EXPERIMENTS IN MARKING YOUNG CHINOOK SALMON ON THE COLUMBIA RIVER, 1916 TO 1927

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INTRODUCTION

As one of the most important means of studying the life histories of salmon, the Bureau of Fisheries, in cooperation with the Oregon Fish Commission, has conducted an extensive series of marking experiments during the past 11 years. In these experiments young, artificially reared salmon were marked by removing certain of the fins and then were liberated in the streams on which the various hatcheries are situated. The experiments that were begun during 1916 and 1917 were described in United States Bureau of Fisheries Economic Circular No. 45. Other experiments have been initiated since then and are described here for the first time.

In this report are presented the data collected up to and including the season of 1927 as the result of marking young chinook salmon. Additional returns are to be expected during the next two or three years from some of the experiments described herein, and a number of experiments have been started from which no returns are yet due.

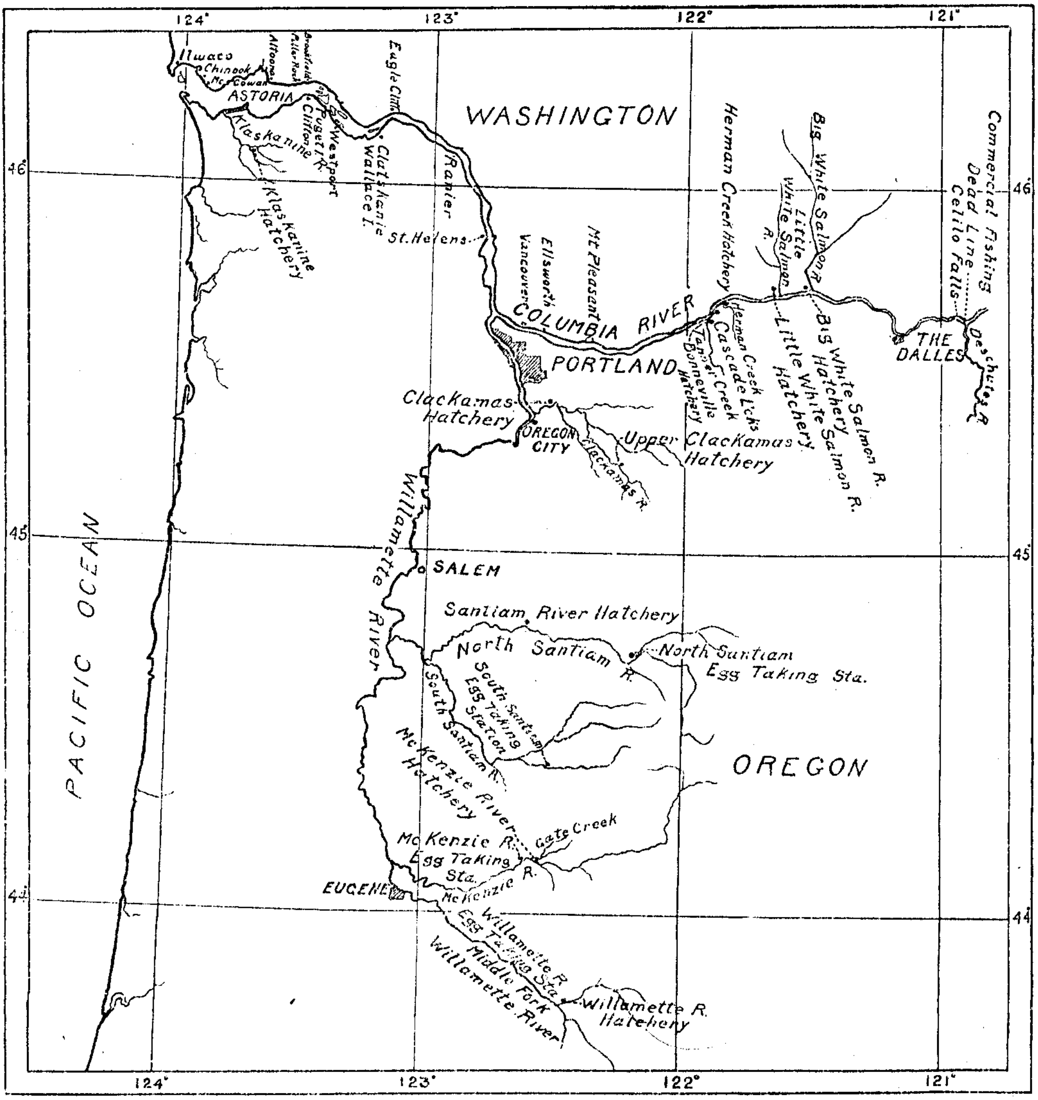
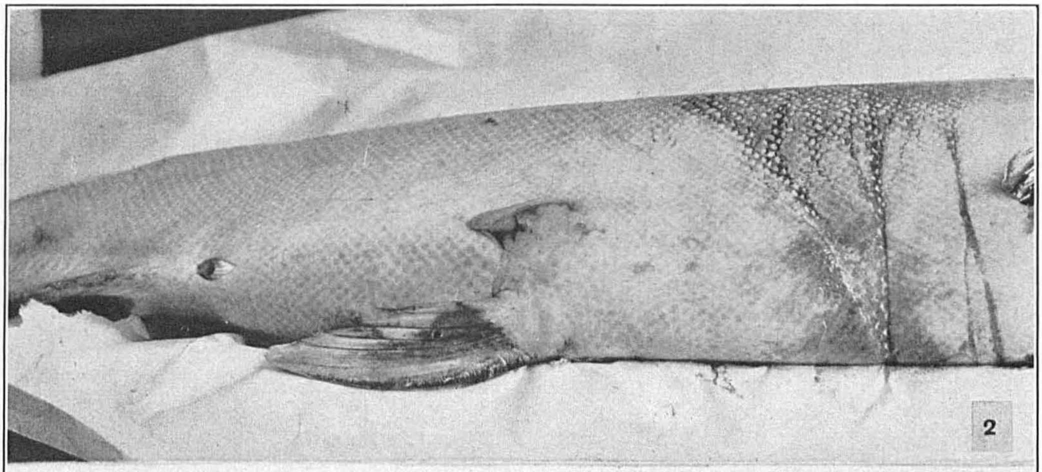


FIG. 1.—A portion of the Columbia River and its tributaries, showing the location of hatcheries and the localities in which marked salmon were recovered

The experiments have been planned with the advice and cooperation of Dr. C. H. Gilbert, Commissioner of Fisheries Henry O'Malley, and R. E. Clanton, formerly director of hatcheries for the State of Oregon, and the success of the work has depended largely upon the aid received from these officials. The actual marking of the young fish was under the direct supervision of the writers, who were assisted ably by numerous hatchery operatives.



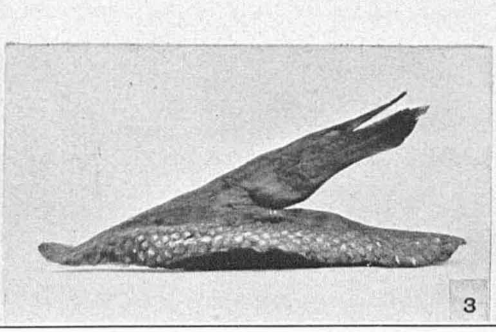


FIG. 2.—Chinook salmon marked by the removal of the adipose fin and the right ventral fin. Illustrating a typical scar resulting from the removal of a ventral fin

FIG. 3.—A typical scar resulting from the removal of the posterior half of the dorsal fin

It had previously been determined that the rayed fins regenerated if not removed very close to the body of the fish, regeneration being most complete when only a part of the distal portion of a fin was removed. When the fins were carefully removed without leaving any stubs of the rays, there was slight regeneration of a soft, fleshy tissue but no indication of regeneration of fin rays. The appearance of the scars on the adult fish recovered gives further evidence of the slight amount of regeneration. In these the point where the removed fins were inserted is typically represented by a slight growth of flat or slightly projecting, soft scar tissue, the surface of which is invariably smooth and bears no scales. In some cases, fin rays have partly regenerated, but even in extreme cases the regenerated stub consists of only three or four rays less than one third the length of those of a normal fin. A typical scar resulting from the removal of one ventral fin is shown in Figure 2. The appearance of the dorsal fin when the posterior half has been removed, as in experiment No. 4, is shown in Figure 3.

In order to test the immediate effects of the marking some of the marked fish in each case and as a matter of routine were retained in the hatchery until they had recovered fully. It was necessary to take this precaution in order that the percentage of return might not be affected by an unusually high mortality resulting from the operation and the handling incidental to marking. In two instances experiments were begun that had to be abandoned on account of the high mortality. These two, however, presented unusual conditions, for in all other instances there was no serious mortality; in fact, in most cases the fish showed no signs of injury from the operation.

The removal of fins from young salmon as a means of marking them for identification when they return to fresh water to spawn has been practiced for many years. The earlier investigators who employed this method used marks that were duplicated easily in nature or that did not persist throughout the life of the fish. As a result, the reported returns from their experiments seem to have consisted, for the greater part, of fish whose fins had been mutilated accidentally. The conclusions based upon this erroneous evidence have since been shown to be incorrect, and the reliability of this method of marking has been questioned. It therefore seems advisable to point out the causes of error in the earlier experiments and to emphasize the precautions taken in this series of experiments to assure positive identification of the marked fish and thus to prevent similar confusion.

The greatest cause of error in the earlier experiments was the failure of the investigators to realize that salmon occasionally lose one or more of their fins in other ways, and that as a result, if only one fin is removed experimentally, the mark may be duplicated accidentally. For example, Hubbard removed the adipose fin from chinook fingerlings at the Clackamas hatchery in Oregon in 1895.[1] The reported returns from this marking are so greatly opposed to the known facts of the life history and growth of chinook salmon that they are obviously in error, and there can be no question that they included fish not marked by Hubbard. In 1903 Chamberlain marked sockeye salmon at Naha River, Alaska, by removing the two ventral fins.[2] Returns from this marking were reported as late as 1911, when the

[1] For a description of the experiment and returns, see Oregon Fisheries Department (1898 and 1900) and Gilbert (1913).

[2] For a description of the experiment and returns, see Marsh and Cobb (1908, 1909, 1910, and 1911); and Chamberlain and Bower (1913).

fish would have been in their ninth year, an age greater than the maximum attained by sockeye salmon. Chamberlain later observed fish with both ventrals lacking and concluded that they were not of his marking.[3]

Another unsatisfactory mark, which has been used on several occasions on the Columbia River, is the removal of a small piece of the caudal fin. In some cases the tip of the dorsal lobe of the fin was removed, but more frequently a small U-shaped piece was clipped out of the posterior margin of the fin. These marks are unsatisfactory for two reasons: First, because the caudal fin frequently is mutilated in nature; and second, because, as mentioned above, fin rays regenerate rapidly unless they are removed at their base. Supposed marks of this nature are brought to the attention of the authors every season. They have been found on all species of salmon and on the steelhead and cutthroat trout, although no such marks have been applied to any but chinook salmon. The condition observed most frequently is a U or V shaped notch in the posterior margin of the fin. The rays that form the margin of the notch generally are bent and distorted. Occasionally the distortion extends for a considerable distance back into the fin, indicating that the notch was much larger originally and that it was reduced by regeneration. Some of these supposed marks obviously are the results of attacks by seals or sea lions. In some cases this is indicated clearly by tooth marks, which can be traced across the side of the fish and across the caudal fin to the apex of the notch.

By marking two or more widely separated fins in the present series of experiments we believe we have obviated, as nearly as may be, the possiblity of having our marks duplicated by accidental means. The validity of every record of recovery of marked fish has been checked by careful examination of the scars resulting from the removal of the fins. Where there has been any question as to the validity of the marks the records have been excluded. The scars, particularly those resulting from the removal of the ventral fins, have been found to be so uniform and characteristic in appearance as to make it seem almost impossible for them to be produced by other means than amputation with a clean-cutting instrument. It is not hard to conceive that an occasional fish might lose one or more of its fins as the result of attack by enemies, or that among the many thousands of salmon there might be a few that would fail to have the full quota of fins at birth; but it is difficult to imagine how such loss could result in scars that indicate the removal of the fins at their very insertion and leave the surrounding tissue and pelvic bones normal. It is inconceivable, also, that such improbable accidental loss could occur to hundreds of salmon at the same time and in just such a manner as to confound the results of our experiments. Furthermore, the evidence of scale readings entirely corroborates the evidence of our marks—a most unlikely occurrence if the scars were the result of accidental mutilation.

Marsh and Cobb (1908), in discussing the returns from Chamberlain's experiments, describe the "scars" of the two ventral fins as follows: "In most cases there was scarcely a trace of the missing fins, the skin at the site of the base of this pair of fins being overgrown with scales." In no case in the present series of experiments have the scars resulting from the removal of the ventral fins been overgrown with

[3] Chamberlain and Bower, 1913, pp. 29-31.

scales, and the locations of the fins are indicated clearly by an abrupt change in the contour of the body at that point and by a slight growth of scar tissue. Fish lacking the ventral fins and appearing as those described by Marsh and Cobb have been observed by the present authors, but invariably these fish have had all other fins present and normal, indicating that they were not marked fish of this series. Furthermore, the pelvic bones invariably were absent, which would indicate further that the scars were not the result of amputation but probably were caused by abnormal development. During the marking of many hundreds of thousands of young salmon we have observed fish occasionally with one or both ventral fins missing. Possibly one fish in ten thousand will show this abnormality. It has been noted also that the adipose fin is missing in about the same number of fish, but we have never observed a case in which both the adipose and the ventrals were affected. The theoretical probability of finding such a case in nature would be about one in one hundred million, a contingency so remote as to be of no practical importance whatsoever.

During the years that the Columbia River marking experiments have been in progress, Dr. J. O. Snyder, of Stanford University, has conducted a similar but less extensive series of experiments in California.[4] His method of marking and other details of his experiments have been nearly identical with ours, and his results also have been approximately the same. The outstanding features of his results are as follows: Salmon marked on the Klamath River were found in the ocean as far south as Monterey Bay; those marked on the Sacramento River were found in the ocean both north and south of the mouth of that river. Notwithstanding this extensive migration, all returned at maturity to the river system in which they were liberated. The proportion of marked fish recovered was approximately the same as in the Columbia River experiments. The scales of the adult fish have been found to be a correct and reliable record of the age and life history of the fish.

Snyder recently conducted an experiment designated to determine the more minute details of the homing instinct of salmon. Satisfactory returns were obtained from this experiment during the seasons of 1926 and 1927, but the results have not been published.

The collection of data from returning adults has proved difficult. One of the authors or some other representative of the Bureau of Fisheries has spent the greater part of each season in the commercial fishing district searching for marked salmon; however, the one or two persons could observe only a small proportion of the salmon taken from the river, as the fish are divided between about 20 canneries distributed along 200 miles of the river. It has been necessary, therefore, to depend largely upon assistance from fishermen, cannery employees, and hatchery men. Theodore F. Rich and W. H. Spaulding aided materially in this work during the seasons of 1919 and 1920. The greatest assistance was rendered by the Oregon Fish Commission, which since 1920 has paid rewards for records of the recovery of marked fish. During 1920 and 1921 a reward of 50 cents for each record was offered. From that time until about the middle of the season of 1926 the reward was $1, but because of the many records of marked sockeye salmon recovered during 1926 it became necessary to reduce the rewards to 50 cents during the latter half of the season. A reward of 50

[4] See Snyder, 1921, 1922, 1923, and 1924.

cents was paid during the season of 1927. Most of the returns have come as a result of these rewards.

On account of the manner in which the data were collected it is necessary to accept the measurements of the fish with some reservation. In all probability the data as to sex are reliable, but those as to length, weight, and time of capture are less dependable. Measurements of length and weight were made by persons usually untrained, and it is more than likely that instruments for taking accurate measurements were not available to them. It is also possible that the length was measured differently; for example, the rays of the caudal fin may have been included in some measurements and excluded from others.

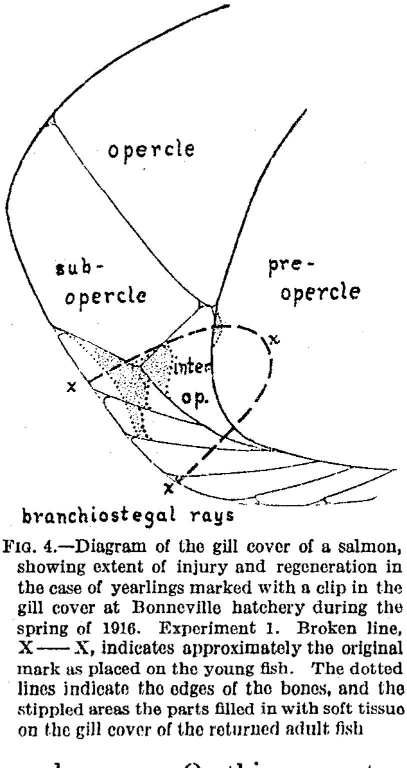


FIG. 4.—Diagram of the gill cover of a salmon, showing extent of injury and regeneration in the case of yearlings marked with a clip in the gill cover at Bonneville hatchery during the spring of 1916. Experiment 1. Broken line, X —— X, indicates approximately the original mark as placed on the young fish. The dotted lines indicate the edges of the bones, and the stippled areas the parts filled in with soft tissue on the gill cover of the returned adult fish

These experiments were planned with several purposes in mind. First and foremost they were designed for the very practical purpose of testing the relative efficiency of various procedures in artificial propagation. It is believed that this method of investigation, more than any other, promises information of vital importance in the upbuilding and improvement of current hatchery practices. The experiments also bear upon important problems in the life history of the salmon, such as the home-stream theory both as applied to entire river systems and to the tributaries of a single system, the factors affecting the age at maturity, the time of entering the river, and the hereditary character of the quality of the flesh. And finally, an examination of the scales of marked fish, the history of which is known aids materially in the interpretation of various difficult types of scales frequently encountered in general collections from the regular runs. On this account special attention has been paid to the scales and detailed measurements and ring counts are given in the accounts of the several experiments.

EXPERIMENT NO. 1. BONNEVILLE HATCHERY, FEBRUARY-APRIL, 1916

Eggs from: Willamette River, 1914.
Reared and marked at: Bonneville hatchery.[5]
Mark used: Removal of adipose fin and U-shaped clip in right gill cover.
Number marked: 4,000.
Liberated: In Tanner Creek during February, March, and April, 1916.
Age: Approximately 18 months.[6]

These fish had been reared in the ponds at the hatchery with a much larger number of sockeyes of the same age. It was during the course of the marking of 50,000 of the sockeyes that these few yearling chinooks were marked incidentally. As no special attempt was made to select chinooks, comparatively few were handled.

[5] For location of hatcheries and fishery locations, see fig. 1.

[6] The ages given are counted from the time the eggs were taken and include the period of incubation. This is done on account of the confusion arising in counting the age from the time of hatching, due to the variable length of the incubation period, which is dependent upon temperature.

For the same reason the mark adopted was not the best. It was felt that the clip in the gill cover would not prove satisfactory and that nearly complete regeneration might be expected. The results have shown this to be the case. In order to reduce the possibility of complete regeneration the clip was placed low on the opercle, so as to cut through the branchiostegal rays, the interopercle, and into the preopercle. The line *X*——*X* on the diagram (fig. 4) indicates the approximate extent of this clip.

A number of specimens were held in a tank at the hatchery for several months and the process of regeneration noted. At the end of about four months the clipped section was regenerated almost completely, so that but a slight indentation of the margin of the gill cover remained. This regenerated tissue seemed to be mainly soft, however, while the bones apparently were regenerated more slowly.

Fifty specimens were preserved for reference during the course of the marking. These average 134.6 millimeters (5.3 inches) in length. The scales show a more or less well-defined growth of the first year, followed by a band of wider rings representing the second year's growth. Figure 5 illustrates a scale showing a well-defined winter band terminating the first year's growth, and Figure 6 a more typical scale in which the boundary between the first and second years is not shown so definitely. The average number of rings in the first year's growth is 15.2 and in the second 6.6. The average length of the anterior radius of the scale is $\frac{46.5}{120}$ millimeter to the end of the first year and $\frac{68.9}{120}$ millimeter to the periphery.[7] The complete data for this collection are given in Table 1.

TABLE 1.—*Chinook-salmon yearlings marked at Bonneville hatchery March 2 and 11, 1916*

Length in millimeters (mid-value of class)	Scale record																							
	Number of rings																							
	First year's growth											Second year's growth												
	11	12	13	14	15	16	17	18	19	20	23	1	2	3	4	5	6	7	8	9	10	11	13	14
105					1										1									
115			2	2	1	(1)		1						1	2	2	1							
125		3	2		2	2	1		2				1	2	2	3	2	1	1					
135			1	3	2	2		1	1		(1)			1	3	2	1	2			1			
145			2	2	2	1		1								1	4				2	1		
150	1		1	1			2													2		1		1
160		1																				1		
175			1		1																	1	1	
195							1	1		1											2			
Total	1	4	9	8	9	6	4	4	3	1	1	----	1	4	8	8	8	3	2	2	5	4	1	1
Average	15.2											6.6												

[7] In practice the image of the scale, as projected by a camera lucida to the level of the base of the microscope, is measured by means of a millimeter scale. The magnification of this projected image used in making this study is 120 diameters. For the sake of convenience the measurement is given as a fraction, the numerator of which is the measurement of the image and the denominator the magnification used.

TABLE 1.—*Chinook-salmon yearlings marked at Bonneville hatchery March 2 and 11, 1916*—Contd.

Length, in millimeters (mid-value of class)	Scale record																		Males	Females	Total
	Length of anterior radius, in millimeters×120																				
	First year's growth (mid-value of class)							Second year's growth (mid-value of class)													
	32.5	37.5	42.5	47.5	52.5	57.5	62.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	82.5	87.5	97.5	117.5			
105				1					1										1		1
115		1	(4)	1				1		4									4	2	6
125		2	4	5			1		2	4	3	3							7	5	12
135		1	2	3	(2)	3				2	1	3	4						7	4	11
145			3	4	2					1	1	2	3	1	1				7	2	9
150	1		2	1		1							1	1	1	1	1		4	1	5
160			1													1			1		1
175		1	1												2					2	2
195					2		1							1		1		1	3		3
Total	1	5	17	15	6	4	2	1	3	11	5	8	8	3	4	3	1	1	34	16	50
Average	46.5							68.9											[1] 135.2	133.4	134.6

[1] In this and subsequent tables the averages given at the foot of the columns of frequencies represent the average length in millimeters.

NOTE.—Groups in parentheses each contain 1 individual whose scales show no second year's growth.

A slight narrowing of the rings about midway in the first year's growth is apparent in some of the scales. (See fig. 6.) This narrowing or check is comparable to that which the senior author (Rich, 1920) observed in the scales of many seaward migrants and has termed "primary check." In this connection the term "primary" was intended to be descriptive from the standpoint of time, but to some readers it has given the impression of first in the order of importance. In view of this confusion of meaning it seems advisable to discontinue its use and to introduce the more general term "incidental check," to be applied to all checks other than annuli, which represent a winter in the life of the fish. The significance of this check, formed during the first year's residence in fresh water, is not always clear, but it has been shown in some cases to have resulted from some abrupt change in the environmental conditions. (Rich, 1920.)

Only one adult fish has been recovered that unquestionably shows the mark used in this experiment. This fish was a male weighing 48 pounds (21.8 kilograms) and was taken in one of the wheels near The Dalles, Oreg., on May 4, 1920. The adipose fin was entirely lacking and the right opercle showed unmistakably the scar resulting from the clipping. Figure 4 shows the approximate extent of the scar. One other specimen was obtained that probably is of this series. This doubtful specimen was taken on May 28, 1920, near Warrendale, Oreg., and was sent by the finder to the Oregon fish commission. The data, including scars, were forwarded to the writers, together with data from several other marked fish. En route the package was damaged badly, and from this specimen only the scar of the adipose fin remained. It is not known whether the gill cover was included in the original shipment or not.

The scales of these fish are similar and show that they were in their sixth year. The central portions of the scales, the "nuclei" (representing the growth of the first year), are typical of the stream type described by Gilbert (1913) and correspond closely to the scales of the young fish preserved at the time of marking. Figure 7 shows a scale from the one undoubted marked fish, and Figure 8 shows the nuclear area enlarged. The margins of the scale are rather badly absorbed, and the winter band of the fifth year and the beginning of the sixth year's growth do not show. The width of the outer (fifth) summer band is conclusive evidence, however, that the fish was actually in the sixth year and not in the fifth, as might appear to be the case. In the majority of fish taken at this time of year, whose scales are complete, the new growth of the current year has seldom more than three or four rings. Frequently the marginal rings are those of the preceding winter. The marginal band of summer rings shown on the scales of this fish is virtually as wide as the summer band of the preceding (fourth) year and particularly in view of the fact that serious absorption of the scale had taken place, could not possibly be interpreted as being the new growth of the current year. The remainder of the scale offers no difficulty whatever to interpretation.

EXPERIMENT NO. 2. KLASKANINE HATCHERY, JULY AND AUGUST, 1916

Eggs from: Willamette River, 1915.
Reared and marked at: Klaskanine hatchery.
Mark used: Removal of right ventral fin and anterior half of dorsal fin.
Number marked: 50,000.
Liberated: In Klaskanine River during July and August, 1916.
Age: Approximately 11 months.

A collection of 50 specimens was preserved on July 16, 1916. The average length is 81.8 millimeters (3.2 inches). Their scales vary but slightly in general appearance. In general the rings are strong and well spaced, indicating that a vigorous and uniform growth had been maintained. In this respect these scales resemble closely those of wild fish, although as a rule the scales of hatchery fish show a more irregular growth. An occasional incidental check is found (see fig. 10), and in many the narrower marginal rings indicate that the slower growth of the fall and winter had begun. Figure 9 shows a typical scale. The average number of rings is 9.3, and the average length of the anterior radius is $\frac{36.2}{120}$ millimeters. The detailed data are given in Table 2.

TABLE 2.—*Chinook-salmon fingerlings marked at Klaskanine hatchery July 16, 1916*

Length in millimeters (mid-value of class)	Scale record: Number of rings						Scale record: Length of anterior radius in millimeters×120 (mid-value of class)									Males	Females	Total
	7	8	9	10	11	12	29	31	33	35	37	39	41	43	45			
67.5	1	1	1				1	2								2	1	3
72.5		1		1					1	1						1	1	2
77.5		2	12	4				2	6	6	3	1				9	9	18
82.5		2	4	5	1				2	3	3	3	1			7	5	12
87.5		1	5	2	1			1			4		4			7	2	9
92.5			1		1	1						1	1		1	1	2	3
97.5				2	1							1	1	1		3		3
Total	1	7	23	14	4	1	1	5	9	10	10	6	7	1	1	30	20	50
Average	9.3						36.2									82.6	80.5	81.8

Only one individual with this mark was recovered. This fish was found by a Chinese butcher at one of the canneries in Astoria, who preserved the scars but no other data. The mark is perfectly clear, although it is worthy of note that the posterior half of the dorsal fin had not grown normally. The rays were short, and their tips bent backward as though the resistance of the water had modified the growth as the growth of trees is modified by the prevailing winds. The exact date of capture is not known, but it was some time between May 25 and June 21, 1920.

The scales of the adult fish (fig. 11) show clearly the four complete years of growth and a narrow marginal band of wide "summer" rings, which represent the beginning of the fifth year's growth. Scales from the skin attached to the scars were the only ones available for study, as a sample of scales taken from the central portion of the body was not preserved. While the details of the life history may be as readily obtained from perfect scales taken from unusual regions of the body as from the more typical ones taken from the central portion, they are not as satisfactory for comparative studies. In this case, for instance, it is not as easy to compare the nuclear portion of the adult scale with the scales taken from the young fish preserved at the time of marking. Taking this into consideration, the nuclear portion of the adult scale (fig. 12) does, however, correspond fairly well with the typical scales of the young fish (figs. 9 and 10).

EXPERIMENT NO. 3.—LITTLE WHITE SALMON RIVER HATCHERY, JULY AND AUGUST, 1916

Eggs from: Little White Salmon River, 1915.
Reared and marked at: Little White Salmon River hatchery.
Mark used: Removal of left ventral fin and the posterior half of dorsal fin.
Number marked: 50,000.
Liberated: In Little White Salmon River during July and August, 1916.
Age: Approximately 10 months.

The average length of 50 unselected specimens preserved on July 28, 1916, is 54.4 millimeters (2.1 inches). The scales have an average of 4.8 rings and an average anterior radius of $\frac{20.2}{120}$ millimeters. Table 3 gives in detail the data relative to these fish. Figure 13 shows a typical scale from an individual 60 millimeters in length.

TABLE 3.—*Chinook-salmon fingerlings marked at Little White Salmon River hatchery July 28, 1916*

Length in millimeters (mid-value of class)	Scale record: Number of rings					Scale record: Length of anterior radius, in millimeters×120 (midvalue of class)							Males	Females	Total
	3	4	5	6	7	15	17	19	21	23	25	27			
42.5		1					1						1		1
47.5	3	4	3			1	2	6		1			4	6	10
52.5	2	3	10	2		1	1	6	5	2	1	1	13	4	17
57.5		4	5	5				3	4	4	2	1	7	7	14
62.5			1	5	1					2	4	1	4	3	7
67.5					1						1		1		1
Total	5	12	19	12	2	2	4	15	9	9	8	3	30	20	50
Average	4.8					20.2							54.5	54.2	54.4

Adults developing from these marked fish were found among the spawning fish taken for purposes of artificial propagation in the Little White Salmon River in 1918, 1919, and 1920, when the fish were in their third to fifth years. One 3-year-old, four 4-year-olds, and one 5-year-old were recovered in this way. In addition to those taken in the parent tributary, one was taken in the lower Columbia in 1919 and another was taken by purse seine in the ocean near the mouth of the Columbia in 1920. Table 4 gives the detailed data regarding the adult fish.

TABLE 4.—*Chinook salmon marked at Little White Salmon River hatchery during the summer of 1916, when approximately 10 months old, and recovered during the seasons of 1918, 1919, and 1920*

Date of capture	Place of capture	Sex	Length, in inches	Weight, in pounds	Scale of record: Number of rings: To first incidental check	Scale of record: Number of rings: Total stream growth	Scale of record: Length of anterior radius, in millimeters ×120: To first incidental check	Scale of record: Length of anterior radius, in millimeters ×120: Total stream growth
1918 [1]	Little White Salmon River hatchery	Male	19.5	9	5	12	16	31
Aug. 25, 1919	Astoria	Female			6	16	23	46
Oct. 3, 1919	Little White Salmon River hatchery	do	33.5		6	16	20	45
1919 [1]	do				7	20	20	52
Do.[1]	do				6	16	21	47
Do.[1]	do				5	18	14.5	41
Aug. 21, 1920	Ocean	Female	39	27	7	15	23	42
Sept. 27, 1920	Little White Salmon River hatchery	do	36.75		7	17	27	60

[1] Date not reported.

The scales of the fish recaptured at the hatchery were absorbed to such an extent that no part of the original margins remained. As there is no criterion by which the amount of absorption may be determined, it is impossible to determine the age from such scales. A scale from the 3-year-old fish recovered at the hatchery is illustrated in Figure 14. The two fish taken before they reached the spawning grounds have complete scales marked by the expected number of summer and winter bands. Scales from these fish (4 and 5 years old, respectively) are shown in Figures 15 and 17.

The nuclei of the scales of these fish present peculiarities that may be discussed more conveniently in connection with the scales of the adult fish in experiment No. 8. The discussion of them therefore will be deferred until the latter have been considered.

EXPERIMENT NO. 4.—BONNEVILLE HATCHERY, SEPTEMBER, 1916

Eggs from: Umpqua River, 1915.
Reared and marked at: Bonneville hatchery.
Mark used: Removal of right ventral fin and posterior half of dorsal fin.
Number marked: 25,000.
Liberated: In Tanner Creek during September, 1916.
Age: Approximately 12 months.

Fifty specimens were preserved on September 13, 1916. These average 67.6 millimeters (2.7 inches) in length. The average number of rings on the scales is 9.2, and the average length of the anterior radius is $\frac{31.8}{120}$ millimeters. (See Table 5.) In a large proportion of cases the scales are characterized by a distinct narrowing, an incidental check, some five or six rings from the center. A narrowing of the marginal rings is typically present also, indicating the beginning of the slower winter growth. Figure 21 shows a typical scale with a distinct incidental check five rings from the center and the narrower winter rings at the margin. Figure 20 shows a scale from the smallest fish of the collection. This fish was only 47 millimeters (a little less than 2 inches) in length, and the scale shows only five rings, with no indication of either the incidental check or the marginal winter rings.

TABLE 5.—*Chinook-salmon fingerlings marked at Bonneville hatchery September 13, 1916*

Length, in millimeters (mid-value of class)	Scale record: Number of rings							Scale record: Length of anterior radius, in millimeters×120 (mid-value of class)											Males	Females	Total
	5	7	8	9	10	11	12	23	25	27	29	31	33	35	37	39	41	43			
47.5	1								1										1		1
57.5		1	2					2	1										2	1	3
62.5			5	7	4					3	3	4	4	1	1				8	8	16
67.5			3	5	5				1	1	2	1	2	2	2	2			7	6	13
72.5			1	2	4	1						1	2	2	3				4	4	8
77.5				3	3	2								2	1	3	1	1	5	3	8
82.5							1						1							1	1
Total	1	1	11	17	16	3	1	2	3	4	5	6	9	7	7	5	1	1	27	23	50
Average	9.2							31.8											67.3	67.8	67.6

Thirty-six adult fish from this experiment were reported from the commercial fishery during the season of 1920, when the fish were in their fifth year. Table 6 gives the data regarding these recaptures. The males average 33.8 inches (85.8 centimeters) in length and 22.5 pounds (10.2 kilograms) in weight. The females average 35.3 inches (89.7 centimeters) in length and 20.7 pounds (9.4 kilograms) in weight. One record of 40 pounds in weight, which is obviously in error, has not been considered in the average. No significance can be attached to the lower average length for males than for females, as the average for the former is based on only four specimens and, as previously mentioned, the measurements are subject to considerable error. With reliable data, males usually are found to average greater than females in both length and weight.

TABLE 6.—*Chinook salmon marked at Bonneville hatchery during the fall of 1916, when approximately 12 months old, and recovered during the season of 1920*

Date of capture	Place of capture	Sex	Length, in inches	Weight, in pounds	Scale record: Number of rings: Stream growth	Scale record: Number of rings: Intermediates	Scale record: Length of anterior radius, in millimeters×120: Stream growth	Scale record: Length of anterior radius, in millimeters×120: Stream growth plus intermediates
May 13	Astoria	Female	40	31	10	9	29	50
May 17	Ilwaco	do	35.4	21.5	11	6	35	52
May 18	Astoria	do		[1] 16 or 21	9	11	23	52
Do	do	do		[1] 16 or 21	8	0	20	0
May 21	do	do	31	[2] 18	12	11	39	65
May 22	Sand Island	Male		[3] 40	9	11	30	70
May 25	Astoria	Female	35.5	20	12	15	36	74
May 28	Warrendale				11	9	33	55
May 31	Altoona	Male	33	23	12	4	35	46
June 1	Sand Island		34.5	17	8	4	24	35
June 3-5	Warrendale	Female	37.25	20	13	6	31	46
Do	do	do	38	21.5	12	9	34	64
Do	do	Male	38	25	10	11	30	60
June 5	Wallace Island	Female	36.25	28	10	8	29	50
Do	Altoona	do	32	21	10	3	35	45
June 7	do	Male	32	23	9	11	31	64
June 11	Sand Island		36.25	30	9	9	29	53
					6	9	20	44
					8	7	30	45
					15	8	35	55
					10	8	33	54
Prior to June 21	Found in canneries at Astoria				15	7	30	48
					19	0	56	0
					9	13	29	68
					7	12	23	57
					11	9	33	55
	Ilwaco	Male	32	19	10	17	30	46
	do	Female	32	19	12	12	38	72
	do	do	32	16	11	9	38	70
May or June	35 miles above Astoria	do	37	17	14	9	58	90
	do	do	37	17	15	10	40	72
					12	7	38	56
					11	11	35	68
					14	10	46	70
No date					12	11	38	66
					11	13	35	73

[1] The records accompanying these two specimens were confused, so that it was impossible to tell which specimen weighed 16 pounds and which 21 pounds.
[2] The data here are not exact, as the fish had been cleaned before the data were taken.
[3] The excessive weight given for this individual is undoubtedly an error.

The examination of the scales of these marked adults has shown, as would be expected from their known history, that the nuclei are all of the "stream" type, and that there are invariably three complete years of ocean growth and usually a marginal band of wider rings representing the beginning of the fourth year in the ocean—the fifth in the life of the fish. (See figs. 22, 24, 26, and 28.)

Particular interest attaches to the examination of the nuclear portions of the scales of these fish on account of the light they throw on the interpretation of scales from unmarked fish. The chief difficulties in the interpretation of the scales of chinook salmon are those associated with the growth of the first year, and positive information as to the significance of various phenomena, such as is obtainable from marked fish, is especially desirable. The nuclei of the scales of these fish consist in a central portion of true stream growth, which is usually surrounded by a more or less distinct band of intermediate rings, which in turn is surrounded by the wider rings of ocean growth formed during the second year. Although the scales are all similar, there is considerable variation, which it is important to consider in some detail.

The true stream growth is relatively small, as compared with the usual size of stream nuclei, and is often poorly defined with marginal winter rings that are not as typical as those on the scales of wild fish. An incidental check was found on the scales of 13 individuals. The number of rings within the incidental check ranges from 4 to 9 and averages 5.8. The general appearance of the stream growth in these adult scales corresponds exactly with that of typical scales from the young fish preserved at the time of marking. (Compare figs. 20 and 21 with the stream growths in figs. 23, 25, 27, 29, 30, and 31.) The average number of rings in the stream growth of the adult scales (see Table 6) is 11, as compared with an average of 9.2 on the scales of the young fish. The average length of the anterior radius to the edge of the true stream growth is $\frac{34.1}{120}$ millimeters, as compared with $\frac{31.8}{120}$ millimeters for the young fish. It is apparent from these figures that the check considered here as terminating the true stream growth was formed at approximately the time when the fish were liberated at the hatchery. Immediately outside of this true stream growth is usually found a band of distinctly wider rings forming the intermediate growth. The term "intermediate" has been applied by Gilbert and others to the band of rings frequently encountered between the true stream and the undoubted ocean growth, the rings of which are intermediate in width between the stream and ocean rings. It frequently, though not always, is developed during the time spent in the brackish water of the estuaries during the seaward migration. The intermediate growth shown on the scales of the marked fish of this lot is usually fairly wide, averaging 9 rings and ranging from none (fig. 29) to 15 rings (fig: 27). Not infrequently the outer rings of the intermediate band widen gradually and merge into the ocean growth, so that it is difficult to set a definite boundary between the two (fig. 23). In extreme cases, where both the stream and the intermediate bands are poorly defined, the true character of the nucleus is so obscured that were the scales presented without additional data the nuclei might be mistaken for the ocean type. Figures 29 and 31 show such nuclei. These scales show considerable gradation from a pure stream type of nucleus to what we have designated a "composite nucleus." This type will be discussed in more detail later in this report in connection with another experiment, which throws light on the interpretation of these scales.

EXPERIMENT NO. 5. LITTLE WHITE SALMON RIVER HATCHERY, JUNE AND JULY, 1917

Eggs from: McKenzie River, 1916.
Reared and marked at: Little White Salmon River hatchery.
Mark used: Removal of adipose fin and dorsal fin.
Number marked: 44,500.
Liberated: In Little White Salmon River during June and July, 1917.
Age: Approximately 10 months.

The average length of 45 unselected specimens of young fish preserved on July 18, 1917, is 47.4 millimeters (1. 9 inches). The scales have an average of 4.4 rings, and the average length of their anterior radii is $\frac{16.0}{120}$ millimeters. No peculiarities are noticeable in the scale growth. A typical scale is shown in Figure 32. The detailed data for these 45 specimens are given in Table 7.

TABLE 7.—*Chinook-salmon fingerlings marked at Little White Salmon River hatchery July 18, 1917*

Length in millimeters (mid-value of class)	Scale record																Males	Females	Total
	Number of rings							Length of anterior radius, in millimeters ×120 (mid-value of class)											
	0	1	2	3	4	5	6	7	9	11	13	15	17	19	21	25			
37.5	1	1	1	1	1			1		4							4	1	5
42.5		1	2	3	6	1			1	2	5	3	2				7	6	13
47.5				1	3	4	1				1	3	4	1			7	2	9
52.5						3	11					1	3	6	3	1	8	6	14
57.5						1	3							1	3		1	3	4
Total	1	2	3	5	10	9	15	1	1	6	6	7	9	8	6	1	27	18	45
Average	4.4							16.0									46.9	47.9	47.4

One adult specimen, a female 27 inches (69 centimeters) in length and weighing 10.5 pounds (4.8 kilograms), was recovered. It was taken during spawning operations in the Little White Salmon River on October 13, 1920. The anterior half of the dorsal fin was somewhat regenerated, but there was little question of the reliability of the mark.

The scales show such an extreme amount of absorption (fig. 33) that they are useless for determining the age. Only one complete year of the ocean growth remains. The nucleus is usually large and poorly differentiated and probably represents the composite type to be discussed later. A slight check may be seen about four rings from the center, which possibly was formed at or just before the time when the fish was marked and liberated. It is impossible to determine the exact boundary of the first year's growth, but apparently there is an unusually wide band of intermediate rings, including perhaps as many as 16 of the rings immediately within the undoubted ocean growth.

The fish that spawn in the McKenzie River, from which the fish marked in this experiment originated, enter the mouth of the Columbia in the spring and therefore constitute part of the so-called "spring" run, which is of the highest quality and the maintenance of which is especially to be desired. The primary object of this experiment was to test the effect of liberating young fish belonging to a race that normally enters the river during the spring into a stream such as the Little White Salmon (which is populated mainly by a race of fish that normally enters the river during late summer or fall). The great amount of absorption exhibited by the scales of the one specimen recaptured would indicate that it had spent considerable time in fresh water. The absorption is noticeably greater than that of the scales of other fish taken during the spawning season in the Little White Salmon. (See fig. 14, showing a scale from a fish only 3 years old.) If the amount of absorption of the scales can be taken as indicating the length of time spent in fresh water, it would follow that this individual had entered much earlier than the usual run that populates the Little

White Salmon River. Apparently there has been a tendency for the fish hatched from eggs taken from early-running fish to enter the fresh water early, even though planted in a stream typically inhabited by a late-running race. A more complete discussion of this question is given in connection with later experiments, which offer more conclusive evidence.

EXPERIMENT NO. 6.—HERMAN CREEK HATCHERY, MARCH, 1920

Eggs from: Willamette and McKenzie Rivers, 1918.
Reared and marked at: Herman Creek hatchery.
Mark used: Removal of both ventral fins and the adipose fin.
Number marked: 20,000.
Liberated: In Herman Creek during March, 1920.
Age: Approximately 18 months.

The eggs from which these fish developed were hatched at Bonneville and the fry were transferred to Herman Creek soon after hatching. During June, 1919, the greater number of the fish in the ponds were liberated, but those marked in this experiment lingered in the pond and became mixed with sockeyes of the same age, which had been placed in the ponds a few days after the chinooks were liberated. It was in the course of the marking of the sockeyes that the chinooks were segregated and marked.

Twenty-nine specimens preserved during the course of the marking average 107.5 millimeters (4.2 inches) in length. Their scales have an average of 13.8 rings and an average anterior radius of $\frac{42.2}{120}$ millimeters. (See Table 8.) Scales from 26 of the 29 individuals have an incidental check inclosing an average of 8.4 rings (radius $\frac{30.1}{120}$ millimeters). The winter check usually is absent but is represented on a few scales by one or two broken rings at the margin of the scale. Two specimens have a fairly distinct winter check followed by a couple of rings of the rapid growth of the second year. (See fig. 35.) Figure 34 illustrates a scale in which both the incidental check and the winter check are lacking.

TABLE 8.—*Chinook-salmon yearlings marked at Herman Creek hatchery during March, 1920*

Length in millimeters (mid-value of class)	Scale record																										Males	Females	Total
	Number of rings										Length of anterior radius in millimeters×120 (mid-value of class)																		
	9	10	12	13	14	15	16	17	18	19	27	29	33	35	37	39	41	43	45	47	49	51	53	55	59	63			
77.5		1										1															1		1
82.5			1								1																1		1
92.5			1			1										1		1									1	1	2
97.5				1	1	1										1		1	1								2	1	3
102.5	1	2		2	1	1							1	1	2	1	1		1								5	2	7
107.5			1	1		1													1			1		1			2	1	3
112.5		1		1	1	2								2					2			1					3	2	5
117.5								1		1											1		1				2		2
122.5				1			1									2											2		2
127.5										1																1	1		1
137.5							1													1							1		1
147.5									1																1		1		1
Total	1	4	3	6	3	6	2	1	1	2	1	1	1	3	2	5	1	2	5	1	1	2	1	1	1	1	22	7	29
Average	13.8										42.2																109.3	103.1	107.

One adult fish that returned to spawn in its fourth year was taken during the season of 1922; 29 five-year-olds were reported during the season of 1923, and 18 were taken during the season of 1924, when they were in their sixth year. Tables 9 and 10 give the data regarding these captures.

TABLE 9.—*Chinook salmon marked at Herman Creek hatchery during the spring of 1920, when approximately 18 months old, and recovered during the seasons of 1922, 1923, and 1924*

Date of capture	Place of capture	Sex	Length, in inches	Weight, in pounds	Scale record, first year	
					Number of rings	Length of anterior radius, in millimeters×120
1922: Sept. 10–19	Cascade Locks					
1923:						
May 1–5	Lower Columbia	Female	36	18		
May 1–5	do	Male	30	11		
May 1–5	do	do	36	17		
May 1–5	do	Female	25	11		
May 1–5	do	do	36	19		
May 3	do	do	36	17	17	52
May 3	Westport		23	13.5	15	52
May 4	do	Male	34	14	13	44
May 4	Lower Columbia	Female	35	22	16	44
May 6	Tongue Point	Male	26.5	19	16	44
May 7	Astoria	do	34.75	20	13	33
May 8	Rainier	do	36.5	21	16	44
May 8	Bonneville	do		18	14	39
May 9	Rainier	do	35.5	21.5	17	37
May 9	Sand Island	Female	38	20	16	52
May 10	Westport	do	41	28.5	17	62
May 13	Cascade Locks	Male	26	10	16	41
May 14	Altoona	Female	35	19	19	67
May 17	Smith Point	do	35	17	17	47
May 17	do		36	18	17	52
May 20	Ellsworth	Male	36	15	14	41
May 22	Bonneville	do	26.5	8	21	60
May 25	Sand Island	Female	35	15.5	13	45
May 26	do	do	38.5	23		
May 26	Tongue Point	do	31	13		
May 28	Lower Columbia	Male	26.75	7	15	36
June 17	Mouth Herman Creek	Female	35	16	23	65
July 31	Cascade Locks		32	15	15	41
Oct. 1	Herman Creek					
1924:						
May 3	Ranier		38	20	13	32
May 4	The Dalles	Female	35	16	10	41
May 6	Warrendale	do	36.75	21	17	45
May 6	The Dalles	do	39.25	22.5	19	54
May 6	Corbett	Male	35.5	17.75	14	42
May 6	Lower Columbia		28	34	19	60
May 7	Clatskanie		38	22	15	54
May 9	The Dalles	Female	39.5	23		
May 10	Warrendale	Male	36	19.75	20	54
May 10	The Dalles	Female	36.5	21	18	50
May 20	Bonneville		26	16	16	44
May 23	do	Male	39.5	25		
May 26	do	Female	32	13		
May 15–31	The Dalles	do			16	45
June 7	Warrendale	Male	43.5	30.5		
June 28	Bonneville	Female	34.75	15	18	51
June 29	The Dalles	do	40	25	15	41
July 15	Chinook	do	29	18.25		

TABLE 10.—*Chinook salmon marked at Herman Creek hatchery during the spring of 1920, when approximately 18 months old, and recovered during the seasons of 1923 and 1924*

Age	Average length		Average weight	
	Inches	*Centimeters*	*Pounds*	*Kilograms*
Fifth year, 1923:				
Males	31.7	80.5	15.1	6.9
Females	35.1	89.1	18.4	8.4
Sixth year, 1924:				
Males	38.6	98.0	23.2	10.5
Females	35.9	91.1	19.6	8.9

This experiment adds more conclusive evidence to that given by experiment No 5 regarding the influence of heredity on the time when the adult salmon return to fresh water. In this experiment, as in experiment No. 5, the progeny of salmon that enter the river in the spring were liberated in a tributary normally inhabited by fall-running chinooks. Of the 47 recaptures reported from the commercial fishery, 40 were taken during May, and two-thirds of these were taken during the first 10 days of the month. In other words, the run seems to have been well under way when the season opened on May 1. With the exception of the one fish taken on July 15, 1924, even those caught during June and July probably entered the river during May, as their scales were greatly absorbed and the fish themselves were reported to be dull, soft, and thin rather than plump and bright, as are fish that have recently left the ocean. The condition of the fish taken on July 15 was not reported, but judging from its scales, which were less absorbed than those of many of the fish taken during May, there is no reason to believe that it had been in the river for any length of time. The scales of the fish taken during September, 1922, were absorbed to an extent indicating that the fish had entered the river some time before being caught; but this alone is not sufficient evidence to justify the conclusion that it left the ocean as early as the majority of the fish returning from this marking. In view of the fact that such a large proportion of the fish are known to have entered the river during a very short period in the spring, the two possible exceptions need not affect the general conclusion that the factors determining the time of entering fresh water are hereditary and are not altered by conditions of early environment. Additional data regarding this important question are furnished by later experiments.

The fact that salmon return to spawn in the river system from which they migrated as fry or fingerlings, even though the eggs from which they developed may have been taken from another river, has been demonstrated in many instances. Gilbert (1919) has shown that sockeye salmon, of the Frazer River at least, return to the particular spawning district in which they spent their early life. The authors have numerous unpublished data that indicate that the same is true in general of the chinook salmon of the Columbia. This series of experiments offers an unusual opportunity to observe this tendency, both as regards natural and transplanted runs. In this particular experiment fish were transplanted from one tributary to another of the same system. The absence of heredity as a factor in determining which tributary the resulting adult fish chose to enter is shown by the fact that a constant search at the Willamette and McKenzie egg-taking stations (where the eggs from which these fish developed were taken) revealed no marked fish. Their failure to enter the Willamette is shown further by the fact that the majority of those recaptured were taken in the main Columbia River above the mouth of the Willamette. Not only did they fail to return to the tributary in which they originated, but the majority also failed to return to the tributary in which they were reared and liberated. Only one entered Herman Creek. This one, a female, was found about 1 mile above the mouth of the creek on October 1, 1923.

Herman Creek was observed on several occasions during the season of 1923, but prior to the visit of October 1 it had not seemed necessary to look for fish above the hatchery station, because a small dam used to divert water into the rearing ponds had been impassable since late in May. The appearance of at least a dozen adult fish in the rearing ponds (which they had entered with the intake water) prompted a more thorough investigation of the creek. Between the hatchery station and a small power dam, about 1 mile above, 5 living and 14 dead fish were found. All were inspected carefully for the absence of fins, but only one marked fish was found. Unquestionably these fish entered the creek early in the spring, because not only was the dam impassable, but the creek became so low early in the summer that nearly all of the water was diverted through the ponds, leaving the creek virtually dry for a distance of several hundred feet.

The appearance of an occasional adult chinook salmon in Herman Creek during the spring is not an unusual occurrence, but this was the first time that any number of spring chinooks had been reported from there. A second run was reported in 1926, when 130 spring chinooks ran into the creek.

Additional data regarding the tendency of salmon to return to a particular tributary to spawn were secured from later experiments.

The scales of the adult fish present nothing unusual. Their nuclei are typical of the stream type and are identical with the scales of the young fish at the time of liberation. (See figs. 37 and 39.) The majority of those having perfect scales show an incidental check inclosing an area marked by an average of 8 rings and having an average anterior radius of $\frac{28.4}{120}$ millimeters. As mentioned above, the scales of the young fish showed an incidental check inclosing an average of 8.4 rings and with a radius of $\frac{30.1}{120}$ millimeters—a remarkably close correspondence. The average total number of nuclear rings is 16.2, and the average total radius is $\frac{47.5}{120}$ millimeters. (See Table 9.) The scales of the adult fish are characterized further by a comparatively small growth during the first year in the ocean. Figures 36 and 38 illustrate typical scales from mature fish in their fifth and sixth years, respectively.

EXPERIMENT NO. 7.—BONNEVILLE HATCHERY, OCTOBER, 1920

Eggs from: Willamette, McKenzie, and Santiam Rivers, 1919.
Reared and marked at: Bonneville hatchery.
Mark used: Removal of adipose fin and right ventral fin.
Number marked: 65,000.
Liberated: In Tanner Creek during October, 1920.
Age: Approximately 13 months.

A sample of 50 fingerlings preserved on October 14, 1920, averages 96.6 centimeters (3.8 inches) in length. The rings of the scales are regular in shape and evenly spaced, giving evidence of comparatively rapid and uninterrupted growth. The average number of rings is 15.3, and the average length of the anterior radius is $\frac{46.6}{120}$ millimeters. A typical scale is shown in Figure 40. The complete scale and length records are given in Table 11.

TABLE 11.—*Chinook-salmon fingerlings marked at Bonneville hatchery October 14, 1920*

Length, in millimeters (mid-value of class)	Scale record																						Males	Females	Total
	Number of rings								Length of anterior radius, in millimeters ×120 (mid-value of class)																
	11	12	13	14	15	16	17	18	33	35	41	43	45	47	49	51	53	55	57	59	61	67			
82.5		1	1	1						2	1													3	3
87.5	1		1		1	2	1		1		3		1					1					2	4	6
92.5				6	1	2	1	2				2	6	2		1			1				6	6	12
97.5			2	2	2	2	3	2	1	1		2	1	2	1	2	1	1		1			5	8	13
102.5				2	3	3	3				1		2	1	1	2	1	1	1	1			3	8	11
107.5			1				1						1						1				2		2
112.5					1								1										1		1
122.5								1														1	1		1
132.5							1														1			1	1
Total	1	1	5	11	8	9	10	5	2	3	5	4	12	5	2	5	2	3	3	2	1	1	20	30	50
Average	15.3								46.6														98.0	95.6	96.6

From the standpoint of adult fish recovered this has been one of the most successful experiments with chinook salmon, 252 having been taken. One 3-year-old was taken by troll in the ocean near the mouth of the Columbia River, and the rest were taken in the Columbia River, 8 of them during 1923, 215 during 1924, and 28 during 1925. Records of the time and place of capture are given in Tables 12 and 13.

TABLE 12.—*Chinook salmon marked at Bonneville hatchery during the fall of 1920, when approximately 13 months old, and recovered during the seasons of 1922, 1923, and 1925*

Date of capture	Place of capture	Sex	Length, in inches	Weight, in pounds	Scale record, first year	
					Number of rings	Length of anterior radius, in millimeters ×120
1922: August 9	Ocean	Male	23.25	5.5	15	42
1923:						
May 1-5	Lower Columbia	Female	32	16		
May 1-5	do	Male	31	13		
May 1-5	do	Female	28	14	18	49
May 1-24	do			11	24	78
May 7	Ocean	Female	30	12.5	14	42
May 9	Astoria	do	32	18	24	70
May 16	Lower Columbia	Male	26	9	16	47
May 22	Mount Pleasant	do	25.5	8	19	68
1925:						
May 1	The Dalles	do	37.75	22	22	66
May 2	Bonneville	do	45.25	39.75	17	48
May 3	Warrendale cannery		42	27	17	47
May 4	Ellsworth cannery	Male	27	18	18	51
May 4	Bonneville	Female	34.75	13	18	51
May 4	Cascade Locks	Male	41	28.25	25	81
May 5	Rainier	Female	32	13	24	63
May 5	Bonneville	Male	46.5	42.5	20	69
May 5	Warrendale cannery		36	20		
May 5	Dodson cannery		47	50	17	57
May 7	Bonneville	Male	40.5	27	17	48
May 8	Dodson cannery	do	43	37	26	69
May 8	do	Female	38.5	22	21	65
May 9	Warrendale cannery	Male	24	25	19	47
May 11	Dodson cannery	do	38	23	14	35
May 14	Ellsworth cannery	Female	34	21	18	51
May 14	do	do	37.5	25	14	62
May 20	Warrendale cannery	do	38	20	24	57
May 16	Cascade Locks	Male	48	40	23	74
May 29	Bonneville	Female	37.5	21.5	20	51
June 3	Warrendale	Male	36.5	18	19	53
June 10	Warrendale cannery	Female	37.5	21	22	62
During May, exact date not recorded.	Pillar Rock	Male	35	19	17	48
	do	Female	40	35	15	45
	Dodson cannery	do	34	21	16	45
	do			26	15	38
	do				18	48

TABLE 13.—*Chinook salmon marked at Bonneville hatchery during the fall of 1920, when approximately 13 months old, and recovered during the season of 1924*

Place of capture [1]	Date of capture								Total
	May				May 29–June 4	June		Date unknown [2]	
	1–7	8–14	15–21	22–28		5–11	12–18		
Mouth of Columbia–Vancouver	15	5	5	1	1			1	28
Vancouver–Cascade Locks	24	29	8	6	4	2	1	4	78
Cascade Locks–Celilo Falls	40	47		5				1	93
Unknown (above Vancouver)	9	3		2		1			15
Total	88	84	13	14	5	3	1	6	214

[1] One fish taken near Astoria during February is not included in this table.
[2] All during May.

The detailed length and weight data are given in Tables 12, 14, and 15. The average sizes appear in Table 16. These averages can not be relied upon as accurately representing the size of the fish at the three ages, because, as has been mentioned, the individual records are not dependable. The figures for the 5-year-olds (as a result of the large number of data comprising them) probably are quite accurate. The small number of records for the 4-year-olds makes the averages for that age group least dependable.

TABLE 14.—*Chinook salmon marked at Bonneville hatchery during the fall of 1920, when approximately 13 months old, and recovered during the season of 1924*

Length, in inches (mid-value of class)	Males	Females	Length, in inches (mid-value of class)	Males	Females
23.5	1	2	38.5	7	11
26.5	1		39.5	8	7
27.5	1	2	40.5	9	
28.5	1	1	41.5	4	
29.5	2	3	42.5	4	
30.5	2	4	43.5	3	
31.5	3	2	47.5	1	
32.5	7	5			
33.5	5	5	Total	91	91
34.5	6	11			
35.5	8	10	Average, inches	36.7	35.2
36.5	9	13	Average, centimeters	93.2	89.4
37.5	9	15			

TABLE 15.—*Chinook salmon marked at Bonneville hatchery during the fall of 1920, when approximately 13 months old, and recovered during the season of 1924*

Weight, in pounds (mid-value of class)	Males	Females	Weight, in pounds (mid-value of class)	Males	Females
10.5	2	1	27.5	1	1
11.5	2	2	28.5	6	1
12.5	2	1	29.5	1	2
13.5	2	5	30.5	3	
14.5	1	3	31.5	3	
15.5	4	2	32.5	3	
16.5	5	9	33.5	1	
17.5	3	6	34.5	2	1
18.5	9	5	35.5	2	
19.5	3	9	36.5	1	
20.5	5	13	41.5	1	
21.5	2	7	42.5	1	
22.5	6	9			
23.5	6	4	Total	90	91
24.5	4	2			
25.5	3	4	Average, pounds	23.0	20.1
26.5	6	4	Average, kilograms	10.5	9.1

TABLE 16.—*Chinook salmon marked at Bonneville hatchery during the fall of 1920, when approximately 13 months old, and recovered during the seasons of 1923, 1924, and 1925*

Age	Average length		Average weight	
	Inches	*Centimeters*	*Pounds*	*Kilograms*
Fourth year, 1923:				
Males	30.8	78.2	10.0	4.5
Females	30.5	77.5	15.1	6.9
Fifth year, 1924:				
Males	36.7	93.2	23.0	10.5
Females	35.2	89.4	20.1	9.1
Sixth year, 1925:				
Males	38.6	98.0	28.3	12.9
Females	36.4	92.5	21.2	9.6

The consistency with which these fish entered fresh water during the early part of the season greatly outweighs the few doubtful cases in other experiments in showing that the time at which the adults enter fresh water is determined by heredity and is not affected by early environment. The parents of the fish marked in this experiment were of the early spring run that spawns in the headwaters of the Willamette River. The fingerlings marked were reared at Tanner Creek, where only salmon of the fall run are found normally; but the time when the adult marked fish returned to fresh water to spawn was not altered by this change in their early life. This is shown most clearly by the records of the 1924 recoveries. (See Table 13.) Of the 208 recoveries for which the date of capture is known, 82 per cent were taken during the first two weeks after the season opened on May 1. The largest catches were made during the first four days of the season. The date of the latest recovery from this experiment was June 13.

The evidence from this experiment, regarding the factors that influence the adult salmon to return to a particular tributary to spawn, is in complete agreement with that derived from experiment No. 6. As in experiment No. 6, none returned to the tributaries in which the eggs were taken. Approximately one-half of the reported recaptures were made in the Columbia several miles above the mouth of Tanner Creek, where the fingerlings were liberated, whereas only three ran into Tanner Creek. From these facts it is evident that heredity has no effect on the tendency in question and that early environment is an influencing but by no means controlling factor.

Scales from all of the recaptured adult fish were examined microscopically in the usual manner. Evidence of absorption, which normally sets in soon after the fish enter fresh water, was found in nearly all cases. In the majority the original margin was removed entirely, but there remained at least a part of the last winter band, which in fish that leave the ocean in the spring lies just within the margin of the complete scale. In a few of the 5-year-olds and most of the 6-year-olds the last winter band was entirely lacking, but a wide band of well-spaced rings following the preceding winter check is ample assurance that the fish were in their fifth and sixth years, respectively. Typical scales from fish recovered during their third, fourth, fifth, and sixth years are shown in Figures 41, 42, 43, and 45.

The nuclei of the scales of 50 of the 5-year-olds and of all of the other age groups were measured for comparison with the scales of the fingerlings. All were distinctly of the stream type. The range of variation in size and number of rings was shown most clearly by the measurements of the 50 unselected 5-year-olds, which are tabulated in Table 17. The average number of rings was 18.4; the average length of the anterior radius was $\frac{51.8}{120}$ millimeters. These measurements are slightly greater than those for the fingerling scales, which averaged 15.3 rings and a radius of $\frac{46.6}{120}$ millimeters. As a rule the rings were very regularly spaced and unbroken, but there was an occasional incidental check, which probably was formed at the time of planting. In a few cases the typical stream and ocean growths were separated by a few rings of intermediates. Nuclei of average, large, and small size are illustrated in Figures 44, 46, and 47, respectively.

TABLE 17.—*Chinook salmon marked at Bonneville hatchery during the fall of 1920, when approximately 13 months old, and recovered during the season of 1924*

Length of anterior radius, in millimeters × 120	Scale record, first year																
	Number of rings																
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	27	Total
32-33									1								1
34-35		3	1	1													5
36-37	1	1															2
38-39		1															1
40-41							1										1
42-43					1	2		1									4
44-45					1	1	1				1						4
46-47						1		2									3
48-49							1		2								3
50-51							1		2	1	1						5
52-53									1		2						3
54-55											1						1
56-57							1	1									2
58-59										1	3			1			5
62-63									1	2	1						4
64-65													1				1
68-69															1		1
70-71												1					1
76-77													1				1
82-83														1			1
90-91																1	1
Total	1	5	1	1	2	4	5	4	7	4	9	1	2	2	1	1	50

EXPERIMENT NO. 8.—LITTLE WHITE SALMON RIVER HATCHERY, JULY AND AUGUST, 1920

Eggs from: Little White Salmon River, 1919.
Reared and marked at: Little White Salmon River hatchery.
Mark used: Removal of adipose fin and left ventral fin.
Number marked: 24,000.
Liberated: In Little White Salmon River during July and August, 1920.
Age: Approximately 10 months.

A sample of 40 specimens preserved during the course of the marking averages 49.6 millimeters (2 inches) in length. Their scales average $\frac{16.2}{120}$ millimeters in radius and have an average of 3.5 rings. (See Table 18.) A typical scale is illustrated in Figure 48. This sample is represented by an unusually large proportion of males, the males exceeding the females nearly 3 to 1. This uneven representation of sexes could not be due to error in recognition of the sexes, as the gonads, though small, are distinctly differentiated and independent determinations by the two authors agree in every case.

TABLE 18—*Chinook-salmon fingerlings marked at Little White Salmon River hatchery during July and August, 1920*

Length, in millimeters (mid-value of class)	Scale record: Number of rings				Scale record: Length of anterior radius, in millimeters × 120 (mid-value of class)							Males	Females	Total
	2	3	4	5	11	13	15	17	19	21	23			
42.5	1	1			1	1						1	1	2
47.5		5	7				4	5	2	1		10	2	12
52.5	2	11	9	4		3	4	6	8	4	1	18	8	26
Total	3	17	16	4	1	4	8	12	10	5	1	29	11	40
Average	3.5				16.2							49.6	49.6	49.6

The first returns from this experiment were reported during the season of 1923 when the fish were in their fourth year; 17 were reported from the commercial fishery and 4 were secured in the parent tributary. During the season of 1924, 22 were reported—14 from the commercial fishery, 7 from the parent tributary, and 1 from the Big White Salmon River egg-taking station. The detailed data are given in Table 19. The average lengths and weights are given in Table 20.

TABLE 19.—*Chinook salmon marked at Little White Salmon River hatchery during the summer of 1920, when approximately 10 months old, and recovered during the seasons of 1923 and 1924*

Date of capture	Place of capture	Sex	Length in inches	Weight in pounds	Number of rings: To first incidental check	Number of rings: Total first year	Length of anterior radius, in millimeters × 120: To first incidental check	Length of anterior radius, in millimeters × 120: Total first year
1923:								
July 3 [1]	Lower Columbia	Male	34	15.5	10	23	32	70
July 14 [1]	do	do	34.5	15	10	19	28	49
July 19 [1]	do	do	34	15				
Aug. 15	Sand Island	do	41	27	9	30	24	91
Aug. 16	Lower Columbia	Female	24	30	5	24	18	66
Aug. 16	Sand Island	do	38	21	9	31	32	99
Aug. 17	Lower Columbia	do	39	24	12	25	28	62
Aug. 18	Sand Island	Male	37	20	9	23	26	60
Aug. 18	do	do	32	23	9	21	29	118
Aug. 20	Ocean	do	36.5	26	8	19	21	47
Aug. 20	Lower Columbia	Female	34	27.5	7	23	26	70
Aug. 20	do	do	26	10	8	22	23	54
Aug. 22	Astoria	Male	37	25	7	20	23	52
Aug. 23	Sand Island	do	40	26	8	22	28	65
Aug. 23	do	Female	34.75	20	9	28	26	99
Sept. 13	Tongue Point	do	39	23	9	28	29	88
Sept. 17	Lower Columbia	do	36	18	8	30	24	94
Sept. 24	Little White Salmon River hatchery	do	38.5		11	33	34	112
Sept. 24	Little White Salmon River hatchery	Male	38.75		9	18	32	57
Sept. 26	Little White Salmon River hatchery	Female	38.5		8	28	24	86
Sept. 28	Little White Salmon River hatchery	do	38.75					

[1] These dates probably incorrect. Evidence from other sources has shown that observer who reported them made other errors.

TABLE 19.—*Chinook salmon marked at Little White Salmon River hatchery during the summer of 1920, when approximately 10 months old, and recovered during the seasons of 1923 and 1924*—Con.

Date of capture	Place of capture	Sex	Length in inches	Weight in pounds	Scale record, first year: Number of rings: To first incidental check	Scale record, first year: Number of rings: Total first year	Scale record, first year: Length of anterior radius, in millimeters×100: To first incidental check	Scale record, first year: Length of anterior radius, in millimeters×100: Total first year
1924:								
Aug. 2	Sand Island	Female	42	36	12	26	34	78
Aug. 5	do	do			8	29	23	91
Aug. 9	Astoria	Male	39	39	9	25	31	71
Aug. 9	McGowan, Wash	Female	40	32	6	27	24	91
Aug. 10	Sand Island	Male	34	29	7	29	23	92
Aug. 12	do	do	46	40	11	28	32	92
Aug. 14	do	do	45.5	42	9	27	28	99
Aug. 15	do	Female	31	26.5	7	24	24	76
Aug. 16	Clifton	Male	42	52	8	27	23	83
Aug. 16	Astoria	Female	41	40	13	24	37	71
Aug. 18	Lower Columbia	do			10	27	41	92
Aug. 19	McGowan, Wash	do	40	35	8	23	24	68
Aug. 23	Sand Island	do			13	19	41	55
Sept. 11	St. Helens	Male	34	32				
Sept. 20	Little White Salmon River hatchery	Female	43.5		7	28	28	92
Sept. 20	Little White Salmon River hatchery	Male	44		6	19	21	52
Sept. 27	Little White Salmon River hatchery	Female	42.25					
Sept. 28	Little White Salmon River hatchery	do	42		12	32	31	107
Sept. 30	Little White Salmon River hatchery	do			6	15	37	63
Oct. 2	Little White Salmon River hatchery	do	41.5		7	23	24	73
Oct. 6	Little White Salmon River hatchery	do	42		11	38	31	83
No date	Big White Salmon River				7	28	28	92

TABLE 20.—*Chinook salmon marked at Little White Salmon River hatchery during the summer of 1920, when approximately 10 months old, and recovered during the seasons of 1923 and 1924*

Age	Average length		Average weight	
	Inches	*Centimeters*	*Pounds*	*Kilograms*
Fourth year, 1923:				
Males	36.5	92.7	22.2	10.1
Females	35.1	89.2	21.7	9.9
Fifth year, 1924:				
Males	40.6	103.1	39.0	17.7
Females	40.7	103.4	33.9	15.4

One of the objects of this experiment was to determine at what time of year the salmon propagated at the Little White Salmon River hatchery pass through the commercial fishing district on their spawning migration. The date of the earliest reliable record of a recapture is August 2 and the latest recovery from the commercial fishery is September 17. The records of three that were reported as taken during July are believed to be incorrect, as the person who reported them is known to have made other errors in reporting marked fish. The period August 15 to 20, inclusive, during which nearly half of the recaptures reported from the commercial fishery were taken, may be designated as the time of the height of the run. A closed season for commercial fishing is responsible for the lack of recaptures during the period August 25 to September 10.

This was the first experiment in which any number of the adult marked fish returned to the tributary in which they had been liberated as fingerlings. There appears here to be some significance in the fact that the fingerlings were liberated in their native tributary. In most of the other experiments the fingerlings were liberated in a tributary other than that from which the eggs were secured. Even in this experiment the homing was not perfect, as is shown by the recovery of one of the fish in the Big White Salmon River.

The nuclei of the scales of the adult fish from this experiment are of particular interest because of their wide variation and the light these variations throw on the interpretation of the scales of wild fish of unknown history. Scales with typical stream and ocean nuclei, representing, respectively, migration to the ocean before the scales are formed and after the first year's growth is completed, are identified easily and offer no particular problems; but as the senior author has shown (Rich, 1920), the seaward migration of chinooks in the Columbia is not confined to these two periods but is distributed throughout the year. In view of this variation in the time of migration one would expect to find corresponding variations in the scales, ranging from the typical stream type to the typical ocean type, with transitional stages having varying proportions of stream and ocean growth. A third possible variable in the nature of the scale rings is to be expected as a result of the intermediate environment of the estuary, under the influence of which the fish grow more rapidly than in fresh water but not as rapidly as in the ocean. Such variations in the scales have been observed. Gilbert draws attention to them in his first paper on the scales of the Pacific salmon (Gilbert, 1913). The senior author, in extending the work of Gilbert to a more comprehensive study of the chinook salmon of the Columbia River, encountered such a wide range of variation in the nuclear types that he found it necessary to make a careful study of the seaward migrants before continuing with the study of adult scales. The study of the seaward migrants was necessarily confined to the stream and estuary growth, and it was impossible to trace the growth and movement of particular individuals through their life in the ocean. This opportunity to study the scales of mature fish of known age and early history is therefore of great value.

The nuclei of the scales of all of the adult fish in this experiment have a central portion of closely spaced rings, which is set off from the remainder of the scales by an incidental check formed by a slight narrowing of the rings or by contrast with the wider rings immediately following. The cause of this check is not evident. Its formation does not seem to have been coincident with marking or liberation, as the scales of the fingerlings at the time of marking had 3 to 5 rings, whereas there were 5 to 13 rings when the check was formed. It is sufficient in this connection to note that this incidental check is present in all cases and that the portion inclosed by it is typical of stream growth.

The area of the scale between this incidental check and the first winter check shows a wide range of variation. One extreme of variation is shown in Figure 49, which illustrates a scale in which the band following the incidental check consists of rings similar to those inclosed by it. These two bands, representing the entire first year's growth, form a fairly typical stream nucleus. The opposite extreme is illustrated by Figure 50. Except for the small central portion of stream growth, this scale is typical of the ocean type. The band following the first incidental check in this case is more than twice the width of that in Figure 49, and the rings are spaced more widely. This nucleus is fairly representative of a type very commonly found among the chinook salmon of the Columbia River and for which the term "composite nucleus" is proposed. This term will be used to designate nuclei comprised of both stream and ocean growth.

Many intergrading stages of composite nuclei are found among the scales of this collection. The transition from the typical stream type toward the ocean type is so gradual as to make it impossible to divide the group of nuclei into two classes on the basis of the presence or absence of ocean growth during the first year. Two nuclei that fall about midway between the two extremes of variation are shown in Figures 51 and 52. Some of these intergrading stages probably involve estuary growth. A fish may have spent a part of the first year in each of the three environments, or it may have remained in the estuary during the latter part of the first year. A second incidental check, which is to be found in many of the nuclei, may represent the change from the stream to the estuary or from the estuary to the ocean.

Typical scales of adult fish in their fourth and fifth years are shown in Figures 53 and 54. These also show further variations in the composite type of nucleus.

Returning now to a consideration of the scales of the mature fish in experiment No. 3 we find nuclei similar to some of those in this collection. Eight adult fish were recaptured, the scales of all of which have a central area that unquestionably is stream growth. In all but one this area appears to represent nearly the entire first year's growth but is not terminated by the winter check, which usually is found at the margin of the stream type of nucleus. (See figs. 14 to 18.) This condition, combined with the presence of rings of only moderate width surrounding the stream growth suggests that the fish may have entered the ocean or at least the estuary before the winter check was formed. The check at the twenty-third ring in Figures 17 and 18 may represent the winter check in that scale. In the others the boundary of the first year's growth is not shown definitely.

The stream growth in seven of these is broken by an incidental check at the fifth to seventh rings. (See Table 4 and figs. 14 to 18.) The area inclosed by this check evidently represents the margin of the scale at the time the fish were marked and liberated.

In the eighth scale of this collection (fig. 19) the stream growth extends only to a point corresponding to the first incidental check in the other seven. From this point the rings widen gradually into the second year's growth, leaving no mark to indicate the termination of the first year's growth. This nucleus is more typically a composite type than are the other seven.

EXPERIMENT NO. 9.—BONNEVILLE HATCHERY, SEPTEMBER AND OCTOBER, 1921

Eggs from: McKenzie River, 1920.
Reared and marked at: Bonneville hatchery.
Mark used: Removal of adipose fin and both ventral fins.
Number marked: 50,000.
Liberated: In Tanner Creek during September and October, 1921.
Age: Approximately 13 months.

A sample of 50 fingerlings preserved on August 24, 1921, averages 93.3 millimeters (3.7 inches) in length. The average number of rings on the scales is 13.1, and the average length of the anterior radius of the scales is $\frac{43.9}{120}$ millimeters. (See table 21.) An incidental check at 6 to 10 rings from the center is to be found in about half of the scales (see fig. 55); in others (see fig. 56) there is a slight crowding of the rings, which is not sufficiently pronounced to be termed a check.

TABLE 21.—*Chinook-salmon fingerlings marked at Bonneville hatchery August 24, 1921*

Length in millimeters (mid-value of class)	Scale record																												Males	Females	Total
	Number of rings										Length of anterior radius, in millimeters × 120 (mid-value of class)																				
	7	9	10	11	12	13	14	15	16	17	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	61			
72.5		1			1						1						1													2	2
77.5		1	2	1										1	1		2												3	1	4
82.5		1	2				1		1			1				1	1	1							1				1	4	5
87.5	1		1		1	5	2		1				1			1			3	2	1	2			1				5	6	11
92.5						1	3		1									1				1	2					1	1	4	5
97.5					1	1	2	1		1					1					1	1	1			1	1			3	3	6
102.5				1		2	1	2	3	1							1					1	1	1	4	1	1		9	1	10
107.5				1	1		1		1								1	1	1				1						2	2	4
112.5						1	1												1									1	2		2
122.5										1																		1		1	1
Total	1	3	5	3	4	10	11	3	7	3	1	1	1	1	2	2	6	3	5	3	2	5	4	1	7	2	1	3	26	24	50
Average	13.1										43.9																		95.3	91.0	93.3

The returns from this experiment are represented by three 4-year-olds recovered during 1924, thirty-three 5-year-olds recovered during 1925, and six 6-year-olds recovered during 1926. The detailed data regarding these recoveries are given in Table 22. The 5-year-old males average 31.3 inches (79.6 centimeters) in length and 30 pounds (13.6 kilograms) in weight. The females of that age average 34.3 inches (87.1 centimeters) in length and 19.5 pounds (8.9 kilograms) in weight. The 4-year-olds and 6-year-olds are represented by too few individuals to give reliable averages.

TABLE 22.—*Chinook salmon marked at Bonneville hatchery during the fall of 1921, when approximately 13 months old, and recovered during the seasons of 1924, 1925, and 1926*

Date of capture	Place of capture	Sex	Length, in inches	Weight, in pounds	Scale record first year	
					Number of rings	Length of anterior radius in millimeters × 120
1924:						
May 6	Warrendale	Male	25.75	13	17	54
May 17	Astoria cannery	do	36.5	18	17	53
May 14	Warrendale cannery	do			26	73
1925:						
May 2	do	do	25.4	31	19	51
May 3	Astoria cannery	do	34.5	20	15	56
May 4	do	Female	35	20	19	54
Do	Sand Island	do			13	39
Do	St. Helens	do	35.5	8.5	14	51
Do	do	do	27.25	30.25	14	44
Do	Rainier	do	35	15		
Do	Ellsworth cannery	do	37	28	22	65
Do	do	Male	26	17.5	22	54
Do	Bonneville	Female	37.5	17.5	20	59
May 5	Astoria cannery	do	30	12.5	14	44
Do	Ellsworth cannery	do	32	24.5	13	39
Do	Bonneville	Male	32.75	11.25	21	69
May 6	Ellsworth cannery	do	36.5	27.75	19	42
Do	Warrendale cannery		36.5	17	20	62
Do	do		35	17	17	56
May 8	Dahlia, Wash	Male	41	29	22	59
Do	The Dalles	Female	35	18	14	47
May 11	Warrendale cannery	do	38	18	18	54
May 12	Ellsworth cannery	do	32.5	20	21	60
May 16	do	do	37	26	18	48
May 29	Bonneville cannery	Male	23.5	14.5	17	53
Do	Warrendale cannery		37	16		
June 2	do	Female	36	16	20	60
June 18	Astoria cannery	do	30		17	53
Date of capture not reported	Pillar Rock	Male	28	9	20	51
	Pillar Rock cannery	do	38	22	21	56
	Ellsworth cannery	do	22	17	21	51
	Warrendale cannery	Female	37	19		
	do		37.5	21		
	do				22	56
	do	Male	37	21		
	do		44	34	23	56
1926:						
February	Clatskanie, Oreg		42	37	17	53
May 2	Ellsworth cannery		37	32	19	63
May 4	do		35	17		
May 5	Cascade Locks	Female	41	27	27	71
May 14	Ellsworth cannery	do	36.5	24	18	57
May 27	do	Male	37	23.5	18	50

As in all other experiments with chinook salmon of the spring run, these adults entered fresh water during the early part of the season. They returned to the Columbia River but not to the tributary in which they were liberated. One of the 6-year-olds was taken in February. This is additional evidence that the marked spring chinooks start their spawning migration some time before the commercial fishing season opens on May 1.

The scales of the adult fish have typical stream nuclei surrounded by ocean growth, which is divided by distinct annual checks into the expected number of summer bands. The margins of many of the scales have been absorbed, but enough of the scale remains in every case to show that the fish is of the correct age. The scale of a 5-year-old (shown in fig. 60) illustrates well the extent of absorption. As an illustration of the scale of a fish in its sixth year, one from the fish caught in February has been selected. (See fig. 61.) It will be noted here that the winter check of the fifth year is represented by only a slight narrowing of the marginal rings and that no new growth of the sixth year is present.

The scales of one of the fish recovered during 1924 are very unusual. One of them is shown in Figure 58. The nucleus of this scale is the largest in the collection, and the radius of the scale to the second winter check is unusually small. This makes the second year's growth appear extremely slight. The cause of such unusual growth proportions is unknown. It is possible that this fish remained in fresh water for a part of the second year, in which case the nucleus would represent more than the first year. A more typical scale of a fish in its fourth year is shown in Figure 57.

This experiment is nearly an exact duplicate of experiment No. 7. Both involved the progeny of the spring run of chinooks that spawn in the headwaters of the Willamette River. The fingerlings in both cases were reared at Bonneville and liberated at approximately the same time of the year. The fingerlings preserved in experiment No. 7 are slightly larger than those in experiment No. 9, but this difference may well be due to the difference of about six weeks in the dates on which the samples were preserved. The size of the fish at the end of the first year, as shown by the size of the nuclei, was nearly identical.

The number of returns from these experiments, however, differs widely. The recoveries from experiment No. 7 represent 0.39 per cent of the fingerlings marked, whereas only 0.08 per cent (less than one-fourth as many) were recovered from experiment No. 9. No satisfactory explanation for this difference has been suggested. It could not have been due to a failure of our data to be representative of the actual returns. This may be seen by comparing the returns from the two experiments during the season of 1925. The 5-year-olds that returned from experiment No. 9 were nearly equaled by the 6-year-olds in experiment No. 7, whereas invariably a much larger proportion of fish from any brood mature during their fifth year than during the sixth. These two groups of fish were running simultaneously, and there is no reason to believe that the cannery employees and others who were searching for marked salmon selected one mark in preference to the other.

EXPERIMENT NO. 10.—BONNEVILLE HATCHERY, AUGUST AND SEPTEMBER, 1922

Eggs: McKenzie and Santiam Rivers, 1921.
Reared and marked at: Bonneville hatchery.
Mark used: Removal of adipose fin and right ventral fin.
Number marked: 100,000.
Liberated: In Tanner Creek during August and September, 1922.
Age: Approximately 12 months.

A sample of 25 of the fingerlings preserved on August 28, 1922, averages 76 millimeters (3 inches) in length. Their scales have an average of 11.6 rings and an average anterior radius of $\frac{33.9}{120}$ millimeters. The scales of all but two of the fingerlings show an incidental check about 7 rings from the center. The incidental check is followed typically by 3 to 5 rings, which stand out as distinctly heavier and more widely spaced than those preceding the check. (See fig. 62.) The length and scale data are given in Table 23.

TABLE 23.—*Chinook-salmon fingerlings marked at Bonneville hatchery August 28, 1922*

Length, in millimeters (mid-value of class)	Scale record: Number of rings						Scale record: Length of anterior radius, in millimeters × 120 (mid-value of class)								Males	Females	Total
	9	10	11	12	14	15	23	29	31	33	35	37	43	45			
62.5		2	1				1		2							3	3
67.5		3	1					2	1	1						4	4
72.5	1	1	2	2				1	2	2	1				3	3	6
77.5		1	1	1		1				1		2		1	2	2	4
82.5				1		1				1			1		1	1	2
87.5			1	1	3					1		1	3		5		5
92.5					1								1			1	1
Total	1	7	6	5	4	2	1	3	5	6	1	3	5	1	11	14	25
Average	11.6						33.9								81.2	71.8	76.0

Returns from this experiment were obtained during the years 1924 to 1927, when the fish were in their third, fourth, fifth, and sixth years. The 3-year class is represented by 1 recovery, the fourth by 4 recoveries, the fifth by 39, and the sixth by 31. The data relating to these recoveries are given in Table 24.

TABLE 24.—*Chinook-salmon fingerlings marked at Bonneville hatchery during the fall of 1922, when approximately 12 months old, and recovered during the seasons of 1924, 1925, and 1926*

Date of capture	Place of capture	Sex	Length, in inches	Weight, in pounds	Scale record, first year: Number of rings: Stream growth	Number of rings: Intermediates	Length of anterior radius, in millimeters ×120: Stream growth	Length of anterior radius: Total
1924: May 3	The Dalles	Male	18	3	13	4	43	52
1925:								
May 1	Bonneville	do			20	0	42	0
May 11	Cascade Locks	do	25	9	16	0	44	0
May 15	Astoria	Female	28.25	10.5	28	0	74	0
No date	Warrendale cannery	do	40	35	25	0	60	0
1926:								
May 1	Ellsworth cannery		39					
May 3	do		32.5	18.5				
Do	do	Female	35	17.5				
Do	Rainier	Male	38	14				
Do	Ellsworth cannery	Female	37.5	24	18	6	56	71
May 4	do	do	34	21	18	12	54	87
Do	Warrendale cannery	do	37	20	20	5	53	74
May 5	Ellsworth cannery		34	17				
Do	do		40	33				
Do	do		40	39				
Do	do	Female	35.5	24	17	7	45	66
Do	Warrendale cannery	Male	34.5	15.5				
Do	do	Female	34	15	15	7	54	75
Do	do	do	36	19	18	4	59	72
Do	Ellsworth cannery	do	37	25	16	4	39	50
Do	Cascade Locks	do	37	22	17	7	42	63
May 6	Warrendale cannery	Male	34	21	18	5	59	72
Do	Ellsworth cannery	do	33	24	18	6	56	72
Do	Warrendale cannery	do	38	27	16	5	50	63
May 7	Ellsworth cannery	Female	32	14	14	5	42	56
Do	do	Male	29.5	19.5	13	6	36	50
May 8	do	do	28.5	18	12	5	39	56
Do	Warrendale cannery	do	34	17.5	16	11	44	69
May 10	do	do	36	18	17	6	56	72
May 11	Cascade Locks	Female	38.75	25.5	15	5	45	57
Do	Ellsworth cannery	Male	38	29	16	0	48	0

TABLE 24.—*Chinook-salmon fingerlings marked at Bonneville hatchery during the fall of 1922, when approximately 12 months old, and recovered during the seasons of 1924, 1925, and 1926*—Contd.

Date of capture	Place of capture	Sex	Length, in inches	Weight, in pounds	Scale record, first year: Number of rings: Stream growth	Scale record, first year: Number of rings: Intermediates	Scale record, first year: Length of anterior radius, in millimeters ×120: Stream growth	Scale record, first year: Length of anterior radius, in millimeters ×120: Total
1926—Continued.								
May 15	Ellsworth cannery	Female	32	17	14	0	38	0
May 16–22	Dixon Entrance, southeastern Alaska	do	36	19	17	6	44	62
May 17	The Dalles	Male	38.5					
May 25	Ellsworth cannery	Female	28	18	11	4	29	36
June 4	do	do	34	21	12	8	36	54
June 8	do	Male	40	36	16	8	48	72
Do	do	Female	36	24.5	21	2	50	56
Sept. 23	Warrendale cannery	do	36	23.5	22	10	63	93
	Ellsworth cannery	Male	31	17	17	0	44	0
	do	Female	34	18	19	0	54	0
No date	do		15	13			30	39
	Warrendale cannery	Female	33	15	18	0	48	0
	Tanner Creek							
1927:								
Feb. 22	Astoria cannery	Female	48	32				
Feb. 24	do	Male	48	37				
May 1–3	Warrendale cannery				18	0	46	0
Do	do	Male	45	40	13	5	35	46
Do	do				19	0	49	0
May 4	do							
May 1–6	Ellsworth cannery				16	0	55	0
Do	do				15	4	41	48
May 8	do				17	4	50	63
Do	do				17	6	54	68
Do	do				15	11	42	74
May 9	do				19	6	54	71
Do	do				12	0	41	0
May 4-9	Warrendale cannery				22	0	56	0
Do	do	Female	35	30	15	12	40	80
Do	do	do	41	30	14	8	44	65
Do	do	Male	22	12	21	7	47	62
Do	do	do	44	31				
May 10	do							
May 11	do							
May 10–11	do				21	8	58	86
May 12	Vancouver	Male	38.5	25	14	5	44	55
May 13	Ellsworth cannery				14	8	30	48
May 16	Astoria	Male			14	7	35	50
May 14–19	Ellsworth cannery							
May 20	do				12	0	39	0
May 12-29	Warrendale cannery				21	0	65	0
Do	do				15	9	46	70
June 18	Ellsworth cannery				13	4	41	49
June 21	The Dalles	Female	39.5	24	14	0	45	0
July 5	Warrendale cannery	do	39	24	15	4	44	58

One of the 5-year-olds was caught by troll in the ocean off the coast of southeastern Alaska, approximately 600 miles from the mouth of the Columbia River. This record is of much interest, because it corroborates data obtained from other sources showing that salmon travel great distances in the ocean. The tagging of adult salmon caught by troll in the ocean has shown that chinooks found as far north as Queen Charlotte Islands, British Columbia, may later enter the Columbia River (Williamson, 1927). This record extends the known range of the Columbia River chinooks to include southeastern Alaska.

In this experiment we find, for the sixth time, the progeny of the spring run of salmon entering fresh water on their spawning migration at a definite and regular time of the year. As in the other similar experiments, the majority of the recoveries were reported during the first week of the commercial fishing season. Only 14 of the 75 recoveries were made after the middle of May.

One of the 6-year-olds, which was caught on September 23, represents an exception to this rule. As only one other exception was found, this record has been checked carefully to determine if it is authentic. The scars were found to be typical of those produced by marking, and no reason for questioning any part of the data presented itself. The nuclei of the scales from this fish do not agree exactly with those of the other fish recovered from this experiment; but the record could not be invalidated on this score, because the nuclei in the collection show a wide range of variation, one extreme of which might be represented by the scale in question. The age indicated by the scales is correct.

Three possible explanations for the irregularity of this record might be suggested: 1. It may be an authentic exception to the rule that the progeny of the spring run return in the spring. 2. The fingerling from which this fish developed may have been one from the fall run of chinooks that by accident became mixed with the spring chinooks at the hatchery. 3. The fish may have lost the fins by some other means. As there is no evidence that the second or third possibility is true, the first must be accepted tentatively.

One of the 5-year-olds returned to Tanner Creek and was recovered in the spillway from the hatchery ponds in which it was reared as a fingerling. This is the fourth of the marked spring chinooks that has returned to the tributary in which it was liberated.

The nuclei of the scales of the adult fish in this collection are more variable than those of any other marked spring chinooks. Most of the variations may be grouped into a single general type, however. In this general type the nucleus consists predominately of stream growth surrounded by a narrow band of intermediates. (See Table 24.) The presence of the band of intermediates at the end of the first year typically results in a gradual transition in the nature of the rings and obscures the points of demarcation, both between the stream and intermediate growth and between the intermediate and ocean growth. The scale shown in Figure 63 is a good example of this condition. A scale with the three types of growth more clearly differentiated is illustrated in Figure 64. In some cases the intermediates are distinctly differentiated from the ocean growth but closely resemble the rings of stream growth. A scale of this nature is illustrated in Figure 65. Without a series of scales with which to compare it, this nucleus might be considered as a pure stream type.

The band of intermediates varies in width from a maximum of 12 rings, as shown in Figure 66, to none, as shown in Figure 67. Figures 63 and 64 show more average widths. The apparent absence of intermediates in some cases may be due to a lack of contrast between them and the rings of stream or ocean growth. It is especially difficult to distinguish the intermediates when they are only 1, 2, or 3 in number. An extremely wide band of intermediates combined with a slight contrast between the stream and intermediate growths gives the nucleus in Figure 66 the appearance of an ocean type, and it is possible that the outer rings of this nucleus actually were formed in the ocean. If this be the case, the nucleus should be classed as a composite type.

The stream growth shown on these scales generally is divided into two parts by an incidental check, the inner of which corresponds to a similar portion observed on the scales of the fingerlings.

The presence of the band of intermediates within the nucleus of these scales indicates that the fish migrated, at least to the estuary, during their first year. Spring chinooks normally remain in the stream for their entire first year, and it is believed that the probable reason for these fish leaving fresh water before that time was the unfavorable nature of conditions in Tanner Creek, where the fingerlings were liberated. It would be impossible for this small creek to support the large numbers of fingerlings that are liberated in it each year from the hatchery. Similar conditions and scale peculiarities were found in experiment No. 5. Intermediate rings have not been found among the other marked spring chinooks, probably because they were liberated at about the end of the growing season.

Typical scales of mature fish in their third, fourth, and fifth years are shown in Figures 68, 69, and 70.

EXPERIMENT NO. 11.—KLASKANINE HATCHERY, AUGUST, 1922

Eggs from: Willamette River system, 1921.
Reared and marked at: Klaskanine hatchery.
Mark used: Removal of adipose fin and dorsal fin.
Number marked: 50,000.
Liberated: In Klaskanine River during August, 1922.
Age: Approximately 10 months.

An unselected sample of 20 fingerlings preserved on August 18, 1922, averages 73.5 millimeters in length. The anterior radius of the scales of these fish averages $\frac{31.0}{120}$ millimeters in length. The average number of rings is 9.8. All but two of the scales have an incidental check, which incloses 5 to 9 rings and is followed by 1 to 5 more widely spaced rings. The size and scale data are given in Table 25. A typical scale is illustrated in Figure 71.

TABLE 25.—*Chinook-salmon fingerlings marked at Klaskanine hatchery August 18, 1922*

Length, in millimeters (mid-value of class)	Scale record: Number of rings					Scale record: Length of anterior radius, in millimeters × 120 (mid-value of class)									Males	Females	Total
	8	9	10	11	12	23	25	29	31	35	37	39	41	45			
57.5	2	1				1	1	1							2	1	3
62.5			1					1								1	1
67.5	2		1	1		1	1			1		1			1	3	4
72.5	1	1	1			1		1	1						1	2	3
77.5			1	1	1			1			2				2	1	3
82.5		2		1				2	1						2	1	3
87.5					2							1		1	1	1	2
92.5				1									1		1		
Total	5	4	4	4	3	3	2	6	2	1	2	2	1	1	10	10	20
Average	9.8					31.0									75.2	71.8	73.5

Only one adult fish that could be identified as belonging to this experiment has been recovered. This one, a 5-year-old, was found during the spring of 1926 in the spillway from the rearing ponds at the Klaskanine hatchery. The scales of this fish are absorbed at the margin, but at least a trace of the fourth winter check is to be found at some points. The nucleus is of the composite type. (See figs. 72 and 73.) The bands of stream and ocean growth in the nucleus are of about equal widths, the combined radius being $\frac{107}{120}$ millimeter. At the margin of the stream growth are five rings, which may be intermediates.

It is interesting to note that here, as in experiment No. 10, a spring chinook, upon being liberated in a tributary that normally supports only a fall run, left fresh water before the end of the first year.

EXPERIMENT NO. 12.—BIG WHITE SALMON RIVER HATCHERY, MAY AND JUNE, 1923

Eggs from: Big White Salmon River and Spring Creek, 1922.
Reared and marked at: Big White Salmon River hatchery.
Mark used: Removal of adipose fin and left ventral fin.
Number marked: 100,000.
Liberated: In Columbia River at Big White Salmon River hatchery during May and June, 1923.
Age: Approximately 8 months.

The Big White Salmon River hatchery is situated at the mouth of a small creek (Spring Creek) that empties into the Columbia River about 1 mile below the mouth of the Big White Salmon River. At this point the Columbia River is paralleled closely by a high cliff, and at the base of this cliff a large spring breaks out and forms a small creek, which flows for only a few hundred yards across a sand bar to the Columbia River. It is from this spring that the creek derives its name. By constructing a dam across the mouth of the creek a rearing pond for salmon fingerlings was formed. The same pond is used for holding adult salmon from the time they reach the creek until they are ready to spawn. In its natural condition the creek was not accessible to salmon and none were known to attempt to enter it, but since the hatchery has been operated there a thousand or more adult chinooks annually attempt to find spawning grounds there, and their eggs are taken for artificial propagation. No attempt is made to keep the eggs taken in Spring Creek separate from those taken in the Big White Salmon River. As a result the fingerlings marked in this experiment developed from eggs taken at both places.

The first few thousand marked fingerlings were liberated in Spring Creek, but at the mouth of the creek they were attacked by predatory fishes (probably the squawfish, *Ptychocheilus oregonensis*), which congregated there in large numbers, presumably attracted by food drifting out from the pond and occasional fingerlings that escaped from the hatchery. The rest of the marked fingerlings were carried to a little cove in the Columbia about 100 yards below the mouth of the creek, where apparently they were not molested by predatory fishes.

A sample of 50 fingerlings preserved on June 12, 1923, averages 52.2 millimeters (2 inches) in length. Their scales have an average of 5.9 rings and an average anterior radius of $\frac{20.6}{120}$ millimeters. A typical scale is illustrated in Figure 74. The detailed data are given in Table 26.

TABLE 26.—*Chinook-salmon fingerlings marked at Big White Salmon River hatchery June 12, 1923*

Length, in millimeters (mid-value of class)	Scale record															Males	Females	Total
	Number of rings						Length of anterior radius, in millimeters×120 (mid-value of class)											
	3	4	5	6	7	8	11	15	17	19	21	23	25	27	29			
42.5	1		1				1		1								2	2
47.5	1	2	5	3	1			1	2	3	4	2				7	5	12
52.5			5	10	5				2	7	5	3	1	1	1	13	7	20
57.5			1	8	4	2			1	2	5	1	2	3	1	8	7	15
62.5						1									1	1		1
Total	2	2	12	21	10	3	1	1	6	12	14	6	3	4	3	29	21	50
Average	5.9						20.6									52.3	51.9	52.2

This experiment has produced a greater number of returns than any other experiment with chinook salmon. A total of 453 fish (0.45 per cent of the number liberated as fingerlings) has been recovered. Four that matured during their second year were taken near Astoria during August, 1924. Sixty-two 3-year-olds were taken in the commercial fishery during the season of 1925; an additional 25 returned to Spring Creek that season, and 1 ran into the Big White Salmon River. Ten of those reported from the commercial fishery were taken by troll in the ocean. During the season of 1926 two hundred and seventy-one 4-year-olds were recovered—230 in the main Columbia River, 5 in the ocean, 33 in Spring Creek, and 1 in each of three tributaries that empty into the Columbia not far from the mouth of Spring Creek. Five-year-olds recovered during the season of 1927 totaled 90; 66 were reported from the commercial fishery and 24 ran into Spring Creek. One also was reported from the Little White Salmon River egg-taking station, but as the scars showing which fins were lacking were not preserved this report is not presented as a valid record of the recovery of a marked fish. A few 6-year-olds from this experiment may be recovered during the season of 1928.

Nearly all of the adult fish recovered from the commercial fishery were found after they had reached the canneries. As a result it was generally impossible to determine just where the fish were caught. As the recoveries for which the exact place of capture was reported are too few to be of any significance, the data from the commercial fishery have been grouped into three general localities—(1) the ocean, (2) the lower Columbia, which includes from the mouth of the river to Vancouver, Wash., and (3) the upper Columbia, including the portion of the main Columbia from Vancouver to the upper limit of the commercial-fishing district. The recoveries are tabulated according to place and date of capture in Table 27.

TABLE 27.—*Chinook salmon marked at Big White Salmon River hatchery during the spring of 1923, when approximately 8 months old, and recovered during the seasons of 1924, 1925, and 1926*

Place and date of capture	1924	1925	1926	1927
Ocean:				
May 22			1	
June 14		1		
July 22				1
July 26		1	1	
Aug. 4		1		
Aug. 6			1	
Aug. 9			1	
Aug. 14		1		
Aug. 22		1	1	
Aug. 25 [1]				1
Sept. 1		1		
Sept. 12				1
No date		4		
Total		10	5	3
Lower Columbia:				
June 16		[2] 1		
Aug. 2	2			
Aug. 4				1
Aug. 6			1	
Aug. 7			2	
Aug. 8			2	
Aug. 9			1	
Aug. 10		1	2	
Aug. 11		1	1	
Aug. 12			5	1
Aug. 13			5	
Aug. 14			1	
Aug. 15				1
Aug. 16			5	2
Aug. 17		1	5	1
Aug. 18			5	2
Aug. 19		2	4	4
Aug. 20			2	4
Aug. 21			5	1
Aug. 22	1	3	1	2
Aug. 23			7	1
Aug. 24		2	7	3
Aug. 25 [1]	1	3	15	6
Aug. 29		[2] 1		
Sept. 2			[2] 1	
Sept. 10			3	3
Sept. 11		2	21	3
Sept. 12		4	17	6
Sept. 13			16	1
Sept. 14			8	
Sept. 15		4	10	1
Sept. 16		1	6	1
Sept. 17		1	3	
Sept. 18			1	
Sept. 20			5	
Sept. 21		1	2	
Sept. 23				1
Sept. 25			1	
Lower Columbia—Continued.				
Sept. 26			2	
Oct. 2				1
No date		9	11	10
Total	4	37	183	56
Upper Columbia:				
Sept. 12		3		1
Sept. 13		1	7	2
Sept. 14		3	1	1
Sept. 15		5	6	
Sept. 16		2	9	1
Sept. 17			8	
Sept. 18			1	2
Sept. 20			1	
Sept. 21		1		
Sept. 22			2	
Sept. 23			10	
No date			2	
Total		15	47	7
Spring Creek:				
Sept. 8		1		
Sept. 10			1	
Sept. 11		3		
Sept. 14		4		
Sept. 15		3	1	
Sept. 16				1
Sept. 19		4		
Sept. 20				3
Sept. 25			1	
Sept. 26				1
Sept. 27			1	
Sept. 29			1	1
Oct. 1			17	
Oct. 2		5		13
Oct. 4			2	
Oct. 5		2		
Oct. 6		2		
Oct. 7		1	5	
Oct. 8				2
Oct. 11			1	
No date			3	3
Total		25	33	24
Big White Salmon River:				
Sept. 30		1		
Oct. 5			1	
Total		1	1	
Little White Salmon River: Sept. 29			1	
Tanner Creek: No date			1	

[1] A closed season for commercial fishing accounts for the absence of records from the Columbia River during the period Aug. 25 to Sept. 10.

[2] The place of capture for this recovery was not reported. As it is from a cannery that handles a large quantity of troll-caught salmon, this fish probably was caught in the ocean.

The length and weight data for the adult fish appear in Tables 28 and 29. Because of the unreliability of measurements made by so large a number of persons as have reported marked salmon, lengths and weights were not required during the season of 1927. This accounts for the relatively few size data for that season.

TABLE 28.—*Chinook salmon marked at Big White Salmon River hatchery during the spring of 1923, when approximately 8 months old, and recovered during the seasons of 1924, 1925, and 1926*

Length, in inches (mid-value of class)	Fish in their second year, 1924, males	Fish in their third year, 1925		Fish in their fourth year, 1926		Fish in their fifth year, 1927	
		Males	Females	Males	Females	Males	Females
21.5	1						
22.5	2	1		1			
23.5		2	2				
24.5		4	2		1		
25.5			1	1	3		
26.5		4	1	1			
27.5		1	1		2		
28.5		6	2	4	2		
29.5		7	2	3	1		
30.5		6		4	3		
31.5		2		8	6		
32.5		8	1	8	4		
33.5		2		12	2		
34.5		5	1	12	17		1
35.5				7	23		2
36.5			1	8	12	1	5
37.5				11	16		3
38.5				7	13	1	5
39.5				10	10		1
40.5				10	2		2
41.5				4	3	1	2
42.5				5		3	2
43.5							1
Total	3	48	14	116	120	6	24
Average length	22.2	30.0	28.2	35.6	35.5	40.7	38.5

TABLE 29.—*Chinook salmon marked at Big White Salmon River hatchery during the spring of 1923, when approximately 8 months old, and recovered during the seasons of 1924, 1925, and 1926*

Weight, in pounds (mid-value of class)	Fish in their second year, 1924, males	Fish in their third year, 1925		Fish in their fourth year, 1926	
		Males	Females	Males	Females
5.5	1				
6.5	2		2		
7.5		3			
8.5			1		
10.5				1	
11.5		2	2	2	1
12.5		4		2	
13.5		1	4		1
14.5		4		1	
15.5		4	1	2	3
16.5		3	1	6	3
17.5		4		5	2
18.5				7	4
19.5		1		1	5
20.5		3		4	6
21.5		1	1	5	6
22.5				8	7
23.5				8	8
24.5		1		9	11
25.5				2	15
26.5				6	5
27.5				1	4
28.5				6	8
29.5				1	2
30.5				9	3
31.5				4	2
32.5				3	3
33.5				3	
34.5				2	
35.5				3	
38.5				1	
40.5				1	
42.5				1	
Total	3	31	12	104	99
Average weight	6.2	15.3	12.7	24.5	23.8

The recoveries reported by the fishermen who troll for salmon in the ocean add to our meager knowledge of the movements of salmon in the ocean. Sixteen of the 18 fish taken by this means were caught by trollers who operate out of the

Columbia River ports. These records indicate that some of these fish were to be found within a short distance of the mouth of the Columbia during the entire fishing season of each year. Recoveries from this district range in date from May to September. The two remaining records of recoveries in the ocean are from more remote localities. Both are from the west coast of Vancouver Island—one from near Barkley Sound, taken on August 6, 1926, the other from near Ucluelet, British Columbia, taken on August 9, 1926. These two recoveries agree with data obtained from tagging experiments in showing that fish that will enter the Columbia River during the fall may be found only a short time before at a considerable distance up the coast.

The data for the recoveries of 4-year-olds give the best indication of the time of the spawning migration. Appearing first at the mouth of the Columbia River during the first week of August, these fish increased in abundance up to August 25, when a closed season for commercial fishing cut off our records. When fishing was resumed on Septemer 10 they were caught at the mouth of the river in even greater numbers than during August, and they appeared for the first tme in the vicinity of Cascade Locks. About the middle of September the run began to drop off, and by the 1st of October the fish disappeared completely from the commercial fishery.

The dates of recovery at Spring Creek give little indication of the time at which the fish reach the creek, because most of them were not discovered until spawning time. The hatchery records of the general run into Spring Creek are more reliable for this purpose. These records show that the majority of the fish enter the creek during September. Starting early in the month, about half of the run has passed by the 20th and only a few come in after the 1st of October. The fish are nearly ready to spawn at the time they enter the creek, but, in the absence of a gravel bottom on which to spawn, they retain their eggs and sperm. This makes it possible to delay the stripping process until most of the fish have matured. The bulk of the eggs then are taken in one or two days. This restricted egg-taking period accounts for the bunching of recoveries at Spring Creek.

The data at hand indicate that most of the adult fish that escaped the commercial fishery returned to Spring Creek to spawn. Eighty-two were recovered in that creek, and only four are known to have chosen other tributaries. The records from the commercial fishery of the upper Columbia are such that it is impossible to determine whether the fish were caught above or below the mouth of Spring Creek, but none was reported definitely from above that point, and one of the best fishermen from that region has reported that he searched for marked salmon but found none. Although a few of the fish have gone astray, there can be no question that most of them sought and, if not previously captured, found the very small tributary from whence they came.

The scales of these adult marked fish present an interesting series of composite nuclei, which, when studied as a group, offer no problems to one who is familiar with scales of this type. To the inexperienced observer, however, the many incidental checks that characterize this type would constitute a perplexing problem. A scale that is representative of this collection is illustrated in Figures 75 and 76. The innermost 5 or 6 rings of this scale are slightly lighter and more closely spaced than those immediately surrounding them. This portion of the scale corresponds exactly with the entire scale of the fingerlings at the time of liberation. (See table 26 and fig. 74.) At about 15 rings from the center a second break in the continuity of the rings (an incidental check) may be seen. Still a third break is to be found at 35 rings. From this point there is a gradual widening of the rings into the rings of rapid growth of the second year. Following this second summer's growth is a band of closely spaced rings representing the second winter. This is followed in turn by the rapid growth of the third summer, the third winter check, and finally by a narrow marginal band of more widely spaced rings of the fourth summer. The last band and in some places even the third winter check have been removed by absorption.

An inexperienced observer might find difficulty in determining which check on this scale represents the first winter. If he decided upon the second check (at 15 rings), he would be forced to consider the third check (at 35 rings) as representing the second winter. His interpretation then would be that the fish was in its fifth rather than its fourth year. An experienced observer would not have this difficulty. His interpretation would be based upon a knowledge of the general nature of the different types of nuclei and the impression he gained from the appearance of the whole scale, neither of which is described easily. In this particular case the portion of the scale inclosed by the second check does not resemble a stream nucleus and it is too small to represent an ocean nucleus. Futhermore, the band between the second and third checks (in comparison to the other summer bands) is too narrow to represent a second year's growth in the ocean. Even a relatively inexperienced person probably would interpret correctly the age of this scale if he compared it with a series of scales of the same general type.

TABLE 30.—*Chinook salmon marked at Big White Salmon River hatchery during the spring of 1923, when approximately 8 months old, and recovered during the seasons of 1924, 1925, and 1926*

Length of anterior radius, in mm.×120 (mid-value of class)	Scale record of first year's growth											
	To first incidental check				To second incidental check				Total			
	Fish in their second year, 1924	Fish in their third year, 1925	Fish in their fourth year, 1926	Fish in their fifth year, 1927	Fish in their second year, 1924	Fish in their third year, 1925	Fish in their fourth year, 1926	Fish in their fifth year, 1927	Fish in their second year, 1924	Fish in their third year, 1925	Fish in their fourth year, 1926	Fish in their fifth year, 1927
7.5			2									
12.5	1	4	5	4								
17.5	2	16	14	23								
22.5	1	27	38	26								
27.5		12	11	13			2	1				
32.5		3	1	1		2	3	9				
37.5				1	2	6	19	8				
42.5					1	12	12	11				
47.5					1	10	11	16				
52.5						9	18	19			2	
57.5						11	13	5			1	1
62.5						6	5	6				3
67.5						5	2	2		5	7	5
72.5						5	1	1			4	3
77.5						6	1	2		3	4	4
82.5										9	5	8
87.5							1		1	1	11	6
92.5							1			3	8	11
97.5									3	11	10	8
102.5										6	8	6
107.5										7	5	4
112.5										5	12	10
117.5										1	8	4
122.5										3	2	4
127.5										4	4	2
132.5										3	3	0
137.5										2	1	1
142.5										6	1	
147.5										2		
152.5										1		
Total	4	62	71	68	4	72	89	80	4	72	96	80
Average	17.2	21.6	20.8	20.6	42.5	54.0	48.9	49.5	93.8	105.5	97.6	95.2

TABLE 31.—*Chinook salmon marked at Big White Salmon River hatchery during the spring of 1923, when approximately 8 months old, and recovered during the seasons of 1924, 1925, and 1926*

Number of rings	Scale record of first year's growth											
	To first incidental check				To second incidental check				Total			
	Fish in their second year, 1924	Fish in their third year, 1925	Fish in their fourth year, 1926	Fish in their fifth year, 1927	Fish in their second year, 1924	Fish in their third year, 1925	Fish in their fourth year, 1926	Fish in their fifth year, 1927	Fish in their second year, 1924	Fish in their third year, 1925	Fish in their fourth year, 1926	Fish in their fifth year, 1927
3		2	1									
4	1	1	4	3								
5		12	14	11								
6	3	16	20	19								
7		19	20	21								
8		9	9	10								
9		3	1	4								
10			1									
11			1			1	3	3				
12						6	4	2				
13					2	1	9	10				
14					1	7	10	8				
15						11	11	11				
16					1	7	16	17				
17						10	11	7				
18						6	11	8				
19						8	6	8				
20						4	3	3			2	
21						5	2				1	
22						3	1	1		2	1	2
23						1		1		3	4	4
24										1	6	5
25						1	1			7	3	3
26								1	1	3	7	9
27						1	1		1	2	6	3
28									1	4	5	10
29										8	12	7
30										7	15	8
31										5	7	5
32									1	5	12	4
33										5	4	3
34										5	2	11
35										6	2	2
36										3	2	3
37										2	3	
38										1	2	
39										2		1
40										1		
Total	4	62	71	68	4	72	80	80	4	72	96	80
Average	5.5	6.4	6.4	6.5	12.5	17.0	16.1	16.0	28.2	30.5	29.2	29.3

These nuclei are complicated further by the presence of an incidental check in the second year. This check may be seen in Figure 78. In this case the check is not sufficiently pronounced to cause any trouble. Ordinarily it causes no trouble in so far as age determination is concerned, but it may lead to some question as to what point on the scale represents the end of the first year's growth. This is especially true where the nucleus is poorly differentiated. The scale shown in Figures 79 and 80 gives difficulty on this score. If the check at 39 rings is the winter check, this nucleus is among the largest in the collection, the second summer band is extremely narrow, and the usual incidental check in the second year is absent. If, however, the check at 23 rings is the first winter check, the nucleus falls at the lower end of the range of size and the usual check formed at the time of liberation is lacking; but the second summer band, with its incidental check, is typical of this collection. The latter explanation appears to be the more logical.

Figures 81, 78, and 75 illustrate scales of fish that matured in their second, third, and fourth years, respectively.

EXPERIMENT NO. 13.—SALMON (IDAHO) HATCHERY, AUGUST, 1924

Eggs from: Little White Salmon River, 1923.
Reared and marked at: Salmon (Idaho) hatchery.
Mark used: Removal of both ventral fins and the adipose fin.
Number marked: 50,000.
Liberated: In the Lemhi River on August 22, 1924.
Age: Approximately 11 months.

A sample of fingerlings preserved at the time the remainder were liberated averages 58.1 millimeters in length. The scales average $\frac{22.2}{120}$ millimeters in radius and have an average of 7.8 rings. The innermost three or four rings frequently are conspicuously finer and more closely spaced than those nearer the periphery. A typical scale from a fingerling of average size is shown in Figure 82. The size and scale data are tabulated in Table 32.

TABLE 32.—*Chinook-salmon fingerlings marked at Salmon (Idaho) hatchery August 22, 1924*

Length in mm. (mid-value of class)	Scale record: Number of rings					Scale record: Length of anterior radius, in mm. ×120 (mid-value of class)									Males	Females	Total
	6	7	8	9	10	15	17	19	21	23	25	27	29	31			
47.5		1				1										1	1
52.5	2		1			1			2						2	1	3
57.5	2	4	6	1	2		2		6	1	3	1	2		7	8	15
62.5		2	1	3	1			1	2		2		1	1	3	4	7
67.5		1		1					1					1	2		2
Total	4	8	8	5	3	2	2	1	11	1	5	1	3	2	14	14	28
Average	7.8					22.2									58.9	57.3	58.1

Two 3-year-olds and sixteen 4-year-olds were recovered from this marking. Others, which will mature in their fifth year, will return to spawn during the season of 1928. The detailed data concerning the recoveries appear in Table 33.

TABLE 33.—*Chinook salmon marked at Salmon (Idaho) hatchery during the fall of 1924, when approximately 11 months old, and recovered during the seasons of 1926 and 1927*

Date of capture	Place of capture	Scale record, first year: Number of rings: To first incidental check	Number of rings: Total stream growth	Number of rings: Intermediates	Length of anterior radius, in millimeters×120: To first incidental check	Length of anterior radius: Total stream growth	Length of anterior radius: Intermediates
1926:							
Aug. 10	Astoria cannery	7	15	9	22	41	74
During August	Cathlamet	7	16	0	27	46	0
1927:							
July 11	Ocean	7	19	0	21	51	0
July 25	do	7	15	7	21	36	56
July 28	do	5	14	5	15	39	55
Aug. 12	Ilwaco cannery	7	17	6	20	43	63
Aug. 13	Astoria cannery						
Aug. 16	Altoona cannery	9	18	0	17	51	0
Aug. 17	do						
Aug. 17	Chinook cannery	7	16	0	16	57	0
Aug. 17	Astoria cannery						
Aug. 20	do	7	18	0	27	63	0
Aug. 23	do	4	14	8	16	44	76
Aug. 24	Ilwaco cannery	9	16	6	23	45	64
Aug. 25	Astoria cannery	4	12	10	15	36	61
Aug. 25	do	6	16	6	17	45	67
Aug. 25	do	5	14	7	19	39	60
During September	do						

The chief purpose of this experiment was to furnish further information regarding the conditions that determine whether a given chinook will return at maturity as a part of the so-called spring or fall runs. Several experiments with the progeny of the spring run have shown that a change in the early environment does not alter the time of year at which the mature fish will start their spawning migration. This experiment furnishes similar evidence regarding chinooks of the fall run. In this case eggs from a run that enters the Columbia River during August and September and spawns at a distance of approximately 150 miles from the ocean were transferred to a station at approximately five times that distance from the ocean, where only a spring run of chinooks naturally spawns.

If these fish were to become adapted to the conditions under which they spent their early life, they would be expected to return to spawn in the headwaters where they were liberated. They would be expected to store in their bodies a quantity of fat sufficient to furnish energy for the long migration in fresh water. They would also be expected to leave the ocean early enough to allow time for the long migration before spawning time. None of these conditions seems to have prevailed. The time at which they passed through the lower Columbia on their spawning migration was no earlier than that of the Little White Salmon River chinooks that remained under natural conditions. As in the case of the latter, they appeared in the commercial catches of the lower Columbia during the last two-thirds of August. None of these fish returned to the Lemhi River, where they were liberated, nor did any enter the Little White Salmon River, where the eggs were taken. In fact, none were recovered as spawners. If any of them succeeded in passing the commercial-fishing district, we have no knowledge of where they went or whether they succeeded in reaching suitable spawning grounds. Records of the quantity of fat stored in the body of the fish were obtained for only four individuals. Although these records were merely approximations based upon the appearance of the flesh, they indicate that the quantity of fat was about average for fish of the fall run, which is much less than that of chinooks of the spring run.

The nuclei of the scales of the fish that were recovered in this experiment show very little variation. All have a central area of 12 to 19 rings (anterior radius $\frac{36}{120}$ to $\frac{63}{120}$ millimeters) of stream growth, which in most cases is surrounded by a band of from 5 to 10 rings of intermediates. (See Table 33.) The stream growth is broken by an incidental check, which incloses from 4 to 9 rings. A typical nucleus is shown in Figure 85. Scales from fish recovered during their third and fourth years are shown in Figures 83 and 84.

CONCLUSIONS

PERCENTAGE OF RETURN

The reported returns from these experiments range from 1 out of 50,000 liberated to 1 out of each 300 liberated. These figures have very little significance, however, because they represent not the total returns but an unknown and varying proportion of the total. As has been pointed out in the introduction, the authors and other employees of the Bureau of Fisheries who have assisted them with the collection of data have been unable to observe personally more than a small fraction of the fish taken from the Columbia during the time when these experiments were in progress. It has been necessary, therefore, to depend upon fishermen and cannery employees for most of the records of returning marked fish. The number of persons who have searched for marked fish and the conditions that affect the efficiency of their efforts have varied so greatly as to make it impossible even to estimate with any degree of accuracy what proportion of the total recaptures have been reported. The apparent failure of some of the early experiments probably was due in part to the fact that no inducement was offered to those finding marked salmon to report their captures. The first real interest on the part of fishermen and cannery employees came in 1920 as a result of the Oregon fish commission's offer of a reward of 50 cents for each record of the capture of a marked fish. An increase in the reward to $1 in 1922 caused a greater response from those connected with the industry, but even with this inducement a great deal of encouragement and publicity was required to get people started reporting their captures. The system of collecting data has been improved constantly, until during the last few years it is believed that most of the recoveries have been reported.

Another source of error is in connection with the escapement; that is, those fish that succeeded in evading the commercial gear and continued on to the spawning grounds. In the experiments involving fish from Little White Salmon River and Big White Salmon River, nearly all of the escaped fish probably returned to their parent tributary and were caught in the course of the egg-taking operations. This is not true, however, of experiments involving chinooks of the spring run, the greater part of which did not enter the tributary in which they were liberated but continued on up the Columbia. No record is available of those that succeeded in passing the upper limit of the commercial fishery.

In view of the many sources of error it is useless to assign the experiments to rank in the order of success; but so little is known of the results of either natural or artificial propagation that even an approximation of the general success of these experiments will be of interest. Experiment No. 12 was the most successful, the reported recoveries representing 0.45 per cent of the fingerlings liberated. Experiment No. 7, with the reported recoveries representing 0.39 per cent of the liberation, stands second. The records of this experiment are not accurate, in that they do not include the escapement, which continued on up the main Columbia beyond the commercial-fishing district. Third in success is experiment No. 6, with 0.24 per cent recovered. Here again the escapement is not represented. Experiment No. 8, with 0.18 per cent recovered, is fourth. In these four experiments the records from the commercial fishery are believed to represent the majority of the marked fish that were caught. The returns that have not come to our attention certainly would not add enough to make the totals more than 1 or 2 per cent of the liberation.

SUCCESS OF LONG AND SHORT PERIODS OF REARING

One of the most important problems confronting those interested in the artificial propagation of salmon is the determination of the length of time the fingerlings should be held at the hatchery in order to get the greatest return. Some hatchery men prefer to liberate their fingerlings very soon after the yolk sack is absorbed, whereas others are of the opinion that best results are obtained from much longer rearing.

Two of the more recent marking experiments were designed to provide an answer to this question. Each of these involved five lots of marked fingerlings, which were liberated at varying ages. None of the fish in these experiments have reached maturity to date and have not been discussed in this report; but even the comparatively unreliable records of return from the various experiments herein described give some indication of the relative success of the long and short periods of rearing.

For consideration thereof the experiments may be arranged in groups. Those involving the progeny of the spring run into the Willamette River may be taken as one group. This will include experiments Nos. 1, 2, 5, 6, 7, 9, 10, and 11. In this category the longer periods of rearing have given the best results, virtually no returns having been obtained from fingerlings liberated during midsummer. Experiments Nos. 3, 8, and 12, which involved fingerlings derived from the fall runs into the Little White Salmon and Big White Salmon Rivers, form another group. In this case better results have come from a very short period of rearing than from liberating during midsummer. The success of the longer periods of rearing has not been determined for this group. On the basis of what is known of the habits of these two classes of chinooks we might have expected such results as have been obtained. As fingerlings of the spring run normally spend the entire first year in fresh water, best returns would be expected from the longer period of rearing. This is especially true if the fingerlings are forced by unfavorable conditions to leave the river as soon as liberated. In the case of the fall chinooks, which normally leave the stream soon after the yolk sac is absorbed, the shorter period of rearing might be expected to be the most successful.

INTERPRETATION OF SCALES

It is hardly necessary now to argue for the validity of the methods developed for determining the age and other features of the life history of salmon by means of a microscopic examination of their scales. These methods already have given abundant proof of their value, especially through the careful and extensive researches of Gilbert on the sockeye salmon. It is important to note, however, that the scales of these fish of known history corroborate fully the theory that the arrangement of the concentric rings (circuli) provides an accurate record of the previous history.

Moreover, a study of the scales of these marked fish has aided materially to solve the many perplexing problems that have arisen in the interpretation of the scales of the chinook salmon, particularly in connection with the early history as recorded in the nuclear area of the scales. Frequent mention of these matters has been made in the discussion of the returns obtained from the various experiments. It has been shown, particularly, that the growth of the first year (the "nuclear" growth) is subject to numerous variations, which intergrade so completely that it is impossible to draw any sharp line of distinction. At one end of the series we have the typical stream nucleus, denoting that the first year was spent entirely in fresh water, and at the other end the typical ocean nucleus, denoting that the fish ran out to the ocean immediately after emerging from the gravel of the spawning beds and spent the entire first year there. The majority of the Columbia River chinooks, however, have neither typical stream nor typical ocean nuclei but apparently have spent part of the first year in fresh water and part in the ocean. The result has been a nuclear area composed in part of stream growth, with fine, narrow rings, and in part of ocean growth, with wide, strongly marked rings. This is amply explained by the habit of the young fish in the Columbia of migrating throughout the year and not, as in many other cases, during a definite and restricted season (Rich, 1920). According as the length of time in fresh water is short or long, the amount of stream growth is less or greater; in the first instance the nuclei approach the ocean type and in the second they approach the stream type, and the intergradations apparently are complete. For these nuclei, composed in part of stream and in part of ocean growth, we propose the term "composite nuclei."

A further complication arises as a result of the presence on many scales of "intermediate" growth—that formed during the life in the estuary while on the seaward migration. The rings formed at this time are "intermediate" in position and in appearance between the stream and ocean rings and vary so materially that it is difficult to distinguish them with certainty, sometimes from the stream rings and at other times from the ocean rings. Nuclei composed only of stream rings and intermediates blend indistinguishably with certain types of composite nuclei.

As a result of these variations the first year's growth on the scales of Columbia River chinooks frequently is very confusing and presents, in extreme cases, as many as four or five checks, each of which might easily be mistaken for an annulus by an inexperienced observer. As a matter of fact, however, with experience this confusion is eliminated almost completely, at least in so far as the determination of age is concerned. It may never be possible to interpret correctly the details of history recorded in a complicated composite type of nucleus, but that is relatively immaterial for practical purposes as long as there is no error in age determination, and our experience with the scales of fish of known history has provided sufficient information so that such errors may be eliminated almost entirely.

TIME OF ENTERING FRESH WATER

Perhaps the most important contribution which these experiments have made to our knowledge of the biology of the salmon is that relating to the hereditary character of the factors that determine the time of year when the adults enter fresh water and begin their migration to the spawning grounds. The great practical value of determining beyond question whether this is strictly an hereditary character or not is associated with the fact that the early run of chinooks (spring chinooks) is of much better quality and is, consequently, of much greater value to the fishery than the later run (fall chinooks). The spring fish are sought most earnestly, and the maintenance of the spring run has been the chief concern of those interested in practical conservation. This question has been asked frequently: Is it necessary to breed from fish of the spring run in order to produce spring fish, or is it possible, by proper handling of the progeny of the fall run, to produce fish that will return as adults to fresh water early in the spring?

The evidence of these marking experiments shows beyond question the heritable quality of this character. In 8 of the 13 experiments the young fish were derived from eggs taken either on the Willamette River or its tributaries, the McKenzie and the

Santiam, where the spawning runs are composed exclusively of salmon that enter the Columbia early in the spring. The fish were reared and liberated on tributaries of the Columbia that normally are inhabited by fall-running salmon only, but the marked fish returned to the river as adults during the spring. Of the 390 adults that have been recovered from these experiments, 365 were taken before June 1, and there is some evidence that all but two of those taken after that date had entered the river some time before they were caught. These fish not only were subjected to an unnatural environment during their early lives but also were liberated at various ages, ranging from 7 to 18 months. Neither of these conditions seems to have changed the time of their return to fresh water.

A converse experiment (experiment No. 13), in which the progeny of fall chinooks were reared and liberated under conditions normal to spring chinooks, has given similar results. All of 16 mature fish recovered from this experiment started their spawning migration in the fall.

Another interesting feature of the spawning migration demonstrated by these experiments is the comparatively short time during which the fish from each tributary leave the ocean. As has been pointed out, chinooks that spawn in the Willamette, McKenzie, and Santiam Rivers with but few exceptions enter the Columbia River before the 1st of June. The fish that developed from eggs taken on the Little White Salmon and Big White Salmon Rivers were found to be passing though the commercial fishing district in August and September. All the fish in experiment No. 4, which were introduced from the Umpqua River, were caught during a period of less than a month, beginning May 13. It seems fairly clear that the fish belonging to any given tributary enter the main river from the ocean at a definite and characteristic time. This is an important point, as it gives additional evidence of the existence of local races in the tributary streams and shows that each race is present in the main river only a comparatively short time. Knowing, further, that each race is self-propagating, it becomes perfectly apparent that all parts of the salmon run in the Columbia River must be given adequate protection if the run as a whole is to be maintained. The protection of only one or two portions of the run will not be sufficient, inasmuch as certain races will be left entirely unprotected.

AGE AT MATURITY

The relation between the reported returns and the actual returns has varied so greatly as to make only a general consideration of the age at maturity justifiable. For this purpose the experiments again may be divided into two classes—those involving spring chinooks from eggs taken on the Willamette River and its tributaries and those involving salmon from the Big White Salmon and Little White Salmon Rivers, which enter fresh water during the latter part of the season.

Mature spring chinooks that were in their third to sixth years have been recovered. In every case the greatest number matured in their fifth year. The 6-year-olds have always exceeded the 4-year-olds, and the 3-year-olds are represented by only two recoveries.

The data relating to the fall chinooks are very inadequate, but they indicate that the fourth and fifth years are the prevailing ages at maturity. On the whole, the fish of this class mature one year younger than the spring chinooks. A few males mature in their second year, and a significant number of both males and females return in their third. No 6-year-olds have been recovered as yet. From the standpoint of growth, however, there is very little difference in the time of maturing; that is, the two classes mature after approximately equal intervals of rapid growth. The rate of growth in fresh water is so low, in comparison to that in the ocean, that a year of fresh-water growth is insignificant in comparison to two or more years of ocean growth. The size attained, therefore, is proportional to the length of time spent in the ocean. The fall chinooks normally enter the ocean early in their first year, whereas the spring chinooks remain in the streams for an entire year before going to the ocean. In addition, the former remain in the ocean for three or four months of the rapid-growing season of the year in which they mature, whereas the spring chinooks start their spawning migration so early in the year that they make little or no growth during the last season. As a result of the earlier seaward migration and later spawning migration the fall fish spend approximately one full growing season more in the ocean than do the spring chinooks of the same age and have spent about the same time in the ocean as spring chinooks one year older. The relation between ocean residence and time of maturing is therefore about the same for the two classes.

HOMING INSTINCT

The so-called "parent-stream" theory or "home-stream" theory is now substantiated by such a wealth of evidence that it seems nearly superfluous to state that none of the salmon marked on the Columbia have been recovered in any other river system.

The records of marked Columbia River chinooks taken off the coast of British Columbia and southeastern Alaska show something of the wide oceanic migrations of these fish and are in agreement with the results of the tagging experiments. The tagging experiments in British Columbia in 1925 (Williamson, 1927) showed conclusively that a large percentage of the spring (chinook) salmon caught by troll in these northern waters originated in the Columbia River. In view of this wide range in the ocean, the fact that no marked fish were reported in any other stream than the Columbia indicates clearly the force and discrimination of the homing instinct as it affects the return to the home stream.

It is evident, furthermore, that under normal circumstances salmon predominantly return to spawn in the tributary in which they spent the early part of their lives, although they have been shown not to do so in some instances. It is important to note, in this connection, that the transplanted fish have shown no tendency to return to the stream from which the eggs were taken. The homing instinct is not a purely hereditary matter, therefore, but is determined largely by the early environment. These experiments have shown that under certain circumstances the return to the home tributary is by no means invariable and that the major part of a run may fail to return to the tributary in which it was reared and liberated. Experiment No. 7 gave the most conclusive evidence on this point. Nearly half of the 252 adults recovered from this experiment were taken in the Columbia River several miles above the mouth of Tanner Creek, where the fingerlings were liberated. As only three were taken in Tanner Creek, it is apparent that the majority chose not to enter that tributary and continued up the main river. Six other experiments, which, like experiment No. 7, involved spring chinooks that were liberated in tributaries other than the one in which the eggs from which they developed were taken, have given similar results. From these experiments only four returns to the place of liberation have been reported. It may be concluded tentatively that, in part at least, some element in the complex known as the homing instinct is hereditary, so that the instinct does not function perfectly in the case of transplanted fish. It seems possible that this might be a determining factor in the establishment or rehabilitation of salmon runs by means of artificial propagation.

The experiments with chinooks of the fall run have resulted in much greater returns to the place of liberation. Ninety-nine of the 504 recoveries recorded for the experiments with salmon of this group were caught at the hatcheries at which the fingerlings were reared and liberated. Five of these fish entered near-by tributaries, but no others are definitely known to have strayed, the remainder having been taken either in the ocean or in the Columbia River below the mouth of the home tributary. The most striking instance of this return to the home stream is that to Spring Creek. This stream is so extremely small that it is difficult to see how the salmon could find it at all, and yet 82 of the fish marked here were recaptured here as adults, while only 4 were taken in other spawning tributaries. This is the most definite evidence known to us of the validity of the home-stream theory as applied to tributaries.

The reason for this difference in the homing of the spring and fall chinooks is not shown conclusively by the data at hand. It seems, however, that the homing instinct is disturbed to some extent by transplanting the eggs from one tributary to another, the disturbance being greatest when the eggs are transferred to tributaries that offer least favorable conditions for the returning mature fish. The marked spring chinooks in every experiment were transplanted in tributaries that could not support a spring run. The fall chinooks, on the other hand, were liberated in either their native stream or another that offered favorable conditions for a fall run. While by no means conclusive, the evidence indicates that the transplanting of eggs from one tributary to another has an unfavorable influence on the homing instinct of the resulting fish. This is a matter of considerable importance in fish-cultural operations, particularly in cases where attempts are made to rehabilitate runs by transplantation from other streams. So far as these experiments go, they indicate that a better practice would be to stock each stream with eggs native to that stream.

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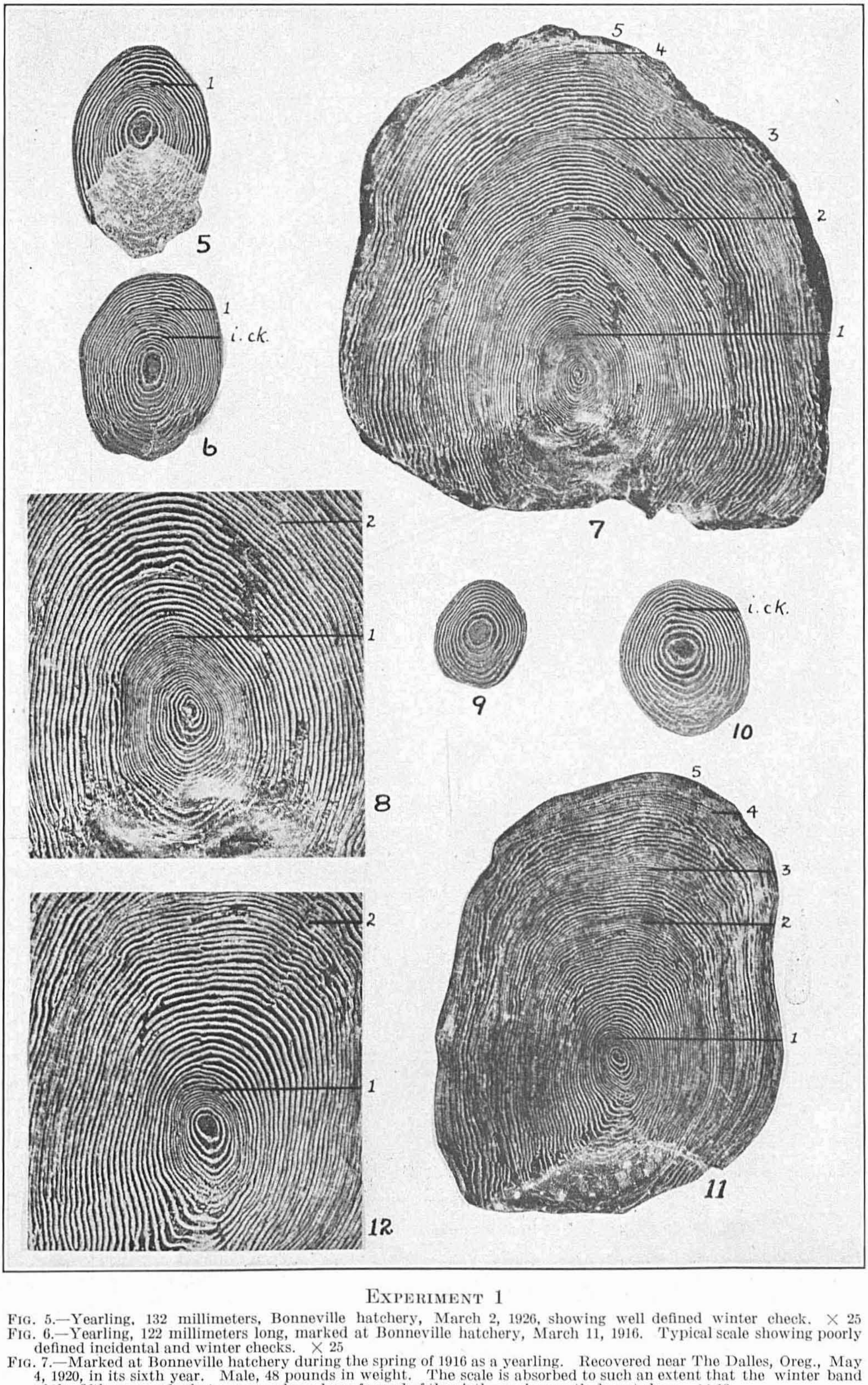
EXPLANATION OF FIGURES

The magnifications indicated in all of the legends are only approximate. Abbreviations used in the figures: *i. ck.* indicates incidental check; *st. gr.*, stream growth; *int.*, intermediate growth; *1*, *2*, *3*, etc., the age of the fish in years when the corresponding points on the scales were marginal.



EXPERIMENT 1

FIG. 5.—Yearling, 132 millimeters, Bonneville hatchery, March 2, 1926, showing well defined winter check. × 25

FIG. 6.—Yearling, 122 millimeters long, marked at Bonneville hatchery, March 11, 1916. Typical scale showing poorly defined incidental and winter checks. × 25

FIG. 7.—Marked at Bonneville hatchery during the spring of 1916 as a yearling. Recovered near The Dalles, Oreg., May 4, 1920, in its sixth year. Male, 48 pounds in weight. The scale is absorbed to such an extent that the winter band of the fifth year and whatever may have been formed of the sixth year's growth do not show. × 13

FIG. 8.—Nuclear region of the scale shown in Figure 7. × 25

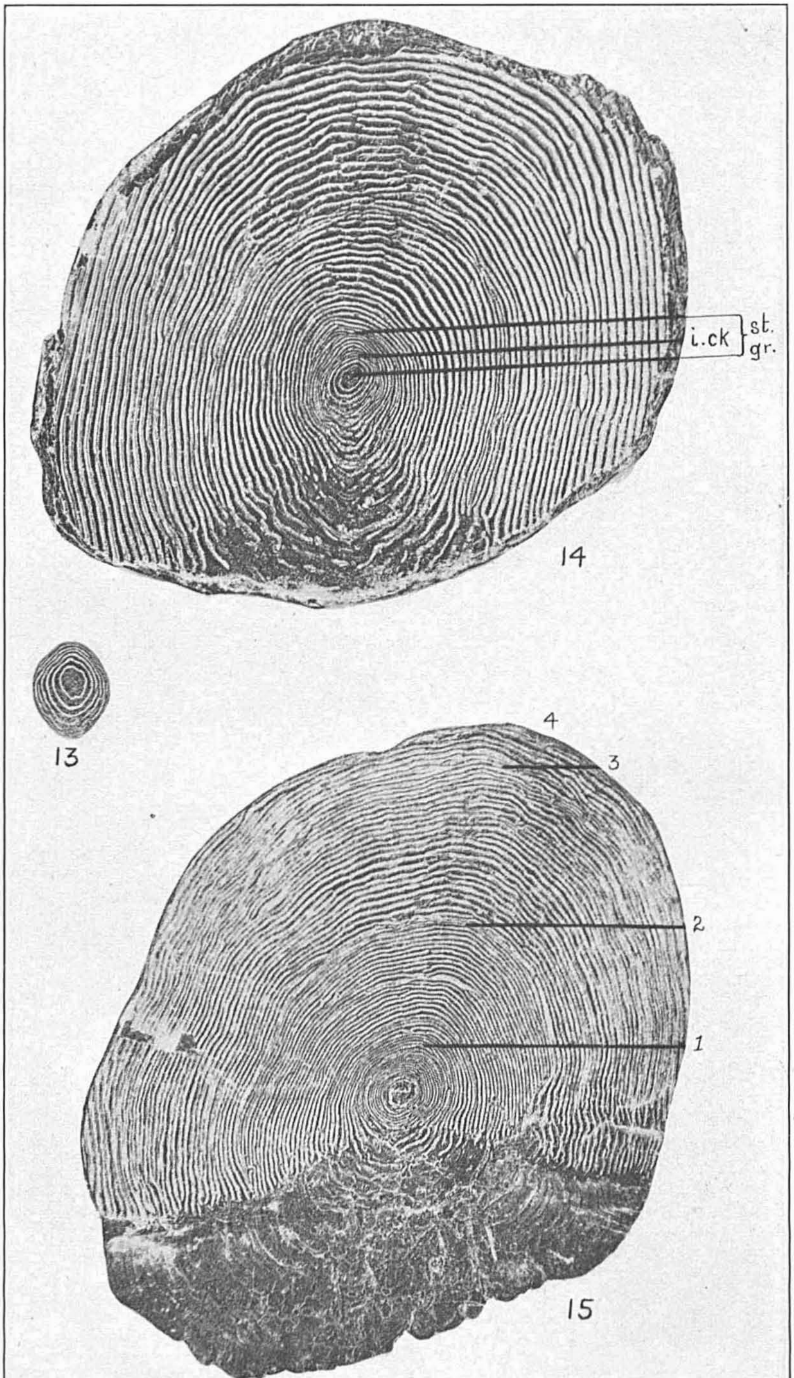
EXPERIMENT 2

FIG. 9.—Fingerling, 81 milimeters, Klaskanine hatchery, July 16, 1916. A typical scale with no incidental check. × 25

FIG. 10.—Fingerling, 94 millimeters long, marked at Klaskanine hatchery, July 16, 1916, showing incidental check. × 25

FIG. 11.—Marked at Klaskanine hatchery during the summer of 1916, when approximately 11 months old. Recovered at Astoria, Oreg., between May 25 and June 21, 1920, in its fifth year. This scale was taken from the skin attached to the scar of the dorsal fin, which accounts for its small size. × 13

FIG. 12.—Nuclear region of scale shown in Figure 11. × 25

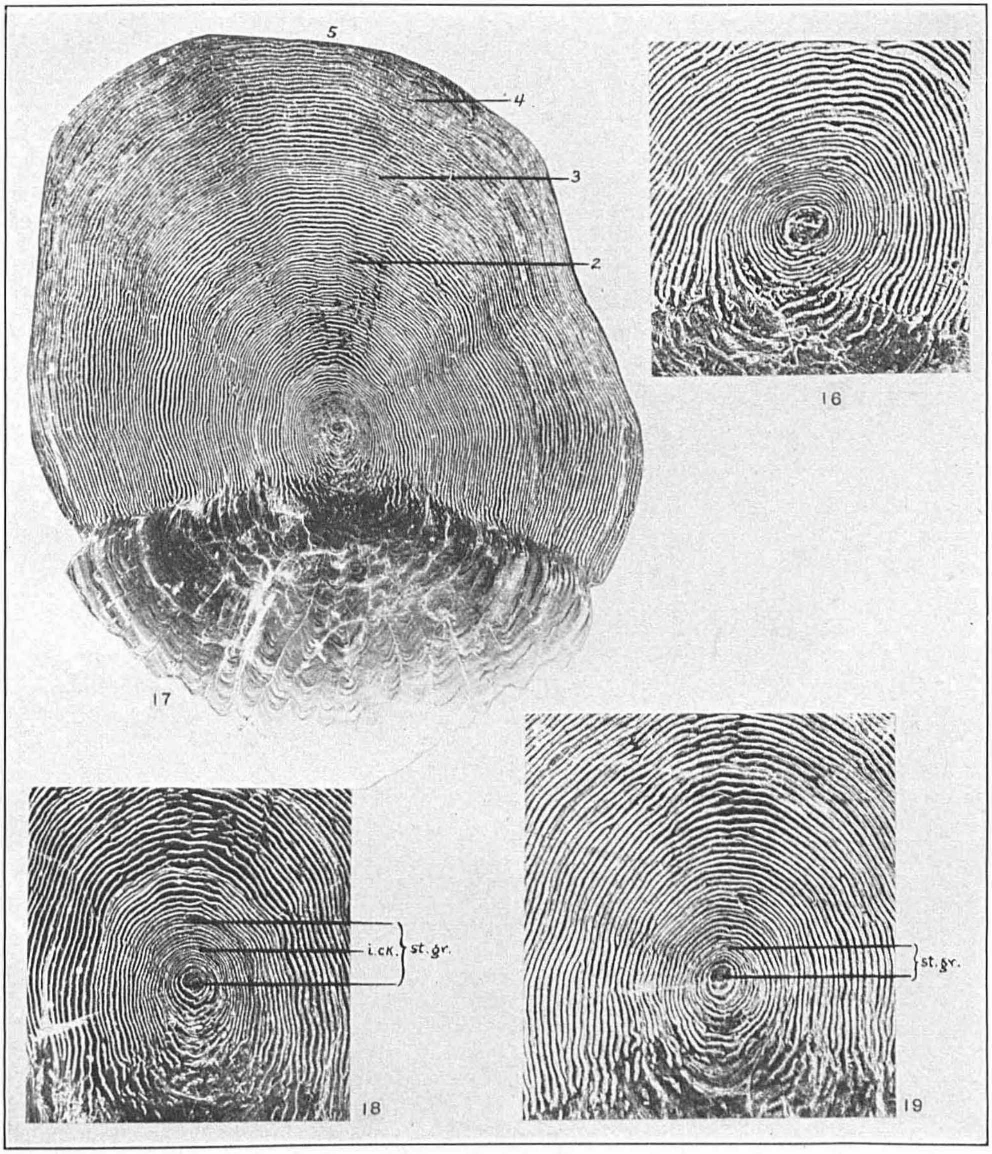


EXPERIMENT 3

FIG. 13.—Fingerling, 60 millimeters long, marked at Little White Salmon River hatchery July 28, 1916. × 25

FIG. 14.—Marked at Little White Salmon River hatchery during the summer of 1916 when about 10 months old. Recovered as a spawning fish in the Little White Salmon River during the fall of 1918, in its third year. Male, 19.5 inches long. A considerable portion of the third year's growth has been lost by absorption. × 25

FIG. 15.—Marked at Little White Salmon River hatchery during the summer of 1916, when about 10 months old. Recovered at Astoria, Oreg., August 25, 1919, in its fourth year. Female. No data as to size. × 13



EXPERIMENT 3

FIG. 16.—Nuclear region of scale shown in Figure 15. × 25

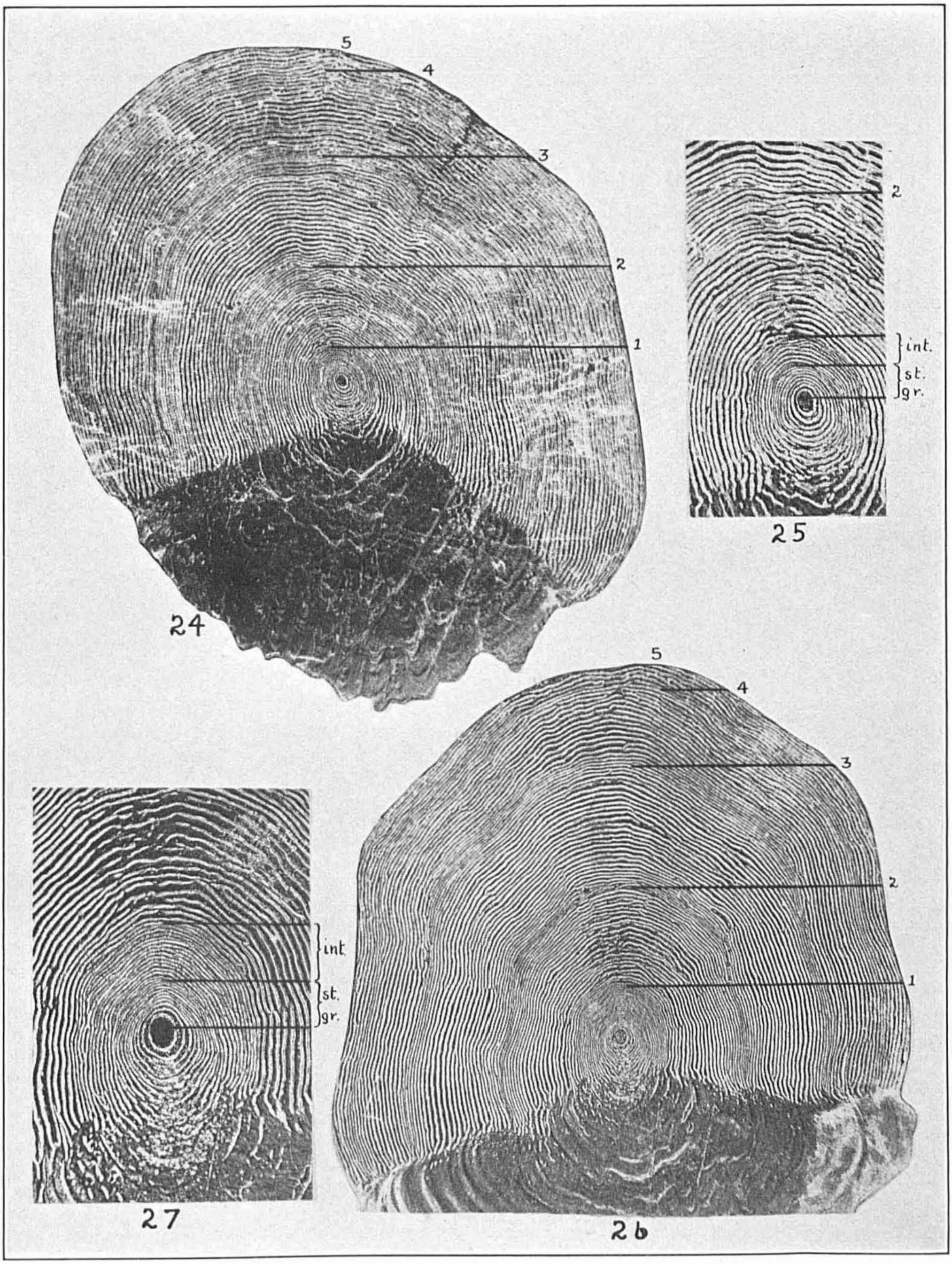
FIG. 17.—Marked at Little White Salmon River hatchery during the summer of 1916, when about 10 months old. Recovered by purse seine off the mouth of the Columbia River, August 21, 1920, in its fifth year. Female, 39 inches long and weighing 27 pounds. × 13

FIG. 18.—Nuclear region of scale shown in Figure 17. × 25

FIG. 19.—Marked at Little White Salmon River hatchery during the summer of 1916, when about 10 months old. Recovered in the Little White Salmon River, September 27, 1920, in its fifth year. Female, 36.75 inches in length. × 25

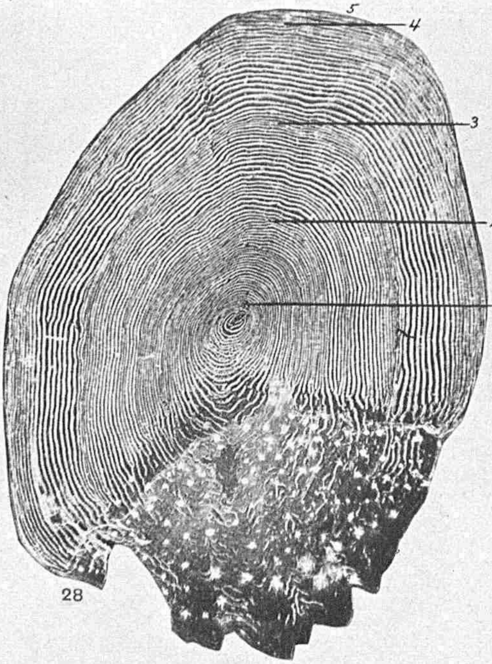
Experiment 4

Fig. 20.—Fingerling, 47 millimeters long, marked at Bonneville hatchery, September 13, 1916. Smallest fish in the collection. × 25
Fig. 21.—Fingerling, 69 millimeters long, marked at Bonneville hatchery, September 13, 1916. Typical scale showing incidental check. × 25
Fig. 22.—Marked at Bonneville hatchery during September, 1916, when approximately 12 months old. Recovered at Astoria, Oreg., May 21, 1920, in its fifth year. Female, 31 inches long and weighing 18 pounds. × 13
Fig. 23.—Nuclear region of scale shown in Figure 22. A poorly differentiated nucleus. × 25



EXPERIMENT 4

FIG. 24.—Marked at Bonneville hatchery during September, 1916, when approximately 12 months old. Recovered at Wallace Island, June 5, 1920, in its fifth year. Male, 26.25 inches long and weighing 28.25 pounds. × 13
FIG. 25.—Nuclear region of scale shown in Figure 24. A more clearly differentiated nucleus. × 25
FIG. 26.—Marked at Bonneville hatchery during September, 1916, when approximately 12 months old. Recovered at Astoria, Oreg., May 25, 1920, in its fifth year. Female, 35.5 inches long and weighing 20 pounds. × 13
FIG. 27.—Nuclear region of scale shown in Figure 26, showing wide band of intermediate growth. × 25



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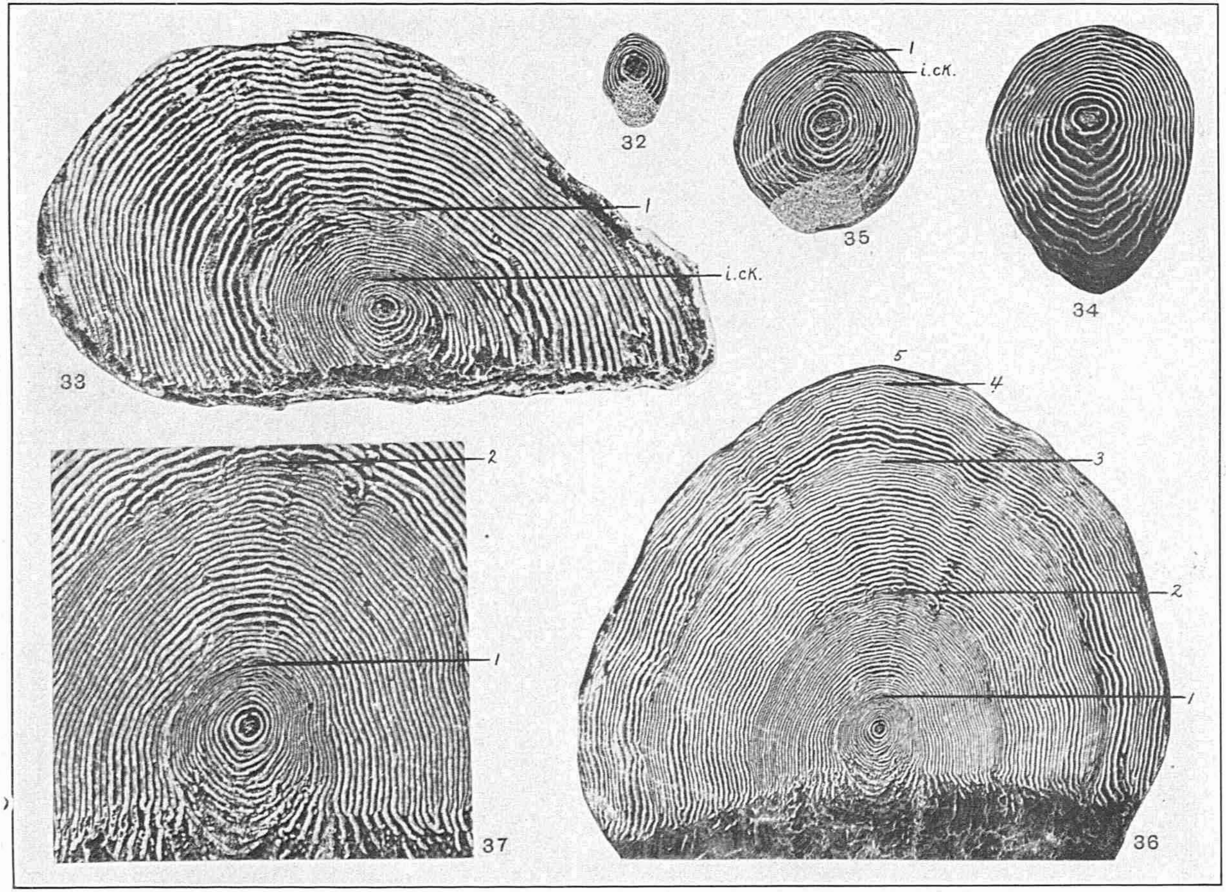
Experiment 4

Fig. 28.—Marked at Bonneville hatchery during September, 1916, when approximately 12 months old. Recovered at Astoria, Oreg., May 18, 1920, in its fifth year. Female, either 16 or 21 pounds in weight. This scale was taken from the skin attached to the scar of the dorsal fin, which accounts for its small size. This is the most confusing scale in the entire collection from marked chinook salmon. In the absence of knowledge of the early history of the fish, the check marked 2 might have been mistaken for the first winter check. × 13

Fig. 29.—Nuclear region of scale shown in Figure 26. × 25

Fig. 30.—Marked at Bonneville hatchery during September, 1916, when approximately 12 months old. Recovered near Altoona, Wash., June 5, 1920, in its fifth year. Female, 32 inches long and weighing 21 pounds, showing nucleus lacking incidental check and having only two or three rings of intermediate growth. × 25

Fig. 31.—Marked at Bonneville hatchery during September, 1916, when approximately 12 months old. Recovered at Ilwaco, Wash., May 17, 1920, in its fifth year. Female, 35.4 inches long and weighing 21.5 pounds, showing a very poorly differentiated nucleus. × 25



EXPERIMENT 5

FIG. 32.—Fingerling, 55 millimeters in length, marked at Little White Salmon hatchery, July 18, 1917. × 25

FIG. 33.—Marked at Little White Salmon River hatchery during the summer of 1917, when approximately 10 months old. Recovered as a spawning fish in the Little White Salmon River, October 12, 1920, in its fourth year. Female, 27 inches long and weighing 10.5 pounds. Record of all but the first 2 years' growth has been eaten away by absorption of the scale. × 25

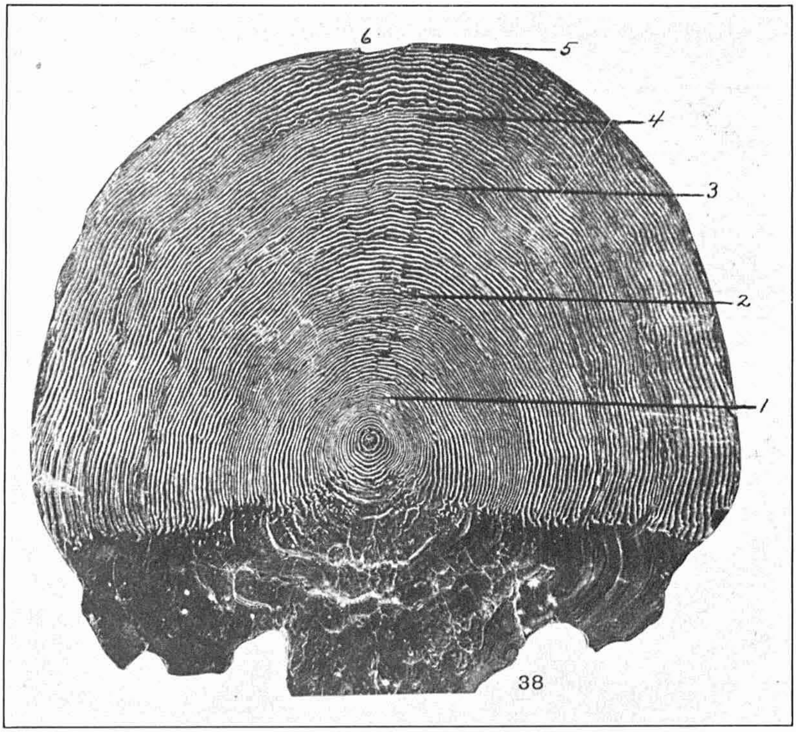
EXPERIMENT 6

FIG. 34.—Fingerling, 145 millimeters, marked at Herman Creek hatchery March, 1920, showing absence of incidental and winter checks. × 25

FIG. 35.—Fingerling, 126 millimeters in length, marked at Herman Creek hatchery during March, 1920, showing incidental check, winter check, and three rings of rapid growth of the second year. × 25

FIG. 36.—Marked at Herman Creek hatchery during the spring of 1920, when approximately 18 months old. Recovered at Ellsworth, Wash., May 20, 1923, in its fifth year. Male, 36 inches long and weighing 15 pounds. × 13

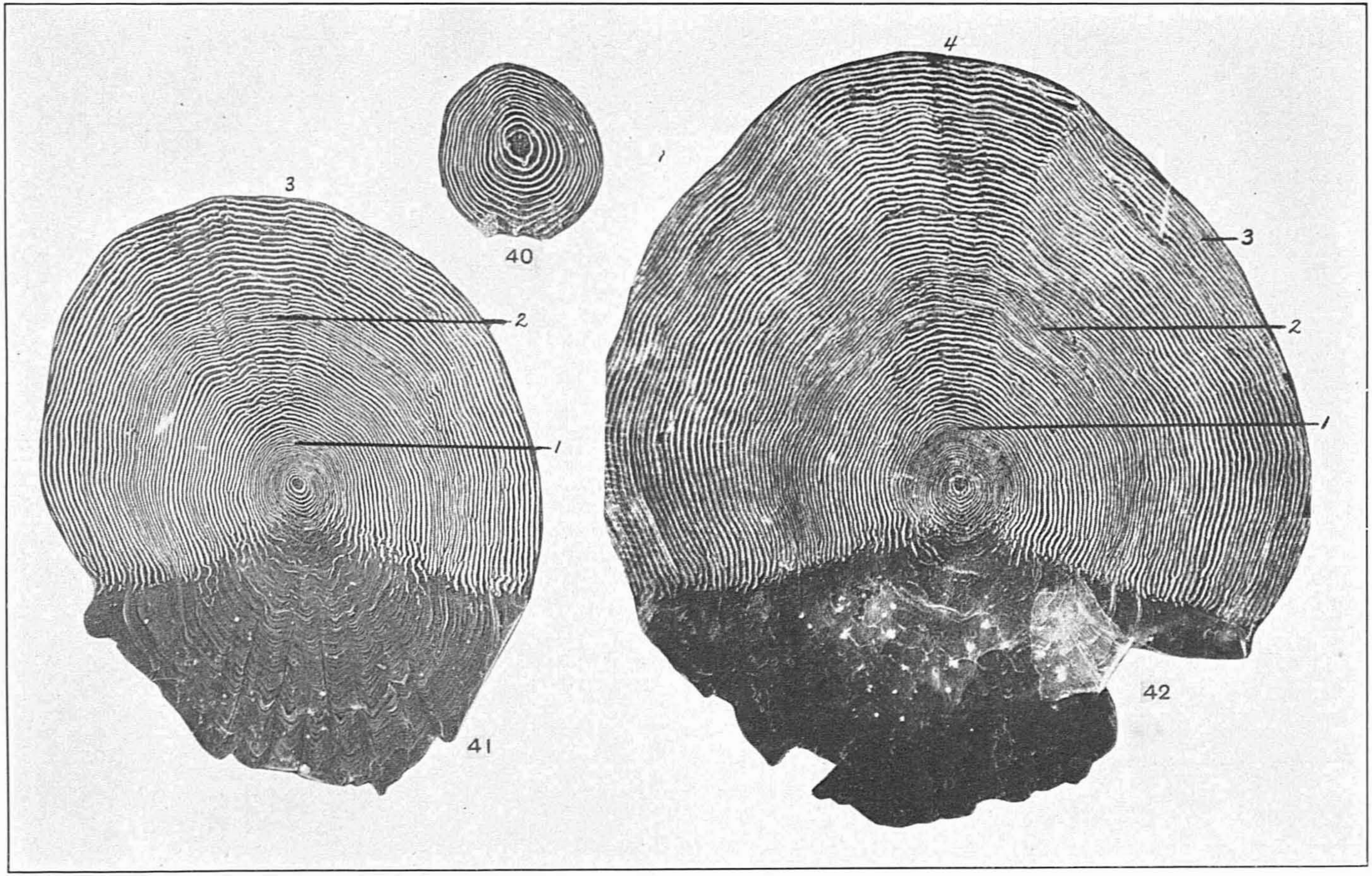
FIG. 37.—Nuclear region of scale shown in Figure 36. × 25



EXPERIMENT 6

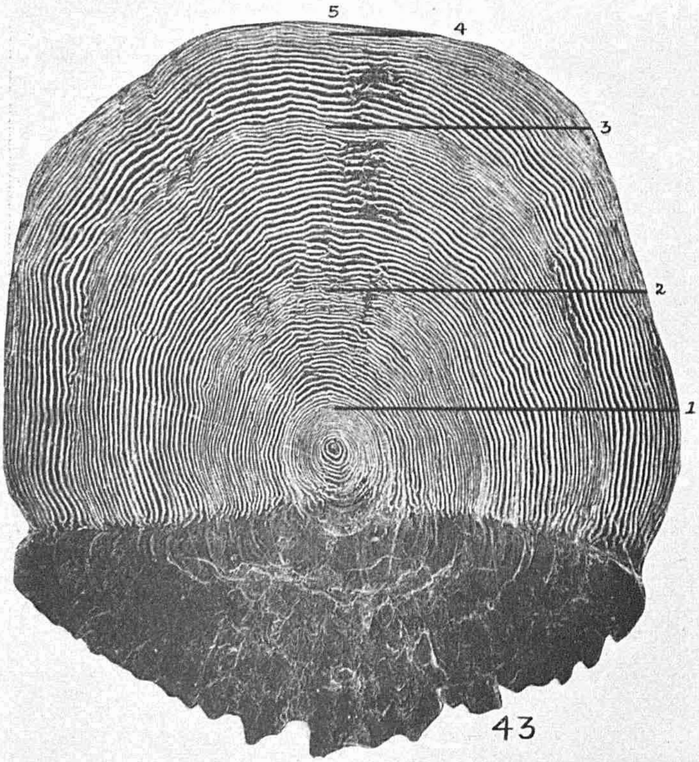
FIG. 38.—Marked at Herman Creek hatchery during the spring of 1920 when approximately 18 months old. Recovered at Clatskanie, Oreg., May 7, 1924, in its sixth year. Length, 38 inches; weight, 22 pounds. × 13

FIG. 39.—Nuclear region of scale shown in Figure 38. ×25



EXPERIMENT 7

FIG. 40.—Fingerling 102 millimeters long marked at Bonneville hatchery October 14, 1920. × 25
FIG. 41.—Marked at Bonneville hatchery during October, 1920, when approximately 13 months old. Recovered by troll in the ocean on August 9, 1922, in its third year. Male, 23.25 inches long and weighing 5.5 pounds. × 13
FIG. 42.—Marked at Bonneville hatchery during October, 1920, when approximately 13 months old. Recovered in the lower Columbia, May 9, 1923, in its fourth year. Female, 32 inches long and weighing 18 pounds. × 13



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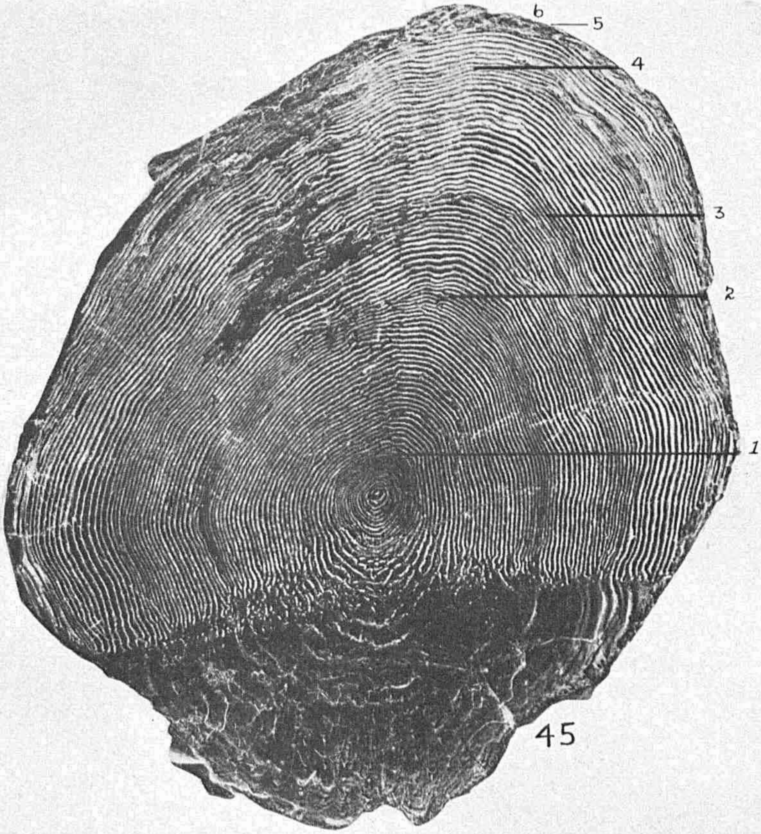
EXPERIMENT 7

FIG. 43.—Marked at Bonneville hatchery during October, 1920, when approximately 13 months old. Recovered at Westport, Oreg., May 1, 1924, in its fifth year. Female, 38 inches long and weighing 22 pounds. ×13

FIG. 44.—Nuclear region of scale shown in Figure 43, showing nucleus of average size. ×25



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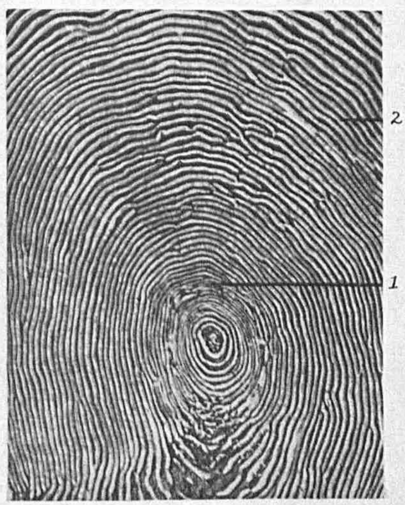

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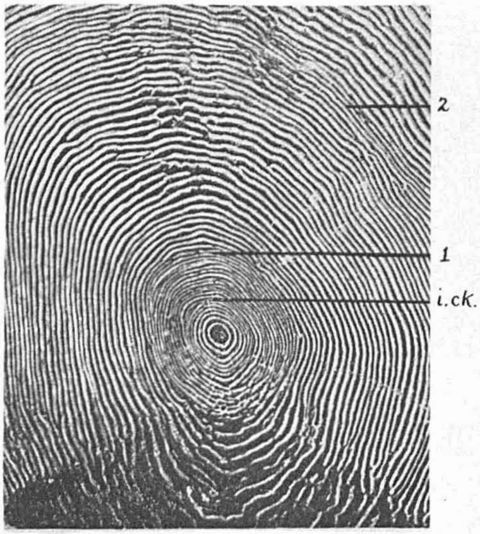
Experiment 7

Fig. 45.—Marked at Bonneville hatchery during October, 1920, when approximately 13 months old. Recovered near Bonneville, Oreg., May 7, 1925, in its sixth year. Male, 40.5 inches long and weighing 27 pounds. The last half year's growth has been removed by absorption of the scale. × 13

Fig. 46.—Marked at Bonneville hatchery during October, 1920, when approximately 13 months old. Recovered at Cascade Locks, Oreg., May 8, 1924, in its fifth year. Female, 32.5 inches long and weighing 13 pounds, showing an extremely large nucleus. × 25

Fig. 47.—Marked at Bonneville hatchery during October, 1920, when approximately 13 months old. Recovered at Corbett, Oreg., May 6, 1924, in its fifth year. Female, 34.5 inches long and weighing 18 pounds, showing an extremely small nucleus. × 25



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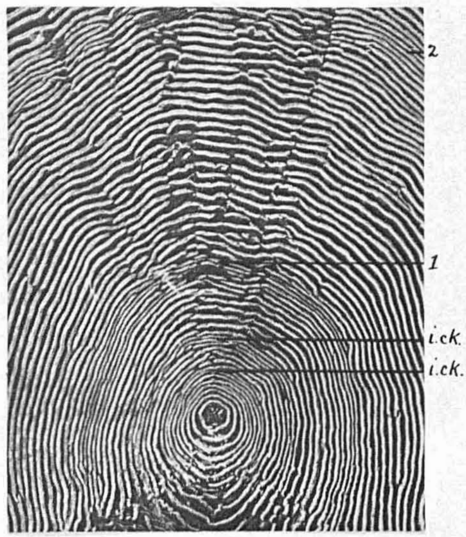

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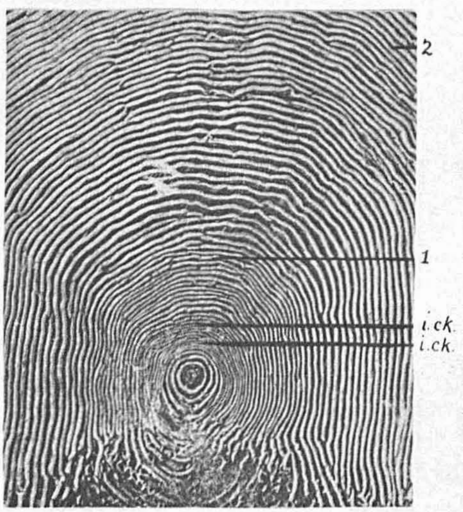

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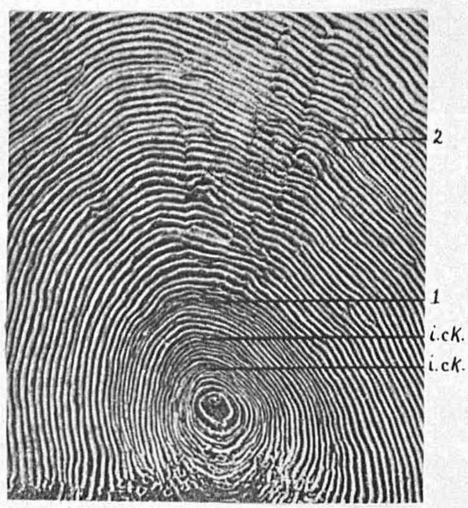

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Experiment 8

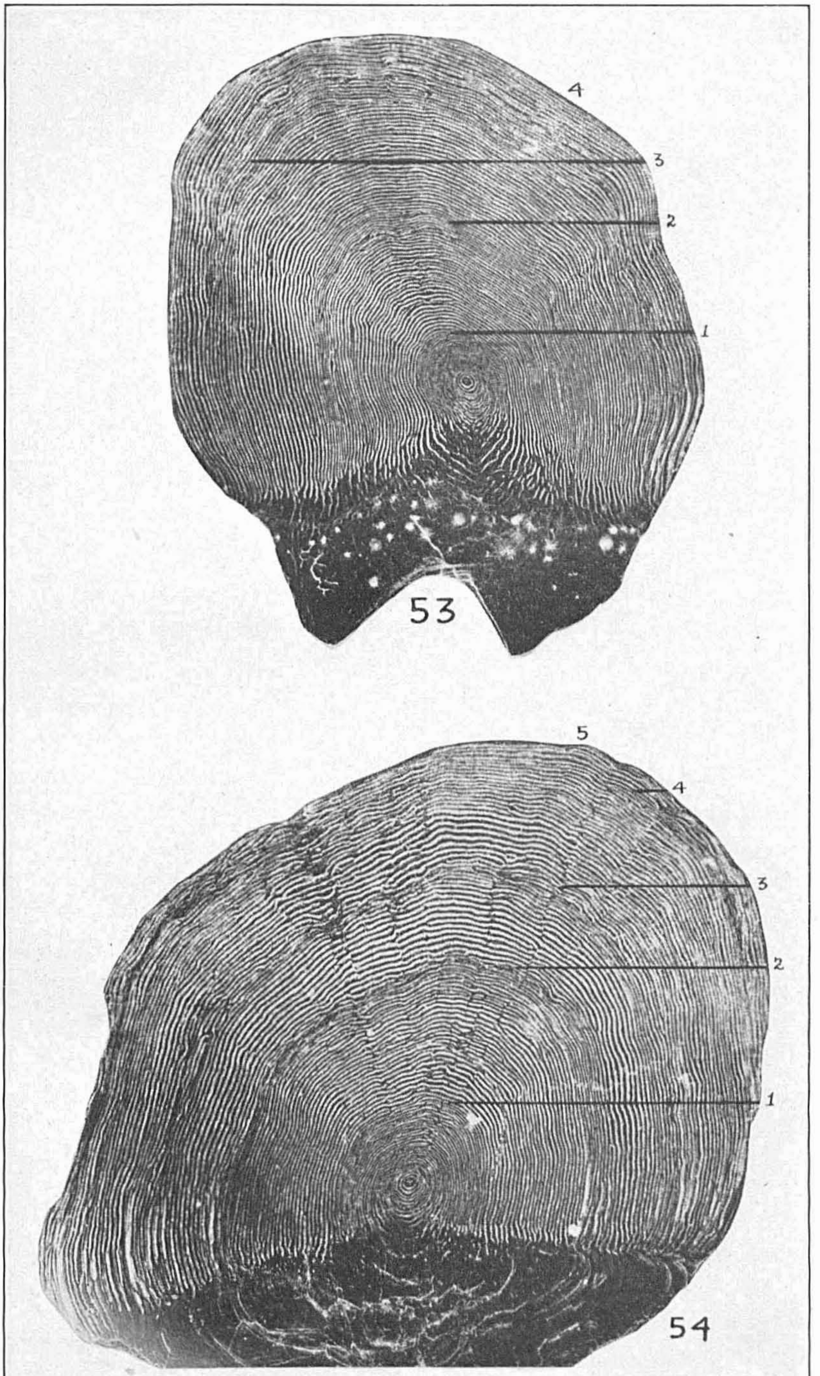
Fig. 48.—Fingerling, 50 millimeters, marked at Little White Salmon River hatchery summer of 1920. × 25

Fig. 49.—Marked at Little White Salmon River hatchery summer of 1920, when approximately 10 months old. Recovered at Astoria, Oreg., August 22, 1923, in its fourth year. Male, 37 inches long and weighing 25 pounds. × 25

Fig. 50.—Marked at Little White Salmon River hatchery summer of 1920, when approximately 10 months old. Recovered at Sand Island, August 14, 1923, in its fourth year. Male, 45.5 inches long and weighing 42 pounds. × 25

Fig. 51.—Marked at Little White Salmon River hatchery summer of 1920, when approximately 10 months old. Recovered at Sand Island, August 23, 1923, in its fourth year. Female, 39 inches long and weighing 23 pounds. × 25

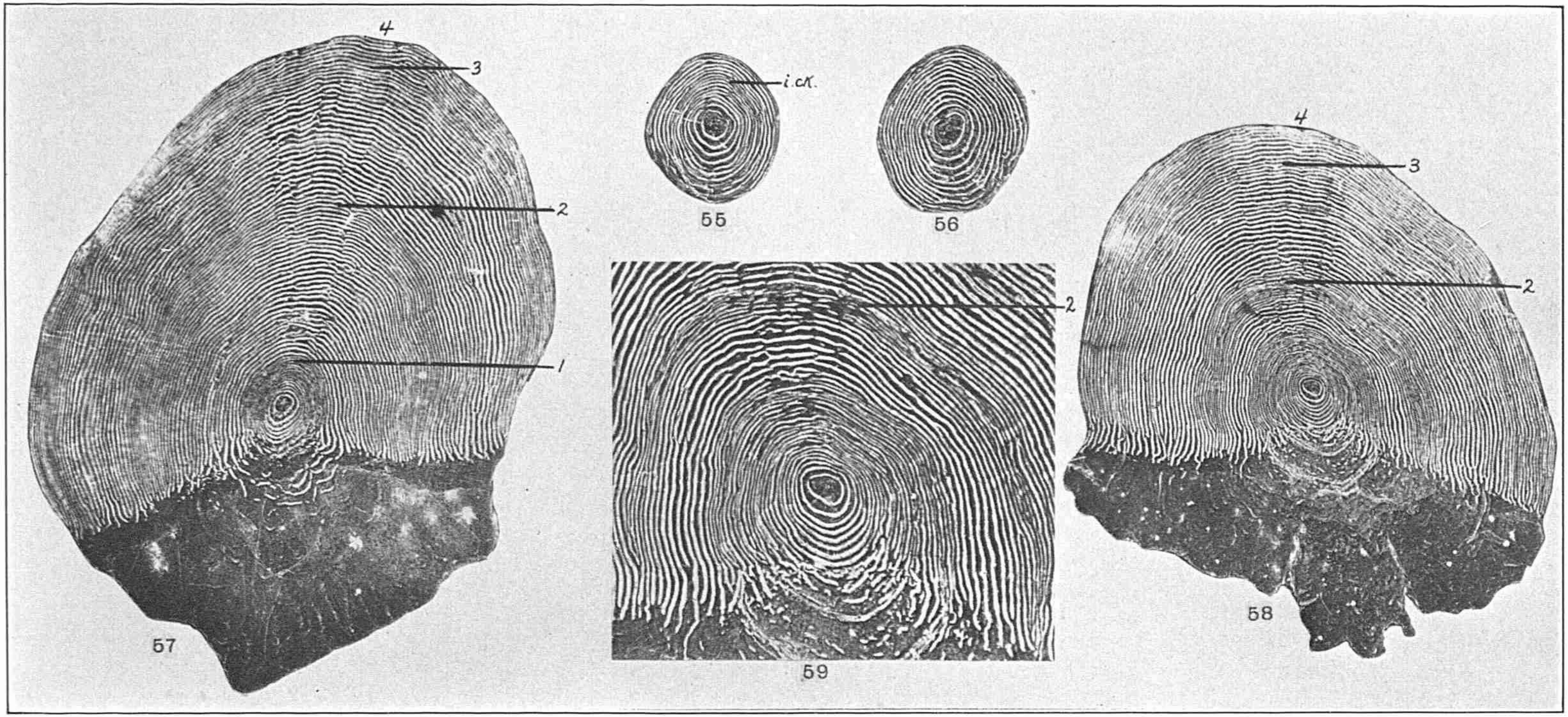
Fig. 52.—Marked at Little White Salmon River hatchery summer of 1920, when approximately 10 months old. Recovered in the lower Columbia, August 20, 1923, in its fourth year. Female, 26 inches long and weighing 10 pounds. × 25



Experiment 8

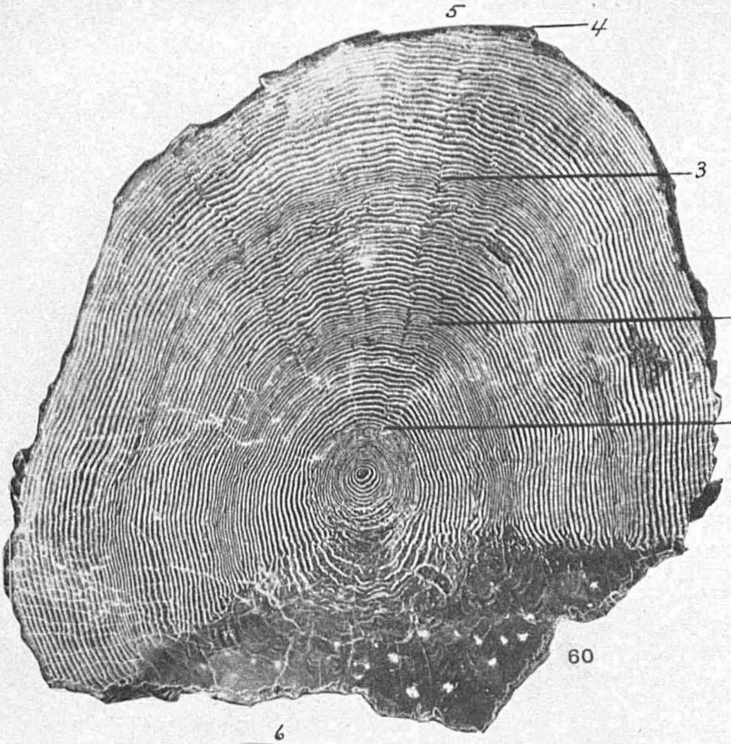
Fig. 53.—Marked at Little White Salmon River hatchery during the summer of 1920, when approximately 10 months old. Recovered in the lower Columbia, August 17, 1923, in its fourth year. Female, 39 inches long and weighing 24 pounds. × 13

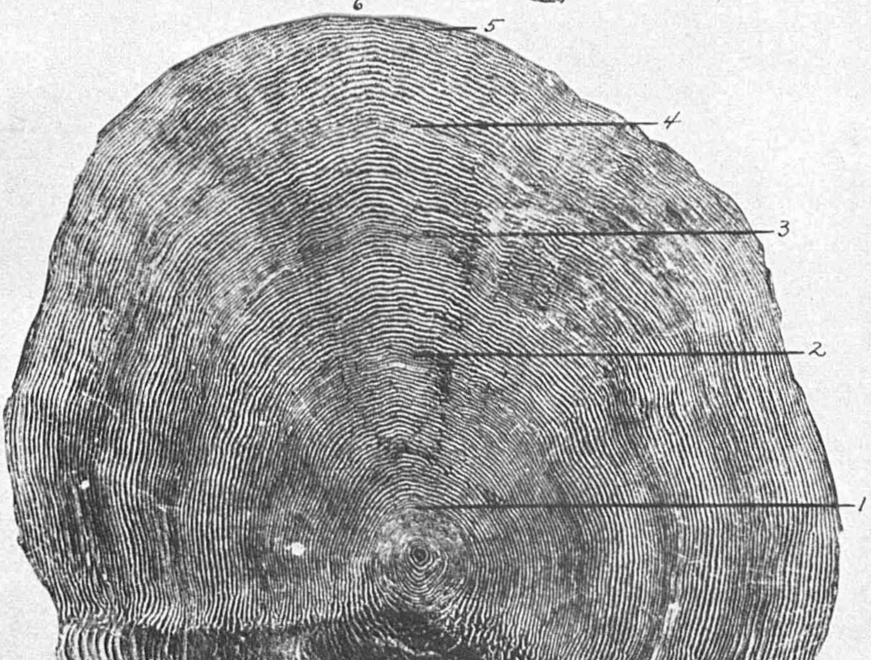
Fig. 54.—Marked at Little White Salmon River hatchery during the summer of 1920, when approximately 10 months old. Recovered at Sand Island, August 10, 1924, in its fifth year. Male, 33.9 inches long and weighing 29 pounds. × 13



Experiment 9

Fig. 55.—Fingerling, 82 millimeters long, marked at Bonneville hatchery, August 24, 1921, showing a distinct incidental check. × 25
Fig. 56.—Fingerling, 106 millimeters long, marked at Bonneville hatchery, August 24, 1921, showing absence of incidental check. × 25
Fig. 57.—Marked at Bonneville hatchery during the fall of 1921, when approximately 13 months old. Recovered at Warrendale, Oreg., May 6, 1924, in its fourth year. Male, 25.75 inches long and weighing 13 pounds. × 13
Fig. 58.—Marked at Bonneville hatchery during the fall of 1921, when approximately 13 months old. Recovered at Astoria, Oreg., May 17, 1924, in its fourth year. The growth proportions in this scale are very unusual. (See p. 244.) × 13
Fig. 59.—Nuclear region of scale shown in Figure 58. × 25

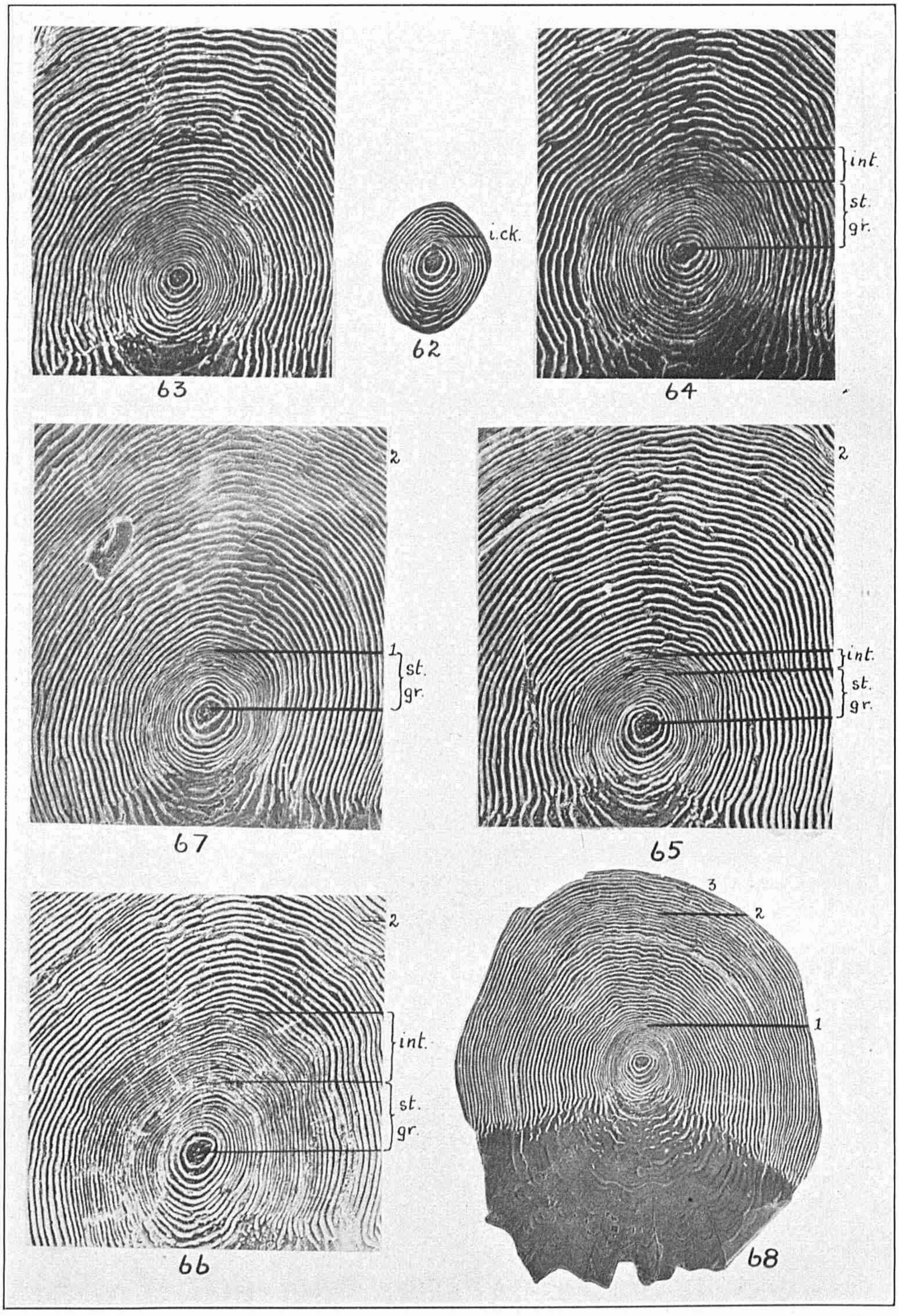




EXPERIMENT 9

FIG. 60.—Marked at Bonneville hatchery during the fall of 1921, when approximately 13 months old. Recovered at Dahlia, Wash., May 8, 1925, in its fifth year. Male, 41 inches long and weighing 29 pounds. The fourth winter band and whatever was formed during the spring of the fifth year have been removed by absorption of the scale. × 13

FIG. 61.—Marked at Bonneville hatchery during the fall of 1921, when approximately 13 months old. Recovered at Clatskanie, Oreg., during February, 1926, in its sixth year. No data as to sex; length 42 inches, weight 37 pounds. The rapid growth of the sixth year had not started at the time the fish was caught. × 13



EXPERIMENT 10

FIG. 62.—Fingerling, 78 millimeters, marked at Bonneville hatchery August 28, 1922. A typical scale. × 25

FIG. 63.—Marked at Bonneville hatchery fall of 1922, when approximately 12 months old. Recovered at CascadeLocks, Oreg., May 5, 1926, in its fifth year. Female, 37 inches and 22 pounds. A poorly differentiated nucleus. × 25

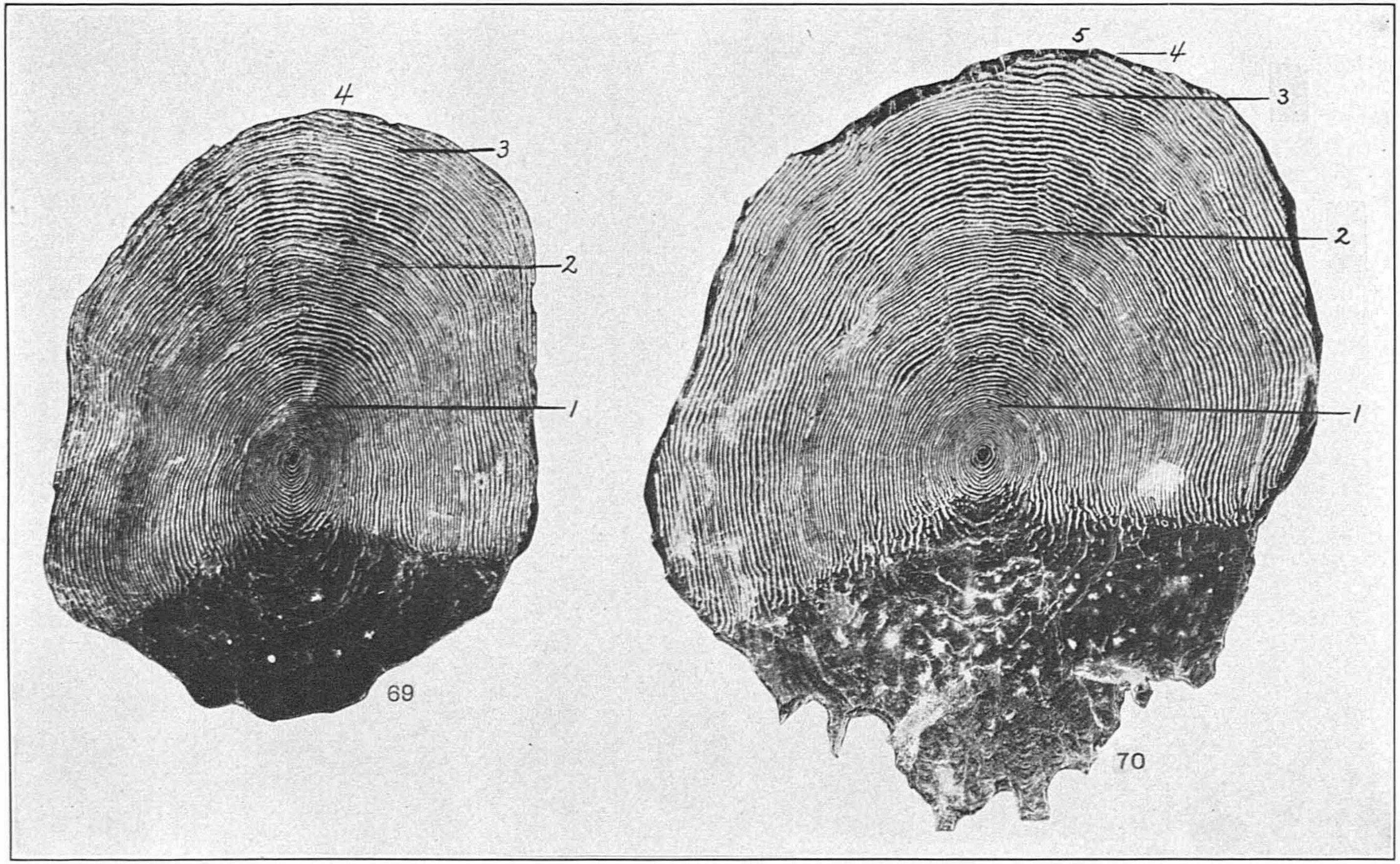
FIG. 64.—Marked at Bonneville hatchery during the fall of 1922, when approximately 12 months old. Recovered in a cannery at Warrendale, Oreg., May 10, 1926, in its fifth year. Male, 36 inches long and weighing 18 pounds, showing a clearly differentiated nucleus. × 25

FIG. 65.—Marked at Bonneville hatchery during the fall of 1922, when approximately 12 months old. Recovered in a cannery at Ellsworth, Wash., May 7, 1926, in its fifth year. Male, 29.5 inches long and weighing 19.5 pounds, showing intermediate growth that closely resembles stream growth. × 25

FIG. 66.—Marked at Bonneville hatchery during the fall of 1922, when approximately 12 months old. Recovered in a cannery at Ellsworth, Wash., May 4, 1926, in its fifth year. Female, 34 inches long and weighing 21 pounds, showing a nucleus with an extremely wide band of intermediate growth. × 25

FIG. 67.—Marked at Bonneville hatchery during the fall of 1922, when approximately 12 months old. Recovered in a cannery at Ellsworth, Wash., May 15, 1926, in its fifth year. Female, 32 inches long and weighing 17 pounds, showing a nucleus with no intermediate growth. × 25

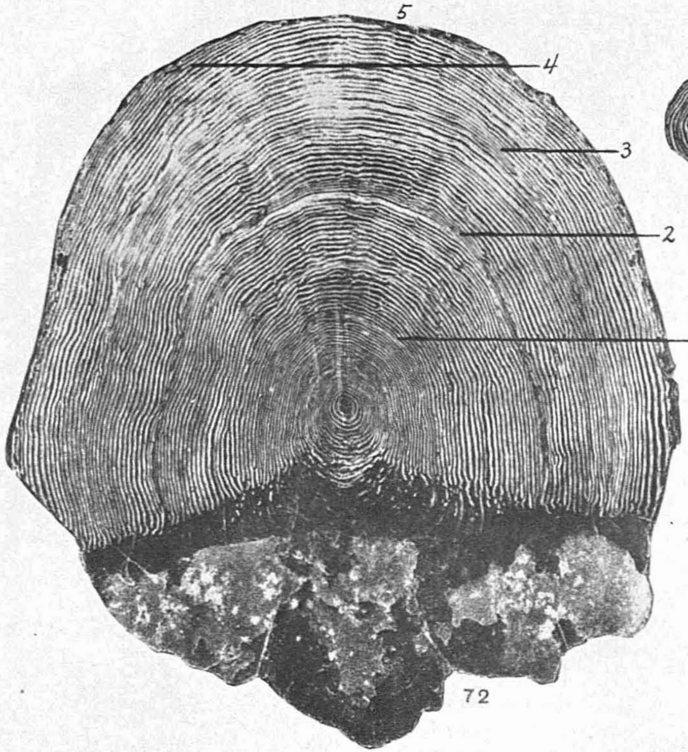
FIG. 68.—Marked at Bonneville hatchery during the fall of 1922, when approximately 12 months old. Recovered at The Dalles, Oreg., May 3, 1924, in its third year. Male, 18 inches long and weighing 3 pounds. × 13



EXPERIMENT 10

FIG. 69.—Marked at Bonneville hatchery during the fall of 1922, when approximately 12 months old. Recovered in a cannery at Warrendale, Oreg., during the spring of 1925 in its fourth year. Female, 40 inches long and weighing 35 pounds. × 13

FIG. 70.—Marked at Bonneville hatchery during the fall of 1922, when approximately 12 months old. Recovered at Cascade Locks, Oreg., May 5, 1926, in its fifth year. Female, 37 inches long and weighing 22 pounds. The fourth winter band and whatever was formed during the fifth spring have been removed by absorption of the scale × 13



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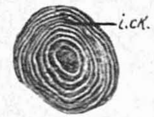

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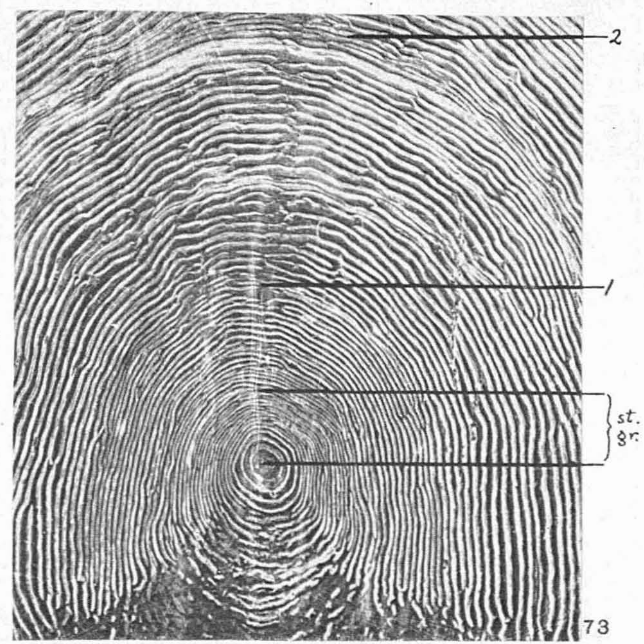

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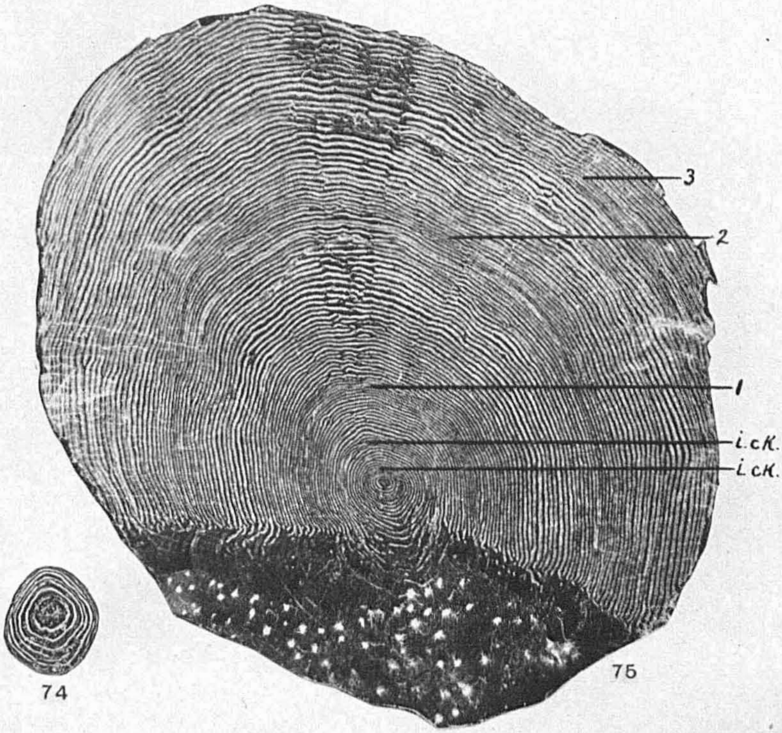
EXPERIMENT 11

FIG. 71.—Fingerling, 75 millimeters long, marked at Klaskanine hatchery, August 18, 1922. A typical scale. × 25

FIG. 72.—Marked at Klaskanine hatchery during the summer of 1922, when approximately 10 months old. Recovered at the Klaskanine hatchery during the spring of 1926, in its fifth year. The margin of the scale has been slightly removed by absorption. × 13

FIG. 73.—Nuclear region of scale shown in Figure 72. × 25



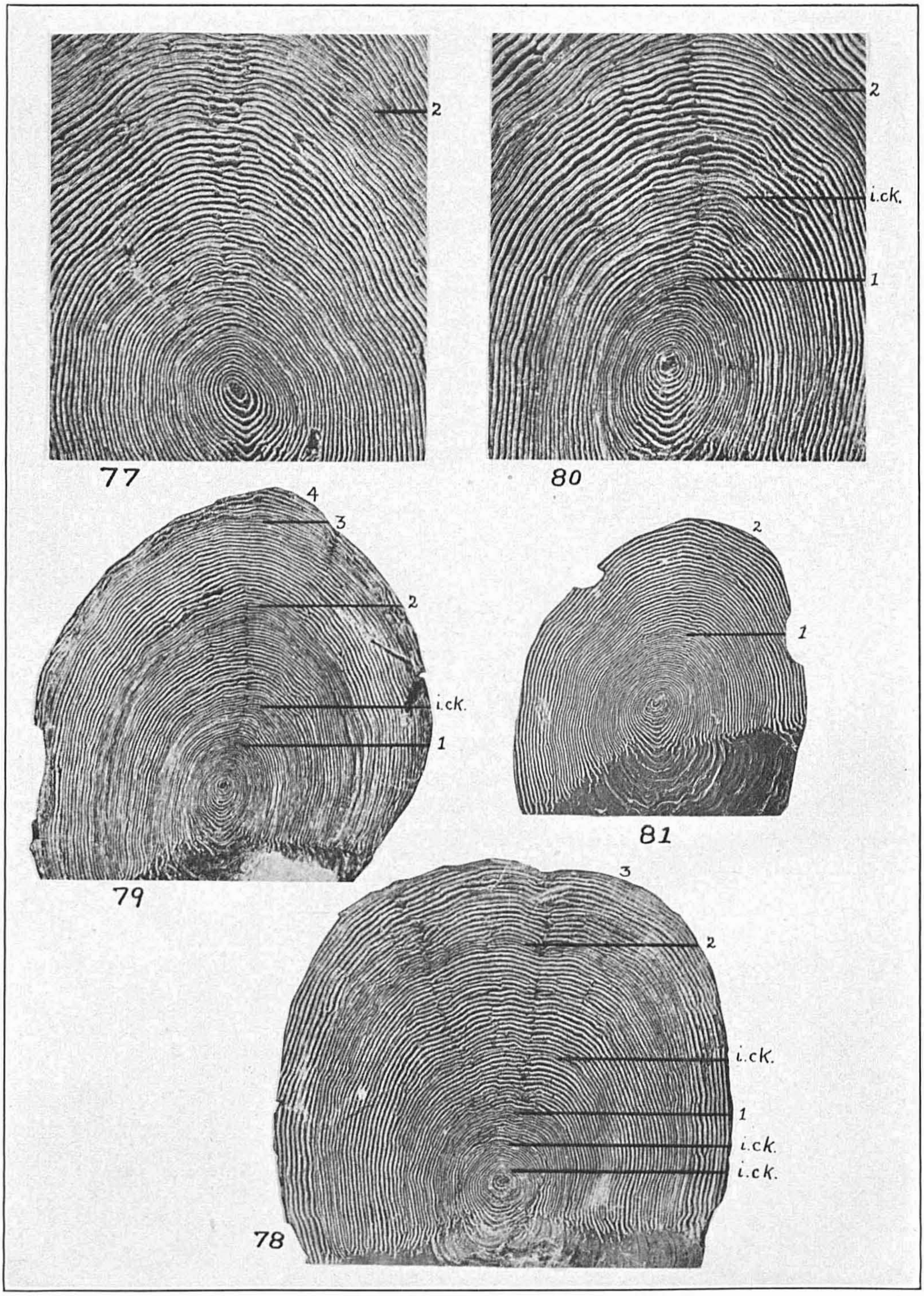
74

75

76

EXPERIMENT 12

FIG. 74.—Fingerling, 56 millimeters in length, marked at Big White Salmon River hatchery, June 12, 1923. × 25
FIG. 75.—Marked at Big White Salmon River hatchery during the spring of 1923, when approximately 8 months old. Recovered at Ilwaco, Wash., August 19, 1926, in its fourth year. Male, 39.3 inches long and weighing 30 pounds. × 13
FIG. 76.—Nuclear region of scale shown in Figure 75. × 25



EXPERIMENT 12

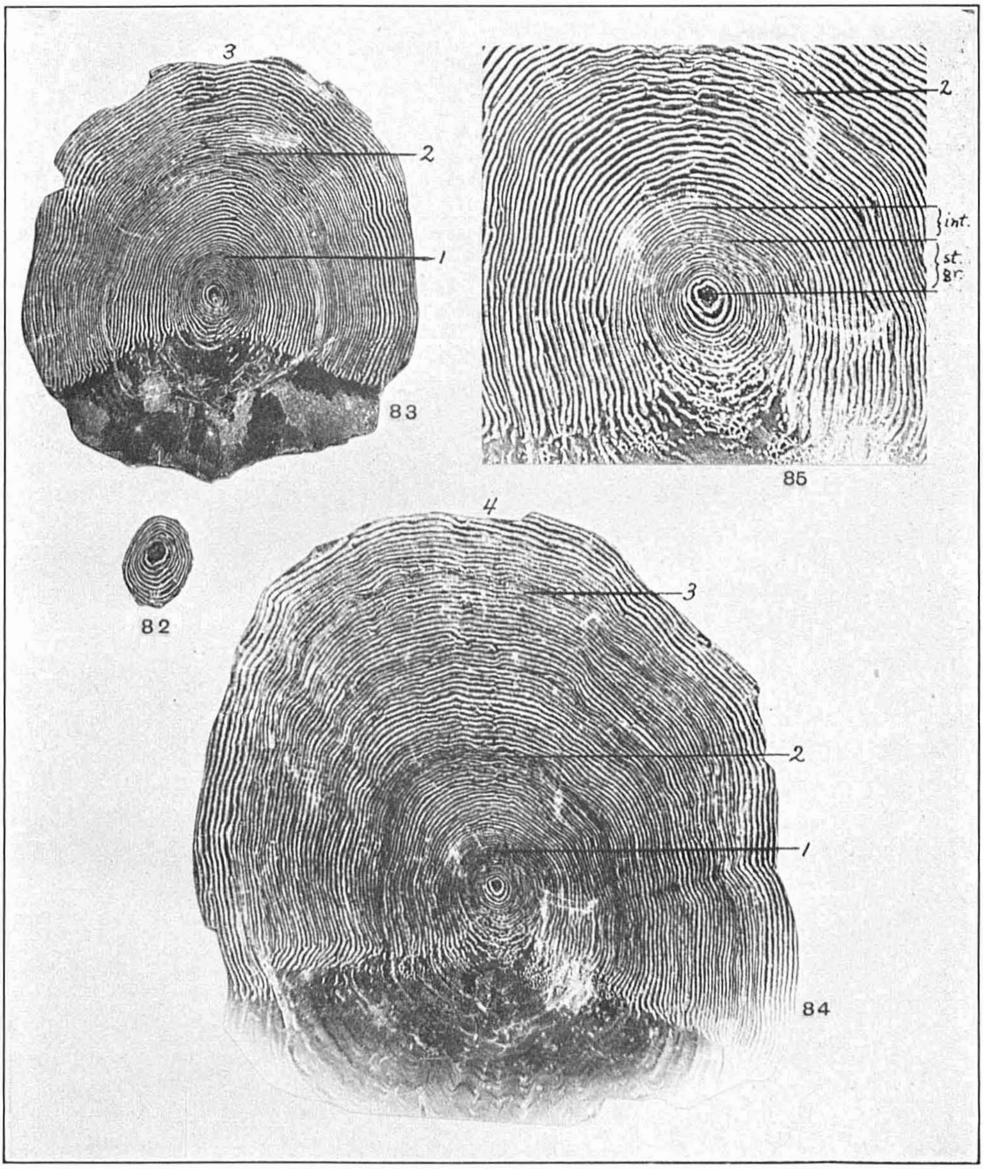
FIG. 77.—Marked at Big White Salmon River hatchery during the spring of 1923, when approximately 8 months old. Recovered at Astoria, Oreg., August 23, 1926, in its fourth year. Male, 39 inches long and weighing 28.5 pounds, showing a poorly differentiated composite nucleus. The first year's growth blends so gradually into that of the second year that it is impossible to determine where the first year ends and the second begins. × 25

FIG. 78.—Marked at Big White Salmon River hatchery during the spring of 1923, when approximately 8 months old. Recovered at Pillar Rock, Wash., August 25, 1925, in its third year. Male, 26 inches long and weighing 12 pounds, showing an incidental check in the second year, which is not sufficiently pronounced to be confused as an annulus. × 13

FIG. 79.—Marked at Big White Salmon River hatchery during the spring of 1923, when approximately 8 months old. Recovered at Astoria, Oreg., August 24, 1926, in its fourth year. Female, 37 inches long and weighing 22.25 pounds, showing an incidental check in the second year, which might be mistaken for an annulus. A part of the fourth summer's growth has been removed by absorption of the scale. × 13

FIG. 80.—Nuclear region of the scale shown in Figure 78. × 25

FIG. 81.—Marked at Big White Salmon River hatchery during the spring of 1923, when approximately 8 months old. Recovered at Astoria, Oreg., August 2, 1924, in its second year. Male, 22 inches long and weighing 5 pounds. × 13



EXPERIMENT 13

FIG. 82.—Fingerling, 58 millimeters long, marked at Salmon (Idaho) hatchery, August 22, 1924. × 25

FIG. 83.—Marked at Salmon (Idaho) hatchery during the fall of 1924, when approximately 11 months old. Recovered in an Astoria cannery, August 10, 1926, in its third year. Male, 25 inches long and weighing 9 pounds. × 13

FIG. 84.—Marked at Salmon (Idaho) hatchery during the fall of 1924, when approximately 11 months old Recovered in the ocean on July 25, 1927, in its fourth year. × 13

FIG. 85.—Nuclear region of scale shown in Figure 84. × 25