 20 at a haul for about a week, and caught them occasionally till the middle of June. I think the report reliable, as the salmon was a new fish for the bay, and would attract much attention. This indicates that the fry may reach the ocean at the age of three months. The water at Marshall is pure sea water.

Specimens have been taken in brackish water in Suisun and San Pablo bays, but not enough to determine their movements. A few about 10 weeks old have been taken at Benicia in water that was about 20 per cent sea water.

Effect of sea water on alevins and fry.—To determine the effect of sea water on alevins and fry, 25,000 eyed eggs were taken from Battle Creek hatchery to the Hopkins Seaside Laboratory at Pacific Grove. The eggs were received at the laboratory December 10, 1898, and most of them hatched on the 17th, which date was taken as the basis for determining their age in the various experiments. Those not being experimented with were cared for as alevins and fry ordinarily are.

The first experiments were made by putting a few alevins directly from fresh water into battery jars filled with various mixtures of fresh and sea water. In the later experiments glass tanks 2 and 3 feet long were used, and the water was kept running. The experiments were begun when the alevins were 6 days old. It was found that at this age they could live indefinitely in water that was 25 per cent sea water. Those about 40 days old could live in 50 per cent sea water, and at 50 days 75 per cent. Those 60 days old could live in 95 per cent, though there was considerable loss. Ninety-five per cent was as nearly pure sea water as could be obtained, the laboratory pump being broken and the tank partly filled with fresh water. The loss was much less when the density alternated between a high and low percentage, which indicates the value of the change of density in the estuaries with the rise and fall of the tides.

When the younger alevins were placed in 50 per cent sea water or stronger, the yolk was solidified, becoming much like soft rubber. The blood was driven from the body, making it appear bleached, and the adipose membrane at each edge of the tail adjacent to the caudal fin turned white. The circulation was retarded and the fish became sluggish. The only noticeable effects on the older alevins were sluggish movements and an inability to keep a horizontal position. Sometimes death was immediately preceded by violent and spasmodic swimming in any and all directions. The same actions were noticed in minnows placed in a strong mixture of sea water.

The following table gives a record of the experiments. The percentage of sea water is reckoned by taking pure sea water as a standard of 100, a mixture of equal parts of fresh and sea water being 50 per cent. The percentage of dead alevins at any one time is not based on the original number with which the experiment began, but on the number left in the vessel the previous day, *e. g.*, if we start with 40 alevins and 10 die the first day, that is 25 per cent; if 15 die the second day, that is 50 per cent.

Table showing effect of salt water on alevins.

Day of experiment.	Age.	Percentage died.						
		Exp. 1.	Exp. 2.	Exp. 3.	Exp. 4.	Exp. 5.	Exp. 6.	Exp. 7.
		Fresh water.	25 per cent sea water.	50 per cent sea water.	75 per cent sea water.	Sea water.	Few changed from No. 2 to 50 per cent.	Few changed from No. 6 to 75 per cent.
1	6	0	0	0	0	0		
2	7	0	0		20	100	0	
3	8	0	2	0	100		0	0
4	9	0	0	100			0	100
5	10	0	0				0	
6	11	0	0				100	
7	12	0	0					
8	13	0	0					
9	14	0	0					
10	15	0	7					
11	16	0	0					
12	17	0	3					
13	18	0	0					
14	19	0	0					
15	20	0	0					
16	21	2	17					
17	22	0	0					
18	23	0	7					
19	24	0	0					
20	25	0	0					
21	26	0	0					
22	27	0	8					
23	28	0	0					
24	29	2	0					
25	30	0	0					
26	31	0	0					
27	32	0	0					
28	33	2	0					
29	34	0	0					
30	35	0	0					
31	36	Discontinued.						

Day of experiment.	Age.	Percentage died.						
		Density raised gradually to—			Placed directly into sea water.	Experiment 12.		
		25 per cent.	50 per cent.	75 per cent.		Age.	Percentage sea water.	Percentage died.
		Exp. 8.	Exp. 9.	Exp. 10.	Exp. 11.			
1	12	0	0	0	0	19	50	0
2	13	2	0	85	100	20	50	0
3	14	0	7	50		21	50	50
4	15	5	8	100		22	50	7
5	16	0	7			23	50	0
6	17	29	89			24	50	33
		50 per cent.						
7	18	11	10			25	50	43
8	19	9	100			26	50	0
9	20	0				27	50	50
10	21	10				28	75	0
11	22	15				29	75	50
12	23	45				30	75	100
13	24	8						
14	25	63						
15	26	50						
		75 per cent.						
16	27	25						
17	28	33						
18	29	100						

Table showing effect of salt water on alevins and fry.

Day of experiment.	Experiment 13.			Experiment 15.			Experiment 16.		
	Age.	Percentage sea water.	Percentage dead.	Age.	Percentage sea water.	Percentage dead.	Age.	Percentage sea water.	Percentage dead.
1	26	10	0	33	0	0	33	0	0
2	27	15	0	34	10	2	34	5	1
3	28	25	1	35	35	0	35	15	5
4	29	35	1	36	40	3	36	20	5
5	30	50	7	37	50	5	37	25	5
6	31	65	84	38	55	7	38	30	1
7	32	75	100	39	60	7	39	35	2
8	-------	-------	-------	40	65	84	40	40	4
9	-------	-------	-------	41	65	58	41	45	3
10	-------	-------	-------	42	70	83	42	50	2
11	-------	-------	-------	43	80	66	43	52	6
12	-------	-------	-------	44	90	100	44	70	10
13	-------	-------	-------	-------	-------	-------	45	70	20
14	-------	-------	-------	-------	-------	-------	46	80	41
15	-------	-------	-------	-------	-------	-------	47	65	23
16	-------	-------	-------	-------	-------	-------	48	60	2
17	-------	-------	-------	-------	-------	-------	49	60	8
18	-------	-------	-------	-------	-------	-------	50	60	7
19	-------	-------	-------	-------	-------	-------	51	65	0
20	-------	-------	-------	-------	-------	-------	52	85	0
21	-------	-------	-------	-------	-------	-------	53	70	0
22	-------	-------	-------	-------	-------	-------	54	65	0
23	-------	-------	-------	-------	-------	-------	55	93	2
24	-------	-------	-------	-------	-------	-------	56	50	0
25	-------	-------	-------	-------	-------	-------	57	93	0
26	-------	-------	-------	-------	-------	-------	58	98	0
27	-------	-------	-------	-------	-------	-------	59	95	8
28	-------	-------	-------	-------	-------	-------	60	95	0
29	-------	-------	-------	-------	-------	-------	61	Discontinued.	

Experiment 1 was made to check the others, showing that the loss was not the result of being confined in battery jars.

Experiment 2 shows that 25 per cent sea water has but little deleterious effect upon alevins over 5 days old.

Experiments 3 to 7 show that alevins of 6 to 10 days of age can not live in sea water of 50 per cent or over, either when put directly from fresh water into the mixture or when the density is gradually raised.

Experiments 8 to 11 show that alevins 12 days old can live longer in 50 and 75 per cent sea water than those only 6 days old. Some of the 12-day alevins lived 7 days in 50 per cent sea water, while the 6-day ones lived but 3 days. The older alevins lived one day longer in 75 per cent, but died the first day in pure sea water, as did the 6-day individuals.

Experiment 12 shows that when 19 days old they live longer yet in 50 per cent. Two lived 2 days in 75 per cent after having been in 50 per cent for 9 days. The one that lived till the twelfth day was a week older.

Experiment 13 shows that a gradual rise from a density of 10 per cent sea water when 26 days old to 75 per cent when 32 days old was fatal. In a similar way a gradual rise from fresh water when 33 days old to a density of 90 per cent when 44 days old was fatal, as is shown in experiment 15.

Experiment 16 indicates that alevins 50 to 60 days old can bear a high density of sea water, but that they can withstand it better if the density, instead of increasing regularly, alternates between high and low. It does not show the exact age at which the fry can live in sea water, and it is doubtful whether this can be determined accurately in aquaria. Whether it can or not, the time was not at my disposal to carry the observations further.

As a whole, the experiments show three important points. First, the fry can not live in sea water until several weeks after the yolk-sac is absorbed; second, when able to live in sea water they can not go directly from fresh water to sea water, but must pass gradually; third, they are greatly aided by an alternation of densities such as is obtained by passing through an estuary. For these reasons it would not be well to plant fry in a stream that does not reach the ocean through an estuary.

Change of color during migration.—The color of young salmon depends much on the character of the water in which they live. Those in small, cold streams are much more dusky and have the parr marks strongly developed. They become lighter in color upon entering the main river. Those in brackish and salt water are bright silvery on the sides, with the back sea green. Parrs 4 to 6 inches in length, found in Battle Creek and similar places, have the sides bright silvery, the back olive brown, with the upper end of the parr marks making regular shadings along the back. Specimens 2.6 inches in length from Rodeo, San Pablo Bay, May 18, have distinct parr marks; 2.7 inches, from Benicia, May 13, have lost them. Sometimes the caudal fin is reddish; sometimes there are yellowish stripes on the ventral and anal fins, especially with fry about 1.5 inches long.

Summary of observations on migration.—The fry begin their downstream migration as soon as they are able to swim. In the clear water they travel more at night; in muddy water, as much or more during the day. Much of the time they float downstream tail first, and in the larger streams they travel more or less in schools. In the larger streams their downstream movement is not dependent upon the height of the water, but upon age. From October to April, inclusive, over 99 per cent that pass the vicinity of Battle Creek are of the same size, 1.5 inches long. They pass down the river at the rate of about 10 miles a day, and are about 6 weeks reaching brackish water, being 3 months old at that time. They are probably 4 or 5 months old when they reach the ocean. The ebb and flow of the tide in the estuary, causing an alternation in the density of the water, is apparently beneficial.

SUMMER RESIDENTS IN THE RIVERS.[a]

General account.—In the upper portion of the Sacramento River there yet remained, after the winter and spring migration in 1898, a large number of young salmon. In the vicinity of Sims we found from 700 to 1,000 in the various pools. We found them common in the McCloud at Baird in September, and in Fall River in August. These summer residents, as they may be called, are confined to the headwaters—the clear streams with rocky bottoms. They do not stay much of the time in the very swift current or riffles, but remain in the more quiet pools. Here they feed on aquatic insects and take the angler's fly the same as trout.

Most of the data concerning the summer residents was obtained from investigations near Sims, in Hazel Creek, and the river below its mouth. Hazel Creek is a small mountain stream, with many pools and gravelly riffles, and is a favorite spawning stream both for salmon and trout. The two lower pools, which are about a quarter of a mile from the mouth, were seined several times during the summer and fall, and it was from this work that we learned much that we know of the habits of the fry remaining in the streams during the summer. In the table below one of these pools is called the upper and the other the lower.

The Sacramento River in the vicinity of Sims is about 40 or 50 feet wide, and during the summer has an average depth of about 3 feet. It is very swift except

[a] These notes on the "summer residents" are given largely as a matter of record. While the conclusions drawn in some cases are scarcely warranted, yet the available data point toward them, and too many of the estimates closely approximate each other to be the result of mere chance.

in the pools, which were the only places that could be seined. Seven of these pools were seined frequently, and for convenience in keeping notes we numbered them A, B, C, D, E, F, and G, beginning with the upper.

In July and August all specimens taken in Hazel Creek and in the river near by were marked by cutting off the adipose fin with a pair of small curved scissors. This enabled us to know when we were taking specimens that had been taken before.

Upstream movement.—The following is a record of the seining in Hazel Creek. The data for each seine haul consists of the date, the pool where it was made, the number of fry previously marked in this pool, number of days since the last were marked, total number taken, and number of marked fishes taken.

Record of seine hauls in Hazel Creek.

Date.	Pool.	Previously marked.	Days since last marking.	Total catch.	Catch of marked fish.	Date.	Pool.	Previously marked.	Days since last marking.	Total catch.	Catch of marked fish.
May 17.	Lower	----------	----------	14	----------	Sept. 18	Lower	104	32	52	39
				20	----------		Upper	107	32	40	36
July 9	do	----------	----------	55	----------	Oct. 18	Lower	104	62	125	37
Aug. 17	do	48	39	49	12		Upper	107	62	94	48
	do	48	39	45	5	Nov. 18	Lower	104	93	93	22
	do	48	39	30	2		Upper	107	93	118	54
	Upper	0	----------	78	1	Dec. 18	Lower	104	123	4	1
	do	----------	----------	53	1		Upper	107	123	0	0
	do	----------	----------	37	0						

It will be seen from the table that in seining the lower pool in August, 19 young salmon were obtained that had been marked in July. As there had been but 48 marked in this pool in July, it indicates that at least 40 per cent of the fishes that were in this pool July 9 remained until August 17.

In the upper pool we found two July-marked fishes in August, where none had been marked in July. As the lower pool is about 100 yards from the upper, this indicates that at least 4 per cent of the fishes in the lower pool had ascended the stream that distance.

There were 104 specimens marked in the lower pool during July and August; 39, or 38 per cent of these, were found there in September; 36, or 35 per cent of the 107 marked in the upper pool in August, were found in September. Only one haul of the seine was made in each place in September.

In August four-sevenths of the marked fishes found in the lower pool were taken in the first haul of the seine. (When more than one haul was made the marked fishes taken were held till the seining was over, in order that they might not be counted twice.) Assuming that the same proportion was taken in the one haul in September, we would reason that there were 68 marked salmon in the lower pool that month; 68 would be 65 per cent of the number marked—that is, 65 per cent of the fishes in Hazel Creek on August 17 remained until September 18. This approximates the estimates made for the pools in the river below the mouth of Hazel Creek. (See notes below.)

In a similar way, 36 per cent of the 104 marked in the lower pool were found in one haul in October, and 45 per cent of the 107 marked in the upper pool. Thus there was a loss of 2 per cent over the previous month in the lower pool, and a gain of 10 per cent in the upper, indicating an upward movement.

But the upward movement is indicated better by the simple statement of numbers, as given in the table. In September there were 39 marked fishes taken in the lower pool to 36 in the upper; in October the ratio was 37 to 48, and in November it was 22 to 54. It is difficult to see how this can mean anything else than that the young salmon in Hazel Creek continued to work their way upstream during September, October, and November.

This table shows an increase in the number of salmon in October. The average of two hauls in May was 17; one in July gave 55; six in August gave an average of 49; two in September averaged 46; two in October 110; two in November 103. The simple fact of there being more fishes found on later dates would not indicate an upward movement; they might have come downstream. The larger percentage of marked fishes in the upper pool, however, would indicate an upstream movement.

Several places above the upper pool were fished in October—one place within 15 yards of it—but no marked salmon were found. This would indicate a lack of upward movement; but, all the data being considered, it is evident that there was at least a slight upward movement in October and November.

In December the young salmon had all disappeared from the upper pool, and only 4 were found in the lower. One of these was a specimen marked in July or August. That is, 1 out of 200 remained after the December rise. It is evident from this that practically all the young salmon left the creek between November 18 and December 18. There was a heavy rain in the vicinity on November 28 and 29 (precipitation over 2 inches), and there can be little doubt that the salmon all left at that time.

Migration during summer.—Pool B (see plate 11) of the river is separated from Pool A (at the mouth of Hazel Creek) by a rapid about 150 yards long with a fall of about 4 feet. It is over 6 feet deep, with large angular rocks along one edge affording excellent hiding-places for young salmon. It required three men to seine this pool well, one to throw out the seine from a large rock at the upper end, and two to pull it in. When there were but two of us, one would pay out the seine from a riffle above the pool; the other would wade out as far as possible in the lower end of the pool and pull the seine down with a rope. When the seine was stretched through the pool it was pulled ashore. Obviously such work was not very satisfactory.

The following table gives a record of the catch at each haul of the seine in Pool B in July and August. Four hauls were made in this pool in May, about 50 young salmon being taken in one haul. The specimens caught in May represented two sizes, such as were found in Hazel Creek on the same date, but there were very few of the smaller size. These smallest were probably from a few late-spawning individuals.

The table gives for each haul of the seine in July and August, (1) the date, (2) number of young salmon caught, (3) number previously marked and released in the pool in July, (4) time since the July-marked fishes were released, (5) number of July-marked fishes caught, (6) number previously marked in August, (7) time since the August-marked fishes were released, (8) number of August-marked fishes taken.

These data may be used to estimate the number of young salmon in the pool by making the following proportion for any particular haul of the seine: The number of marked fishes taken is to the total number of marked fishes known to be in the pool (having just been released), as the total number taken is to *the total number in the pool.* The results, of course, are variable, and it is only by a number of trials that we can get near the probable truth. The value of the estimates is not enhanced by there being no marked fishes taken at certain hauls. In such cases, however, there were but few of either kind. The estimate made from each seine haul is given in the table.

The freshly marked specimens could be distinguished from those marked a month previously by the latter having the scar healed.

Table of data obtained from seining Pool B.

Date.	Number of young salmon caught.	Number previously marked in July.	Time since July marking.	Number of July-marked fishes taken.	Number previously marked in August.	Time since last August-marked fishes were released.	Number of August-marked fishes taken.	Estimated number of young salmon in pool.
July 9	177							
	23	167	1 to 2 hours	0				
	25	190	3 hours	6				792
Aug. 14	22	209	36 days	5				
	29	209	do	9	15	1 to 4 hours	1	435
Aug. 15	17	209	37 days	4	34	1 day	1	578
	9	209	do	0	46	30 minutes	0	
	29	209	do	6	55	do	1	1,595
	9	209	do	1	77	do	0	
Aug. 16	30	209	38 days	9	83	1 day	6	415
	56	209	do	13	98	4 hours	9	621
	14	209	do	2	132	30 minutes	3	616
Aug. 18	8	209	40 days	0	141	2 days	1	423
Average								685

The chief value of this table is in the estimates given in the last column. The estimate of the number of young salmon in the pool ranges from 415 to 1,595. Half of the estimates come within 107 of the average, which is 685. This average is probably not far from the actual number.

Pool C is quite similar to Pool B, and was seined in much the same way. When two worked it, one had to hang the net on the rocks on one side, then swim across to the other side, when both pulled the seine off the rocks and hauled it inshore at the lower end of the pool.

The following table gives a record for Pool C similar to that given for Pool B. In the only haul made in July, two of the four fishes taken had been marked. They had evidently come down from the pool above. Likewise in August four August-marked fishes were taken in the first haul, though none had yet been marked in this pool. In making the estimates of the number in the pool these four are considered, being added to the "number previously marked in August."

Table of seine hauls in Pool C.

Date.	Number of young salmon taken.	Number previously marked in July.	Time since July marking.	Number of July-marked fishes caught.	Number previously marked in August.	Time since last marking.	Number of August-marked fishes caught.	Estimated number in pool in August.
July 9	4	0		2				
August 15	92	2	36 days	3	0		4	
	26	2	do	2	83	2 hours	2	1,181
	39	2	do	2	105	30 minutes	2	1,908
	2	2	do	0	140	do	1	288
August 16	32	2	37 days	0	141	1 day	5	928
	10	2	do	0	168	30 minutes	5	344
August 18	32	2	39 days	1	173	2 days	10	566
Average								861

The data obtained from Pool C gives a larger estimate for the total number in the pool than that for Pool B (C, 861; B, 685). In the seven hauls of the seine in this pool in August there were 8 July-marked fishes secured. In the ten hauls in Pool B 49 were secured. From these two statements we determine that 18 per cent of the July-marked fishes of the two pools were in the lower pool in August. ($8 \div 7 \times 10 = 11$, $49 + 11 = 60$, $11 \div 60 = .18$.) Only 1 per cent was released there, leaving 17 per cent to migrate. Some of these may have drifted over while faint from being confined in the net, but we think not many. We never saw any do so, though we often watched them for that purpose. It is safe to say that most of them went over voluntarily. We would expect this, as the connection between the two pools is quite deep, though swift. It is even remarkable that no more than 17 per cent passed to the lower pool. It is conceded that the estimates in the tables above are liable to considerable errors. There are always some unknown quantities in the equations, yet the results appear trustworthy.

Pool D is below the lower railroad bridge, and was quite unimportant. It was seined but once, a large rock at the lower end of the pool making seining impracticable. Six young salmon were taken. It was one of these six that was taken in the first haul in Pool E. The two pools are continuous.

Pool E is a portion of the river about 75 yards long, immediately below and not separated from D, ending above a long riffle. It was the only pool that could be entirely covered by the seine. The bottom is mostly covered with cobblestones, and there are large rocks along one shore. These afforded hiding-places for the young salmon while the seine was being drawn. It was seined many times in August.

The following table gives the record of the catch at each haul of the seine made in the pool, giving (1) the date, (2) the number caught, (3) the number previously marked and released in the pool, (4) the number of marked fishes taken, (5) the estimate of the number of young salmon in the pool, and (6) the variation of this estimate from the average estimate. On the 16th and 17th of August the seining was carried on continuously, the time required for making a haul and counting and marking the parrs being from 20 to 30 minutes. The marked specimen taken in the first haul was one of the six from Pool D.

Record of seine hauls in Pool E.

Date.	Number of young salmon caught.	Number previously marked.	Number marked fish caught.	Estimated number of young salmon in pool.	Variation of estimate from average estimate.
August 16, p. m	66	1	1		
	148	66	13	751	−271
	146	197	30	992	− 30
August 17, a. m	83	312	38	682	−340
	47	357	19	883	−139
	19	385	4	1,804	+782
	64	400	25	1,024	+ 2
	149	439	62	1,055	+ 33
	71	525	40	932	− 90
	35	556	15	1,297	+275
August 17, p. m	19	576	9	1,216	+194
	3	586	3	586	−436
Total for 24 hours	850	586	259	[a] 1,022	
August 18	0		0		
September 18	178		97	[a] 1,075	
October 18	29		5		

[a] Average.

The purpose of the work in this pool was to determine the number of young salmon that might be found in a pool. The estimates are made in the same way as in the case of Pools B and C. The third haul, as noted in the table, may be taken as an example: 30, the number of marked fishes taken, is to 197, the number marked previous to this haul, as 146, the total number taken, *is to 992, the total number in the pool.* The estimates vary from 586 to 1,829, but several of them are not far from a thousand. The average of the estimates is 1,022, which is probably near the truth.

September 18 we seined the pool again, catching 178 young salmon, 97 of which, a little over half, had been marked. By looking at the table above it can be seen that a little over half of the estimated number in the pool were marked in August—586 out of 1,022. If an estimate is made of the number in the pool in September, by assuming that all the marked fishes remained in the pool, the result will be the following proportion: 97, the number of marked fishes taken in September, is to 586, the number marked during August, as 178, the total catch in September, *is to 1,075, the total number in the pool*, which is remarkably close to 1,022.

If there had been much of a migration between August 18 and September 18 we would have taken a larger proportion of unmarked fishes. If there were no migration we would expect to get marked fishes in proportion to the total catch as 586 to 1,022, which was the proportion of marked fishes in the pool in August. The record for September, 97 marked out of a total of 178, is very nearly that ratio, indicating that there was little or no migration between August 18 and September 18.

August 17 we fished two pools, F and G, about a quarter and a half mile, respectively, below where any fish had been marked, catching 13 and 115 salmon. We also caught 57 in Pool G in September. Neither at this nor at any other time have we found marked salmon below the pool in which they were released, except in the case of Pool C, above referred to. The one marked salmon taken in the first haul in Pool E was released in the upper end of that pool.

It is especially worthy of note that none of the 591 fishes taken in Pool E had been marked in the pools above the previous month. If any had left the upper pools, they had not stopped in the vicinity.

Summary on number and movements.—The estimate of the number of young salmon in August in Pool B is 685, in C 861, and in E 1,022. Pool E is much longer than the others, and might very well have more fishes than either. From these estimates it is probable that there were about 10,000 young salmon to the mile in the Upper Sacramento during the summer of 1898, or between a half and three-quarters of a million in all the headwaters of that stream.

There is little migration of the young salmon between May and December. Where pools are separated by shallow riffles, no evidences of migration could be found. If connected by deep water, it was found that about 17 per cent of those in the upper passed to the lower. In Hazel Creek there was an upward migration of 4 per cent during July, and a larger—about 12 per cent—during September. There was no diminution in number either in Hazel Creek or the river up to November—even an apparent increase. There was a slight migration, however, during the whole period, indicated by the disappearance of the larger marked specimens.

This residence in the headwaters during the summer is probably due to low water. It has been noticed many times, both in the streams and in the hatcheries, that young salmon dread going over a fall. When the river is very low, as it is every summer, the rapids become almost like waterfalls, thus preventing downstream migration. A slight rise obliterates the fall and at the same time makes it difficult to find food; hence the decided migration in December. The abundance of food appears to be of some importance when we notice that there was a scarcity of food in September and also a slight increase in migration that month, although the water was the lowest of the season.

Young salmon were reported abundant in the pools near Sims the 1st of May, 1899, and they doubtless remained during the summer, as was found during 1898.

Growth in fresh water.—It has been shown above ("Migration, general investigations of 1898") that the size of young salmon found in May was the same for all parts of the river. This was true also in July for the portions of the river in which they were found.

The following shows the measurements of young salmon taken in the Sacramento in July, 1898. Bold-faced type indicates where the average sizes fall. For Dunsmuir, Redding, and Battle Creek the numbers given indicate the total number of fish taken. None were taken below the latter point. All were taken between July 9 and 13.

Table showing size of young salmon taken during July, 1898.

Size.	Number of specimens.					Size.	Number of specimens.				
	Dunsmuir.	Sims.	Hazel Creek.	Redding.	Battle Creek.		Dunsmuir.	Sims.	Hazel Creek.	Redding.	Battle Creek.
2.1 inches			1			3 inches	**1**	**1**	1		
2.2 inches						3.1 inches	1			**0**	
2.3 inches			1		1	3.2 inches			1		
2.4 inches					1	3.3 inches				1	
2.5 inches	1					3.5 inches		1		1	2
2.6 inches	1	3	1	1		3.6 inches		1			
2.7 inches			1			3.7 inches	1	1	1		
2.8 inches	1		**0**			3.9 inches		1			
2.9 inches		1		1	**0**	4.3 inches		1			

Note that the average sizes in the above table are from 2.8 inches in Hazel Creek to 3.1 inches at Redding. In comparing this table with that for the month of May (see above), it will be seen that the average size increased from 2.4 inches in May to 3 inches in July, an increase of 0.6 inch in two months. This is also the amount of increase if only the smallest specimens in Hazel Creek are considered. They increased from 1.5 inches in May to 2.1 inches in July. This is an increase of 0.3 inch per month for fishes averaging under 3 inches in length. Each table shows that there was a greater variation at the upper stations.

The growth of 0.3 inch per month is also shown by the following table of measurements of specimens taken at Sisson in May and August. The average sizes are indicated by heavy-faced type. In computing the average for May, the four largest fish are not counted, as they evidently belonged to the summer run of adults instead of the fall. Measurements of specimens taken in the river at the mouth of the creek in August are given for comparison with those from the creek. The average size in May was 2.2 inches; in August, a little over three months later, it was 3.3 inches, the increase in size of those remaining in the creek being one-third inch per month. The growth was probably a little greater than that, the larger specimens migrating.

Table showing increase in size of young salmon at Sisson.

Size.	Number of specimens.			Size.	Number of specimens.		
	Sullaway Creek.		River, Aug. 19.		Sullaway Creek.		River, Aug. 19.
	May 15.	Aug. 19 and 25.			May 15.	Aug. 19 and 25.	
1.6 inches	2			2.9 inches	1	2	1
1.7 inches	2			3 inches			
1.8 inches	5			3.1 inches		2	4
1.9 inches	2			3.2 inches		1	4
2 inches	2			3.3 inches		**1**	5
2.1 inches	1			3.4 inches		2	2
2.2 inches	**2**			3.5 inches		1	1
2.3 inches	4			3.6 inches		2	3
2.4 inches	2			3.7 inches	2		
2.5 inches	1			3.8 inches		3	1
2.6 inches	3		1	3.9 inches	1		
2.7 inches	3		2	4.3 inches		1	
2.8 inches		3	3	4.5 inches	1		

The above shows the amount of variation in the young salmon of approximately the same age. All were released from the Sisson hatchery. The oldest were hatched

December 23, 1897, and the youngest January 23, 1898. The largest were 2.9 inches long, the smallest 1.6, a difference of 1.3 inches, which can not be accounted for by the one month difference in age. There was still a difference of 1 inch in August, when they were 3.8 and 2.8 inches long.

The following is a table of measurements of specimens taken in Hazel Creek during various months. They are thought to be representative, though the specimens were selected. We picked out extremes and what we thought to be average sizes.

Table of measurements of specimens from Hazel Creek.

Size.	Number measured.				Size.	Number measured.			
	May.	July.	Sept.	Dec.		May.	July.	Sept.	Dec.
1.5 inches	2				3.0 inches		1	1	
1.6 inches	5				3.1 inches				1
1.7 inches	3				3.2 inches				1
1.8 inches	1				3.7 inches		1	2	
2.1 inches		1			3.8 inches			1	
2.3 inches		1			3.9 inches				1
2.6 inches		1			4.2 inches		1		1
2.7 inches	4	1			4.3 inches			2	
2.8 inches	2		1						

The above measurements indicate two ages in May, but the youngest were doubtless from a few, probably a single pair of fishes, that spawned much later than usual. The oldest were from the regular fall run of adults. The difference between these two sizes in May was 0.9 inch. The two sizes are not discernible after May, those shown in the table being due to the selections of specimens, which is not the case for May, however. The growth is indicated by the increase in size of the smaller specimens. The smallest specimens were: In May 1.5 inches, July 2.1 inches, September 2.8 inches, December 3.1 inches, the intervening period in each case being 2, 2, and 3 months, and the increase being 0.6, 0.7, and 0.3 inch, respectively, or 0.30, 0.35, and 0.10 inch per month. The total growth in 7 months, as shown by the smallest specimens, was only 1.6 inches, and for the last 3 months 0.1 per month.

Pool A is at the mouth of Hazel Creek It is a semicircular pool of quiet water at one side of, but not at all separated from, the main channel. It is over 6 feet deep, and the seine had to be hauled by means of ropes. As the seine was stretched across the mouth of the pool and hauled in at the upper end, with the ends close to the banks, there was but little chance for the fish to escape. The pool was fished monthly, beginning with August.

The following table gives the number and size of the young salmon taken in Pool A during the season, and also indicates how many were marked fishes and had therefore remained since August. As the measurements were made on live fishes they could not be made accurately enough to be given in tenths. There was one 2-inch fish taken in October, but it was not counted, as it evidently belonged to a different run. We marked and returned to the pool all of the fishes taken in August. None were marked in any other month. At another haul in September, not recorded in the table, 82 specimens were taken, 32 being marked, which was a larger proportion by 7 per cent than in the haul recorded in the table for that month. No marked fishes were taken in December. The record of one haul in pool E for September is given for comparison with one made in pool A on the same date. It shows that specimens from pool E were smaller than those from pool A, which was the deeper pool.

Table giving size of young salmon taken in Pool A, Sacramento River near Sims, with a comparative record from Pool E.

Date.	Size in inches.													Average size.	Total number.
	3	3¼	3½	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6		
POOL A.															
August 18	3	11	25	11	11	6	3	4	3	....	1	1	2	3.91	81
September 19:															
Marked	....	2	3	10	4	3	....	2	....	....	....	....	....	3.86	24
Unmarked	1	2	11	15	12	7	2	1	....	....	....	....	....	3.84	51
Total	1	4	14	25	16	10	2	3	....	....	....	....	....	3.85	75
October 18:															
Marked	....	....	....	2	7	8	4	....	1	....	....	....	....	4.20	22
Unmarked	1	3	1	7	12	14	15	3	2	1	....	....	....	4.19	59
Total	1	3	1	9	19	22	19	3	2	1	....	....	....	4.19	81
November 18:															
Marked	....	....	....	1	6	4	3	1	....	....	....	....	....	4.20	15
Unmarked	....	4	9	9	20	27	34	8	2	....	....	....	....	4.19	113
Total	....	4	9	10	26	31	37	9	2	....	....	....	....	4.20	128
December 18:															
Marked	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Unmarked	1	2	2	....	....	1	1	....	....	....	....	....	....	3.61	7
Total	1	2	2	....	....	1	1	....	....	....	....	....	....	3.61	7
POOL E.															
September 18:															
Marked	....	23	37	21	13	3	....	....	....	....	....	....	....	3.59	97
Unmarked	4	25	30	21	1	....	....	....	....	....	....	....	....	3.47	81
Total	4	48	67	42	14	3	....	....	....	....	....	....	....	3.53	178

The main value of this table is in showing the size of the young salmon in different months. The average size in August was 3.91 inches; that of the August-marked specimens taken in September, 3.86 inches, a very slight decrease. It will be noted later that there was a scarcity of food in September, which would account for a slight migration. In October the average size of the marked specimens increased to 4.20 inches, but remained the same in November. In the one month, September 18 to October 18, there was an increase of 0.34 inch, but the total increase for the three months, August 18 to November 18, was but 0.29 inch, or 0.10 inch per month. This small increase for the total period indicates either that the growth was very slow or that the migration during that time almost compensated for the growth. During September, probably owing to a scarcity of food, the migration was a little greater, and as a result the fishes were smaller September 18 than they were a month before. There was a decrease of 0.6 inch in December, when nearly all had left the pool.

From measurements made on specimens taken at Olema, we have the following table for age and size of young salmon remaining in fresh water:

Age.	Size, inches.			Increase per month, average.
	Smallest.	Largest.	Average.	
Three months	1.7	2.6	2.2	0.4
Five months	2.8	3.3	3.0	.4
Twelve months	....	....	5.5	.36
Seventeen months	....	....	7.0	.35

The growth in fresh water is, therefore, very slow, and in artificial propagation every effort should be made to prevent their remaining in the river over summer. The growth in salt water is much more rapid. The salmon should reach the ocean when about 3 inches long, and grow to be 36 inches in twenty-four months, which would be an increase of about 1.4 inches per month.

Gastric parasites.—Of 209 fresh-water specimens examined in the investigation of food of young salmon, 31 had parasites in the stomach. The parasites were of two or three kinds, one elongated, the others short and grain-like. They have not been studied, except to note the date and size of the fish. It is evident that residence in fresh water is conducive to the growth of parasites in the stomachs of young salmon.

Month.	Number examined.	Number with parasites.	Percentage with parasites.
January	9	1	11
February	10	0	0
March	10	0	0
April	15	0	0
May	50	4	8
July	21	1	5
August	20	3	15
September	18	3	17
October	30	8	23
November	15	3	20
December	11	8	73
Total	209	31	15

Size.	Number examined.	Number with parasites.	Percentage with parasites.
1.4 to 2 inches	61	3	5
2.1 to 3 inches	57	3	5
3.1 to 4 inches	53	10	19
4.1 to 5 inches	30	12	40
5.1 to 6.3 inches	8	3	38
Total	209	31	15

Diseased parrs.—Only two diseased young salmon from the streams have been met with. One was found dead, covered with fungus, near Sims in 1898; the other, 5 inches long, was taken in the trap at Battle Creek, September 28, 1900. The upper lobe of the caudal fin was wanting, and the remainder, with the caudal peduncle, was covered with fungus.

Mature male parrs.—In October, 1897, several mature males, between 4 and 5 inches long, were taken at Sisson. In January, 1898, two males, 5.5 inches long and known to be only a year old, were taken above the Bear Valley dam near Olema; one was mature. In August, 1898, a 4-inch mature male was taken at Sisson. Four of the 6 young salmon taken at Fall River Mills in August, 1898, were males, all with the genital organs mature. Mature male parrs were frequently taken at Battle Creek fishery in October and November, 1898. The sex of a number of parrs, 4 to 6 inches long, from the general collection was determined; 15 were mature males, 2 immature males, and 12 were females. These mature male parrs can usually be distinguished by their more dusky color and by the slightly distended abdomen. Examined under the microscope, the milt is apparently the same as that from adults. A few eggs from a female of ordinary size were fertilized by milt from a 4.7-inch male. The fertilization was complete, all of the eggs hatched, and the alevins were of normal appearance. No explanation of this early maturing of males can be made, and nothing is known of their future history. They feed the same as other young salmon and apparently are not attracted by mature females as the adult males are. It may be that they return from the ocean as the stunted form known as grilse. It is probable that several months' residence in fresh water causes the generative organs to mature both in the adults and in the young males.

Temperature notes.—The following table shows the number of young salmon taken at one haul of the seine in water of various temperatures. It indicates but little, except that young salmon may reside during the summer in water having a temperature of 64 degrees. The 25 taken in Thomas Creek, with a temperature of 68 degrees, were landlocked in a shallow pool.

Table of seine-haul and water-temperature records.

Place.	Date.	53°	54°	55°	56°	57°	58°	59°	60°	61°	62°	63°	64°	65°	66°	67°	68°
Dunsmuir	July 8										6						
Hazel Creek	May 17	14															
Do.	July 9										55						
River at Sims	May 17		50														
Do.	July 9											177					
Do.	Aug. 18												148				
Do.	Sept. 18						178										
Do.	Oct. 18	81															
Redding	May 4							50									
Do.	May 18							66									
Do.	July 11												8				
Do.	Aug. 13																0
Battle Creek	Apr. 30				60					60							
Do.	July 13													2			
Redbluff	Apr. 28												150				
Below Redbluff	July 14 to 31														0	0	0
Mouth of Thomas Creek	May 22													4			25
Vina	May 22								8								
Jacinto	May 23							28									
Grimes	May 27														6		
Rio Vista	May 11															2	
Benicia	May 13							2									
San Pablo Bay	June 17													1			

Conclusion drawn from study of summer residents.—It seems evident from these observations that the later fry that hatch in the headwaters, or are planted there after the spring freshets have passed, are liable to remain till the rains of the following winter. This means a slow growth for at least 6 months, or about a fifth of their growing period. It means the precocious maturing of the males, which may be responsible for the great number of dwarfs known as grilse; and it means that 15 per cent will become infested with gastric parasites. For these reasons it is imperative that the fry from our hatcheries should not be released above Redding after the spring freshets, though they may be released in the headwaters earlier without any detriment, and they certainly should not be held after this time merely for the purpose of feeding. Superintendent Shebley of Sisson Hatchery states, as this paper is going to press, that there are not nearly so many young salmon remaining in the Sacramento River near Sisson during the summer since he has quit holding the fry in the hatchery during the spring for feeding as there were when he did so hold them. There is no advantage in holding fry in the hatcheries for feeding.

FOOD OF YOUNG SALMON.

General study of food in fresh water.—The young salmon feed principally upon floating or drifting insects, either immature or adults. When feeding they often take a station below a stick or rock and catch their food as it floats down on either side. They eagerly catch small insects and larvæ if thrown into the water. Fry 1.5 inches long have been observed to rise to a small fly that alighted on the water. They hardly ever eat encased caddis larvæ, although that is the main food of the trout.

The following is a tabular statement of the stomach contents of 225 young salmon, being based on an examination of about five specimens from each locality each month in the year in which any were taken. The record for each fish examined consists of the station, date, size of fish, and number of specimens of each kind of food or other material found in the stomach. Four forms of insects are recognized in the table, viz, larvæ; pupæ, including nymphs; flying insects; and "terrestrial insects," including adult wingless insects and spiders.

Table of stomach contents of young salmon, Sacramento Basin.

+ indicates presence of certain objects, the number of which was not determined. The totals in last two columns indicate number of fishes in whose stomachs parasites or indigestible material was found.

Station.	Specimen number.	Size of salmon, inches.	Larvæ.	Pupæ.	Flying insects.	Terrestrial insects.	Crustacea.	Gastropods.	Worms.	Unidentifiable.	No. of specimens with—		
											No food.	Parasites.	Wood, seeds, etc.
Sullaway Creek, May 15, 1898	1	1.8	6	2								+	
	2	2.7	38	16			1					+	
	3	3.7		8	1	1							
	4	3.7		7	1							+	
	5	4.7		4									
Total		16.6	44	37	2	1	1					3	
Average		3.3	9	7									
Sullaway Creek, Aug. 25, 1898	6	3.0	4	20									+
	7	3.1	4	5			1						
	8	3.1	8	5	14								+
	9	3.3	3	2	1			1					
	10	3.5	27	1	1			1	1				
Total		16.0	46	33	16		1	2	1				2
Average		3.2	9	7	3								
Sisson, Aug. 19, 1898	11	3.1	11	6									+
	12	3.1	1										+
	13	3.3	20	4	3							+	+
	14	3.5	7	5	3	1							
	15	3.7		2	1								
Total		16.7	39	17	7	1						1	3
Average		3.2	8	3									
Dunsmuir, July 8, 1898	16	2.5	3	12									
	17	3.0	13	4	1								
	18	3.0		5	2								
	19	3.6	2	11									
Total		12.1	18	32	3								
Average		3.0	5	8	1								
Sims, May 17, 1898	20	1.6	13	20									
	21	2.6	7	24	1	1							
	22	3.7	1	18									
	23	3.8		1	2								
Total		11.7	21	63	3	1							
Average		2.9	5	16	1								
Sims, July 9, 1898	24	2.6	17	11	1								
	25	2.6	39	41	3								+
	26	3.5	5	5									
	27	3.9	15	9	1								
	28	4.3	40	13									
Total		16.9	116	79	5								1
Average		3.4	23	16	1								
Sims, Aug. 17, 1898	29	3.3	18	16	1								
	30	3.4	7	2	2								
	31	3.5	7	5									
	32	3.6	19	2	4								
	33	3.8	3	50	7								
Total		17.6	54	75	14								
Average		3.5	11	25	3								
Sims, Sept. 18, 1898	34	3.7	3	2	1							+	
	35	3.8	5	10	7							+	
	36	4.5								+			
Total		12.0	8	12	8					1		2	
Average		4.0	3	4	3								
Sims, Oct. 18, 1898	37	3.1	3	11	3							+	
	38	3.6	2	17	1								
	39	4.1		3								+	
	40	4.1	1	8	1								
	41	4.6	7	6	2								
Total		19.5	13	45	7							2	
Average		3.9	3	9	1								

Table of stomach contents of young salmon, Sacramento Basin—Continued.

Station.	Specimen number.	Size of salmon, inches.	Larvæ.	Pupæ.	Flying insects.	Terrestrial insects.	Crustacea.	Gastropods.	Worms.	Unidentifiable.	No. of specimens with— No food.	Parasites.	Wood, seeds, etc.
Sims, Nov. 16, 1898	42	4.3	6	19	2	2							
Sims, Dec. 18, 1898	43	1.5	7	2								+	
	44	1.6		4									
	45	3.5	21	37	1								
	46	3.5	16	23								+	
	47	3.9	16	18								+	
	48	4.3	13	38								+	
	49	4.7	20	26	3							+	
Total		23.0	93	148	4							5	
Average		3.3	13	21	1								
Hazel Creek, July 9, 1898	60	2.0	2	3									
	61	2.8	3	8									
	62	3.7		3		1							
	63	4.3		3		1							
Total		12.6	5	17		2							
Average		3.2	1	4									
Hazel Creek, Sept. 18, 1898	64	2.8	6	5	2	1							
	65	3.0	4	2	7								
	66	4.1			3								
	67	4.4	1	4	2	1				+			
	68	4.9	2	2	6	1				+			
Total		19.2	13	13	20	3				2			
Average		3.8	3	3	4								
Hazel Creek, Oct. 18, 1898	69	2.6	6	4	2	1							
	70	2.8	5	1	2	3							
	71	3.6	9	17	1								
	72	3.9	1	1	2								
	73	4.3		2									
Total		17.2	21	25	7	4							
Average		3.4	4	5	1	1							
Hazel Creek, Nov. 18, 1898	74	2.9		3	2	1							
	75	3.9	3	9									
	76	4.1	7	3									
	77	4.7		3									
Total		15.6	10	18	2	1							
Average		3.9	3	4									
Hazel Creek, Dec. 18, 1898	78	3.1	1	7	1							+	
	79	3.2		1						+		+	+
	80	3.9	1	1	1							+	
	81	4.2									+		
Total		14.4	2	9	2					1	1	3	1
Average		3.6	1	2	1								
Fall River at Dana, Aug. 28, 1898	50	3.6	45	6						+			
Fall River at mouth, Aug. 29, 1898	51	5.2		48	5					+		+	
	52	5.2	1	32	16	1							
	53	5.3		10	26								
	54	5.6		18	13							+	
Total		21.3	1	108	62					1		2	
Average		5.3		27	16								
McCloud River at Baird, Sept. 16, 1898	55	3.3									+		
	56	3.7		3	1								
	57	3.8									+		
	58	4.4									+		
	59	4.8									+		
Total		20.0		3	1						4		
Average		4.0		1									
Redding, May 4, 1898	82	1.7	4	5	1								
	83	1.8	1	9									
	84	2.2		12	2								
	85	2.5								+			
	86	3.2		4									
	87	3.7		15	1								
Total		15.1	5	45	4					1			
Average		2.6	1	8	1								

Table of stomach contents of young salmon, Sacramento Basin—Continued.

Station.	Specimen number.	Size of salmon, inches.	Larvæ.	Pupæ.	Flying insects.	Terrestrial insects.	Crustacea.	Gastropods.	Worms.	Unidentifiable.	No. of specimens with— No food.	Parasites.	Wood, seeds, etc.
Redding, July 11, 1898	88	2.6	1	6	3				1				
	89	3.0	2									+	
	90	3.8	4		1								
	91	3.5	1										
Total		12.4	8	6	4				1			1	
Average		3.1	2	2	1								
Balls Ferry, Jan. 21, 1899	92	1.4	7	2									
	93	1.5	2	2									
	94	1.5	2	6									
	95	1.6	1	4									
	96	1.6	2	1	1								
Total		7.6	14	15	1								
Average		2.5	3	3									
Balls Ferry, Feb. 19, 1899	97	1.5		1									
	98	1.5		1									
	99	1.5		1									
	100	1.7	2										
	101	1.7								+			
Total		7.9	2	3						1			
Average		1.6		1									
Balls Ferry, Mar. 15, 1899	102	1.5	1	4									
	103	1.5									+		
	104	1.5		2									
	105	1.6		1									
	106	1.6	1	2									
Total		7.7	2	9							1		
Average		1.5		2									
Battle Creek at Longs, Sept. 14, 1898	147	2.9	1	15	2		1						
	148	3.1	10	12	1	1		1					
	149	3.5	10	24	1								
	150	4.0	15		1							+	
	151	4.0	11	12	1								
Total		17.5	47	63	6	1	1	1				1	
Average		3.5	9	13	1								
Balls Ferry, July 13, 1898	107	2.3		4	1								
	108	2.4	2	3									
	109	3.5		1	1								
	110	3.5	1	48	1								
Total		11.7	3	56	3								
Average		2.9	1	14	1								
Battle Creek, Apr. 30, 1898	111	1.5		5									
	112	2.1	1	6	13								
	113	2.5	2	8	1	1							
	114	3.0	12	12	3								
	115	3.5								+			
Total		12.6	15	31	17	1				1			
Average		2.5	3	6	3								
Battle Creek, Nov. 4 to 13, 1898	136	1.5	1		1					+			
	138	1.6		1									
	139	1.7	2	3	2								
	140	4.2	2	3								+	
	141	4.4								+			
	142	4.6		2								+	
	143	4.8								+			
	144	5.4		2	3	1							
	145	6.2		2								+	
	146	6.3											
Total		40.7	5	13	6	2				3		3	
Average		4.1	½	1	1								

Table of stomach contents of young salmon, Sacramento Basin—Continued.

Station.	Specimen number.	Size of salmon, inches.	Larvæ.	Pupæ.	Flying insects.	Terrestrial insects.	Crustacea.	Gastropods.	Worms.	Unidentifiable.	No. of specimens with— No food.	Parasites.	Wood, seeds, etc.
Battle Creek, Oct. 9 to 25, 1898	116	1.4		1						+			
	117	1.8								+	(a)		
	118	1.4									(a)		
	119	1.5		1									
	120	1.5								+			
	121	1.5		1									
	122	1.5			4								
	123	1.5			1						(b)		
	124	1.6	1	1									
	125	4.1	1	1	1							+	
	126	4.1	2	22	2							+	
	127	4.3		10								+	
	128	4.3		8	2							+	
	129	4.3			3							+	
	130	4.6		3	1								
	131	4.6		3	4								
	132	4.7	5	8	15	13							
	133	4.7		2						+			
	134	4.8			1							+	+
	135	5.2								+			
Total		53.0	9	61	34	13				5	1	6	1
Average		3.1	½	3	2	1							
Red Bluff, May 21, 1898	152	1.7											
	153	1.8		26									
	154	2.1	1	8	1						+		
	155	2.5	4	4								+	
	156	2.7		29	1								
Total		10.8	5	67	2						1	1	
Average		2.2	1	13									
Tehama, May 5, 1898	157	1.5	18	2									
	158	2.2			1					+			
	159	2.4	9	3									
	160	3.1		4		1							
	161	3.5	1	3		1							
Total		12.7	28	12	1	2				1			
Average		2.5	6	2									
Chico, May 23, 1898	162	1.8									+		
	163	1.9									+		
	164	2.6	3	4									
	165	3.1	7	2									
	166	3.6	9	5	1					+			
Total		13.0	19	11	1					1	2		
Average		2.6	4	2									
Jacinto, May 24, 1898	167	2.1	3	2									
	168	2.3		3									
Total		4.4	3	5									
Average		2.2	2	2									
Butte City, May 25, 1898	169	1.8	16	3		1							
	170	2.1	4	20									
	171	2.5	8	2									
Total		6.4	28	25		1							
Average		2.1	9	8									
Colusa, May 27, 1898	172	2.1	30		1								
	173	2.4								+			
	174	2.7	8							+			
Total		7.0	38		1					2			
Average		2.4	13										

a Yolk not yet all absorbed.

b Salmon egg, waste from spawning platform.

Table of stomach contents of young salmon, Sacramento Basin—Continued.

Station.	Specimen number.	Size of salmon, inches.	Larvæ.	Pupæ.	Flying insects.	Terrestrial insects.	Crustacea.	Gastropods.	Worms.	Unidentifiable.	No. of specimens with— No food.	Parasites.	Wood, seeds, etc.
Grimes, May 27, 1898	175	2.3		6	1								
	176	2.4	2	1	1								
Total		4.7	2	7	2								
Average		2.3	1	4	1								
Knights Landing, May 29, 1898	177	1.9									+		
	178	2.4		1	1								
	179	2.4		3	1								
	180	2.5		6									
	181	2.6									+		
Total		11.8		10	2						2		
Average		2.4		2									
Sacramento, Apr. 23, 1899	182	1.4			1								
	183	2.0	2	3									
	184	2.0	3	4		1							
	185	2.0	1	2									
	186	2.0	1										
Total		9.4	7	9	1	1							
Average		1.9	1	2									
Walnut Grove, Jan. 20, 1899	187	1.8	1									+	
	188	1.8	2				75						
	189	1.9	1				75						
	190	2.0	6	1			50						
Total		7.5	10	1			200					1	
Average		1.9	3				50						
Walnut Grove, Feb. 19, 1899	191	1.5	3										1
	192	1.6	1	2									
	193	1.7			2								
	194	1.8									+		
	195	1.8	2		2								
Total		8.4	6	2	4						1		1
Average		1.7	1		1								
Walnut Grove, Mar. 21, 1899	196	1.7	7										
	197	1.7	14		2								
	198	1.8	50		2								
	199	1.9			1								
	200	2.1		1	3								1
Total		9.2	71	1	8								1
Average		1.8	14		2								
Walnut Grove, Apr. 23, 1899	201	2.3	1	3	1								
	202	2.5		2									
	203	2.7		2	1	1							
	204	2.7		2									
	205	3.0								+			
Total		13.2	1	9	2	1				1			
Average		2.6		2									
Rio Vista, May 11 and 30, 1898	206	2.0			1								
	207	2.1		1	6								
	208	2.2		2	10					+			
	209	2.2									+		
	210	2.9		1	1								
Total		11.4		4	18					1	1		
Average		2.3		1	4								
General summary of fresh-water stations, 198 specimens.													
Total			788	1,066	376	37	203	3	2	25	12	24	9
Average		2.96	4.0	5.4	1.9	.2	1.0	+	+				

This study shows that young salmon in fresh water feed exclusively on insects, and that immature aquatic insects form by far the larger portion of their food. The general summary of the table shows that approximately half of the food of the specimens studied consisted of pupæ (or nymphs, which were not distinguished from pupæ), one-third of larvæ, and one-sixth of adult winged insects.

There was an increase of flying insects in the food of specimens taken in Sullaway Creek in August, and an increase in amount of food in specimens from Sims during July and August. It was during September, when apparently there was a scarcity of food, that the larger young salmon disappeared from Sims. There was an increase in flying insects in food of specimens from Hazel Creek in September; a scarcity of food and a noticeable lack of larvæ in specimens from Battle Creek in October and November, and a smaller amount of food in specimens from the lower stations. (See summary for May, page 117.)

Two specimens from above Bear Valley Dam, near Olema, taken January 18, 1898, had stomachs gorged with larvæ and pupæ, one having about 50 of the former and 25 of the latter, but no indications of adult insects.

Three specimens, Nos. 117, 118, and 137, of food table, were taken in October and November before the yolk was yet absorbed. One had nothing in its stomach; another had some food, but it was unrecognizable; the third had eaten one larva and two adult insects, besides some other food that was unrecognizable. This indicates that they begin feeding even before the yolk is all absorbed.

The food data, if arranged according to size of fish, would give the following average amounts per fish. This table shows that pupæ and nymphs are the favorite food for all sizes. Those from 1.4 to 2 inches in length feed very little upon adult insects; the largest size feed very little upon larvæ.

Size.	Number examined.	Average number in stomach.		
		Larvæ.	Pupæ.	Adult insects.
1.4 to 2 inches	59	4	3	(a)
2.1 3 inches	53	4	6	3
3.1 4 inches	46	6	8	2
4.1 5 inches	32	3	4	1
5.1 6.3 inches	8	1	14	8

a Indicates an average of less than one.

The following table brings together a statement of the average amount of food found in the stomachs of the young salmon from various stations for the month of May, the only month in which we secured young salmon from many of the lower stations. The table indicates that the important food of the young salmon throughout the basin in May was larvæ and pupæ, of which there was an average of 4.4 of the former and 6.5 of the latter per fish. The fish examined averaged 2.5 inches. It also shows there was a slightly smaller amount of food in specimens from the lower portion of the river. They were not starving, however, and there is no evidence that the passage down the river is detrimental on account of the lack of food. *a* indicates an average of less than one. The numbers in the columns headed "No food" and "Parasites" indicate the number of fishes examined that had empty stomachs or parasites, as the case may be. The totals are taken from the complete table of food, but only for the month of May, and are not the sums of the averages given in this table.

Table showing the average amount of food in stomachs of young salmon from the various stations in May.

Station.	No. of specimens.	Size.	Larvæ.	Pupæ.	Winged insects.	Terrestrial insects.	Crustacea.	Gastropods.	Unidentifiable.	No food.	Parasites.
Sullaway Creek	5	3.3	9	7	(a)	(a)	(a)	(a)			3
Sims	4	2.9	5	16	1	(a)					
Redding	6	2.6	1	8	1				(a)		
Battle Creek fishery	5	2.5	3	6	3	(a)			(a)		
Red Bluff	5	2.2	1	13	(a)				(a)	1	1
Tehama	5	2.5	6	2	(a)	(a)			(a)		
Chico Bridge	5	2.6	4	2	(a)				(a)	2	
Jacinto	2	2.2	2	2							
Butte City	3	2.1	9	8		(a)					
Colusa	3	2.4	9		(a)				(a)		
Grimes	2	2.3	1	4	1						
Knights	5	2.4		2	(a)					2	
Sacramento	5	1.9	1	2	(a)	(a)					
Rio Vista	5	2.3		1	4				(a)	1	
Total	60		262	389	60	6	2	1	7	6	5
Average		2.5	4.4	6.5	.1	.1	(a)	(a)	.1	.1	.1

(a) Indicates an average of less than one.

Food in brackish water.—Relatively few specimens of young salmon have been obtained from brackish water, and the following table gives a list of the food found in nearly all that were caught:

Station.	No.	Size.	Amphipods.	Copepods.	Fish.	Adult insects.	Seeds.	Parasites.
Benicia, Feb. 21 to Mar. 3, 1899	206	1.8				25		
	207	1.9						+
	208	1.9	1			30		
	209	1.9		100		10		
	210	1.9				1		
	211	2.2		150		15		
	212	2.7	2	100				
Total		14.3	3	350		81		1
Average		2.0	+	50		·12		
Benicia, May 13-20, 1898	213	2.1	2			5		
	214	2.3	1			13		
	215	2.5				31		
	216	2.7	1	200		1	1	
	217	3.3	1					
Total		11.9	5	200		50	1	
Average		2.4	1	40		10	+	
San Pablo Bay, May 17-21, 1898	218	1.6				+		
	219	2.1	2					
	220	2.4				35		
	221	2.4				5		
	222	2.5				8		+
	223	2.8	3					+
	224	3.0	2	8				
	225	3.4			1	5		
Total		20.2	7	8	1	53		2
Average		2.5	1	1		7		
Summary for 20 brackish-water specimens.								
Total			15	558	1	104		8
Average		2.3	1	29		9.2		

The chief food of the few brackish and salt water specimens studied were adult insects. Only 5 of the 20 specimens had fed to much extent on copepods, and only 1 had eaten a fish; the species of the fish could not be determined, though it was evidently a smelt (*Osmerus*). No aquatic insects were found, such as were found in specimens from the lower river, which indicates that the fish had been in brackish water at least long enough to digest all fresh-water food.

Classification of the insect food of young salmon.—The following is a classified list of the insects found in the stomachs of young salmon from the Sacramento River, collected during this investigation, as reported by Miss Bertha Chapman. It is evident that in many cases the fish confined themselves largely to food collected at the surface of the stream, as is the case with fish taken at Rio Vista in May, or those taken at Fall River Mills in August; others sought the immature forms living under water, as can be seen from the majority of cases in the list. But in no case can this distinction in feeding habits be definitely made. They seem to have fed indifferently on water and surface forms. These surface forms are almost invariably insects living about streams, and which might therefore easily have fallen into the water from overhanging plants. Much of the stomach contents had been so far digested that it was not possible to identify the insects. Other insects have been partially determined by single wings or particles of the body; but it seemed not so important to carry the classification to species as to determine the types of insects forming the food of young fish. The results of the study are given in the following table:

Classification of insect food for young salmon.

Place.	Date.	Number of fish.	Libellula.	Ephemerida.	Plecoptera.	Orthoptera.	Acridæ.	Corisidæ.	Nabidæ.	Notonectidæ.	Capsidæ.	Jassidæ.	Membracidæ.	Psyllidæ.	Aphidæ.	Trechoptera.	Lepidoptera.	Diptera.	Tipulidæ.	Blepharoceridæ.	Culicidæ.	Chironomidæ.	Ceratopogon.	Simulidæ.
Balls Ferry	January	9																*l*5						*l*2
Walnut Grove	do	39												‡				‡				1		†*l*
Balls Ferry	February	†2		3	†									1										
Walnut Grove	do	†29			‡													‡						‡
Sims	March			1	2													1						
Balls Ferry	do	†23		‡	*l*1									‡				2				‡		
Walnut Grove	do	†30		1	†													‡				2		
Benicia (brackish)	do	4													12							†		
Battle Creek	April	5		2				1	2												*p*3			
Sacramento	do	†18			‡																	‡		†*l*
Olema	do	†28		‡	2													*l*5				*p*2		
Sisson	May	5			‡		1									*p*1		†*l*						
Sims	do	4	6	†*l*	†*l*							3	‡		2	1		*l*3		*l*4				
Redding	do	6			‡*p*											‡*p*		1						
Red Bluff	do	5			†		2															*p*2		*l*2
Tehama	do	5			2			2								2		*l*3						*l*2
Chico	do	5																	‡*p*					‡*l*
Jacinto	do	2																*l*				‡*p*		1
Butte City	do	3																						‡*l*
Colusa	do	3													1			‡*l*						†*l*
Grimes	do	2																				*p*1		
Knights	do	5												1										
Rio Vista	do	5										‡	2		†									
Benicia (brackish)	do	5										3	3		†						†			†
Pinole (brackish)	do	7						2				‡		2	2									
Point Richmond (brackish)	June	1							2															
Dunsmuir	July	†6			‡*l*	†										1		†				×		3
Sims	do	5			†															†				†*l*
Hazel Creek	do	†6			‡													†*l*				×		2
Redding	do	4		1											1	1						*p*2		†*l*
Battle Creek	do	1			†											3								1
Sisson	August	5			‡*l*													‡*l*						*l*4
Dana	do	1		1															*p*1				†	
Fall River Mills	do	4		†	1						1	1	1			×		*l*2						
Sims	do	5		‡	‡							†								‡				†*l*
Sullaway Creek	September	†12		2	‡*l*				2				2											
Sims	do	†9		2	3													×*p*	1	3	1	†		×
Battle Creek	do	†12		†*l*	‡											*l*1	2	*p*1		6	1			†*l*
Sims	October	5		*l*1	‡*l*									×	×									×*l*
Hazel Creek	do	5														6		‡*l*				†*p*		‡*l*
Battle Creek	do	20		†	†								1		2					1				
Sims	November	1			‡	1	1							1	2	2					*p*2	*l*4		*l*3
Battle Creek	do	10			‡							2	2									2		
Sims	December	5			†																			†
Hazel Creek	do	†14		†	‡								2		‡			†*l*						

Classification of insect food for young salmon—Continued.

Place.	Date.	Number of fish.	Leptidæ	Empidæ.	Phoridæ.	Muscidæ.	Dexiinæ.	Anthomyiinæ.	Muscinæ.	Coleoptera.	Staphylinidæ.	Hymenoptera.	Ichneumonidæ.	Braconidæ.	Formicidæ.	Arachnida.	Pseudoscorpions.	Crustaceans.	Parasites.	Woody particles.	Unclassified.	Fish.	Eggs.
Walnut Grove	January	39			*l*					‡						2		†					
Balls Ferry	February	†2				2				3													
Walnut Grove	do	†29								1								†					†
Benicia	do	3				2															†		
Balls Ferry	March	†23										‡											
Walnut Grove	do	†30				‡				2	1				1			†				1	†
Benicia (brackish)	do	4			1								1	2				†				†	
Battle Creek	April	5		†							2				1						†*l*		
Sacramento	do	†18				‡				4													
Olema	do	†28																†					
Sisson	May	5				‡				†													
Sims	do	4				1				*l*2					1	1					3		
Redding	do	6								*l*1													
Red Bluff	do	5								†					2								
Tehama	do	5								*l*3					4								
Jacinto	do	2												1									
Rio Vista	do	5	*p*2								1		1										
Benicia (brackish)	do	5		‡	2	1					1	3				1	1	2		1			
Pinole (brackish)	do	7				2						‡						†					
Dunsmuir	do	†6														2							
Hazel Creek	do	†6													3								
Redding	do	4											1		1								
Battle Creek	do	1								2													
Sisson	August	5		2						1					1								
Dana	do	1								1					×								
Fall River Mills	do	4	2		1		5	5	2	×					4								
Sims	do	5		5		1				‡											‡*l*		
Sullaway Creek	September	†12					3			‡			1	2	3	1				‡			
Sims	do	†9								×			1								‡		
Baird	do	5											1										
Battle Creek	do	†12	*p*3			3				†		1		2	3	3			†				
Sims	October	5										×									‡		
Hazel Creek	do	5											2		2	2							
Battle Creek	do	20								1		1											
Battle Creek	November	10								*l*2		1				2							
Sims	December	5								1													

† Means more than 10. × Means present, but number not known. *p* Means pupa.
‡ Means more than 5. *l* Means larva. *a* Means adult.

The following list of common names will be of assistance to those who are not familiar with the scientific terms used in the above table:

Odonata:
- Libellulidæ ..... Dragon-flies.

Ephemerida .... May-flies.
Plecoptera .... Stone-flies.
Orthoptera:
- Acrididæ .... Grasshoppers.

Hemiptera .... Bugs, lice, aphids, etc.
- Corisidæ .... Water-boatmen.
- Notonectidæ ... Back-swimmers.
- Capsidæ .... Leaf-bugs.
- Jassidæ .... Leaf-hoppers.
- Membracidæ ... Tree-hoppers.
- Psyllidæ .... Jumping plant-lice.
- Aphididæ .... Plant-lice or aphids.

Trichoptera .... Caddis flies or caddice worms.
Lepidoptera .... Moths, skippers, butterflies.
Coleoptera .... Beetles.
- Staphylinidæ ... Rove beetles.

Diptera:
- Tipulidæ .... Crane-flies.
- Blepharoceridæ ...... Net-winged midges.
- Culicidæ .... Mosquitoes.
- Chironomidæ .... Midges.
  - Ceratopogon ...... Punkies.
- Simuliidæ .... Black flies.
- Leptidæ .... Snipe flies.
- Empididæ .... Dance flies.
- Phoridæ .... Humpbacked flies.
- Muscidæ .... Muscids.
  - Dexiinæ .... Nimble-flies.
  - Anthomyiinæ ... Anthomyiids.
  - Muscinæ .... Common flies.

Hymenoptera .... Ants, bees, wasps, etc.
- Ichneumonidæ .... Ichneumon flies.
- Braconidæ .... Braconids.
- Formicidæ .... Ants.

The following is a list of insects having the early stages passed in the water, selected from the set worked over:

Ephemerida.
Plecoptera.
Corisidæ (entire life in water).
Notonectidæ (entire life in water).
Trichoptera.
Tipulidæ.
Blepharoceridæ.
Culicidæ.
Chironomidæ,
Simuliidæ.
Leptidæ.
Coleopterous larvæ.

THE PERIOD OF GROWTH.

Of the ocean life of the salmon very little is known, although it comprises two-thirds of their existence: They have been taken in Tomales Bay when four months old, about 20 miles from the mouth of the stream in which they had been planted, and a few of about the same age have been taken in San Pablo Bay. These were on their way to the ocean and were already in nearly pure sea water. Specimens 8 to 15 inches long are sometimes taken by anglers in San Francisco Bay. In the estuary and along the beach at Karluk, Kadiak Island, Alaska, the writer has seen schools of several hundred 8-inch red salmon that had come inshore with the adults. These were feeding and were not dwarfs on their way to spawning-grounds.

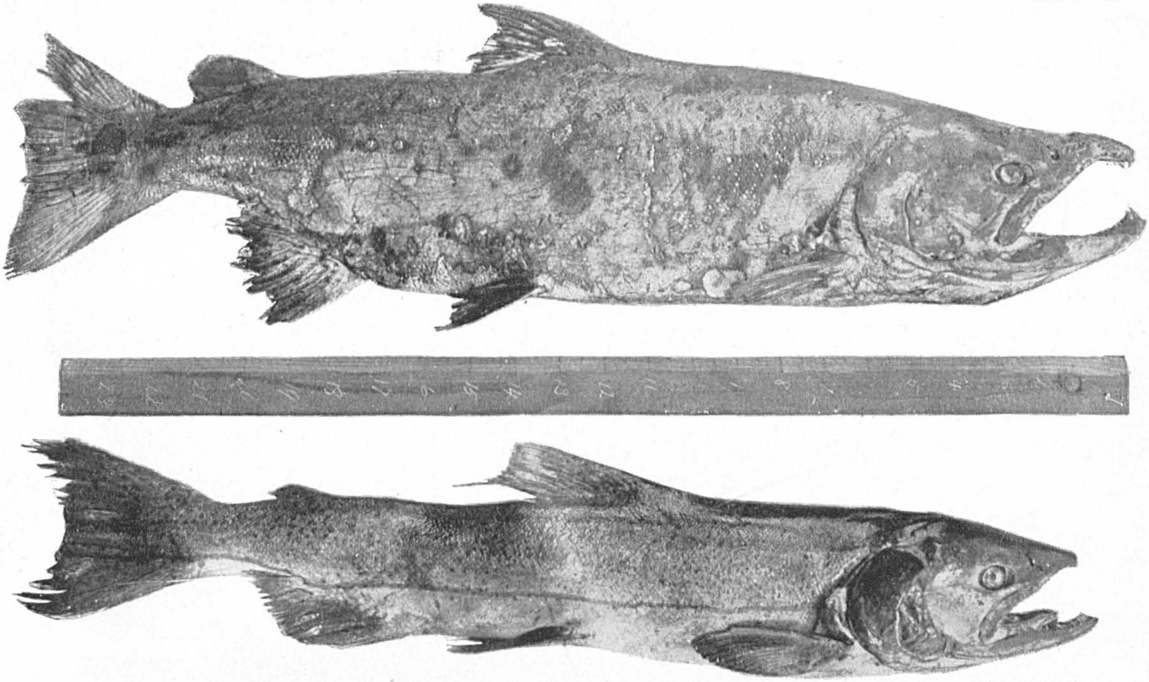
Salmon are sometimes taken in the ocean near San Francisco in paranzella nets and are also captured in large numbers with the troll in Monterey Bay, where they appear in February and are found until the middle of August.

Something of the ocean life of the salmon might be learned by making a study of the food found in the stomachs of individuals taken when they first enter Monterey Bay. At such times a portion of the food taken on their offshore feeding grounds should yet be in identifiable condition. The presence of deep-water fishes or crustaceans would indicate a deep-water life for the salmon.

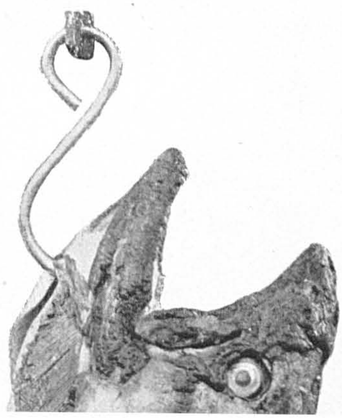
During its life in the sea the salmon is, of course, not entirely free from enemies, and something might be learned of them by studying the scars left by the injuries they inflict where they fail to kill. Injuries and deformities received before entering fresh water were of frequent occurrence among spawning fishes at Battle Creek in 1897, but no particular attention was given them. The males often had the snout twisted or split, or even cut off. Very often there were one or more scars extending obliquely backward and downward on the side above the anal fin. Sometimes two or three were parallel, as if they were scratches made by teeth of some other fish while the salmon was smaller. These scars were more often present on the females. The dwarf females were always injured in some way. Very few injured fishes were observed in 1898. Two had lost the ventral fins, one had lost the lower two-thirds of the opercle, two had deformed backbones. Only one fish, a female, had the oblique and parallel scars mentioned; they were slightly curved and in two series of seven each. This subject is worthy of further consideration.

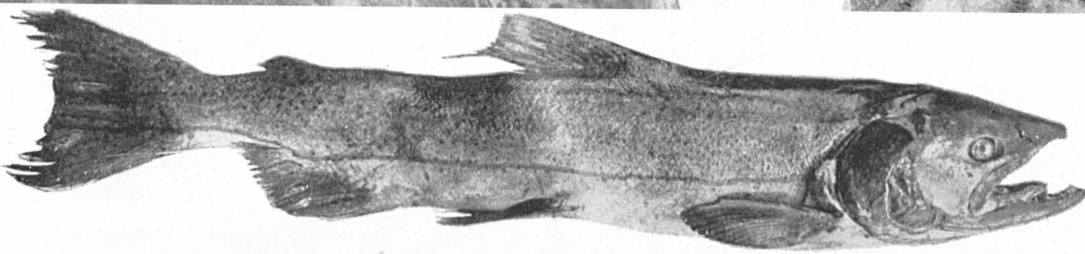
A very characteristic scar, and one that always attracts attention, is that left by the sucking disk of the lamprey. The lamprey has no lower jaw, its mouth being circular and of the size of the end of its head. The gullet ends in the middle of the mouth and is bounded on the upper and lower sides by hooked teeth. There are other smaller hooked teeth above and below these on the disk, and on each side of the disk there are about four short cross rows of teeth, and the whole circumference of the disk is beset with small teeth. When the lamprey attaches itself to another fish the outer row of small teeth leaves a scar somewhat resembling the milling on a coin, which has led imaginative persons to see in the whole scar a resemblance to a brand made by a heated coin. The illustration on plate 13 is made from the photograph of a lamprey scar on the opercle of a blueback salmon found at Karluk, Alaska.

In 1896 5,000 marked fry were released in a tributary of the Columbia River; about 400 of these were taken in 1898, and a few more each in 1899 and 1900. This indicates that most salmon remain in the ocean two years, though a few remain three or four years, as will be seen from the following chapter.



ADULT AND GRILSE FORMS OF MALE SALMON, WITH GENITAL ORGANS MATURE.
The upper is the adult, the lower the grilse. The measure shown is 24 inches long.





ADULT AND GRILSE FORMS OF MALE SALMON, WITH GENITAL ORGANS MATURE.
The upper is the adult, the lower the grilse. The measure shown is 24 inches long.

THE ADULT SALMON.

MIGRATION.

Do salmon return to their native streams?—There is a widespread belief that when a salmon returns to fresh water to breed it seeks the stream in which it was hatched, though there is very little evidence that such is true. Various fishermen claim that they can distinguish the salmon of particular streams by their general appearance, which is incredible. The employees of the Alaska Packers' Association state that the red salmon taken at Uganuk are always smaller than those taken at Karluk, both places on the north coast of Kadiak Island, Alaska; that 13 of the former are required to make a case of canned salmon, while only 11 of the latter are necessary. This seems to indicate that the salmon of the two localities are distinct, but the larger salmon may go to Karluk, not because they have been hatched in Karluk Lake, but because they are larger.

In 1897 855,000 quinnat salmon fry were released in Paper-mill Creek and its tributaries draining into Tomales Bay, California, and 2,000,000 alevins were released in the same streams in 1898. (See "Observations on alevins artificially reared.") In 1900 a few salmon were seen in Paper-mill Creek, and in 1901 they were abundant. In one haul of the seine in the tide-water portion of Paper-mill Creek, covering a section about 150 feet long, 7 quinnat salmon were taken November 16, 1901. It is well known that quinnat salmon did not breed in Paper-mill Creek or its tributaries previous to 1897, for which reason these streams were selected for the experiment. Mr. Thomas Irwin reports that he saw two large salmon in Paper-mill Creek about 1890, but with these exceptions he never saw any fishes in the stream that might be taken for quinnats until 1900. He lives on the banks of the creek and knows the stream thoroughly. His statement agrees with that of other persons.

Paper-mill Creek is not suitable for quinnat salmon, being entirely too small, but it is frequented by dog salmon and steelheads.

But there is no conclusive evidence that the fishes which were found in Paper-mill Creek in 1900 and 1901 were the same individuals released there three or four years previously. They may have been merely stray fishes, and their being found there at that time only a coincidence; or their coming into Tomales Bay may have been caused by there being an extra large number of salmon in the ocean, which might very well be, owing to the large output of young from the hatcheries; or those found in Paper-mill Creek in 1900 and 1901 may have been some of those released there, in which case it is very probable that they had never reached the ocean at all, but remained in Tomales Bay. Paper-mill Creek would then be their only stream.

It is incredible that the salmon remember their native stream during their two or three years of ocean life and that they consciously seek it when they desire to return to fresh water. Probably most of them do return to the stream from which they entered the ocean, not because it is their native stream, but because they do not get far away from its mouth, and when ready to return to fresh water it is the first to attract them.

The two runs of salmon.—Adult salmon may be found in the Sacramento River at almost any time of the year. There are, however, two more or less distinct runs, the first of which passes up the river during April, May, and June, and the latter during August, September, and October. The former is known as the spring run, the latter as the fall run.

The salmon of the spring run ascend the river to the headwaters, such as the Upper Sacramento, McCloud River, and Hat Creek, and some of the earlier ones even pass Pit River Falls and ascend Fall River to its source. They are not found in Pit River above the mouth of Fall River. By the time they reach this portion of the stream, the Upper Pit River is very low and the water impure, and the salmon all turn into Fall River. The salmon of this, the spring run, spawn mainly in August.

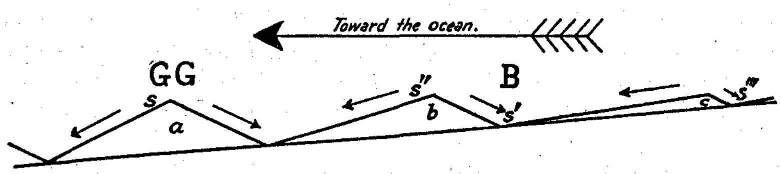
The fall salmon do not ascend the river as far as the spring run, but turn into the lower tributaries or spawn in the main river. They reach their spawning-grounds during the latter half of October, November, and the first half of December, and spawn soon after. The main river is very low at that time of the year, and the portion between Tehama and Redding is an important spawning-ground. (See chart of spawning-grounds, plate 17.)

As a matter of fact there is no definite distinction between the spring and fall runs; that is, there is no time during the summer when there are no salmon running. First there are a few very early salmon that begin running up the river in February, and the number increases until May when it decreases till July; then it increases till the first of September when it again decreases, there being a very few each month until the next spring run.

The spawning seasons merge in the same way. The earliest salmon go farthest upstream, and as the season advances they stop at lower points. The localities and dates of the spawning of the earlier salmon have not been determined, except that Superintendent Lambson, of Baird, reports having seen a pair of spawning salmon in the McCloud at the hatchery on the 20th of April, 1902, which is the earliest record known. By the 1st of October spawning fishes are found as far downstream as Redding, and as far as Tehama by the first of November.

Details of migration.—When the salmon enter San Francisco Bay they come in against the ebb tide, stem the current till the tide changes, and then run out against the flood tide, losing much of the distance gained during the ebb. How it is that they do not lose altogether as much as they gain will be understood from the following explanation: The tide runs up the bay and river as a broad, low wave, on the upper side of which is flood tide and on the lower side ebb tide. When the crest of a wave—that is, slack high water—is at Isleton, the trough, or slack low water, is about at the Golden Gate. This wave is about three hours reaching Benicia and four in reaching Collinsville. The farther up the bay and river it reaches the smaller the wave becomes, the shorter the flood, and (as the flood and ebb combined must equal 12 hours) the longer the ebb.

The following diagram will illustrate the movements of a salmon in passing through the bays: *a*, *b*, and *c* represent the tide wave at successive points as it passes up the bay, ←— indicates ebb tide, and —→ flood tide. Suppose that a



salmon enters the Golden Gate, *GG*, at the beginning of ebb tide, which would be the most favorable time. His position on the wave will be at *s*. If he is able to travel up the bay as fast as the wave he will keep his position near the crest, that is at *s*. But he can hardly do that, especially as the current would be very slight, and in the broad bay hardly strong enough for his guidance. Suppose that by the time he reaches Benicia, *B*, he has fallen behind the wave until he has the position at s'. It is then slack low water, and he can make no headway. Soon the next wave reaches him and he is in flood tide. He will therefore swim back against the current. As the wave is going up the bay and he is going down, he soon gets past the crest and finds himself in the ebb tide at s''. He then turns and stems the ebb tide, and as the wave is going in the same direction he is, he goes much beyond Benicia, *B*, before he again falls back to slack low water at s''', and gets into the flood of the next tide wave.

There is no way of tracing the passage of the salmon through the bays, but from records made at Vallejo, Benicia, and Collinsville it seems to require about a week to reach the mouth of the river after they enter the Golden Gate.

Plate 14 indicates the catch of fish at various places from Vallejo to Sacramento for a certain period, and is intended to show the passage of two schools between the two places. Each division of the diagram indicates the relative amount of salmon taken at the ten places during one day, the unit being the average daily catch at the given place. The vertical spaces indicate tenths of the average daily catch. By a careful study of the diagram the following points will be noted:

On Monday, April 25, there were few fish taken anywhere, the catch being less than the average at all points. This is the more marked because the Monday catch is on an average 25 per cent greater than that of other days, on account of there being no fishing on Sunday. On Tuesday there was a big catch at Vallejo (3.0 times the average), and a slight increase at Benicia (1.1), Dutton (1.2), Black Diamond (1.2), and Collinsville (0.9). There was little or no increase at other points.

On Wednesday, the second day of the run, the catch at Vallejo had fallen off, and by Thursday the run had entirely passed that point. The points on Suisun Bay and along the river as far as Isleton were gained on the second and third days, and the run reached Courtland on Friday, the fourth day. There was no fishing at some of the upper stations on Saturday, that is, Friday night, the law prohibiting fishing from sunrise Saturday to sunset Sunday, and the record for the fifth day is incomplete. This run was two days in passing Vallejo, and four days in going from Vallejo to Courtland.

On Friday, April 29, another run began passing Vallejo, the catch being over three times the average, and the next day it had increased to over six times the average. On Monday the Vallejo catch decreased to 1.9, on Tuesday to 1.7, and on Wednesday to 0.4, the run being five days in passing that place. This new run was not noticed at the other points on Friday, but on Saturday, the second day, it had reached all points up to Collinsville at the mouth of the river. By Monday, the fourth day of the run, it had reached all points from which we have records, the greatest increase being at the stations farther up the river. During the remainder of this week the catch continued to fall off at the lower stations, but continued very large at Sacramento. By Wednesday, the sixth day, it had passed Rio Vista, and Walnut Grove by the seventh. On Friday there was still a big catch at Sacramento (5.9) and at Courtland (3.8). The record is imperfect for Saturday as usual, but apparently the run had passed all stations. To summarize: This run was five days in passing Vallejo. The foremost were four days going from Vallejo to Sacramento, and the run was five days passing Sacramento.

The spring run passes upstream quite rapidly, reaching their spawning-grounds on the McCloud River in about six weeks after entering the river at Collinsville.

The fall run moves more slowly. They are about two months reaching their spawning-grounds, which are not so far upstream. The flood and ebb tides are more nearly equal, owing to the smaller amount of water coming from the rivers, making the passage of the salmon through the bay a little longer. The nets of the fishermen also offer a greater obstruction during the low water and in this way hold the salmon back. In 1900 salmon were taken in abundance in Suisun Bay and in the river as far up as Rio Vista by the middle of August, but were not taken at Sacramento until after the first of September. The low water doubtless made the movement slow, and the taking of from 2,000 to 10,000 daily out of a slow run would account for their nonappearance at Sacramento.

Upon reaching the shoals in the middle portion of the river they cease their migration, having already found good spawning-grounds. In 1898, 1899, and 1900 the water was normally low and a large proportion of the salmon found spawning-places in the main river. The early high water and frequent fall rains in 1897 sent them into the tributaries.

The latter part of September, 1901, 150 salmon were weighed and branded with serial numbers and released in the river near Rio Vista. Three of these were taken at the hatcheries the latter part of November, just at the close of the season. The following is a particular account of these three specimens:

No. 8, a female, was branded September 20, when it weighed 13,930 grams. It was taken again at Mill Creek fishery November 23, when it weighed 10,180 grams, having been 64 days on the road and having lost 26 per cent of its weight.

No. 91, also a female, was branded September 24, when it weighed 8,470 grams. It was retaken at Mill Creek November 20, when it weighed 7,160 grams, its time in passing up the river being 56 days and its loss in weight being 15 per cent. This specimen was returned to the creek after being weighed November 20. It was found dead on the racks 8 days later, when it had spawned all but 20 of its ova. Its weight had decreased 1,860 grams.

No. 43, a male, was branded September 20, when it weighed 10,080 grams. It was taken at Battle Creek November 25, when it weighed 6,275 grams, making its time from Rio Vista 66 days and its loss in weight 25 per cent.

This important experiment proves that the fall salmon travel very slowly, at a rate of 4 or 5 miles a day, and require about two months to reach the spawning-grounds from the mouth of the river.

The salmon of the spring run arrive at their spawning-grounds from two to six weeks or even longer before they are ready to spawn. This time they spend lying quietly in the pools. The fall salmon are more nearly ripe when they reach their spawning-grounds. Indeed, it is probable that many of them cease to ascend the streams only when they are ready to spawn.

Downstream movement.—Under ordinary conditions there is probably little or no downstream movement, yet when the salmon meet with such obstructions as the racks at the fish-culture stations, there is a tendency to go back downstream. At Battle Creek fishery more salmon are taken at the lower end of the pool than at the upper, indicating that they go as far downstream as possible under the circumstances. The large number of fishes in good condition that get caught on the rack

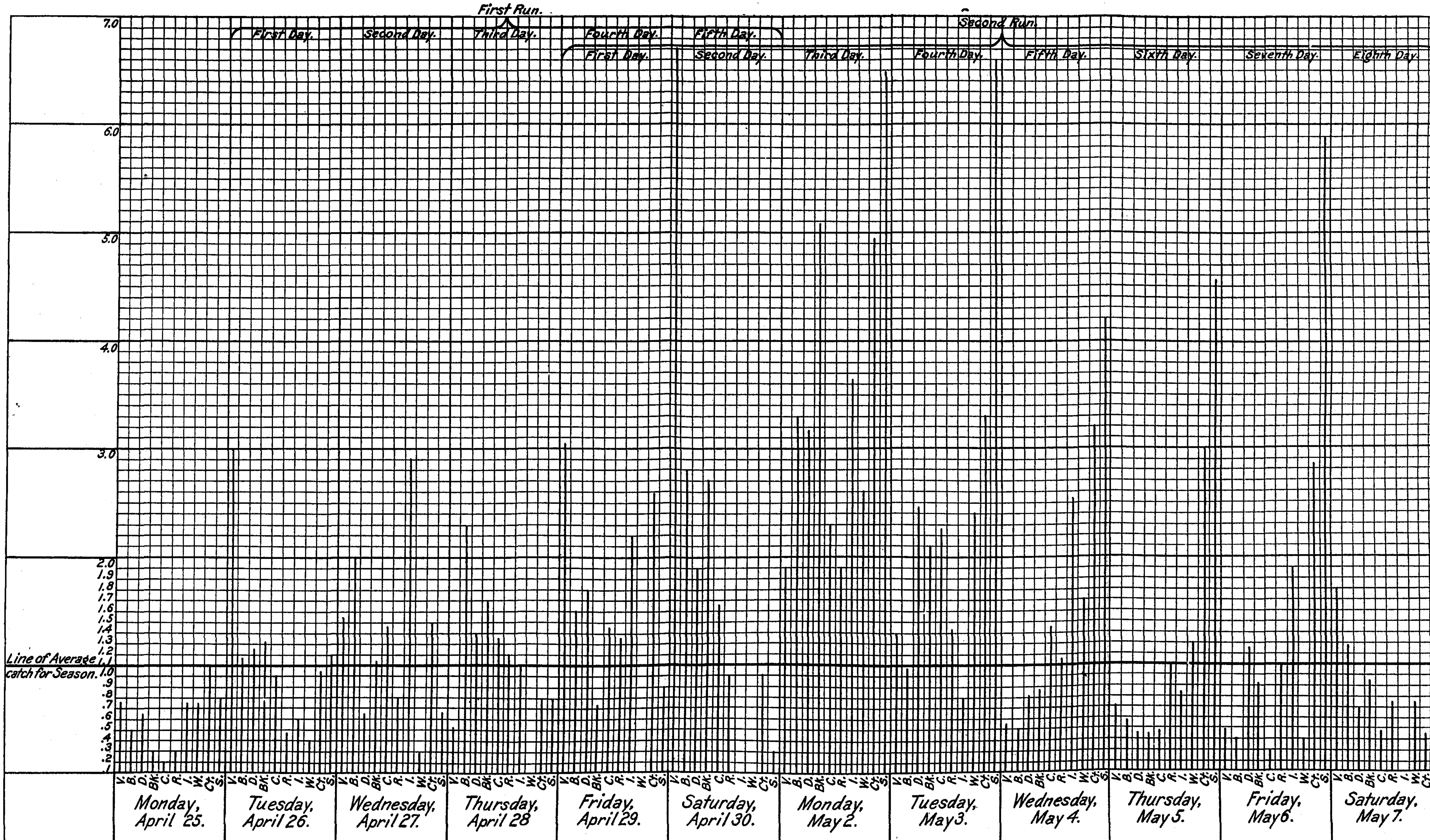


DIAGRAM SHOWING THE PASSAGE OF TWO RUNS OF SALMON FROM VALLEJO TO SACRAMENTO, 1898.

Vertical lines indicate the catch of salmon expressed in tenths of the average catch at each place, each space representing one-tenth.

V, Vallejo; B, Benicia; D, Dutton; Bk, Black Diamond; C, Collinsville; R, Rio Vista; I, Isleton; W, Walnut Grove; Ct, Courtland; S, Sacramento.

indicates an attempt to go downstream. They may frequently be seen coming downstream toward the rack, though I have never seen any try to get through it. When they get close enough to the rack to feel the force of the swift current, they always try to turn back. Eventually they become so weak that they are unable to keep from being carried onto the rack, where many of them perish.

There are also a few fishes that drop downstream as they become exhausted from long residence in fresh water; rarely from spawning. Such were found almost daily on the upper rack at Battle Creek fishery in 1900. Very few of them had spawned, though they were almost completely exhausted and hardly ever lived over a day after coming near the rack. Such specimens usually lie in the less swift water some 10 or 15 yards above the rack, where little effort is required to maintain a position. As they become weaker and the current carries them back toward the rack, they swim back and forth across the creek, their bodies set obliquely to the current, and their tails frequently almost touch the rack. A very little of such exertion soon exhausts them, and frequently they go but a few feet before being carried against the rack, where they die in a few minutes.

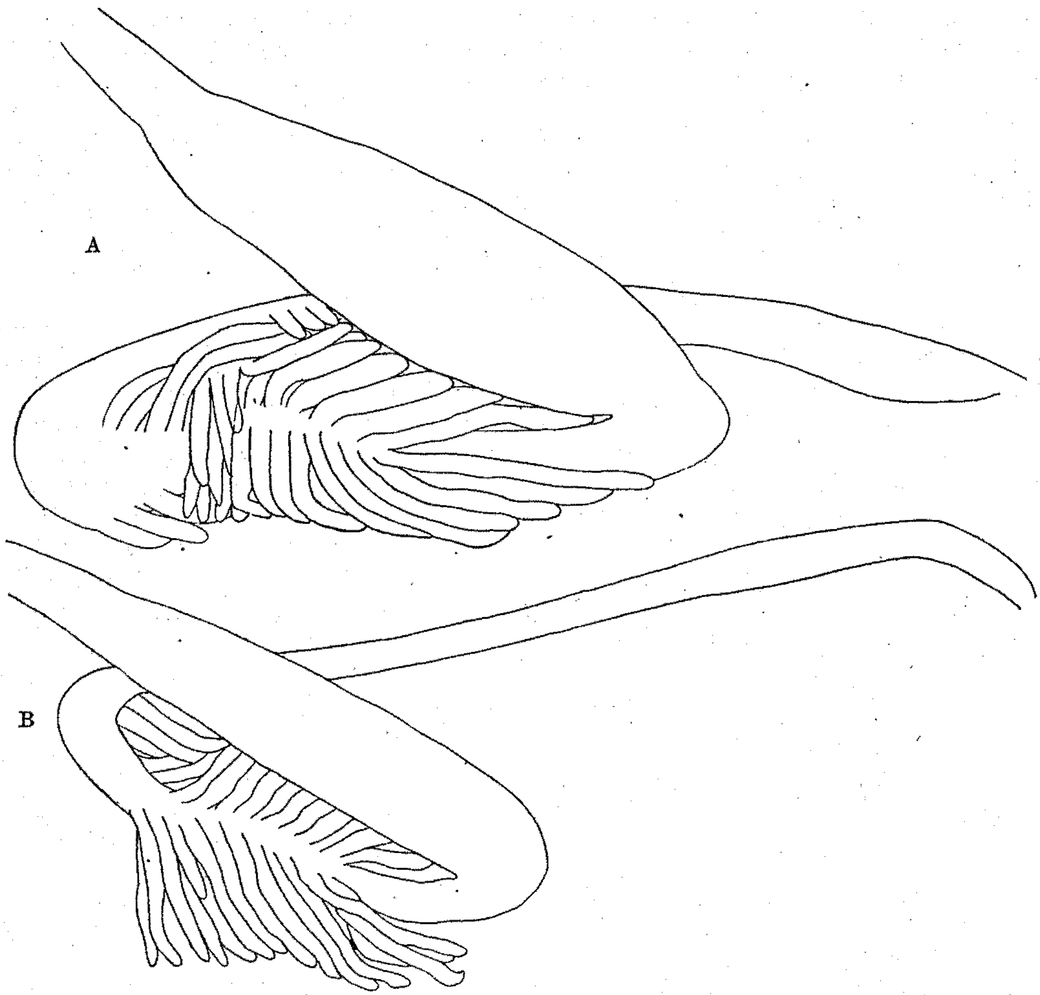
Relation between weather and migration.—It is popularly supposed that the movement of salmon in the rivers is largely determined by weather conditions. Almost any fisherman can tell of a notable run of salmon that accompanied or followed a south wind. Observations made during two years at Battle Creek fishery show that there is no relation whatever between the direction of the wind and the movements of salmon. A strong wind of any direction, however, does apparently cause them to move upstream when they have been lying in a pool for some time. The most notable movement at Battle Creek fishery in 1898 was coincident with a strong north wind. A rain or a slight rise in the water usually causes them to run upstream, but not always. There is apparently no relation whatever between weather conditions and ripening of fish.

CHANGES IN SALMON AFTER ENTERING FRESH WATER.

The alimentary canal.—It is not uncommon for fishes of the salmon family to fast during the breeding season. Such is the case with the Atlantic salmon, the various white-fishes of the Great Lakes, and probably with other species, and it is well known that adult Pacific salmons do not eat while in fresh water. The Sacramento salmon will often snap at bright floating objects and can frequently be taken with the spoon while on their spawning-grounds or while passing up the river. Seventy-five specimens were taken in this way at Jelly Ferry during October and November, 1900. They have never been known to take food, though indigestible material, such as leaves, is sometimes found in the stomach. A 13-inch, mature, sea-run male salmon was taken at Battle Creek fishery in October, 1898. The stomach was contracted the same as in the ordinary adults, but contained two small bits of chitinous substance looking somewhat like portions of the thorax of a grasshopper, but may have been portions of a crustacean.

As they do not eat after leaving salt water, the digestive organs immediately begin to shrivel up. In most of the specimens of the fall run that reach the head of Suisun Bay the stomach and cæca have already contracted and their walls have become firm. Only rarely are they thin and flaccid, as if food had recently been digested. The longer the time since leaving salt water, the more the digestive organs become contracted.

The figures on pages 126-128 illustrate the successive changes in the alimentary canal as observed in specimens from Monterey Bay, head of Suisun Bay, Sacramento River at Sacramento, and at Battle Creek fishery.



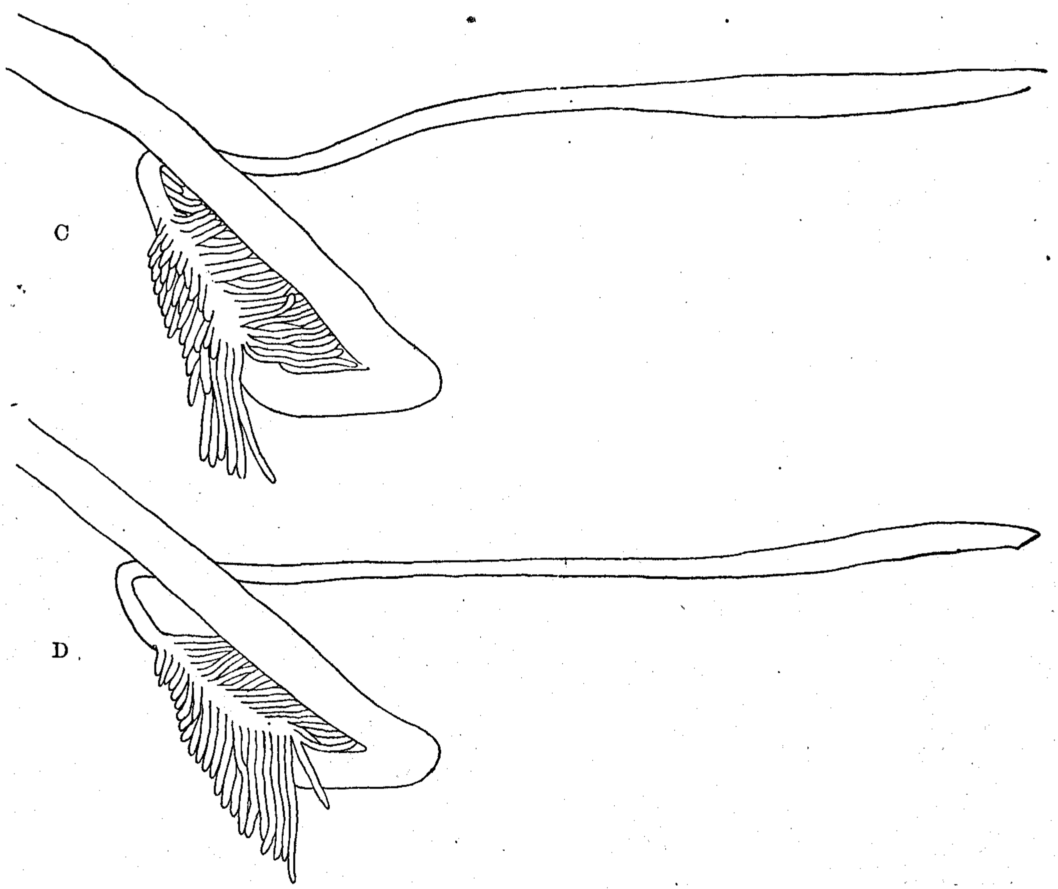
Stomach, pyloric appendages, and part of intestine of two female salmon taken in Monterey Bay, Cal., drawn to same scale. *A*, July 6, 1900, stomach containing food. *B*, July 10, 1900, stomach empty.

The skin.—The most immediate change noticeable in the salmon after leaving the ocean is the great increase in the amount of slime that exudes from the skin upon removal from the water. This point is of physiological interest, but has not yet been studied. By the time the fish reaches the spawning-grounds the skin in most cases has thickened considerably, and frequently the scales are entirely embedded and invisible. In the upper figure of plate 13 the scales can be seen only where the skin has been worn off.

Loss in weight.—Many weights and measurements were made in 1900 for the purpose of determining the loss in weight sustained by the salmon during their residence in fresh water, but our scales proved somewhat inaccurate, and the data can not be used in detail. The loss was shown to be very large, about 35 per cent.

Weights were again taken in 1901 with accurate scales. The results are shown in the tables on pages 128 and 129, which give:

First, the length in centimeters of the specimens weighed, the measurements being made from the nostril to the last joint in the spinal column. The nostril was selected as a point of measurement rather than the tip of the snout because the snout becomes lengthened in breeding males.



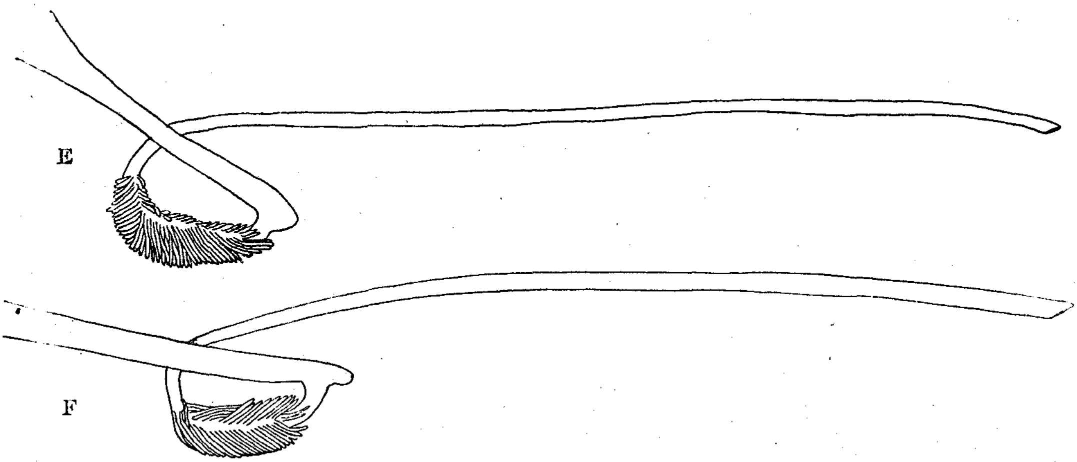
Stomach, pyloric appendages, and intestine of two female salmon drawn to same scale. *C*, Head of Suisun Bay, July 31, 1900, after a fast of a week or two. *D*, Sacramento, August 29, 1900, after a still longer fast.

Second, the average weights of specimens of various lengths delivered at the cannery at Black Diamond September 5 to 11.

Third, similar weights and averages for specimens taken upon their arrival at the spawning-grounds, but before they had begun spawning; also the percentage of loss in weight in these specimens, the average weight of Black Diamond specimens of the same length being taken as a basis in each case. The males were weighed at Battle Creek October 29, the females at Mill Creek November 15.

Fourth, similar weights, averages, and losses of spent fishes, taken either before or immediately after death. Specimens found between October 10 and November 30.

In determining the percentage of loss in the weight of males no account is taken of the loss of milt in spawning, which is very slight, the average total weight of the spent fishes or those just arrived at Battle Creek being compared with the average total weight of Black Diamond specimens of the same length.



Stomach, pyloric appendages, and intestine of two salmon from upper Sacramento River drawn to scale. *E*, Bat Creek, October 20, 1900, a spent female. *F*, Battle Creek, September 15, 1900, a male dying on spawning-grounds.

Table of average weights of male salmon.

Length, centimeters.	At Black Diamond.		On arrival at Battle Creek.			Spent fishes.		
	Number of specimens.	Weight.	Number of specimens.	Weight.	Loss, per cent.	Number of specimens.	Weight.	Loss, per cent.
44	1	2,200	2	1,905	13			
45	1	2,630	2	1,905	24			
46	1	2,580	2	2,375	8			
47	1	2,680	4	2,198	18			
48	3	3,057	5	2,439	20			
49	3	3,167	3	2,700	15	1	2,890	9
50	1	3,060				1	2,770	9
51	2	3,720	2	2,928	21			
52	1	3,910				1	1,630	61
53	1	4,100	2	3,303	17			
56	2	5,295				2	4,025	24
60	2	6,220	1	5,495				
61	2	6,455	1	5,510	15			
63	4	7,236				2	5,533	23
64	3	7,378				1	5,980	20
65	3	8,040	1	6,970	13			
75	2	12,390	1	8,870	28	1	8,535	30
76	4	12,855	1	10,950	15			
78	5	13,192				2	10,768	18
79	3	16,797				1	10,015	40
80	1	15,360	2	13,707	11			
81	1	13,415				1	10,770	20
82	2	16,135				1	11,250	33
83	1	15,670	2	14,175	10			
84	2	17,010	1	15,040	12			
89	1	18,490	1	17,665	10			
Average					16			26

The percentage of loss in ripe females is determined by comparing the total average weight with the average weight of specimens of the same length weighed at Black Diamond, the latter being taken as a basis. The loss percentage as stated for the spent fishes does not include the loss of ova. The percentage is determined by comparing the weight of spent fishes plus the weight of the extruded ova with the weight of Black Diamond fishes of the same length. The weight of the extruded ova is determined by finding the difference in weight between the ovaries of spent fishes and those of fishes just arrived at the spawning-grounds.

Table of average weights of female salmon.

Length, centimeters.	Black Diamond.		Ripe, unspawned.				Spent fishes.			
	Number of specimens.	Average weight.	Number of specimens.	Average weight. Total.	Average weight. Ovary.	Loss, per cent.	Number of specimens.	Average weight. Total.	Average weight. Ovary.	Loss, per cent.
65	1	7,725					1	5,680	67	13
66	17	8,249	2	7,048	1,595	15				
67	15	8,134					1	4,680	80	24
68	9	8,681	2	7,760	2,018	11	1			
69	6	8,949	1	7,720	1,921	14	2	4,988	140	25
70	6	8,981	1	8,390	2,057					
71	4						1	6,340	113	15
72	7	10,227					2	6,573	69	16
73	7	10,060					2	6,398	69	15
74	1	10,700	2	9,095	2,192	15	2	7,450	92	11
76	3	11,508	1	9,930	2,014	14	1	6,060	90	31
77	3	12,330	1	11,600	2,775	6				
78	2	12,220	2	11,995		2				
80	2	14,763	3	11,993	2,372	19	1	10,990	159	11
82	1	14,405					1	8,730	104	24
Average						12				19

The averages of the loss percentages are: For males upon their arrival at the spawning-grounds, 16 per cent; for males at time of death, including loss of milt, 26 per cent; for females upon arrival at the spawning-grounds, 12 per cent; for females at the time of death, not including loss of ova, 19 per cent. The difference between the loss as determined in 1900 and 1901 is accounted for by there having been many more grilse weighed at the spawning-grounds the former year. (See "Two forms of males," page 130.)

Under the heading "Details of migration" (page 124) will be found an account of three salmon that were released in the Sacramento near Rio Vista, after being weighed and branded, and subsequently taken at the Government fisheries. One had lost 15 per cent of its weight, another 25 per cent, and the other 26 per cent during the migration.

One important point to be considered in this study of the loss in weight during migration is the deterioration in the value of the flesh as a food. The loss of 12 or 16 or 25 per cent is entirely in nutriment. If even a very fat beef were starved two months, or until it had lost 16 per cent of its total weight, no one would care to eat of its flesh. But such is the condition of the fall salmon upon their arrival at the upper portion of the river. They have eaten nothing for over two months, and nutriment to the extent of about 16 per cent of their weight has been absorbed, almost wholly from the flesh.

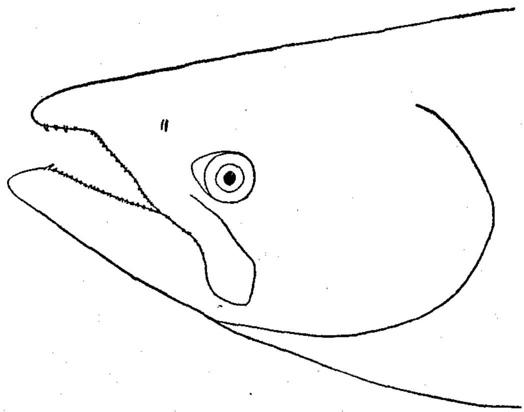
It is evident, therefore, that the fall salmon taken at the upstream points have but little value as food, and their capture should be prohibited.

COMPARISON OF THE SEXES.

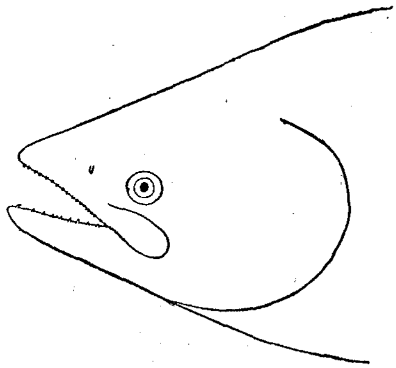
Relative changes in fresh water.—Before entering the fresh water the two sexes are identical in appearance. With the fall run the sex can often be distinguished by the external appearance in specimens taken at the head of Suisun Bay, and it can always be distinguished in normal specimens by the time of their arrival at the spawning-grounds. Soon after entering fresh water several cartilaginous teeth appear in the front of the jaws of the males, and at the same time the jaws begin to grow longer. By the time the males reach the spawning-grounds the jaws are much prolonged and hooked, and the teeth have grown to be large and solid canines; the body becomes deep and slab-sided, and the color usually more or less reddish.

The principal change in the females lies in the diminution in the muscular tissue of the back and sides and in the distension of the abdominal walls on account of the development of the ova. Their color is usually more or less olive. After spawning the female is as thin as the male, but the jaws are not prolonged.

The following illustrations indicate the changes better than descriptions:



Head of male salmon taken at Sacramento, September 5, 1900, showing the beginning of the jaw prolongation and canine teeth while yet cartilaginous.



Head of female salmon taken at Sacramento September 5, 1900. This is also the head of the male in salt water.

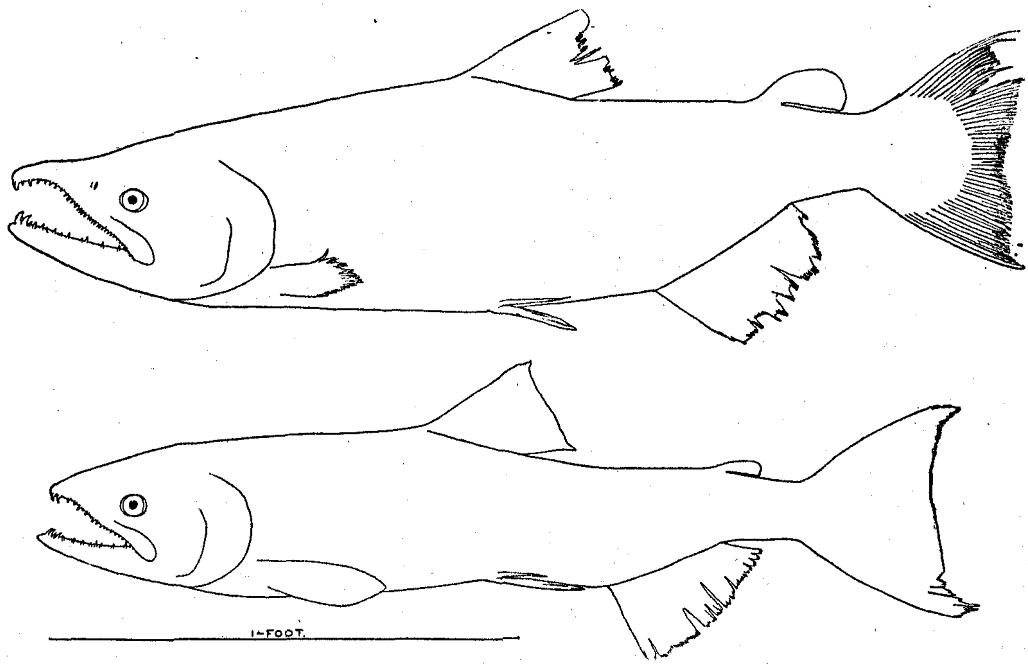
Two forms of males.—The illustrations on page 131 show the two forms of male salmon, known as adult and grilse, that are found in the headwaters. Those here shown were nearly of the same length, though it is very rare to find as small a specimen as the upper that has the adult form, and the lower was a rather large grilse: (See also plate 13, photographs of these same specimens.)

The differences are obvious. The grilse simply fails to develop the characteristics of the breeding male, viz, the prolonged and hooked jaws, the large, hooked teeth, the deep, slab-sided body, and red color, and retains its salt-water appearance except in the loss of flesh. Grilse weigh from a half pound up, and intergrade with the adults both in weight and appearance; specimens with a length of 90 centimeters (35.5 inches) are occasionally found. I have seen two, which, from their olive color, could be distinguished as sea-run fishes, that were only 13 inches long.

At Battle Creek fishery in 1900 the males were nearly all grilse, though there were almost as many of the adult males as there were females. The great preponderance of the grilse over the adult males and females is due to their being too small to be taken by the nets of lawful mesh.

The cause or causes that lead to the production of the grilse form are not known. Mention is made in another place in this report of the sexual maturing of the male parrs that remain in fresh water during their first summer. It it possible that this stunts them and causes the production of grilse. If grilse were simply young individuals that followed the adults into fresh water, we would expect to find females among them. The two forms can not be distinguished except in breeding fishes.

The dwarfed form of the female is practically unknown. Among many thousand specimens handled at Battle Creek fishery only one dwarfed specimen was found. This was 16 inches in total length and weighed 2 pounds. Its ova were mature.



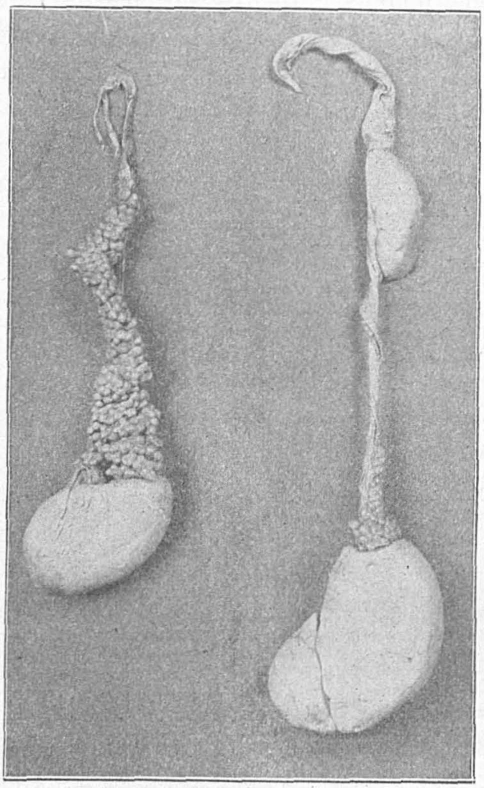
Two spent male salmon, adult and grilse forms, found dead on the rack at Battle Creek fishery October 28, 1900. Length from hinder edge of eye to base of tail, larger specimen 500 mm., smaller 455 mm.; weight, larger specimen, 3,100 grams, smaller 1,200 grams.

Comparative statement of weight and length of the snout in adult and grilse salmon of the same body length.

Length from hinder edge of eye to base of caudal fin (centimeters).	Weight in grams.			Length of snout from hinder edge of eye (millimeters).		Length from hinder edge of eye to base of caudal fin (centimeters).	Weight in grams.			Length of snout from hinder edge of eye (millimeters).	
	Adult.	Grilse.	Excess of adult.	Adult.	Grilse.		Adult.	Grilse.	Excess of adult.	Adult.	Grilse.
40	1,125	1,025	100	68	....	49	2,475	2,375	100	77	70
41	1,650	1,000	650	75	57	49	2,700	1,425	1,275	79	67
43	1,725	1,575	150	66	66	50	2,975	1,725	1 225	92	71
43	2,500	1,600	900	66	65	51	2,775	1,875	900	99	75
45	2,350	1,075	1,275	72	65	54	3,700	2,425	1,275	90	71
46	1,875	1,675	200	72	62	57	3,950	2,775	1,175	95	82
46	2,450	1,525	925	87	65	57	4,000	2,400	1,600	100	72
47	1,875	1,800	75	75	64	77	11,600	7,050	4,550	137	128
47	2,825	1,725	1,100	90	60	79	10,800	8,550	2,250	145	102
47	2,175	1,800	875	71	64						

Hermaphrodites.—I am indebted to Mr. J. P. Babcock, of the California Fish Commission, and to Mr. Chamberlain for two hermaphrodite salmon. Mr. Chamberlain's specimen was discovered by the spawning crew at Battle Creek hatchery in December, 1900; the other specimen was discovered by Mr. F. A. Coles while cleaning fish for the cannery at Black Diamond, and was taken in that vicinity in May, 1901. The accompanying illustration represents the Black Diamond specimen.

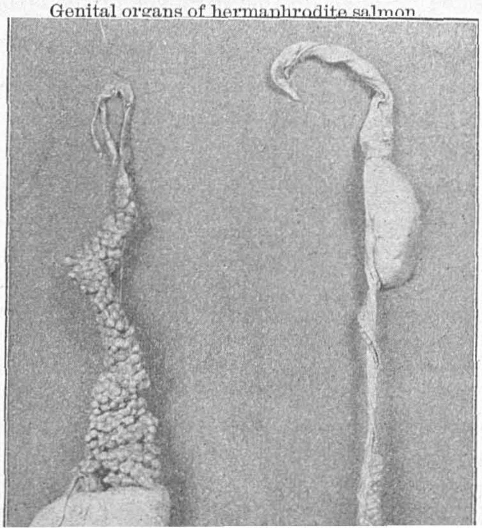
The genital organs of the two specimens are essentially the same in structure. There is but one pair, as in ordinary individuals, but each organ is developed partly as testis and partly as ovary. One organ in the Black Diamond specimen has about 3 inches of the anterior portion well developed as a testis, and nearly mature.



Genital organs of hermaphrodite salmon.

Immediately behind this are a few ova that are about as large as ova ordinarily are in salmon taken in this part of the river. The next 4 or 5 inches of the organ consists merely of the supporting membrane and seminal duct, with half a dozen ova developed in one place. Then follows a portion about 2 inches long developed as testis. The usual seminal duct leads posteriorly. The other organ of this specimen also has the anterior portion developed as testis, while all of the posterior portion is ovarian. While the ova are of normal size, the locality being considered, their number is not over one-fourth as great as would be produced by a similar portion of a normal ovary.

The Battle Creek specimen is similarly developed. Some of the ova are attached, while others are free, as if the fish had been only partly ripe. All are variable in size, but none of normal appearance are as large as the average ova taken at Battle Creek. Many of the ova evidently were dead at the time the fish was taken, and some of these were abnormally large. I understand that



are about as large as ova ordinarily are in salmon taken in this part of the river. The next 4 or 5 inches of the organ consists merely of the supporting membrane and seminal duct, with half a dozen ova developed in one place. Then follows a portion about 2 inches long developed as testis. The usual seminal duct leads posteriorly. The other organ of this specimen also has the anterior portion developed as testis, while all of the posterior portion is ovarian. While the ova are of normal size, the locality being considered, their number is not over one-fourth as great as would be produced by a similar portion of a normal ovary.

Table showing relative number of male and female salmon taken at mouth of river.

Date.	Males.	Females.	Date.	Males.	Females.
Aug. 21	74	158	Sept. 1	163	214
Aug. 22	87	113	Sept. 3	139	163
Aug. 25	4	8	Sept. 4	101	96
Aug. 26	15	22	Sept. 5	124	163
Aug. 28	73	219	Sept. 6	137	195
Aug. 29	135	261	Sept. 7	163	146
Aug. 30	121	202	Sept. 8	136	148
Aug. 31	76	121	Sept. 10	241	316
			Total	1,789	2,545
			Per cent	41	59

During October and November, 1900, Mr. Arthur Sergison caught 76 male and 32 female salmon on spoon hooks at Jelly Ferry.

The following is a statement of the relative number of males and females taken in the seine at Battle Creek fishery in 1900:

Table showing relative number of salmon taken at Battle Creek fishery.

Date.	Males.	Females.	Date.	Males.	Females.
Oct. 12	9	3	Oct. 23	236	22
	86	14		98	18
Oct. 14	187	20		73	4
Oct. 20	45	10	Nov. 1 (river)	12	6
	28	4	Nov. 19	5	2
	20	2			
	22	6	Total	1,107	156
	175	34	Per cent	88	12
Oct. 23	111	11			

Relative weight.—The average weight of all salmon taken at Black Diamond cannery from August 20 to September 10, 1900, varied daily from 21.3 pounds to 23.8 pounds. As the largest specimens taken were invariably males, it is probable that the average weight of the males was greater than that of the females. The reverse was true in the upper river, as will be seen from the following statement of weights of salmon taken by Mr. Sergison at Jelly Ferry:

Table showing relative weight of male and female salmon taken at Jelly Ferry.

Date.	Weight, pounds.		Date.	Weight, pounds.		Date.	Weight, pounds.	
	Males.	Females.		Males.	Females.		Males.	Females.
Sept. 28	4.5	11.5	Oct. 7	10.0	......	Oct. 24	10.0	......
Oct. 1	9.0	8.0	Oct. 8	......	24.0		10.0	......
	31.0	11.5	Oct. 9	3.0	8.0		37.0	......
Oct. 2	3.0	13.0		4.0	......	Oct. 25	4.0	......
	6.0	8.0		12.0	......		5.5	......
	7.0	10.0	Oct. 10	......	14.0		10.0	......
	8.0	13.5	Oct. 12	3.0	7.0	Oct. 26	4.5	......
	11.0	......		4.0	12.0	Oct. 27	8.0	......
	12.0	......		5.0	15.0		4.0	......
	14.0	......		8.0	32.0	Oct. 28	4.0	24.0
Oct. 3	1.5	9.0	Oct. 13	6.0	18.0		10.0	......
	3.0	12.0	Oct. 14	4.0	22.0	Oct. 29	14.0	......
	3.0	14.0		......	24.0		14.5	......
	3.0	23.0	Oct. 16	3.0	......	Oct. 31	38.0	......
	3.5	26.0		4.0	......	Nov. 1	4.5	......
	3.5	34.0		5.5	......		12.5	......
	4.0	......		6.0	......	Nov. 3	8.0	......
	4.0	......		7.0	......		10.5	......
	4.0	......		7.0	......	Nov. 6	......	18.0
	4.5	......	Oct. 17	6.0	11.5	Nov. 10	6.0	10.5
	5.0	......	Oct. 18	5.5	......		23.0	13.0
	6.0	......		6.0	......	Nov. 12	11.5	......
	8.0	......		8.0	......	Nov. 13	10.0	12.0
	9.0	......		38.0	......	Nov. 15	......	24.0
	12.0	......	Oct. 22	3.5	32.5	Nov. 20	21.0	......
	34.0	......	Oct. 23	14.0	......			
Oct. 7	4.5	12.0		29.0	......	Average	9.1	16.8
	7.0	......	Oct. 24	4.0	......			

The average weight of the Battle Creek specimens could not be determined, owing to the selection of the larger males for spawning, but it was certainly less than that given in the Jelly Ferry record.

It will thus be seen that throughout the fall season of 1900 there was a greater proportion of female salmon taken by fishermen in Suisun Bay and the lower river. On the other hand, the small males, being too small to be taken in the regulation net of the market fishermen, were greatly predominant in the headwaters. The evidence here given does not indicate that more of one sex is produced than of the other.

This point should be considered in making laws governing salmon fishing. The small males are not desirable for propagation, either natural or artificial, and on account of their great number they are a nuisance at the Government fisheries. They are simply so much valuable food wasted. The present law prohibits the use of nets that would catch them, and it should be amended. As there are no small females, the small-mesh net would not affect the supply of breeding females. A law prohibiting the taking of small fishes is of value only when the small fishes are growing fishes. But the small salmon that come in from the ocean are not growing fishes. None of the salmon ever return to salt water. Their sole value lies in adding so many pounds to the market supply or in reproducing their kind on the spawning-beds. A large fish is worth more on the markets than a small fish; but so are large cattle worth more on the market than small cattle, yet a stock-raiser would never think of selling his fine cattle and keeping only the runts to breed from. It would be better for the salmon as a species, and therefore better for the salmon industry, if the present minimum net-mesh were made the maximum. A small-meshed net does not catch so many large fishes, which would allow the larger individuals to reach the spawning-grounds. The salmon will certainly deteriorate in size if the medium and larger sizes are taken for the markets and only the smaller with a few of the medium allowed to breed.

NATURAL PROPAGATION.

Spawning habits.—Salmon in spawning usually take a position at the upper end of a riffle where the current is strong and where there are gravel and cobblestones among which the eggs may lodge. After selecting the place the female extrudes a few eggs and then moves away. The male immediately takes her exact position, or perhaps a point one or two feet downstream from it, and extrudes a small quantity of milt. In about five minutes the process is repeated, the female always taking the position first occupied. This they continue day and night for over a week, usually nearly two weeks. I have observed salmon spawning at night, but have never been able to watch one pair until spawning was completed. Branded salmon No. 91, previously referred to, was only eight days in spawning, although some eggs had been extruded before it was taken. Two weeks is the spawning time usually assigned by persons living in the vicinity of salmon streams, which is probably about right.

On account of the difficulty in seeing eggs under water, it has been impossible to determine the rate at which ova are deposited. The motions of the fish show just when ova are being extruded, but observation at a distance of 5 feet, with the aid of a field glass, has failed to disclose the eggs.

The female at irregular intervals turns over on her side and digs her tail into the gravel. If the gravel is fine there is often a considerable hillock thrown up, leaving a hole 6 or 8 inches deep and 2 feet across. This digging is probably not for the purpose of covering the eggs, nor to make a space for them to lie in, but by the violent exercise to loosen the eggs from the ovaries. If the purpose were to cover the eggs it would be repeated every time any were deposited. Gravel does not drift so far as the eggs, and if such were the purpose it would not be accomplished. Besides, it is almost impossible to cover eggs with gravel; the eggs, being almost as light as the water, slide away from the gravel. More than that, a covering of over an inch of even fine gravel kills them. The hillock, by forming an eddy at the bottom of the stream, prevents many eggs from floating away and being devoured by other fishes, but such are liable to be covered too deeply and killed in that way. Some of the fine sediment, however, may settle on the eggs and tend to make them invisible to egg-eating fishes. The "nest" can hardly be made as a place for the eggs to lie in, for the current always carries them below it.

The presence of the other sex is not necessary to excite either to spawning efforts. I have seen the female spawning alone at Battle Creek fishery, and other persons have reported similar observations from other places. In September, 1900, I saw a male spawning alone near Sims, the female having been killed by a sportsman in order to get trout bait. Like observations have been reported by other persons.

Percentage of fertilization.—As one pair of salmon deposits an average of 6,000 eggs the increase would be enormous unless there was great loss at some period. It is usually supposed that the greater part of this loss is due to a lack of fertilization of the ova. The great care necessary to secure perfect fertilization artificially has led fish-culturists to suppose that the percentage of fertilization under natural conditions must necessarily be very low. In artificial fertilization the ova and milt are mixed together in a vessel, insuring a coating of milt or spermatized water over each ovum. In natural spawning the ova are caught in the eddies among the rocks, either near the nest or within a few yards below it. A few seconds after the ova are spawned a small quantity of milt is disseminated in the current to be carried against them. It seems very unlikely that a large percentage could be fertilized under such conditions. The following experiments throw some light on the question:

To determine the percentage of fertilization under as nearly natural conditions as possible a box was built 4 feet wide, 14 feet long, and 15 inches deep, and a strong current of water turned through it. About 5 inches of gravel was put in the upper three-fifths. A pair of salmon were placed in the box October 28, 1897. A female not quite ripe was selected, in order to allow a few days to become accustomed to the place. Pickets nailed to the side prevented the fishes from jumping out. By November 2 they seemed to be at home in the box, and their actions indicated that they were ready to spawn. A few eggs were deposited the next day. On the 4th the male died, having become almost entirely covered with fungus in the one week. Another was put in immediately, but the spawning was interrupted, as it required a day or two to get used to the place. The female died November 12, having deposited but few eggs. No cause of death could be ascertained. Of the 512 eggs deposited, 343 were killed while being deposited. Of the remaining 169, 129 or 76 per cent were fertilized. In the second attempt 82 per cent were fertilized.

In 1898 a pair of salmon were put in a ravine with simply a rack to prevent their going downstream. No eggs were deposited.

So far as the number of eggs killed is concerned this experiment is not a fair test. The level floor of the box made few eddies, and the eggs were washed into the corners and killed. The percentage of fertilization would certainly be no greater than under entirely natural conditions. We would expect the death of the male and the introduction of a new one to cause some eggs to be left unfertilized.

November 18, 1897, I dug up five or six nests in comparatively still water where fishes had been seen spawning for a month. The sand and gravel were thrown into a screen and carefully sifted, but no eggs were found; but on stirring the gravel and cobblestones in a strong current and setting the screen below so as to catch floating objects, 13 eggs were secured; 11 were alive and all fertilized, 4 about 3 days old and the others about 28 days. I could see no indication of fertilization in the dead eggs.

In November, 1898, in order to obtain eggs naturally spawned, I placed a screen obliquely in the water 2 or 3 feet below where salmon were spawning. The screen was covered with small cobblestones, that the eggs might lodge among them and be protected from spawn-eating fishes. The first trial was unsuccessful. The second secured 48 eggs; 30 were dead when found. All of the live eggs were fertilized, the others could not be tested.

The experiment with the screen is not a fair test for the number killed, as the screen caught much gravel which pressed the eggs against the wires, and without doubt killed many more than would have been killed under natural conditions. The 1897 experiment in securing eggs from the stream, when 15 per cent were dead, was a fair test, but the number of eggs was too small to warrant definite conclusions. In both experiments all live eggs were fertilized.

In November, 1900, 39 eggs were secured from natural spawning-beds in Battle Creek, 25 of them evidently fertilized, and 1 certainly not fertilized. The condition of the others could not be satisfactorily determined, as they were killed in securing.

At another time a fish was artificially spawned in the creek on natural spawning beds, a screen being placed below to catch the eggs. A male was held in the same position immediately afterwards and milt expressed. The test was not quite fair, for although there was probably a larger quantity of milt than is discharged at once naturally, yet there was also a larger number of eggs. The eggs being caught by the screen and thereby remaining closer to where the male was stripped was of no advantage, as the life of milt in water is ample to allow it to come to rest. If they had been farther away it would have given time for the milt to become more thoroughly disseminated through the water. The eddies caused by our standing in the water and holding the fish prevented the eggs and milt from floating off in a natural manner. In two trials, 35 per cent were fertilized in the first, and 50 per cent in the second.

These various experiments indicate a high percentage in natural fertilization, probably over 80 per cent. It is significant that all live eggs found that had been spawned naturally, excepting one, were fertilized. The fertilization of dead eggs could not be determined, though they were no more liable to be unfertilized than live ones.

Mortality among ova.—These experiments also point to a high but indefinite mortality from being covered by the gravel. The greatest loss, however, is probably due to spawn-eating fishes. In the middle portion of the river, as at Battle Creek, when salmon are spawning, great numbers of other fishes, mostly the split-tail (*Pogonichthys*), gather about to feed on the spawn. Fifty or more split-tails may often be seen lying a few feet downstream from a spawning salmon, and although each fish may eat but few eggs, all together they probably destroy a large percentage of the eggs spawned in the middle portion of the river.

Trout have been taken near the spawning platform at Battle Creek station with the stomach and throat gorged with eggs, the waste from artificial spawning, and 3 ova were found in the stomach of a trout taken in Mill Creek December 1, 1901, several days after any artificial spawning had been done at the station. As there were several salmon spawning in the creek at that time, there is little doubt that the eggs were secured from natural spawning-beds. Trout are adapted to catching floating objects and are doubtless very destructive to salmon spawn where the salmon breed naturally.

Other fishes, such as the hitch (*Lavinia*), hardhead (*Mylopharodon*), and sucker (*Catostomus*), have not been found to eat salmon spawn, though they probably do; the black-fish (*Orthodon*) has not even been found near the spawning-beds. A large Sacramento pike (*Ptychocheilus*) that had secured spawn from natural spawning-beds was taken in the river near the mouth of Battle Creek in 1900.

Natural versus artificial propagation.—Probably the most important problem yet remaining unsolved in connection with the natural history of the salmon is the efficiency of natural propagation. If we could segregate a certain number of fishes in a small stream, then put a fine screen across below where they are to spawn, and later catch all the alevins and fry produced, we could solve the problem. But a small stream, such as could be experimented with, is liable not to have an average number of fishes to prey upon the spawn and alevins, and the conditions would not be entirely natural. The following statement represents approximately the comparative value of natural and artificial propagation:

Items.	Percentage of loss in propagation.	
	Natural.	Artificial.
Not spawned	1	[a]1
Unfertilized	15	2
Killed before hatching	[b]70	8
Alevins killed	[b]13	[c]2
Total loss	99	13

[a] 10 to 20 per cent if unspawned eggs are not removed by abdominal section.
[b] No definite data
[c] At least 50 per cent if alevins are planted.

From the foregoing it will be seen that the heavy loss in artificial propagation has been in not spawning all the eggs and in planting alevins, both of which can be remedied, as is elsewhere shown in this report. The total loss in artificial propagation should not be 15 per cent.

There is a much greater loss when alevins are planted artificially than when they hatch out naturally:

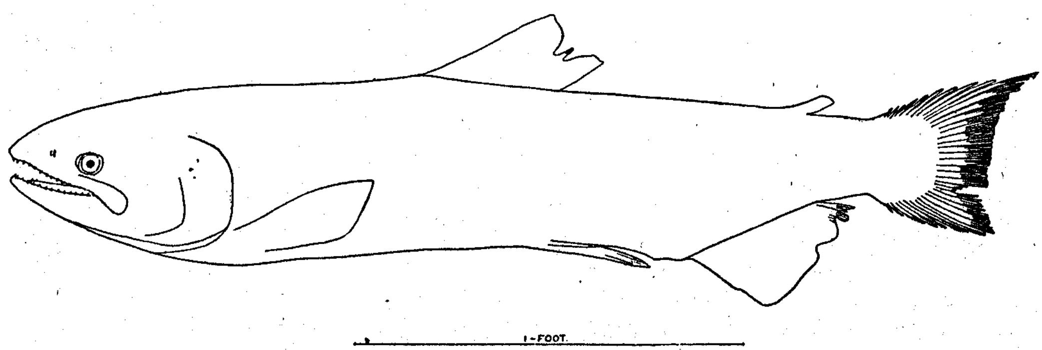
(*a*) From a given number of ova, as those produced by one fish, which is the basis of the percentage, there are more alevins to be destroyed in the case of artificial propagation. In natural propagation they have been already largely destroyed before they become alevins, and there are not 87 per cent left to be destroyed, as in the case of artificial propagation.

(*b*) But even with a given number of alevins the percentage is greater in artificial planting It is not possible to scatter them as well in artificial planting as in natural propagation. No amount of care will prevent their collecting in bunches, which has not been seen in natural propagation.

Something of the value of artificial propagation can be learned from an experiment tried at Clackamas hatchery, Oregon. In March, 1896, 5,000 salmon fry 2.5 inches long were marked by cutting off the adipose fin. The eggs from which the fry were hatched were spawned at Baird hatchery in September, 1895. Mr. Hubbard, superintendent of Clackamas hatchery, who tried the experiment, reported that 375 of the marked fishes were taken in 1898. The smallest weighed 10 pounds, the largest 57 pounds, and the average was 27.7 pounds. Besides these, 5 were taken in the Sacramento River in 1898. A few more were taken both in the Columbia and in the Sacramento in 1899, and also in 1900. The 1900 specimens, however, may have been of those marked in the Sacramento in 1898. From those 5,000 fry 2.5 inches long, costing less than a dollar to produce, fish weighing over 5 tons were taken. That means that for every female fish stripped at the hatchery the fishermen should catch about 5 tons three years later. About 400 of the 5,000 marked fishes were reported taken. We have no means of knowing how many came back to fresh water and escaped the nets, or how many were caught but not noticed.

INJURIES AND DISEASES.

General effects of spawning.—Notwithstanding their long journey from the ocean, the salmon reach their spawning-grounds in good condition. They are not nearly so fat as when they left the ocean, but all their bruises are received after arrival at the spawning-grounds. This fact has already been noted by Evermann (Bulletin United States Fish Commission 1896, p. 191).



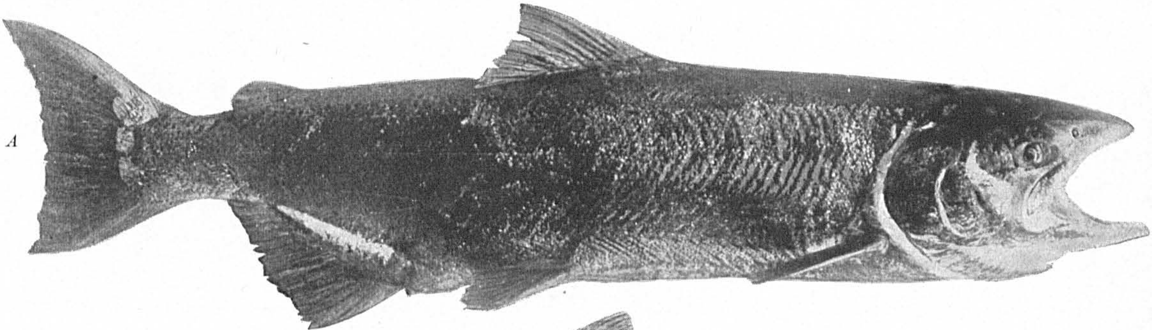
Spawned-out female. Battle Creek, October 20, 1900.

As spawning progresses the abdominal walls of the female contract and she becomes as thin as the male. Her caudal fin is worn off to a mere stub. All fins of both sexes become more or less frayed, the skin wears off the sides of the tail and the prominent portions of the body, such as the edges of the jaws and bases of the fins. Fungus nearly always attacks the gills and the various bruised places and frequently destroys one or both eyes.

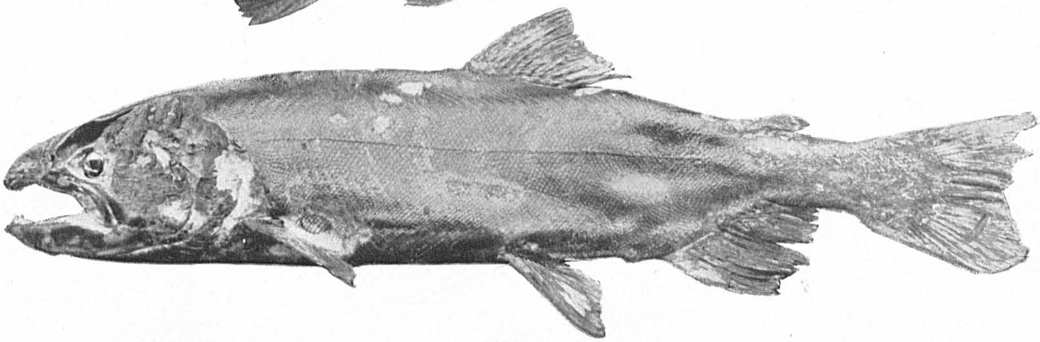
It has been supposed that the exertions of spawning completely exhaust the female and that she dies immediately upon its completion. It would seem rather strange if there were just enough energy to spawn all the ova, and that with the extrusion of the last one the fish should die at once. Observations indicate that the female has considerable energy left after spawning all of the ova, and that she continues on the spawning-beds for some time thereafter. The injuries are received only after most of the ova have been spawned. She probably does not know when the ova have all been extruded, and her instinct compels her, when once spawning has begun, to continue the spawning efforts as long as energy lasts. The complete extrusion of the ova, since it is not noticed, is merely incidental.

In 1900, 14 spent females were taken alive on natural spawning-beds; 7 of them had extruded all ova, in one specimen there was 1 ovum yet unspawned, in two

PLATE 15.



A



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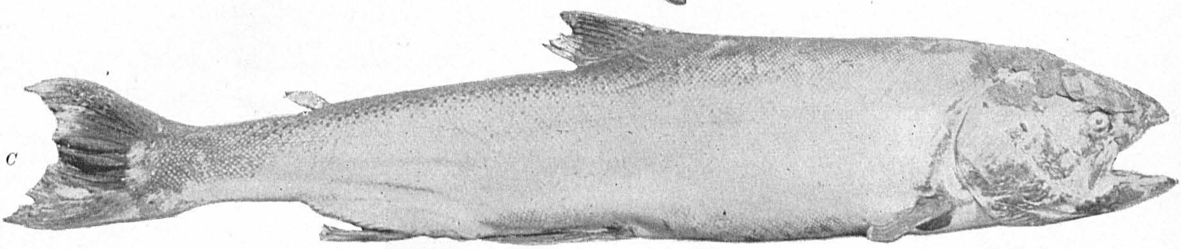

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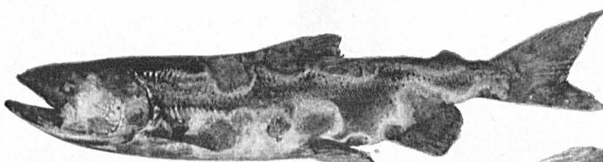

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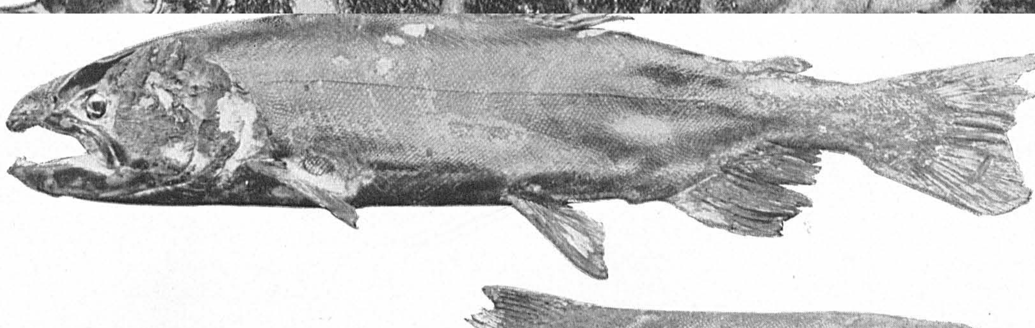

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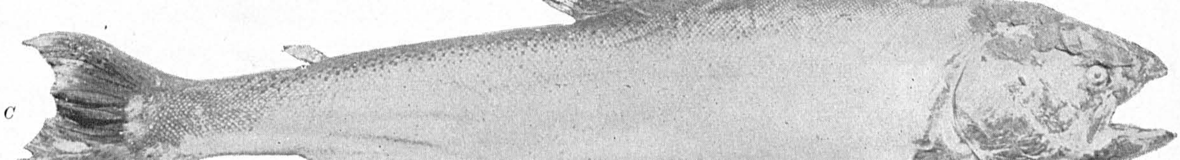


C

there were 2 each, and in the others there were 3, 58, 92, and 107, respectively. If they died immediately after spawning the last ovum we would not have found such a large proportion of live specimens completely spawned out; and if spawning completely exhausted them we would not have found them on riffles but in the more quiet water. In one instance when only one female was taken she was entirely spawned out and had been seen spawning just before the seine was hauled. Of course, it is possible that the last ova were spawned just before hauling the seine, but in any case the fish was far from being in a dying condition. (See plate 16 and fig. A, plate 15.)

Spent salmon.—A few sample field notes on the condition of spent salmon found dead at Battle Creek in 1900 are here given. Several hundred similar specimens were examined during the season.

The following notes refer to spent females:

September 30. Nearly spawned out. Numerous parasites (copepods) and a small patch of fungus on each gill. Top of head without fungus, but with skin worn off. No fungus on body. Fins and skin in good condition.

October 10. But two eggs left in body cavity. Gills about one-fourth covered with fungus; several gill parasites. Skin worn off caudal fin and the rays about half worn off.

October 15. All but 10 eggs spawned. Died in shallow water. Caudal fin entirely worn off, but fish otherwise in good condition. But little fungus. Gills but slightly injured.

October 26. Entirely spawned out, except 2 eggs yet attached to ovary. Half of caudal fin worn off evenly; other fins in good condition. Gills one-third destroyed. Small patches of fungus in various places on body. One eye blinded.

November 1. Specimens Nos. 2 and 3 from the river were of the same length. No. 2 had spawned all but 92 eggs, and No. 3 all but 442. No. 3 weighed 900 grams more than No. 2. The skin was entirely worn off the caudal fin of No. 2, and the rays half worn off. Caudal fin of No. 3 in good condition.

The following notes refer to spent males:

November 5. Badly scarred, one eye blinded, skin worn off edges of fins and jaws. Another specimen, not badly scarred, blind in both eyes, skin worn off snout and edges of fins.

November 6. Skin and flesh worn off in several places behind dorsal and on tail nearly to backbone; skin worn off edges of fins, jaws, and the whole snout; both eyes blinded; gill filaments half destroyed by fungus and parasites.

November 10. One eye blinded; much scarred; little fungus. Another specimen, blind in both eyes; skin worn off jaws and edges of fins; skin dead all over tail and caudal fin; nearly every gill filament with one or more parasitic copepods, and many sloughed off for one-third their length.

Diseases of intestine.—The intestine of the spawning salmon is frequently inhabited by tapeworms, which sometimes completely fill it and extend into the cæca, but I have never found them in the stomach. They were much more abundant in 1898 than in 1900. In addition to the tapeworms the intestine, especially posteriorly, is filled with a viscid, greenish yellow fluid. No examination of this has been made, but it is probably formed by the disintegration of the lining of the intestine, a catarrhal desquamation such as has been found in the Scottish salmon.

Fungus.—Fungus as related to salmon deserves special investigation. Nearly all the salmon that reach the vicinity of Battle Creek fishery during September and October become affected with fungus, which grows in velvety patches on various parts of the body. The points most commonly affected are the top of the head, the gills, fins, and eyes. Of 31 specimens noted on the racks at Battle Creek fishery during October 16, 17, and 18, 1900, 5 were blind in both eyes and 14 others blind in one eye, as a result of fungus.

The following extracts from my field notebook indicate the rapidity of growth of fungus, and show a condition rather worse than the average, though by no means exceptional. The two descriptions refer to the same specimen; first, on September 30, when it was caught and tagged and returned to the creek; and second, on October 4, when it was found dead against the rack:

September 30.—Male, ripe, weight 2,800 grams. A notch in left pectoral, a slit in dorsal; caudal with a few small dead spots, one worn through; 3 parasites on left gill, 7 on right; whole top of head and upper edge of pectoral fins covered with fungus; skin partly worn off sides of tail.

October 4.—Fungus covering following portions of fish; whole top and sides of head to below eyes, lower jaw, back in front of dorsal, edges and bases of pectoral fins, upper side of ventrals, a spot behind right pectoral and one on back before adipose fin, half of adipose fin, spot behind left pectoral, left side below dorsal nearly to lateral line and half way to adipose fin, base of anal on left side, and belly behind ventrals. Left gill with seven streaks of two or three dead filaments each; a little fungus on each dead portion; a small patch of fungus at tip of gill matting together the filaments of all the arches. Right gill with a patch of fungus at tip matting together filaments from all the arches, and another anteriorly on the inner arches. Skin of tail and most of caudal fin dead; some of caudal rays gone.

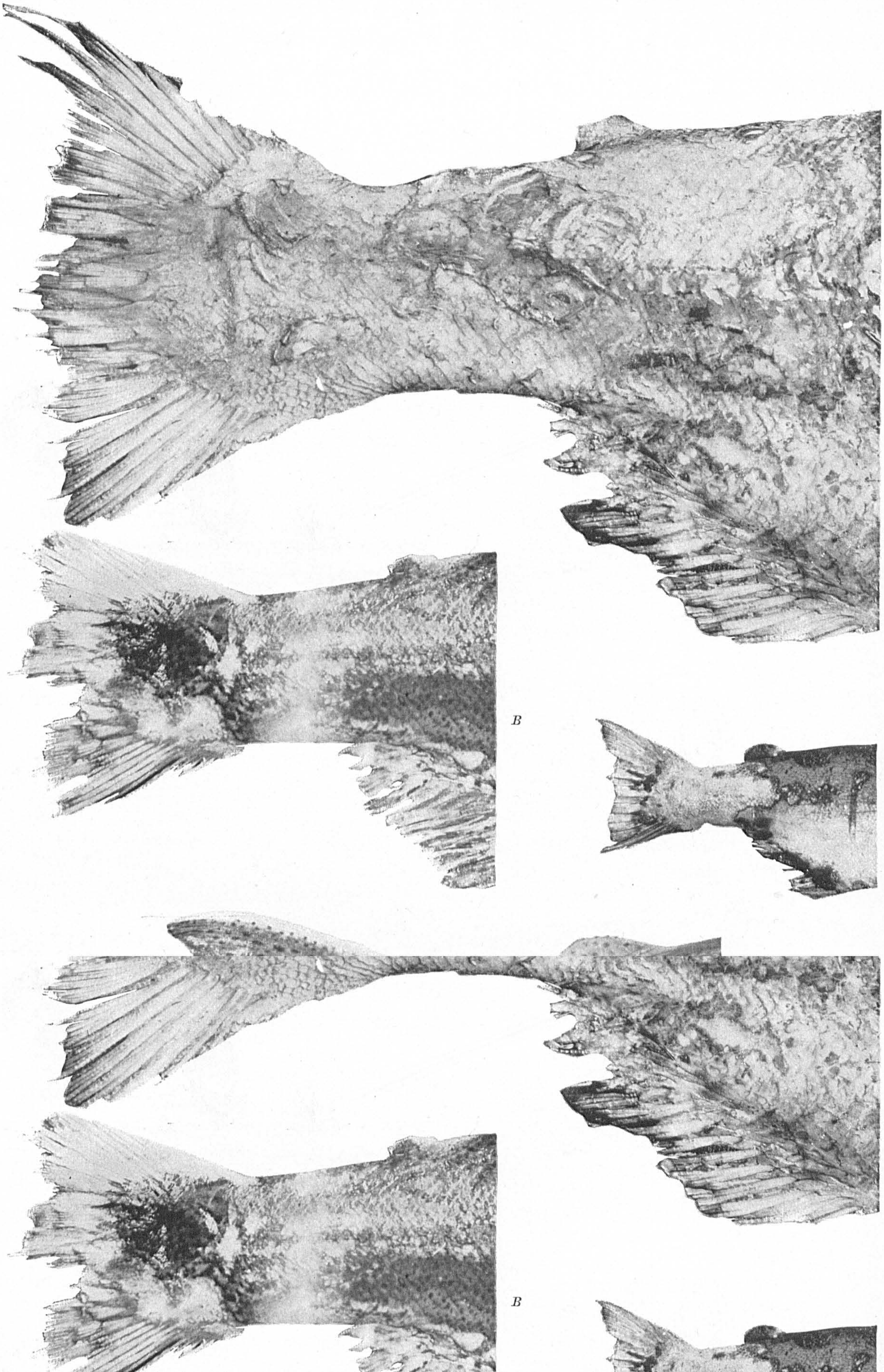
There were worse cases of fungus than the one here described, but this shows what can grow in four days. Another specimen that was in good condition when tagged November 1 was "half covered with fungus" when seen last on the 8th.

The pest almost disappeared in December. Figures D and E of plate 15 show the extent to which salmon are sometimes affected with fungus.

Gill parasites.—Another common pest of the salmon in fresh water is a parasitic copepod which attaches itself to the gill filaments. There are usually not very many on one fish, but sometimes the gills are almost destroyed by them. Plate 15 shows an extreme example. The gills sometimes decay without being affected with fungus or parasites, as was found in a specimen at Battle Creek fishery, October 7, 1900, in which one-third of the gill filaments were dead. (See also plate 13.)

Diseased ova.—In all of the females found dying during September and October, 1900, the ova were more or less diseased. Sometimes there were only a few addled and misshapen ova crowded into the interstices of the healthy ova, but sometimes almost all were addled. Occasionally there were a few abnormally large ova, half an inch or more in diameter, and in a specimen taken October 12, 1900, nearly all were in this condition. In another taken about the same time half were of this character, while the normal ova had been spawned. In another a third of the ova were addled, and the others had absorbed water and were turgid. See fig. C, plate 15.

Length of life of fall salmon after reaching spawning-grounds.—September 30, 1900, numbered metallic tags were attached to 3 male salmon, which were then released in the pool between the racks at Battle Creek fishery; 1 of these was found dead October 5, having survived 5 days. October 22, 36 others were tagged and released in the pool; 27 of these were seen at various times, some of them quite frequently, up to November 1, and 5 of them were found dead within that time, the maximum time being 10 days. On October 25 36 were tagged and released in the creek below the racks; 8 of these were found dead on the racks up to November 10, a period of 16 days. Four were tagged and released in the mouth of the creek, about 2 miles below the fishery, on November 4. One of these was seen on the 5th and again on the 8th, when it was almost dead, a period of 4 days. November 9, 39 were tagged and released in the river below the mouth of Battle Creek; 3 were seen at the fishery on the 16th, 7 days afterwards.



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Altogether 12 tagged fishes were seen after dying, and the average time that they lived after tagging was 11 days. The longest time was 16 days; some had probably been in the creek a few days when tagged, though the freshest were selected. Two weeks is a very fair estimate of the length of life after reaching the spawning-grounds. Branded specimen No. 91, a female, lived but 8 days after reaching the spawning-grounds.

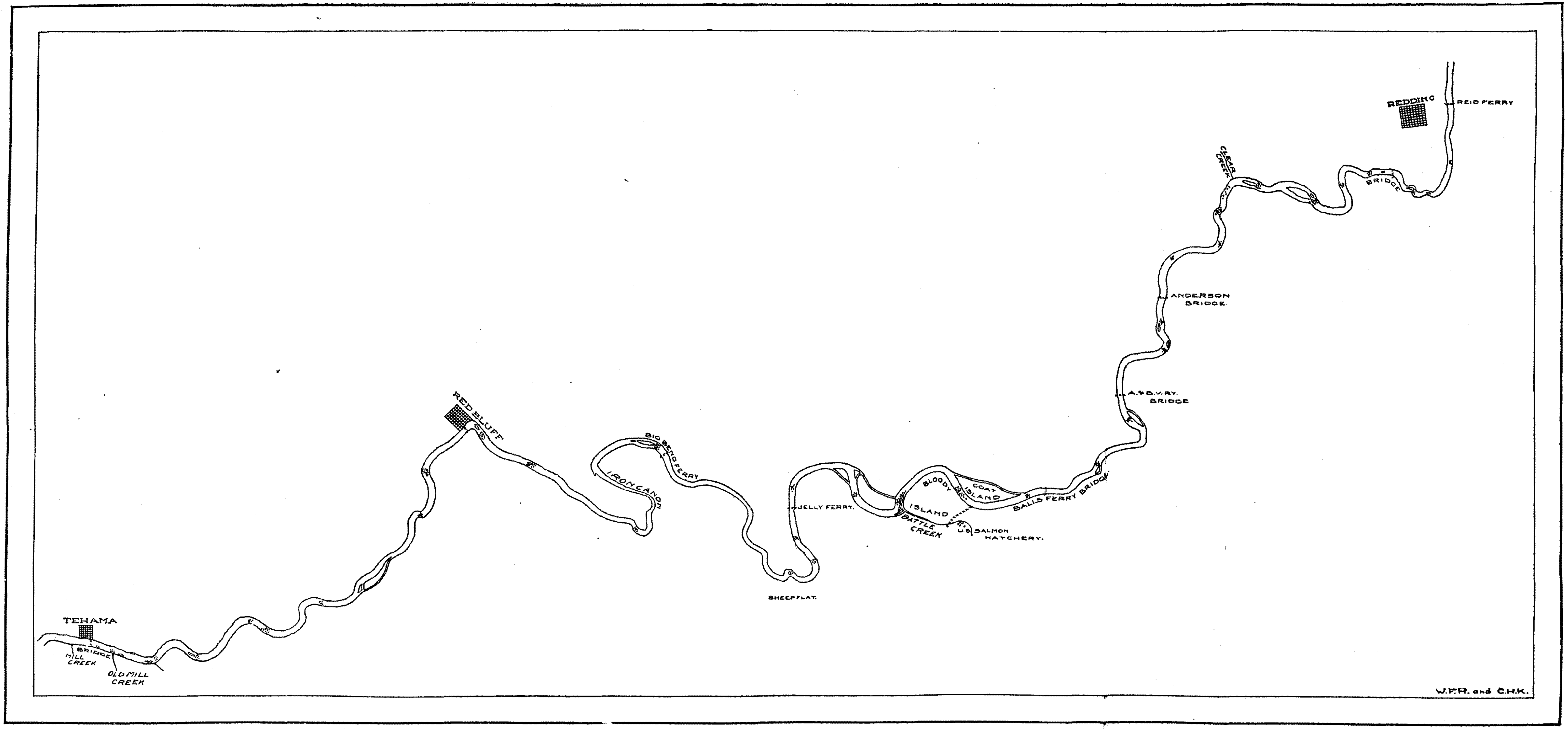
DEATH.

The salmon of the genus *Oncorhynchus* apparently has no instinct whatever to return to salt water after spawning. Worn-out specimens are sometimes seen drifting down stream and have been found as far down as Sacramento, though it is by no means certain that such have been on spawning-beds. In such cases they are simply too weak to stem the current and, according to a Sacramento fisherman, "not fit to look at." Dead salmon rarely float, though the current sometimes washes them along the bottom a short distance. I have seen dead salmon lie for several days in rapids and have seen them in all stages of decay in strong currents. Of the 200 or more dead salmon that were marked and thrown over the upper rack at Battle Creek fishery in 1900, only 2 were carried to the lower rack, which was a half mile further down stream. In small streams the water is often greatly contaminated by the dead fish, and the stench is a great nuisance to people living in the vicinity.

The great variation in size of spawning salmon, together with the occasional presence of certain scars, such as a broken nose, has led many people to doubt whether they all die after spawning once. The variation in size amounts to nothing as an argument, when we know that with about 60 marked fishes known to be of the same age, taken in the Columbia River in 1898, the variation in size was from 10 to 57 pounds. The broken nose could be received at many other times than when spawning.

It is sometimes thought that if a spawned-out salmon would float down stream to salt water it would revive, but such is not the case. Humpback and dog salmon often spawn in small creeks and brooks that empty directly into the ocean, yet they die like other species. They have been seen dying and dead in brackish water. The investigation of the blueback salmon or redfish in Idaho in 1895 (see Bulletin United States Fish Commission 1896, p. 192), when a net was placed across the mouth of a small stream containing about a thousand salmon, proved that that species has no tendency to return to salt water after spawning. Lake Karluk, Kadiak Island, Alaska, is but about 20 miles from the ocean and is a great spawning-place for the blueback salmon. The outlet is shallow near the mouth, and if the salmon ever went back the Indians would be sure to see them, but they do not. In June, 1897, the shore of the lake for miles was lined with the bones of the salmon that had died six to eight months previously.

The fact that all salmon of the genus *Oncorhynchus* die very shortly after spawning once can not be questioned.



SACRAMENTO RIVER BETWEEN REDDING AND TEHAMA. SPAWNING BEDS OF FALL SALMON INDICATED BY CLUSTERS OF DOTS.

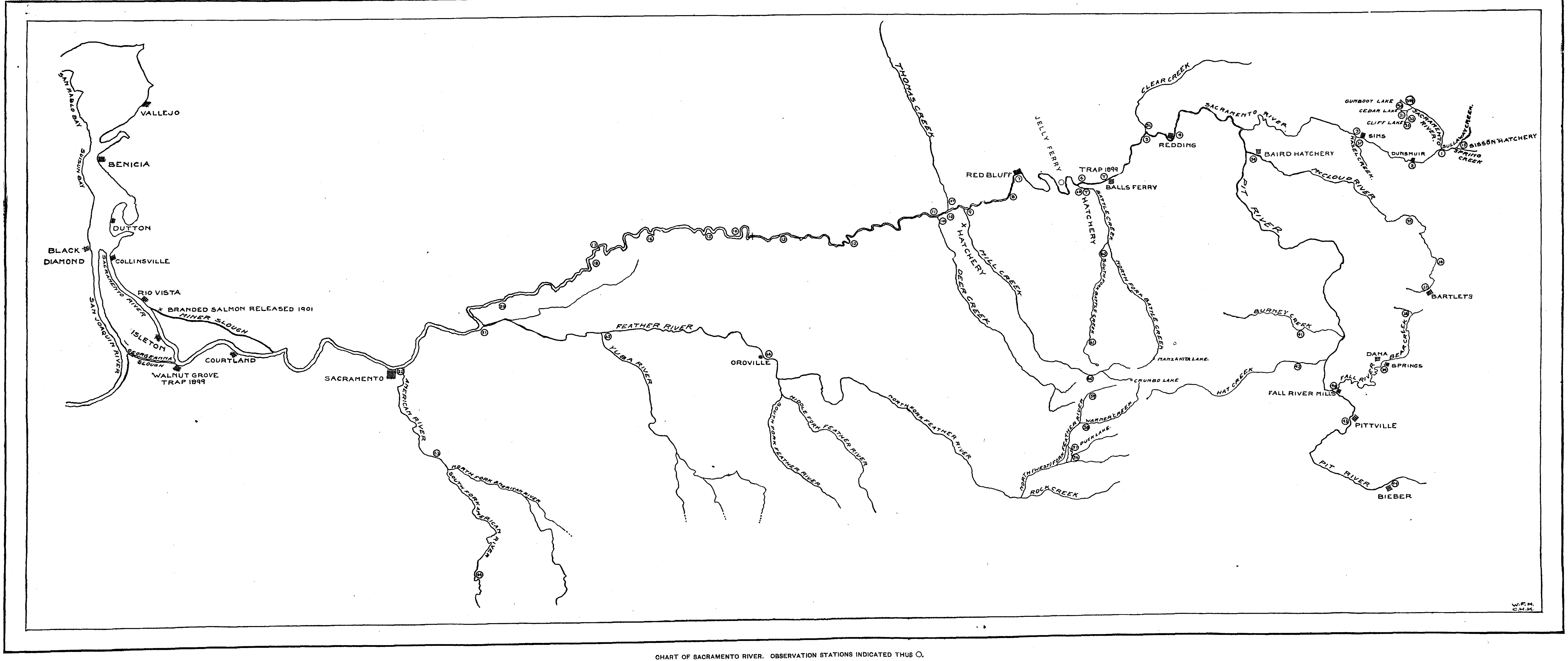


CHART OF SACRAMENTO RIVER. OBSERVATION STATIONS INDICATED THUS O.

NOTES

ON

FISHES FROM STREAMS AND LAKES OF NORTHEASTERN CALIFORNIA NOT TRIBUTARY TO THE SACRAMENTO BASIN.

By CLOUDSLEY RUTTER,

Naturalist, United States Fish Commission Steamer Albatross.

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By CLOUDSLEY RUTTER,
Naturalist, United States Fish Commission Steamer Albatross.

The fishes forming the basis of the following report were collected in 1898 and 1899 while studying the distribution of the fishes of the Sacramento Basin. The collection was studied at Leland Stanford Junior University, where special facilities for study and comparison were afforded by the ichthyological museum.

The localities from which the collection was obtained represent four basins, now distinct, though at one time probably tributary to Lake Lahonton. These basins are Grasshopper Lake, Eagle Lake, Honey Lake, and Truckee River.

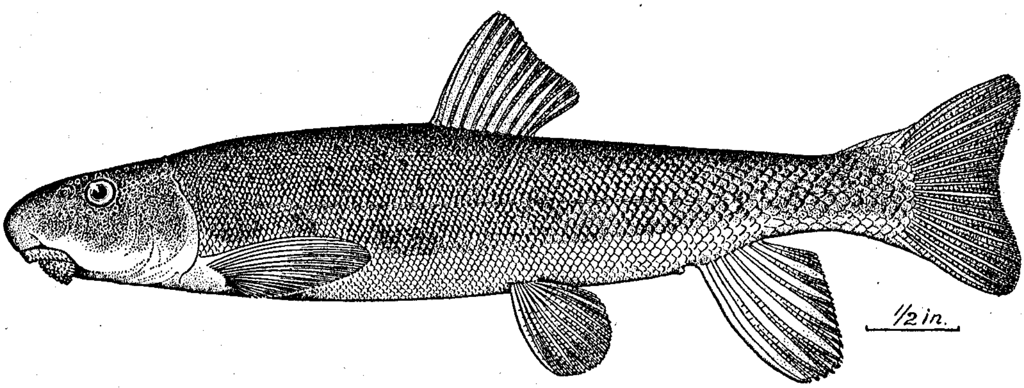
Grasshopper Lake is an alkaline pond, with no outlet, at the southern end of Grasshopper Plains, in Lassen County, and contains no fishes. A species of *Agosia* was found to be abundant in a spring emptying into the lake.

Eagle Lake also has no outlet, the lowest point in the surrounding watershed being over 50 feet above the surface of the lake. Its water is slightly alkaline, though very clear, and near the shore supports thick aquatic vegetation. Only two species of fishes were obtained, the Eagle Lake white-fish (*Rutilus olivaceus*) and a sucker (*Chasmistes chamberlaini*) here described as new. A trout is known to inhabit the lake, but none was obtained.

Two streams were fished in Honey Lake Basin—Willow Creek and Susan River. The former rises at the lowest point in the Eagle Lake watershed, and its upper part is a rough mountain stream. It was fished about 15 miles north of Susanville, where it passes through an extensive meadow. Susan River rises on the eastern slope of Lassen Butte, and above Susanville is a mountain torrent. Its lower part lies in the plains adjacent to Honey Lake and is dry during part of the year.

Collections were made in three streams of Truckee Basin—Little Truckee River, Sage Hen Creek, and Prosser Creek. The former, a considerable stream, 15 to 30 feet wide, with very rocky bottom, drains Webber Lake and Independence Lake, and was fished a short distance below the outlet of the latter. Sage Hen Creek is tributary to Little Truckee River. It is but a small stream, flowing through a narrow wooded valley. Prosser Creek is tributary to Truckee River and drains the table-land north of Truckee. It was fished near Prosser Bar, where it is a meadow stream from 6 to 10 feet wide and 6 inches to 6 feet deep.

The fish fauna of these waters is very limited. Three species are described as new. The collection consists of 9 native and 2 introduced species, distributed as follows: One species, *Agosia robusta*, is common to three of the four basins and is probably to be found in the other basin, Eagle Lake. Another, *Rutilus olivaceus*, is found in all the basins except that of Grasshopper Plains. *Chasmistes chamberlaini*, of Eagle Lake, is not found elsewhere. Honey Lake and Truckee River basins have 5 native species in common—*Pantosteus lahonton*, *Catostomus tahoensis*, *Rutilus olivaceus*, *Agosia robusta*, and *Cottus beldingii*. *Salmo irideus* is found in both basins, but it has been introduced into Truckee Basin, and possibly into Honey Lake Basin. *Leuciscus egregius* is also known from Honey Lake Basin, and *Coregonus williamsoni* and *Salmo henshawi* from Truckee Basin. *Salvelinus fontinalis* has been introduced into the latter basin.



PANTOSTEUS LAHONTON Rutter, new species.

Pantosteus lahonton Rutter, new species.

Head 4.5 in length, depth 5.5; eye 6 in head; D. 10 or 11; A. 7; scales 17–81 to 96–12, 47 to 50 before dorsal. Body terete, caudal peduncle but little compressed; interorbital slightly convex, or flat, width of bone 2.8 in head; eye posterior, 3 in snout, 2.5 in interorbital space, 1.5 in distance between eye and upper end of gill-opening; snout equal to half of head, broadly rounded both vertically and horizontally, projecting beyond the large mouth; 4 rows of papillæ on upper lip, 4 rows across symphysis of lower lip, 10 papillæ in an oblique row from corner of mouth to inner corner of lobe of lower lip; isthmus broader than interorbital, equal to distance between pupils; fontanelle present, but less than half width of pupil in a 6-inch specimen; dorsal inserted from 49 to 52 hundredths of body from tip of snout; ventrals inserted under ninth ray of dorsal, halfway between tip of snout and tip of middle caudal rays; caudal 1.5 in head, deeply emarginate, not forked; pectoral 1.3 in head; height of dorsal about 1.4 in head, the base equal to snout, margin slightly emarginate; ventrals 1.7 to 1.8 in head. Very dark, almost black above, abruptly paler below, lower fins slightly dusky. Maximum length, about 6 inches.

Closely related to *Pantosteus generosus*, but with the following differences, determined by comparison with specimens of that species of the same size from Provo, Utah. The Provo specimens have the dorsal 10 or 11 instead of 9 or 10, as described by Jordan & Evermann.

Species.	Interorbital space.	Scales in lateral line.	Scales before dorsal.	Distance of ventrals from snout equals distance from their insertion—	Caudal fin contained in head.	Width of lower jaw (cartilage) in head.	Rows of papillæ across symphysis of lower lip.	Papillæ on lower lip in oblique row from corner of mouth.
P. lahonton	Flat	81 to 96	45 to 50	To tip of middle caudal rays.	1.2	3.5 to 4, margin convex.	4	10
P. generosus	Convex.	77 to 87	41 to 45	To middle of middle caudal rays.	1	3 to 3.7, margin nearly straight.	2	7

Found in abundance in Susan River, and also in Little Truckee River and Prosser Creek. Types (No. 50587, U. S. Nat. Mus.) from Susan River, collected by Rutter and Chamberlain.

Catostomus tahoensis Gill & Jordan.

Head 4.4 in length, 5 to tip of middle caudal rays; depth 4.8 in length; width of head through opercles equal to its depth; eye 5.5 in head, 2.5 in snout; 2.7 in interorbital space, 1.7 in distance from eye to upper end of gill-opening (by eye is meant the orbital opening, not the eye-ball nor socket); interorbital (bone) 2.3 in top of head; width of isthmus 3.8 in head, a little less than distance between eye and gill-opening, equal to width of opercle, and also equal to distance between corners of mouth. (Measurements made on a 7.3 inch specimen.) D. 11; A. 7; scales 17–89 to 105–16. Body rather slender, profile steep; snout blunt; mouth large, with full lips, covered with rather coarse papillæ which do not become much smaller toward margin of lips; upper lip with about six rows of much-crowded papillæ; lower lip with two rows across symphysis, and about 8 papillæ in a longitudinal row through lobes; posterior margin of lower lip reaching vertical through posterior nostril. Orbital rim but little developed, middle ridge of skull broad, the interorbital space rather high and rounded. Insertion of dorsal in middle of body, its length 1.4 in its height. Insertion of ventrals under fifth ray of dorsal. Length of caudal 1 to 1.1 in head, rather deeply forked, middle ray 1.6 in longest. Anal reaching past base of caudal, its height equaling length of caudal; length of ventrals equals height of dorsal; pectoral a little shorter than caudal. Least depth of caudal peduncle 2.6 in head. Lateral line complete, straight. Peritoneum black. Color nearly black above, slightly mottled with pale yellowish below.

Taken in Willow Creek, Susan River, Little Truckee River, and Prosser Creek. Description based on specimens from Susan River.

Chasmistes chamberlaini Rutter, new species.

One young example, 1.7 inches long, and a dried head 3.3 inches long, which can not be referred to any hitherto described species, were obtained at Eagle Lake. Eye 7 in head, 3 in snout, 2.8 in interorbital bone, 2 in distance from eye to upper end of gill-opening. Premaxillary spines forming a prominent hump, maxillary inclined about 40°, falling far short of anterior nostril, its length from free end to tip of snout just equal to snout in front of nostril, 3.2 in head; lower jaw 3.5 in head. Interorbital (bone) 2 in head, considerably arched transversely; a low, sharp longitudinal ridge along middle suture, showing even in the young example. Nasal spines very prominent; fontanelle closed, covered by a thin bone. Mucus canals prominent, but probably intensified in dried specimen. Lips thin, two rows of papillæ on upper; lower incised to base, lobes small, with scattered papillæ. (The above data from the dried head.)

Cross series of scales 93; D. 10; A. 7. Origin of dorsal in middle of body, ventrals inserted under sixth or seventh ray of dorsal. Pectoral broad, reaching two-thirds distance to ventrals. Ventrals scarcely reaching vent, the outer two rays longest. Anal low, when depressed reaching halfway to caudal. Caudal peduncle long and slender.

Has smaller scales than any other species of the genus. The dorsal and anal are the same as in *C. copei*, but it differs from that species in the broad interorbital and the papillose lips, in addition to the small scales. The sharp ridge on interorbital also seems to be a distinctive character.

Named for Mr. F. M. Chamberlain, of the U. S. Fish Commission steamer *Albatross*.

Type (No. 50588 U. S. Nat. Mus.). Collected in Eagle Lake by Rutter and Chamberlain.

Leuciscus egregius (Girard).

The specimens here noted are not quite so deep as specimens from Winnemucca, Nev., but otherwise can not be distinguished. They have two red stripes along side, with a darker stripe between. Lower part of cheek yellowish, with some yellow along edge of belly. Scales in lateral line 55 to 63. D. 8 or 9; A. 8 or 9. Common in Willow Creek and Susan River.

Rutilus olivaceus (Cope). *Eagle Lake White-fish.*

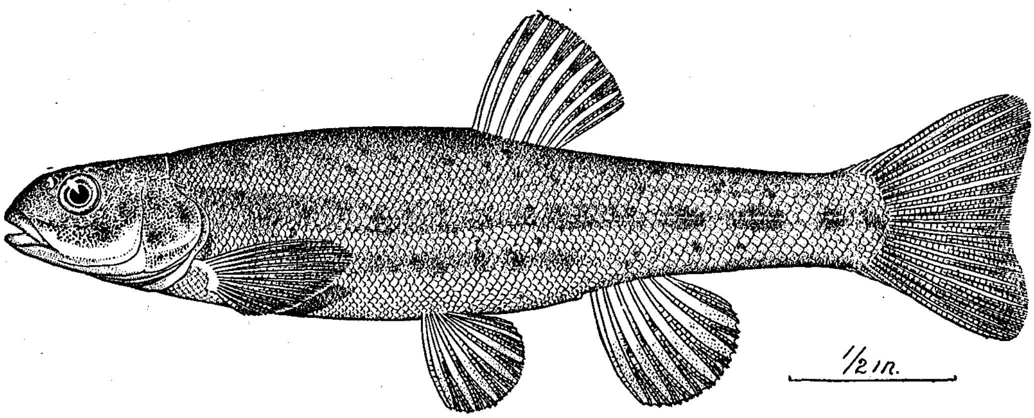
This species was met with in Eagle Lake and Willow Creek, where it attains a length of 8 inches. Head 3.3 to 3.7 in body; depth 3.7 to 4.5; eye 4.4 to 5 in head; insertion of dorsal 0.53 to 0.57 of body from snout. Scales 15–58 to 64–8; D. 8; A. 8; teeth 5–4 or 5–5. Body elongate, little compressed, little elevated, regularly curved from occiput to dorsal, highest over tip of pectoral. Head long; mouth oblique; jaws even, the lower forming a distinct though very obtuse angle with lower profile. Premaxillary on level with lower half of pupil. Top of head slightly concave. Lateral line but little decurved. Tip of depressed dorsal over front of anal. Caudal peduncle long, but little tapering, its length from anal equal to head behind front of eye, its thickness over end of anal equal to snout. This species differs from *Rutilus bicolor* in the finer scales and in having the same number of rays in the anal that it has in the dorsal, *R. bicolor* having one fewer in the anal.

Agosia robusta Rutter, new species.

Body heavy, highest above insertion of pectorals; the ventral outline curved almost as much as the dorsal. Head 3.8 to 4 in body; snout blunt, but little overlapping the premaxillary and never extending beyond it; mouth oblique, barbels usually absent, present on 10 to 50 per cent of specimens from any one locality. Fins small; D. 8; A. 7; pectoral about equal to head behind nostril, variable; caudal moderately forked, middle rays two-thirds length of longest; rudimentary caudal rays forming prominent keels along upper and lower edges of tail; margin of anal slightly rounded, the anterior rays not all produced, not extending beyond posterior rays when fin is depressed. Lateral line nearly always incomplete, but with scattered pores frequently extending to base of caudal; scales 56 to 77, varying about 12 in any one locality. Usually two dusky lateral stripes, the upper extending from snout to caudal, the lower branching off from the upper behind the head and ending along base of anal; cheek abruptly silvery below lateral stripe; tinged with orange about lower jaw, upper end of gill-opening, and at base of lower fins.

Type (No. 50589 U. S. Nat. Mus.). Collected in Prosser Creek by Rutter and Atkinson.

Taken in Spring Creek, Willow Creek, Susan River, Little Truckee River, and Prosser Creek.



AGOSIA ROBUSTA Rutter, new species.

Coregonus williamsoni Girard.

Abundant in streams tributary to Truckee River. A "native white-fish," probably this species, is reported from Bigler (Tahoe) and Donner lakes in the California Fish Commission Report for 1883–84.

Salmo henshawi (Gill & Jordan). *Lake Tahoe Trout.*

Occurs in only the Truckee Basin, and taken in Little Truckee River, Sage Hen Creek, and Prosser Creek. The black spots of sides much larger and fewer than in *Salmo irideus.*

Salmo irideus Gibbons. *Rainbow Trout.*

Readily distinguished from the above by the very small and numerous black spots, as well as by the absence of the red blotch on inner edge of mandibles. Introduced into Truckee Basin, and possibly also into Honey Lake Basin. It was observed in Susan River and Prosser Creek.

Salvelinus fontinalis (Mitchill). *Brook Trout.*

This species has been introduced into Prosser Creek, where specimens were taken.

Cottus beldingii Eigenmann & Eigenmann. *Blob.*

Palatine teeth wanting; no prickles on skin; lateral line broken under posterior rays of dorsal, sometimes a few pores on caudal peduncle, usually none. Top of head covered with minute pimples. Dorsal spines 6 to 8, dorsal rays 15 to 19, anal rays 11 to 14.

Found in Susan River, Little Truckee River, Sage Hen Creek, and Prosser Creek.