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EARLY HISTORY AND SEAWARD MIGRATION OF CHINOOK SALMON IN THE COLUMBIA AND SACRAMENTO RIVERS

By Willis H. Rich

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EARLY HISTORY AND SEAWARD MIGRATION OF CHINOOK SALMON IN THE COLUMBIA AND SACRAMENTO RIVERS.

By WILLIS H. RICH,
Field Assistant, U. S. Bureau of Fisheries.

INTRODUCTION.

HISTORY OF THE INVESTIGATION.

The present study of the chinook salmon (*Oncorhynchus tschawytscha*), of which this paper forms the first contribution, was started in the summer of 1914 at the instance of the U. S. Bureau of Fisheries. The importance and necessity of such a study had been made apparent, especially by the work of Gilbert on the sockeye salmon, and it seemed advisable to extend in detail the outline of the life history of the chinook as given by Gilbert (1913). The method employed—that of analysis on the basis of scale studies—is now too well known and too widely used to need description. The paper just cited and subsequent studies of the sockeye by the same author contain a complete description of the methods employed and form admirable examples of studies prosecuted on this basis.

Our knowledge of the life histories of all the Pacific coast Salmonidæ was distinctly unsatisfactory previous to the discovery of the value of scale studies. The descriptions given by Jordan and Evermann (1896–1900), Jordan (1905), Rutter (1903), Scofield (1898), and Chamberlain (1907), contain the most accurate information regarding the chinook which was available prior to Gilbert's first study. The general features of the early life in fresh water and of the seaward migration were well known, and Chamberlain had shown quite conclusively that the sockeye and chinook salmon mature commonly at about the fourth year, although this is subject to variation. The work of McMurrich (1912) on the chinook salmon, based on the scales, has been shown by Gilbert (1913) to be unreliable because of the small number of specimens examined and an incorrect interpretation of the central (nuclear) area of the scales.

It remained, therefore, for Gilbert (1913) to give us the first accurate description of the general features of the life history of the chinook salmon in his paper, "The Age at Maturity of the Pacific Coast Salmon of the genus Oncorhynchus." In this he shows, among other things, that: (*a*) The chinook, or king, salmon spawn normally either in the fourth, fifth, sixth, or seventh year, the females more frequently in the fourth year; (*b*) the "grilse" are exclusively males and are of two sizes, representing two and three year fish; (*c*) the young may migrate as fry soon after hatching, or may remain in the stream until their second spring, migrating as yearlings; and (*d*) among the fish of any given age, the larger specimens will be those which migrated seaward as fry, although these do not attain the average stature of those fish, one year older, which migrated as yearlings.

In a recent paper Fraser (1917) has verified some of Gilbert's findings and has extended the study to the spring salmon found in the Straits of Georgia. He has worked out quite conclusively the rate of growth during the life in the sea and also the time of formation of the winter check.

The present study is a continuation of that begun by Gilbert, and the results thus far have been in perfect agreement with his, although the material has been much more abundant and diverse. The outline of the life history of the chinook as given by him may be almost indefinitely extended, but it seems most unlikely that results may be obtained which are not in agreement with his original conclusions.

At the beginning of this investigation it was supposed that an examination of the adult scales would give the data necessary for an understanding of the life history. Most of the summer and autumn of 1914 was, therefore, spent on the Columbia River collecting scales and data from adult fish. Small series of young, seaward migrants, were also taken at Astoria and Ilwaco, at the lower end of the Columbia estuary. Several collections of adult scales taken at spawning stations on various tributaries of the Columbia and Sacramento Rivers and collections of yearling chinooks made at Baird, Calif., were available for study through the courtesy of Dr. C. H. Gilbert. Access was also had to a collection of young migrants from the Sacramento River through the kindness of N. B. Scofield, of the California Fish and Game Commission. These various collections were studied during the winter and spring of 1914–15. It was possible to verify the main conclusions reached by Gilbert (1913), as follows: (1) The scales present two types of nuclear growth—one, the stream type, indicating that the fish migrated to the ocean after spending one year in fresh water, and the other, the sea type, indicating that the fish migrated as a fry; (2) the chinook may reach maturity at any time between the second and the seventh year. Those maturing in the second or third year are exclusively males.[a] The prevailing ages at which maturity is reached by the chinooks of the Columbia River are 4 and 5 years, although fish in their sixth year are fairly common. Specimens maturing in their seventh year are very rare.

Although it was possible to distinguish typical specimens of the two types of nuclear growth, it was found that there were many modifications of both types which were often confusing, although at the same time they were very significant. In the case of the young migrants taken in the Columbia estuary, the scales showed a well-defined area of narrower rings succeeded by a marginal band of wider rings. (See Pl. II, fig. 5.) At first it seemed that these fish must be in their second year; but this conclusion was not considered tenable, since, if this were true, the amount of growth which had taken place during the second year would be surprisingly small compared with that taking place in other cases where there was no doubt as to the proper interpretation of the scales. It seemed much more likely that the wide marginal rings represented a period of vigorous growth initiated by the young migrants on reaching the brackish water of the estuary. The problems presented were so complex that it was considered imperative that a careful study be made of the young migrants before proceeding further with the study of the mature fish.

To this end the writer undertook in the spring of 1915 the collection of the necessary data. As a result of unavoidable delay in getting a suitable net for this purpose,

[a] More recently females have been seen maturing in their third year, but in every case the scales indicated unmistakably that the fish had migrated as a fry. This is an important point for future consideration.

effective collecting was not begun until October. Collections were made chiefly on the lower Columbia between the mouth of the Willamette River and the ocean during October, November, and December, 1915. Owing to the unusually severe winter of 1915–16 the river contained so much ice that further collecting had to be deferred until March, 1916. From March until September frequent samples were taken at various points. These collections made in the Columbia River in 1914, 1915, and 1916, the collections from the Sacramento River mentioned above, and certain collections from the smaller coastal streams in California and Oregon contained in the Stanford University collection constitute the material on which this paper is based.

Thanks are due especially to Dr. C. H. Gilbert for assistance and advice given freely throughout the course of this investigation. The author is indebted also to Henry O'Malley, in charge of operations on the Pacific coast, and to Supts. Dennis Winn and Hugh C. Mitchell, of the U. S. Bureau of Fisheries, for advice and assistance in the collection of material. The friendly cooperation of the Oregon Fish and Game Commission, through Supt. R. E. Clanton, has also been of great assistance. John Larson, of the Oregon Fish and Game Commission, accompanied the writer on many of the collecting trips during 1916 and proved an invaluable assistant. To N. B. Scofield, of the California Fish and Game Commission, acknowledgment is due for permission to examine young salmon collected by him from the Sacramento River. Mrs. W. H. Rich aided in the preparation of scales for study and in the correction of manuscript.

STATEMENT OF THE PROBLEMS.

On beginning this work in June, 1914, the following tentative list of the more important problems relating especially to the Columbia River fisheries was made as a guide for determining the character of the future work:

1. What is the value of the hatchery work done on the river? Do the chinook fry planted from the hatcheries return as mature fish; and if so, when, and in what proportions?

2. At what ages do the young migrate to the ocean? What proportions migrate at the different ages, and what are the sizes of these migrants?

3. What age groups are represented in the different runs of the various species (chinook especially), and what are their average sizes and weights? Do these sizes and weights vary during the season?

4. What are the proportions in which these age groups are represented, and do the proportions vary during the season?

5. What are the relative sizes and proportions of males and females?

6. What results are being obtained from the marking experiments started in 1911 on the Sacramento River?

In addition to the above problems it was very soon found that one of the most important practical problems on the Columbia River has to do with the difference between the spring and the fall runs of chinook salmon. This has been kept in mind, therefore, throughout the work. The spring fish are much more valuable than the fall fish, being richer in oil and of better color, and the great desire of the commercial fisheries is to increase the spring run. It is obvious that the only opportunity to influence the history of the salmon is during the early life in fresh water before the young have migrated to the ocean. To do this intelligently, an exact knowledge of the early history, previous

to migration, is necessary. The author has attempted, therefore, to give in this report as complete an account as possible of the early history of the chinook salmon. Important as these observations are, they are merely preliminary to the still more important study of the adult fish. Abundant material is at hand for this purpose, and the author hopes to present in the near future a report covering those problems which relate to the adult fish.

METHODS.

The methods usually employed at the present time in studies of the life histories of fish by means of scale analysis have been followed.

The length of the fish was determined by laying the specimen flat on a rule and measuring from the tip of the snout to the end of the middle rays of the caudal fin. These measurements were made in millimeters.

In counting the number of rings (circuli) on the scales the count has always been made in the anterior quadrant of the scale, since the number of rings has been found to be less variable there than in the lateral quadrants. The different areas of growth, such as the summer and winter bands (annuli), are also more sharply differentiated in the anterior quadrant.

Any measurements of scales and portions of scales which are given, were made by means of a camera lucida. The apparent image of the scale projected to the level of the base of the microscope was measured by a millimeter rule. There is obviously no significance to the actual size of this apparent image, since this would vary with the degree of magnification employed. The only value such measurements have is for comparative purposes. Therefore, the units of measurement have been considered as purely arbitrary, and no actual value is assigned. It seems hardly necessary to state that the same magnification has been used throughout this study. The actual magnification of the image was approximately × 120. This would give an actual value of 0.00834 mm. for each unit of measurement. The measurements as given in the tables were made from the center of the innermost ring along the anterior radius of the scale.

One method of study used has not, to the author's knowledge, been previously described. This is the employment of large series of photographs for the purpose of deciding doubtful points. It not infrequently happens that the scales from different lots of fish will vary consistently in one or more minor characters which are very difficult to determine by the successive examination of scales from individual fish. The memory seems incapable of carrying all the necessary details in such form that a logical conclusion could be reached. When, however, fairly large series of photographs, say 50 of each category, can be spread out side by side, the comparison may be made very readily, and often important conclusions may be drawn.

After some experimenting, in order to reduce the expense of plates, printing, etc., the scheme finally adopted for this purpose was to photograph directly on paper. Bromide paper was tried at first, but it did not prove satisfactory. Either Azo, F, hard X, or contrast Cyco was finally found to give the best results. Since the light values have no particular significance in scale photographs, where the main requirement is to show the lines well, these paper negatives are as favorable for study as prints taken from plates would be. In case duplicates are wanted, these negatives may be used in the same

way as ordinary films and positive prints produced. The prints included with this report were made in this manner. A Leitz photomicrographic apparatus fitted with a 24-mm. mikro-summar was used and a small Bausch & Lomb arc lamp with condensing lens as a source of light. For the magnification used, 35 diameters, Azo, F, hard X requires an exposure of about 90 seconds and contrast Cyco about 15 seconds. The paper is placed in the regular plate holder behind a piece of clear glass. Another piece of glass or of stiff cardboard is placed behind the paper in order to hold it flat. The best focus is one which makes each line of the scale appear on the ground glass as a bright line having a narrow black line in the center. Considerable experience is necessary before one can obtain this focus properly. The size of the arc light will determine the amount of time required for a proper exposure, and the same size of arc should be used, therefore, for all photographs in a series. The printing requires an exposure to bright daylight (not sunlight) of about five seconds.

PRESENTATION OF DATA.

FISH FROM THE COLUMBIA RIVER.

The earliest collections made during any year were taken in the latter part of March and early in April, 1916. At this time a trip was made by launch from Portland to Astoria. Frequent hauls were made at different points, but many were unsuccessful because of the flood stage of the river. Also poor acquaintance with the river made it impossible to select the most favorable spots for seining. A seine 100 feet in length was used. This had half-inch mesh in the wings and one-fourth inch mesh in the bag The smallest salmon fry could be collected with this gear, as is proved by the fact that fry which had not completely absorbed the yolk sac were frequently captured. The later trips were more successful than the earlier ones, since the favorable places for seining had been learned and attention confined to these.

Collections were made March 31, 1916, at Mayger, Oreg., and at Grims Island, near Clatskanie, Oreg. On April 1 and 2 several collections were made at different points in the lower part of the Columbia estuary. The best collections were obtained on Sand Island and near Point Ellice, Wash. One hundred and forty-nine specimens in all were taken. Forty-seven of these were yearlings and 102 were fry. The study of the yearlings will have greater significance if delayed until after the development of the fry during the first year shall have been followed. The collections of fry made on this trip have all been studied separately, but no significant variations appeared, and the data are therefore presented in a single table (1).

Less than one-half of the fry had developed sufficiently to form even the central nuclear plates of the scales. Gilbert (1913*a*) describes a similar condition in the case of the migrating fry of the sockeye. Twenty-three individuals show the central platelets only and 19 have scales well enough developed for rings to be present. The average length[a] is 38.7 mm., with the mode at 38 mm. The average number of rings on the scales of the 19 specimens possessing scales sufficiently developed to show rings is 1.7. The average length of the anterior radius of the scales is 6.3 on the arbitrary scale. (See p. 6.) The following table (1) gives all the data regarding these collections.

[a] The averages employed in this paper are invariably the weighted mean.

TABLE 1.—FRY FROM LOWER COLUMBIA RIVER, MAR. 31 TO APR. 2, 1916.

Length.	Number.	Number of specimens with—		Scale record. [a]	
		Platelets only.	Scales with rings.	Average number of rings. [b]	Average length of anterior radius. [c]
46 to 50 mm	2	0	2	3.0	20.5
41 to 45 mm	19	4	6	2.0	8.5
36 to 40 mm	71	17	9	1.3	5.1
31 to 35 mm	10	2	2	1.5	4.2
Total	102	23	19	.....	.....
Av. 38.7 mm	.....	.....	.....	1.7	6.3

[a] For units of measurement used in the scale records in this and all succeeding tables see explanation on p. 6.
[b] Estimated from those specimens only which have scales with rings.
[c] Estimated from all specimens with either scales or platelets.

It is apparent from this table that the scales are usually formed by the time the fish reach a length of 40 mm. It is not surprising that this condition is subject to a considerable amount of variation, especially when so few individuals are involved. The increase in the number of rings and in the size of the scales parallels the increase in total length of the fish.

Owing to the difficulty in sexing these small fry, no information is available regarding either sex proportions or variations due to sex.

A collection of 62 fry from the Clackamas hatchery, maintained near Oregon City, Oreg., by the U. S. Bureau of Fisheries, was made April 11, 1916. (See Table 2.) It will be interesting to compare this with the wild fish taken in the Columbia River. These hatchery fish average considerably larger than the wild individuals. This is presumably due, at least in part, to the warmer water in which they were hatched and reared. At the time this collection was made the water supply at the hatchery came from a spring, and the temperature was uniformly 50° F. throughout the year. None of the specimens are less than 40 mm. in length. The average is 46.5 mm., with the mode at 43 mm.

TABLE 2.—DATA FOR 62 FRY FROM CLACKAMAS HATCHERY, APR. 11, 1916.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
61 to 65 mm	1	8.0	28.0
56 to 60 mm	4	7.5	25.5
51 to 55 mm	9	7.5	25.8
46 to 50 mm	17	5.5	20.3
41 to 45 mm	24	4.7	17.2
36 to 40 mm	7	3.2	13.7
Av. 46.5 mm	.....	5.4	18.8

The obvious skewing of the curve of length toward the smaller sizes is probably due to constant additions to the smaller fish as a result of the hatching of the eggs spawned later in the season. The data at hand are not sufficient to prove this, however. Almost all the collections of small fry show such skewing which is apparently due to some such fundamental cause as the one suggested. The scales show a progressive increase in

the number of rings and in the length of the anterior radius as the size of the fish increases. In comparison with the fry taken in March and April on the lower Columbia River, one is impressed by the fact that all of these hatchery fish, even the smallest, are provided with scales having well-developed rings. The smallest number of rings found on the scales of any specimen was three. A considerable proportion of the wild fish less than 45 mm. and more than 40 mm. in length have no scales, or at most only platelets. It seems likely that something in the conditions of life at the hatchery is responsible, but no direct evidence proved that this is available. The scales of the larger specimens have already acquired some of the characteristics of the scales of typical hatchery fish. Compared with the scales of wild fish, those from hatchery specimens show an irregular growth. There are frequent minor checks, indicated by narrower rings; but, as a rule, the true winter check is less well marked. The rings themselves are frequently slender and more or less broken. Plate I, figure 9, and Plate IV, figure 3, illustrate scales from hatchery fish. It is possible that a careful study of these characteristics might give a means of identifying adult fish which had been reared for the first few months under hatchery conditions.

In a collection of 26 fry from Cottonwood and Deer Islands, lower Columbia River, on April 13, 1916, the average length of the specimens is 43.2 mm., with the mode at 38 mm. (See Table 3.) The skewing of the curve toward the smaller sizes is even more marked in this collection than in the first one. The average length has increased 4.5 mm., but this seems largely due to the capture of several individuals which were considerably larger than any contained in the first collection, the one made on the lower river March 31 to April 2. The mode of the curve of length has remained the same. No important changes appear in the scale record, although, as would be expected from the larger average size of the fish, a slightly greater proportion has formed scales, and the average number of rings is greater.

Eighteen specimens were sexed. Males and females are in equal numbers, nine each. The average length of the males is 42.3 mm. and of the females 44.1 mm.

TABLE 3.—FRY FROM COTTONWOOD AND DEER ISLANDS, LOWER COLUMBIA RIVER, APR. 13, 1916.

Length.	Number.	Number of specimens with—		Scale record.	
		Platelets.	Scales with rings.	Average number of rings.	Average length of anterior radius.
66 to 70 mm	1	0	1	6.0	23.0
61 to 65 mm	1	0	1	8.0	23.0
56 to 60 mm	1	0	1	5.0	18.0
51 to 55 mm	2	0	2	4.0	25.5
46 to 50 mm	0	0	0	.....	.....
41 to 45 mm	7	0	6	2.3	13.8
36 to 40 mm	13	1	1	2.0	10.5
31 to 35 mm	1	0	0	.....	.....
Total	26	1	12	.....	.....
Av. 43.2 mm	.....	.....	.....	3.3	17.1

A small series of 19 specimens was preserved at the Clackamas hatchery May 2, 1916. (See Table 4.) The average length is 46.7 mm., with the mode at 48 mm. All of the specimens have well-developed scales, none with less than four rings.

Ten of the specimens are males and have an average length of 46.5 mm. The nine females average 46.9 mm.

TABLE 4.—DATA FOR 19 FRY FROM CLACKAMAS HATCHERY, MAY 2, 1916.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
51 to 55 mm	2	6	25.5
46 to 50 mm	10	5.6	24.5
41 to 45 mm	7	4.6	21.0
Av. 46.7 mm		5.3	23.7

Several good collections were made May 10 and 11, 1916. These have been divided into two lots. The first was collected on Puget Island and at Crandall's seining ground on Grims Island. (See Table 5.) These points are located about 30 miles above Astoria. The second lot comprises collections made at several points on the lower part of the estuary, the best series coming from Sand Island and Point Ellice. (See Table 6.)

Two hundred and eighteen fry were taken at Crandall's seining ground and on Puget Island. Thirty-nine yearlings were taken at the same time. The length of the fry ranges from 33 to 98 mm. The average length is 52.5 mm., with the mode at 43 mm. The sex proportion in this collection is 54.1 per cent males to 45.9 per cent females. The average length of the males is 52.3 mm. and of the females 52.8 mm. The following table (5) contains the data for this collection:

TABLE 5.—FRY FROM CRANDALL'S SEINING GROUND AND PUGET ISLAND, LOWER COLUMBIA RIVER, MAY 10, 1916.

Length.	Number.	Number of specimens with—		Scale record.	
		Platelets.	Scales with rings.	Average number of rings.	Average length of anterior radius.
96 to 100 mm	1	0	1	12.0	63.0
91 to 95 mm	3	0	3	10.6	48.0
86 to 90 mm	2	0	2	10.0	48.0
81 to 85 mm	7	0	7	10.0	46.5
76 to 80 mm	7	0	7	9.3	41.0
71 to 75 mm	7	0	7	8.1	41.0
66 to 70 mm	11	0	11	8.1	37.0
61 to 65 mm	14	0	14	6.4	31.0
56 to 60 mm	22	0	22	6.2	28.2
51 to 55 mm	29	0	29	5.2	26.5
46 to 50 mm	30	0	30	4.6	22.6
41 to 45 mm	41	1	38	2.9	16.5
36 to 40 mm	40	6	21	1.3	12.0
31 to 35 mm	4	0	0	.....	.....
Total	218	7	192	.....	.....
Av. 52.5 mm	.....	.....	.....	4.9	22.4

The collections made May 11 in the lower part of the estuary include 103 fry and 10 yearlings. There are 52 males among the fry averaging 46.7 mm. in length. The 51 females average 48.8 mm. The following table (6) gives the data regarding the fry:

TABLE 6.—FRY FROM LOWER PART OF COLUMBIA ESTUARY, MAY 11, 1916.

Length.	Number.	Number of specimens with—		Scale record.	
		Platelets.	Scales with rings.	Average number of rings.	Average length of anterior radius.
81 to 85 mm	1	0	1	9.0	43.0
76 to 80 mm	0	0	0	.....	.....
71 to 75 mm	0	0	0	.....	.....
66 to 70 mm	0	0	0	.....	.....
61 to 65 mm	2	0	2	6.5	33.0
56 to 60 mm	13	0	13	6.2	29.0
51 to 55 mm	14	0	14	5.4	24.9
46 to 50 mm	23	0	23	4.0	21.2
41 to 45 mm	25	0	25	3.2	17.3
36 to 40 mm	22	3	11	1.6	10.5
31 to 35 mm	3	0	0	.....	.....
Total	103	3	89	.....	.....
Av. 47.7 mm	.....	.....	.....	4.2	20.6

In comparing these collections with the ones made the day before, the average smaller size of the fish is the only conspicuous point of difference. This is obviously due to a scarcity of fish of the larger sizes, since the modes of the two curves are the same, 43 mm. The water in the lower part of the estuary is quite brackish owing to the considerable admixture of salt water, while that in the part of the river where the collections of May 10 were made is perfectly fresh. Therefore it would seem probable that on reaching the brackish water the larger fish tended to continue their migration on into the ocean, while the smaller ones remained behind.

The next collection to be considered was made in the Columbia River near the mouth of the Little White Salmon River, about 50 miles above the point where the Willamette River joins the Columbia. This collection was made May 25, 1916, at which time 24 fry and 1 yearling were captured. The fry average 44.6 mm. in length and range from 37 to 61 mm. The mode is at 49 mm. Six specimens have no scales, 7 have only platelets, and 11 have scales with rings. Males and females are present in this collection in equal numbers and are also of equal size, both sexes averaging 44.6 mm. in length. The following table (7) contains the data:

TABLE 7.—FRY FROM COLUMBIA RIVER NEAR MOUTH OF LITTLE WHITE SALMON RIVER, MAY 25, 1916.

Length.	Number.	Number of specimens with—		Scale record.	
		Platelets.	Scales with rings.	Average number of rings.	Average length of anterior radius.
61 to 65 mm	1	0	1	7.0	28.9
56 to 60 mm	4	0	4	6.7	28.0
51 to 55 mm	1	0	1	6.0	23.0
46 to 50 mm	2	0	2	4.0	20.5
41 to 45 mm	4	2	1	1.0	8.0
36 to 40 mm	12	5	2	1.5	8.0
Total	24	7	11	.....	.....
Av. 44.6 mm	.....	.....	.....	4.7	21.3

The smaller size of these fish as compared with those from below the mouth of the Willamette River is distinctly shown and is in accord with our explanation of the excessive proportion of small fish in the collections from the lower river; that is, that smaller fish are constantly being added to those in the estuary as a result of migration from above.

Eight specimens were preserved at the Clackamash atchery, May 27, 1916. These average 56 mm. in length. All have well developed scales. The average number of rings on the scales is 7.5, and the average length of the anterior radius of the scales is 28.5. There are four males averaging 53 mm. in length and four females averaging 59 mm.

A good collection of fry was made near Astoria, in the lower part of the estuary June 12 and 13, 1916. (See Tables 8 and 9.) In all, 132 specimens were taken, and it is worthy of note that none were yearlings. Yearlings do not appear in any subsequent collection from the lower part of the river, and it may be concluded from this that the yearling migrants quit the river for salt water about the first of June, if not earlier. This point is given more detailed consideration later.

Thirty-six of these fry were taken just within the mouth of a small creek near Point Ellice. They differ so distinctly from the remainder of the collection that they are considered separately. (See Table 8.) The average length is but 47.7 mm., with the mode at 38 mm. All of the individuals have formed scales, and in all but one, rings are present on the scales. The average number of rings is 4.1, and the average length of the anterior radius is 20.5. Nineteen of these specimens are males averaging 47.5 mm. in length. Seventeen females average 48 mm.

TABLE 8.—FRY FROM WITHIN MOUTH OF SMALL CREEK NEAR POINT ELLICE, COLUMBIA RIVER, JUNE 13, 1916.

Length.	Number.	Number of specimens with—		Scale record.	
		Platelets.	Scales with rings.	Average number of rings.	Average length of anterior radius.
66 to 70 mm	1	0	1	8.0	33.0
61 to 65 mm	2	0	2	7.0	28.0
56 to 60 mm	4	0	4	7.0	29.2
51 to 55 mm	7	0	7	5.3	25.0
46 to 50 mm	6	0	6	4.3	20.5
41 to 45 mm	5	0	5	3.4	18.0
36 to 40 mm	11	1	10	1.5	13.0
Total	36	1	35	.....	.....
Av. 47.7 mm	.....	.....	.....	4.1	20.5

The remaining 96 specimens collected in the estuary at this time are distinctly larger, averaging 76.5 mm. in length. In these specimens it is found for the first time that the scales of some of the fish have developed the wider marginal rings which have been designated "intermediate rings." This marginal band of wider rings is usually sharply differentiated from the central part of the scale and begins abruptly—not by a gradual increase in the space between rings. It may even be preceded by a slight narrowing, especially in the older fish. Gilbert (1913) has found similar intermediate

growth in sockeye and silver salmon which migrated as yearlings. These intermediate rings represent a period of growth more rapid than the normal growth in fresh water and yet not so vigorous as the true ocean growth (Pl. II, figs. 3, 4, 5, and 6). Intermediate rings are not present on the scales of every specimen, but among the larger fry and yearlings taken in the estuary after the first of June some are always found which show this type of growth at the margins of the scales. For the purpose of ready comparison those fish whose scales show the band of intermediate rings are given separate consideration.

The fry contained in the collection of June 13 which do not show this intermediate growth (80 in number) average 75.2 mm. in length. The length ranges from 53 to 105 mm., with the mode at 73 mm. The average number of rings is 9.6, and the average length of the anterior radius is 38.1. The males number 35 (44 per cent) and average 78.3 mm. The 45 females average 72.8 mm. in length.

Sixteen specimens have scales which show the intermediate growth. These average 83.1 mm. in length. Seven males average 80.3 mm.; and 9 females, 85.3 mm. The following table (9) presents the data for this collection:

TABLE 9.—FRY FROM COLUMBIA ESTUARY, JUNE 12 AND 13, 1916.

EIGHTY SPECIMENS WITHOUT INTERMEDIATE GROWTH.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
101 to 105 mm.	1	11.0	48.0
96 to 100 mm.	0	.....	.....
91 to 95 mm.	6	12.5	50.5
86 to 90 mm.	8	11.2	43.6
81 to 85 mm.	14	10.5	41.9
76 to 80 mm.	8	10.1	38.0
71 to 75 mm.	18	9.2	36.7
66 to 70 mm.	11	9.0	35.0
61 to 65 mm.	7	7.6	30.8
56 to 60 mm.	6	7.0	28.8
51 to 55 mm.	1	4.0	28.0
Av. 75.2 mm.	.....	9.6	38.1

SIXTEEN SPECIMENS WITH INTERMEDIATE GROWTH.

Length.	Number.	Scale record.					Average estimated length of fish at beginning of intermediate growth. [a]
		Number of rings—			Length of anterior radius—		
		To intermediate growth.	In intermediate growth.	Total.	To intermediate growth.	Total.	
91 to 95 mm.	3	12.3	4.6	16.9	33.0	51.3	63.0
86 to 90 mm.	3	13.0	6.0	19.0	26.3	46.3	49.6
81 to 85 mm.	5	10.6	4.6	14.6	26.0	42.0	52.0
76 to 80 mm.	2	10.0	4.0	14.0	25.5	38.0	53.0
71 to 75 mm.	2	8.5	4.0	12.5	23.0	33.0	50.5
66 to 70 mm.	1	9.0	4.0	13.0	23.0	33.0	48.5
Av. 83.1 mm.	.....	11.6	4.6	16.2	26.7	42.4	53.3

[a] For explanation of estimated length of fish in this and succeeding tables see p. 14.

The smaller size of the fish taken within the mouth of the creek near Point Ellice is of interest and may be accounted for by one of two hypotheses: (1) These may be fry which are just migrating from the stream into the Columbia estuary. It is not known definitely whether chinook salmon spawn in this stream, but it is rather unlikely. Two attempts were made to determine this, but only silver salmon were obtained. The stream is quite small and is not a typical chinook stream, being for the most part shallow and with sandy bottom. Furthermore, since the stream is so near the ocean, it should be expected, owing to the warmer and more equable climate, that development would be more rapid than in the higher tributaries. If this were the case, it would be expected, unless growth were modified by some other factor, such as racial difference, that the fish coming from this stream would average larger than those from the higher tributaries. (2) The more probable hypothesis is that the smaller individuals among the migrating fry have run up into the mouth of the stream. This might be for the sake of the probable greater safety in such a location or because of the reduced salinity of the water. It has been shown by Rutter (1903) that the larger fry are more resistant to the effects of salt water, and also that alternations in the salinity of the water are a distinct aid in accustoming the young fish to sea water. The second hypothesis, therefore, seems a reasonable explanation for the presence of the smaller fish in the mouth of this stream. It is quite probable that if these fish remain for any length of time in the fresh water of such a stream it will have a tendency to slow up the growth rate and result finally in developing irregularities of scale growth.

Among those fish taken in the Columbia estuary proper it has been shown that those specimens whose scales show a band of intermediate rings average larger than those whose scales do not show this band. Since the wider rings indicate a more vigorous growth this result was quite to be expected and hardly calls for special comment. It is worthy of note, however, that the estimated length of the fish at the time of beginning this intermediate growth is distinctly less than the length of those fish which have not begun this intermediate growth. This estimated length was found by the method invented by Dahl and since used to advantage by Gilbert, and also by Fraser. This method involves the following proportion:

Total length of scale : total length of fish : : the length of the scale at some particular point : the length of the fish at the time this point was at the periphery of the scale.

By applying this proportion to each individual it is found that in the 16 individuals which have formed an intermediate band the average length at the time this intermediate growth was begun was 53.3 mm. The average length of those fish present in the estuary at this time, but which have not begun the intermediate growth, is 75.1 mm. This shows that the fish whose scales do not have an intermediate band have arrived in the estuary more recently than those whose scales do show this band of wider rings. The greater length of the fish which have been longer in the estuary is the result of the more rapid rate of growth maintained in the estuary as compared with the slower growth in fresh water upstream. The cause of the accelerated growth in salt water is at present unknown but is probably due to the increase in the food supply. One other possibility suggests itself in explanation of the fact that some individuals do not show the more rapid intermediate growth, namely, some individuals may not respond as readily (or perhaps not at all) to the stimuli encountered in the estuary which, in other individuals, initiate the accelerated growth.

One hundred and sixty-six specimens of migrating fry were captured at Point Ellice, July 19, 1916. (See Table 10.) The average length is 92.1 mm., ranging from 60 to 128 mm., with the mode at 93 mm. It will be noted that here and in the subsequent tables there is very little skewing of the curve of length toward the lower end. This indicates, undoubtedly, that no more of the smallest fry are being added from the upper waters. This is proved by the fact that no fry less than 60 mm. in length were taken. Such fry as are entering the estuary from above must be more nearly the same size as the fish already in the estuary.

The scales of these fish show an average of 12.9 rings. One hundred and sixteen have started a more rapid intermediate growth, which is indicated on the scales by a marginal band of wider rings. There is an average of 7.6 rings within the intermediate band, the band itself comprising 5.3 rings. Seventy-six of the specimens are males, averaging 90.1 mm. in length. Ninety females average 93.6 mm.

TABLE 10.—FRY FROM POINT ELLICE, COLUMBIA ESTUARY, JULY 19, 1916.

FIFTY SPECIMENS WITHOUT INTERMEDIATE GROWTH.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
111 to 115 mm.	3	14.3	66.3
106 to 110 mm.	1	11.0	48.0
101 to 105 mm.	4	15.0	56.7
96 to 100 mm.	8	13.2	52.8
91 to 95 mm.	10	12.6	48.0
86 to 90 mm.	5	10.6	43.0
81 to 85 mm.	10	10.5	40.5
76 to 80 mm.	5	11.4	40.0
71 to 75 mm.	1	10.0	33.0
66 to 70 mm.	1	10.0	33.0
61 to 65 mm.	1	9.0	33.0
56 to 60 mm.	1	9.0	28.0
Av. 89.9 mm.		11.9	46.4

ONE HUNDRED AND SIXTEEN SPECIMENS WITH INTERMEDIATE GROWTH.

Length.	Number.	Scale record.					Average estimated length of fish at beginning of intermediate growth.
		Number of rings—			Length of anterior radius—		
		To intermediate growth.	In intermediate growth.	Total.	To intermediate growth.	Total.	
126 to 130 mm.	1	7.0	13.0	20.0	28.0	78.0	43.0
121 to 125 mm.	0						
116 to 120 mm.	8	9.6	7.1	16.7	37.0	63.0	76.5
111 to 115 mm.	4	9.2	7.3	16.5	30.5	60.8	60.5
106 to 110 mm.	8	7.7	7.0	14.7	30.8	57.0	54.5
101 to 105 mm.	9	8.4	6.9	15.3	31.3	56.5	58.0
96 to 100 mm.	12	8.0	5.4	13.4	30.2	51.0	60.5
91 to 95 mm.	22	7.2	5.6	12.8	28.5	48.3	54.5
86 to 90 mm.	23	7.3	4.9	12.2	27.1	44.9	55.5
81 to 85 mm.	14	7.2	4.2	11.4	27.2	41.3	52.6
76 to 80 mm.	7	6.9	4.7	11.6	24.4	39.5	47.3
71 to 75 mm.	5	6.2	4.0	11.2	21.0	36.4	43.0
66 to 70 mm.	1	5.0	5.0	10.0	23.0	28.0	38.0
61 to 65 mm.	2	6.5	5.0	11.5	23.0	35.5	50.5
Av. 93.1 mm.		7.6	5.5	13.1	28.3	49.8	55.3

With few minor exceptions, the results obtained from the study of this collection are similar in all respects to those obtained from a study of the June collections. The difference in length between the fish which have begun the rapid intermediate growth and those which have not is less but is plainly indicated, the fish having the intermediate band being larger. The average estimated length at the time of beginning the intermediate growth is approximately the same, 55.3 mm.

A collection containing 51 specimens was made at Point Ellice, August 12, 1916. Another series of 13 specimens was collected from the same place August 26, 1916. Since no particular difference in these two collections has appeared as a result of their study, they will be considered together. (See Table 11.) The average length is 93.9 mm., ranging from 49 to 122 mm. The mode is at 93 mm. It will be noticed that the average length of this collection is approximately the same as that of the July collection. It might be concluded from this that an average length of 92 or 93 mm is the maximum attained in the estuary, but this conclusion is not borne out by subsequent collections. Forty of these specimens are males, averaging 92 mm. in length. Twenty-four females average 97.2 mm.

The scales do not differ greatly from those of the July collection. The number of rings has increased slightly, although the size of the scale, as indicated by the length of the anterior radius, remains practically the same. The estimated length at the time of beginning the intermediate growth is nearly the same as in June and July. Six of the specimens collected August 26 begin to show at the periphery of the scales narrow rings, indicating the slower winter growth.

TABLE 11.—FRY FROM POINT ELLICE, WASH., AUG. 12 AND 26, 1916.

TWENTY-SEVEN SPECIMENS WITHOUT INTERMEDIATE GROWTH.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
106 to 110 mm	2	18.0	55.5
101 to 105 mm	1	14.0	48.0
96 to 100 mm	4	16.0	54.2
91 to 95 mm	5	14.4	47.0
86 to 90 mm	9	13.7	45.7
81 to 85 mm	1	14.0	43.0
76 to 80 mm	0	.....	.....
71 to 75 mm	1	10.0	43.0
66 to 70 mm	2	10.0	38.0
61 to 65 mm	1	9.0	33.0
56 to 60 mm	0	.....	.....
51 to 55 mm	0	.....	.....
46 to 50 mm	1	4.0	18.0
Av. 87.3 mm	.....	13.5	45.7

TABLE 11.—FRY FROM POINT ELLICE, WASH., AUG. 12 AND 26, 1916—Contd.

THIRTY-SEVEN SPECIMENS WITH INTERMEDIATE GROWTH.

Length.	Number.	Scale record.					Average estimated length of fish at beginning of intermediate growth.
		Number of rings—			Length of anterior radius—		
		To intermediate growth.	In intermediate growth.	Total.	To intermediate growth.	Total.	
121 to 125 mm	1	13.0	7.0	20.0	38.0	63.0	73.0
116 to 120 mm	2	13.5	8.0	21.5	45.5	68.0	80.5
111 to 115 mm	2	13.0	7.5	20.5	38.0	55.5	73.0
106 to 110 mm	3	9.0	9.0	18.0	29.6	58.0	65.5
101 to 105 mm	8	9.1	7.3	16.4	29.6	54.2	58.0
96 to 100 mm	4	9.2	8.2	17.4	30.5	56.7	54.2
91 to 95 mm	9	6.2	9.3	15.5	22.3	51.3	44.1
86 to 90 mm	4	7.5	8.0	15.5	24.4	43.0	51.5
81 to 85 mm	3	6.0	5.8	11.8	23.0	38.0	51.3
76 to 80 mm	1	6.0	6.0	12.0	23.0	43.0	48.0
8 Av. 98.5 mm		8.5	7.9	16.1	28.2	52.3	54.8

Three specimens of young chinook salmon were caught August 23, 1916, by hook and line from the wharf of P. J. McGowan & Sons at Ilwaco, Wash. These young fish were under the cannery and were feeding voraciously on the offal resulting from the cleaning of the adult salmon. Their stomachs were quite filled with eggs and small pieces of kidney, flesh, etc. There was very little evidence that they had been feeding on insects or crustaceans. Several other collections were made under this cannery and one other in Astoria, and in every case the young fish were found to have eaten heavily of the offal. These three specimens are all females averaging 118 mm. in length. The scales of one specimen show a distinct intermediate band of eight rings. The average number of rings on the scales is 21.3. The length of the anterior radius averages 61.3.

Ten specimens of young chinooks were collected in the Clackamas River, August 30 and 31, 1916. (See Table 12.) The collection was made by hook and line near the Clackamas hatchery, about 2 miles above where the Clackamas River flows into the Willamette. Five of these are males averaging 113.8 mm. in length. The five females average 112 mm. Four of the males were approaching maturity, as was indicated by the enlarged and white testes. The average length of these four is 118.2 mm. The scales of these precocious males are in every respect similar to the scales of the other individuals. Such precociously matured males have been previously described by Rutter (1903). The scales of these fish indicate unmistakably that they were fry, less than 1 year old. The scales of 8 out of the 10 individuals show a distinct narrowing of the marginal rings corresponding to the slower growth of the fall and winter. Since the number of specimens is so small, no attempt is made to segregate the specimens showing different types of scale growth.

TABLE 12.—YOUNG CHINOOKS FROM CLACKAMAS RIVER, AUG. 30 AND 31, 1916.

Average length.	Number—		Scale record.				Average estimated length of fish at time of formation of check.
	Total.	With check.	Number of rings—		Average length of anterior radius—		
			To check.	Total.	To check.	Total.	
112.9 mm.	10	7	6.7	20.7	17.3	58.2	43.4

The check found on these scales, while in some respects similar, can not be considered as identical with the check preceding the intermediate rings, which is a feature of the scale growth of the fish taken on the lower river. The central part of the scales, within the check, is composed of a fewer number of rings, is smaller in size, and the rings succeeding the check are not so wide. (See Pl. I, figs. 7 and 8.) While it seems probable that the fundamental causes underlying the formation of these checks are similar (probably a change in the food supply or other environmental conditions), the change in the case of the fish entering the brackish water of the estuary is more profound. In order to distinguish these two types of checks in the discussions, the term "primary check" will be used for that formed in the upper parts of the stream and "migratory check" for that formed on entering the estuary. The next collection to be mentioned will throw further light on this question.

In April and May, 1915, the Oregon Fish and Game Commission planted, from the hatchery at Bonneville, several carloads of chinook fry in a small artificial lake near Seufert, Oreg. The fish were fed daily with offal from Seufert Bros. cannery, which is located at this point. At the time the plant was made the writer measured a small series of the fish. The average length was 44.6 mm. September 2, 1915, a collection of 55 specimens was made by hook and line from this lake and the outlet which connected the lake with the Columbia River. (See Table 13.) The average length was 80.9 mm. Twenty-seven were males averaging 81.5 mm. in length and 28 were females averaging 80.3 mm. There were three mature males in the lot, and these averaged 94 mm. in length. The most interesting point which appeared in the study of this collection has to do with the formation of the primary check mentioned above. Such a check was apparent on the scales of 84 per cent of the specimens, and an average of 6.7 rings was included within this check. The general appearance of the scales is similar to that of fish reared under typical hatchery conditions; that is, the rings are more or less irregularly spaced and may be broken. (See Pl. I, fig. 6.) The central portion was missing from many of the scales examined, so that it was frequently necessary to examine several scales from the same fish before a perfect one was found. Not infrequently a similar central portion would be dislocated in reference to the scale as a whole, as though it had been loosened and turned within the delicate pocket of the skin in which the scale is formed. This appearance has also been described by Gilbert (1914, p. 62), who has found it on the scales of the sockeye salmon. These blank and dislocated centers correspond in size to the area within the check on the perfect scales, and there could be no doubt that the same cause was responsible for all three of these abnormalities in the scale growth. Nineteen specimens (35 per cent) had begun the slower

winter growth, as is indicated by the narrower marginal rings. The following table (13) gives the data regarding this collection. No attempt is made to segregate the few specimens whose scales do not possess this primary check.

TABLE 13.—YOUNG CHINOOKS FROM LAKE AT SEUFERT, OREG., SEPT. 2, 1915.

Length.	Number—		Scale record.				Average estimated length of fish at time of formation of check.
	Total.	With check.	Number of rings—		Length of anterior radius—		
			To check.	Total.	To check.	Total.	
106 to 110 mm	2	2	8.5	14.0	25.5	45.5	63.0
101 to 105 mm	2	2	9.5	17.0	33.0	55.5	63.0
96 to 100 mm	0	0					
91 to 95 mm	3	3	5.6	13.6	21.3	41.3	49.5
86 to 90 mm	7	7	8.3	14.6	28.8	44.4	54.5
81 to 85 mm	12	11	6.7	12.9	22.5	39.2	46.0
76 to 80 mm	11	8	6.1	12.3	21.1	37.5	45.0
71 to 75 mm	12	7	5.6	11.4	17.3	32.5	41.0
66 to 70 mm	5	5	6.4	11.2	18.0	31.0	39.0
61 to 65	1	1	4.0	11.0	13.0	28.0	33.0
Total	55	46					
Av., 80.9 mm			6.7	12.7	22.2	37.9	47.9

The almost exact correspondence between the estimated length at the time of the formation of the primary check and the actual observed length at the time of planting proves conclusively that in this particular instance the altered rate of growth following the formation of the check was in response to the changed environmental conditions resulting from the removal of the fish from the hatchery at Bonneville to the lake at Seufert.

Sixty-nine specimens were collected September 15, 1916, at Crandall's seining ground on Grims Island. In several respects this is an unusual collection. The average length is but 74.4 mm., the smallest recorded since June. The proportion of specimens whose scales show the intermediate growth is also very small, only three in the entire collection. None of the other collections made at this point are remarkable for the small size of the fish as compared with other collections made at the same time of year in other localities, so that it is unlikely that selection has taken place here as was evidently the case with the collection made within the mouth of the small stream near Point Ellice. A possible explanation may be that we are dealing here with a series composed largely, if not wholly, of fish migrating seaward from some particular tributary or region of the Columbia River watershed, in which the fry do not attain, before migration, as large a size as is common for other parts of the watershed. Gilbert (1912*a*) has described such differences among the young migrating sockeyes in different tributaries of the Fraser River system. This explanation seems, therefore, plausible in the case of these young chinooks, although admittedly unproved.

The three specimens which show a band of intermediate rings are among the largest taken and average 89.3 mm. in length. The average number of rings preceding the intermediate growth is 7. The number of intermediate rings averages 9, and the average total number of rings is, therefore, 16. The average length of the anterior radius of the scale is 21.3 to the beginning of the intermediate growth and 47.3 to the

periphery of the scales. The average estimated length at the time of beginning the rapid growth is 39.3 mm. The whole collection contains 36 males and 33 females. The males have an average length of 74.2 mm. and the females 74.8 mm. In the following table (14) are presented the data relative to those specimens whose scales do not show a band of intermediate rings:

TABLE 14.—DATA FOR 66 YOUNG CHINOOKS FROM CRANDALL'S SEINING GROUND, SEPT. 15, 1916.

SPECIMENS WITHOUT INTERMEDIATE GROWTH.

Length.	Number.	Scale record.	
		Number of rings.	Length of anterior radius.
86 to 90 mm	4	15.5	54.0
81 to 85 mm	6	14.9	45.1
76 to 80 mm	20	13.4	42.0
71 to 75 mm	14	12.9	41.0
66 to 70 mm	14	11.9	36.5
61 to 65 mm	7	11.9	33.5
56 to 60 mm	1	13.0	33.0
Av. 73.8 mm	.....	13.1	40.1

Thirty-five young chinooks were taken by hook and line September 17, 1914, from beneath the McGowan cannery at Ilwaco, Wash. The scales of 28 (80 per cent) of these show a marginal band of intermediate rings. As a rule these intermediate rings are distinctly heavier and wider than is the case with the average fish collected elsewhere in the estuary. It is also found that the rings immediately preceding the intermediate band are sometimes distinctly narrower than the more central rings. (See Pl. II, figs. 5 and 7.) This same appearance characterizes the scales of a few specimens from Crandall's seining ground, just mentioned, and, to anticipate, is found in varying proportions in all later collections from the estuary. There are not, however, two distinct categories of scales, one exhibiting a distinct narrowing preceding the intermediate growth and the other without such narrowing. All stages in the development of this band of narrow rings may be observed from examples where the intermediate band begins merely as a sudden widening (Pl. II, fig. 6) to those where the intermediate band is preceded by a very clear and well-marked band of narrow rings (Pl. II, fig. 5). Plate II, figure 7, represents an intermediate condition. Among the seven fish whose scales do not show intermediate growth are five whose scales terminate in narrow rings of the winter type. These are somewhat smaller than the specimens whose scales do show the intermediate band, and there can be little doubt that they are the more recent arrivals from upstream which had not yet begun the intermediate growth.

The scales of some of the specimens contained in this collection have also a more or less well-developed primary check in addition to the migratory check which immediately precedes the intermediate growth. This also is found in varying proportions in the subsequent collections and will be considered more in detail later. Eighteen males average 121.3 mm. in length and 17 females average 124.7 mm. The following table (15) contains the data for this collection:

TABLE 15.—YOUNG CHINOOKS FROM UNDER THE CANNERY, ILWACO, WASH., SEPT. 17, 1914.

SEVEN SPECIMENS WITHOUT INTERMEDIATE GROWTH.

Average length.	Scale record.	
	Number of rings.	Length of anterior radius.
120.2 mm	20.2	59.4

TWENTY-EIGHT SPECIMENS WITH INTERMEDIATE GROWTH.

Length.	Number.	Scale record.				Average estimated length of fish at beginning of intermediate growth.
		Number of rings—		Length of anterior radius—		
		To intermediate growth.	Total.	To intermediate growth.	Total.	
151 to 155 mm	1	17.0	28.0	53.0	88.0	98.0
146 to 150 mm	0					
141 to 145 mm	2	17.0	24.5	55.0	75.0	105.0
136 to 140 mm	1	25.0	30.0	53.0	78.0	98.0
131 to 135 mm	1	20.0	23.0	53.0	58.0	118.0
126 to 130 mm	6	17.0	20.7	48.0	61.0	100.0
121 to 125 mm	5	18.6	21.4	50.0	60.0	105.0
116 to 120 mm	6	16.6	20.3	47.0	59.0	95.0
111 to 115 mm	4	16.2	19.6	45.0	55.0	89.0
106 to 110 mm	0					
101 to 105 mm	2	13.0	19.5	40.0	60.0	70.0
Av. 123.5 mm		17.2	21.4	48.1	62.0	96.8

Seven specimens were collected from the Clackamas River near the hatchery on October 13, 1915. These were obtained by hook and line fishing, and the collection is too small and too variable to deserve detailed attention. The average length is 118 mm., and the average total number of rings on the scales, 21. Several show the primary check, and one at least had apparently started a new period of vigorous growth. This is indicated on the scales by a marginal band of five slightly wider rings. The scales of all of the other specimens terminate in rings of the winter type.

October 16, 1915, a collection consisting of 119 young chinooks was made at Point Ellice, Wash. The total average length is 112.7 mm. Sixty-one males average 112.2 mm. and 58 females 113.3 mm. Twenty-nine specimens (24 per cent) have a distinct intermediate band at the margins of the scales. The scales of the remaining 90 specimens terminate uniformly in narrow winter rings. The scales of a considerable proportion show the primary check about 9 or 10 rings from the center. The following table (16) presents the data.

TABLE 16.—YOUNG CHINOOKS FROM POINT ELLICE, WASH., OCT. 16, 1915.

SPECIMENS WITHOUT INTERMEDIATE GROWTH.

Length.	Number—		Scale record.				Average estimated length of fish at time of formation of check.
	Total.	With primary check.	Number of rings—		Length of anterior radius—		
			To check.	Total.	To check.	Total.	
146 to 150 mm	1	1	16.0	30.0	53.0	93.0	88.0
141 to 145 mm	0	0					
136 to 140 mm	0	0					
131 to 135 mm	1	1	12.0	28.0	38.0	78.0	63.0
126 to 130 mm	2	2	9.0	29.5	28.0	70.5	50.5
121 to 125 mm	8	4	9.7	24.0	26.7	63.0	55.2
116 to 120 mm	19	12	10.6	23.8	30.0	61.7	61.7
111 to 115 mm	23	14	11.0	23.4	32.2	58.5	59.0
106 to 110 mm	23	17	10.0	22.0	28.5	58.0	54.0
101 to 105 mm	9	6	10.8	21.7	29.6	55.7	47.1
96 to 100 mm	4	3	10.3	21.5	26.3	53.0	51.3
Total	90	60					
Av. 113.0 mm			10.6	23.1	30.2	59.8	57.1

SPECIMENS WITH INTERMEDIATE GROWTH.

Length.	Number—		Scale record.						Average estimated length of fish at time of formation of—	
	Total.	With primary check.	Number of rings—			Length of anterior radius—				
			To primary check.	To intermediate growth.	Total.	To primary check.	To intermediate growth.	Total.	Primary check.	Intermediate growth.
131 to 135 mm	2	1	9.0	22.0	25.5	28.0	53.0	68.0	53.0	113.0
126 to 130 mm	1	0		23.0	26.0		53.0	63.0		118.0
121 to 125 mm	1	0		19.0	24.0		48.0	63.0		93.0
116 to 120 mm	5	5	9.8	22.8	25.6	26.0	55.0	66.0	47.0	98.0
111 to 115 mm	5	5	10.6	21.8	25.2	29.0	50.0	60.0	55.0	96.0
106 to 110 mm	9	5	7.0	19.4	22.3	24.0	49.6	53.5	43.0	91.8
101 to 105 mm	4	1	11.0	18.2	21.7	33.0	46.7	56.7	53.0	85.5
96 to 100 mm	2	0		17.0	19.5		48.0	55.5		85.5
Total	29	17								
Av. 111.0 mm			9.25	20.3	23.4	26.8	50.7	60.6	48.9	94.7

In connection with the series just considered another collection made the following day, October 17, 1915, is of considerable interest. This second collection was made by hook and line under one of the canneries located at Astoria, Oreg., the Union Fishermen's Cooperative Cannery. As has been already mentioned, fish taken under these conditions are always found to be feeding heavily on the offal from the cannery. This collection consists of 61 specimens, of which 43 (70 per cent) have scales which show the intermediate growth. The average length of this collection is considerably greater than for the Point Ellice collection, 127.5 mm. The specimens which had begun the rapid intermediate growth average 130.5 mm., and those which had not done so average but 120.2 mm. All of the specimens whose scales do not show intermediate rings have the narrow winter rings at the scale margins. Thirty-three males average 127.9 mm. in length and 28 females 127.0 mm. The following table (17) gives the data for this collection:

TABLE 17.—YOUNG CHINOOKS FROM UNDER CANNERY, ASTORIA, OREG., OCT. 17, 1915.

SPECIMENS WITHOUT INTERMEDIATE GROWTH.

Length.	Number—		Scale record.				Average estimated length of fish at time of formation of check.
			Number of rings—		Length of anterior radius—		
	Total.	With check.	To primary check.	Total.	To primary check.	Total.	
151 to 155 mm	1	0	.....	25.0	.....	88.0	.....
146 to 150 mm	0	0	.....	.....	.....	.....	.....
141 to 145 mm	0	0	.....	.....	.....	.....	.....
136 to 140 mm	0	0	.....	.....	.....	.....	.....
131 to 135 mm	0	0	.....	.....	.....	.....	.....
126 to 130 mm	2	2	9.0	25.5	25.5	68.0	48.0
121 to 125 mm	6	2	6.0	23.3	20.5	68.0	40.5
116 to 120 mm	3	2	6.5	22.6	23.0	58.0	45.5
111 to 115 mm	3	2	10.5	22.0	33.0	56.3	65.5
106 to 110 mm	3	3	7.3	22.3	24.6	61.3	41.3
Total	18	11	.....	.....	.....	.....	.....
Av. 120.2 mm	.....	.....	7.8	23.2	25.2	64.5	48.0

SPECIMENS WITH INTERMEDIATE GROWTH.

Length.	Number—		Scale record.						Average estimated length of fish at time of formation of—	
			Average number of rings—			Average length of anterior radius—				
	Total.	With check.	To check.	Intermediate growth.	Total.	To check.	Intermediate growth.	Total.	Check.	Intermediate growth.
176 to 180 mm	1	0	.....	22.0	34.0	.....	73.0	113.0	.....	118.0
171 to 175 mm	0	0	.....	.....	.....	.....	.....	.....	.....	.....
166 to 170 mm	0	0	.....	.....	.....	.....	.....	.....	.....	.....
161 to 165 mm	0	0	.....	.....	.....	.....	.....	.....	.....	.....
156 to 160 mm	1	1	9.0	23.0	28.0	28.0	58.0	73.0	63.0	123.0
151 to 155 mm	2	2	9.5	24.0	28.5	30.5	65.5	88.0	53.0	115.5
146 to 150 mm	3	3	10.3	24.3	29.3	33.6	66.3	83.0	58.0	118.0
141 to 145 mm	3	2	12.0	24.0	29.0	35.5	64.6	81.3	63.0	109.6
136 to 140 mm	3	2	8.5	22.3	26.9	28.0	58.0	79.6	50.5	106.3
131 to 135 mm	8	6	7.1	22.9	27.0	23.0	58.0	73.0	43.0	106.1
126 to 130 mm	5	4	10.2	21.6	26.0	30.5	59.0	73.0	53.0	106.0
121 to 125 mm	9	6	8.1	20.4	23.8	26.5	56.3	69.2	45.8	103.0
116 to 120 mm	3	3	10.3	20.4	23.0	31.3	51.3	59.6	63.0	104.6
111 to 115 mm	2	2	8.9	20.0	24.0	23.0	50.5	60.5	45.5	90.5
106 to 110 mm	1	1	9.0	19.9	24.9	28.0	43.0	63.0	48.0	78.0
101 to 105 mm	1	1	13.0	22.0	24.0	33.0	53.0	58.0	63.0	93.0
96 to 100 mm	1	0	.....	14.0	15.0	.....	48.0	53.0	.....	93.0
Total	43	33	.....	.....	.....	.....	.....	.....	.....	.....
Av. 130.5 mm	.....	.....	9.3	21.8	26.0	28.2	58.0	73.0	50.9	105.5

Four young chinooks were collected October 22, 1915, from the Little White Salmon River, Wash. These were taken near the hatchery maintained by the Bureau of Fisheries, which is about a half mile above the point where the Little White Salmon enters the Columbia River. These four fish are all females and average 92.5 mm. in length. The average number of rings on the scales is 15.8, and the average length of the anterior radius of the scales, 52.5. There is no indication of wider marginal rings on the scales of these fish.

A collection consisting of 100 specimens was made October 24 to 27, 1914, from under the cannery at Ilwaco, Wash. Ninety-four of these show the marginal band of wider rings. In all cases where the scales do not show intermediate rings the scale growth terminates in winter rings. The average size is greater than that of any other collection studied, 146.7 mm. Most of these fish were measured, a few scales were removed, and the fish were then returned to the river. The fish which were preserved were selected for unusual size. On this account data regarding the number and relative lengths of males and females are not available. The scales of these fish present no unusual features. The following table (18) contains the data:

TABLE 18.—YOUNG CHINOOKS FROM ILWACO, WASH., UNDER THE CANNERY, OCT. 24, 1914.

SPECIMENS WITHOUT INTERMEDIATE GROWTH.

Average length.	Number—		Scale record.				Average estimated length of fish at time of formation of check.
	Total.	With check.	Average number of rings—		Average length of anterior radius—		
			To check.	Total.	To check.	Total.	
121.5 mm	6	3	7.6	21.5	24.3	61.3	49.7

SPECIMENS WITH INTERMEDIATE GROWTH.

Length.	Number—		Scale record.						Average estimated length of fish at time of formation of—	
	Total.	With check.	Average number of rings—			Average length of anterior radius—				
			To check.	Intermediate growth.	Total.	To check.	Intermediate growth.	Total.	Check.	Intermediate growth.
201 to 205 mm	2	1	10.0	21.0	34.0	23.0	65.5	110.5	48.0	123.0
196 to 200 mm	0	0								
191 to 195 mm	2	0		18.0	31.5		58.0	108.0		110.5
186 to 190 mm	1	0		18.0	31.0		68.0	118.0		113.0
181 to 185 mm	0	0								
176 to 180 mm	2	2	8.5	19.0	31.0	28.0	60.5	93.0	53.0	115.5
171 to 175 mm	3	1	10.0	20.0	30.3	28.0	53.0	88.0	48.0	106.3
166 to 170 mm	10	3	6.3	19.1	30.0	21.3	56.5	90.3	38.0	103.5
161 to 165 mm	3	0		20.3	27.6		58.0	86.3		108.0
156 to 160 mm	6	1	12.0	18.3	26.9	48.0	57.1	87.1	88.0	103.0
151 to 155 mm	7	2	8.0	19.7	27.0	23.0	53.7	78.7	48.0	109.4
146 to 150 mm	10	6	10.0	19.4	26.4	29.6	54.2	72.0	58.2	108.0
141 to 145 mm	12	6	9.0	20.5	26.2	24.6	53.8	69.6	52.2	110.5
136 to 140 mm	12	5	7.2	20.9	27.0	24.0	53.0	72.5	46.0	101.3
131 to 135 mm	9	3	10.0	18.9	24.2	26.7	55.0	69.1	55.5	104.1
126 to 130 mm	5	2	10.0	18.8	23.2	25.7	54.6	65.0	53.0	102.0
121 to 125 mm	8	4	7.7	19.5	24.7	24.2	47.3	63.0	48.0	94.8
116 to 120 mm	1	0		20.0	22.0		56.0	63.0		98.0
111 to 115 mm	0	0								
106 to 110 mm	1	0		12.0	14.0		38.0	48.0		88.0
Total	94	36								
Average, 148.3 mm			8.6	19.5	26.6	25.8	54.6	77.2	51.3	99.9

Fifty-two specimens were taken in the McKenzie River near Leaburg, Oreg., November 2 and 3, 1915. (See Table 19.) The Oregon Fish and Game Commission maintains a hatchery here, and the fish were collected just below the point where the hatchery is

located. The average length is 106.4 mm. The males, 24 in number, average 107.1 mm. in length; the 28 females, 106 mm.

A particularly interesting feature of this collection is the fact that a considerable proportion of the specimens have scales which show a distinct widening of the marginal rings. Fourteen (27 per cent) of the specimens have scales of this character. The other specimens all have scales whose marginal rings are of the narrow, winter type. The series of collections from the upper regions of the Columbia River basin is not complete enough to allow conclusions to be drawn regarding the character of this widening of the marginal rings, but it can be shown on material from the Sacramento River that the new growth of the second year usually begins during the fall. Previous to beginning this "new growth" there has been formed a more or less distinct band of narrower rings, the winter band. This is unquestionably the same phenomenon which is evident in the present case, namely, the beginning of the vigorous new growth which will continue during the growing season of the following year.

This question naturally presents itself: If this widening of the marginal rings in the case of the fish from the upper parts of the stream is to be interpreted as the new growth belonging to the second year, is it certain that the similar widening which has been found on the scales of the young fish in the estuary is not, in reality, the same thing which has merely been hastened by the migration to the brackish water in the estuary? In other words, why give different interpretations to the two phenomena?

Similar physiological causes are, in all probablity, behind the accelerated growth in each instance. The intermediate growth, however, is directly the result of changes brought about by the migration into brackish water, while the "new growth" is a response to environmental changes which are independent of any special activity on the part of the fish. The changes resulting in new growth are seasonal and affect all of the fish in any particular locality at nearly the same time of the year. The stimulus is probably not a simple one but is a complex of several factors, such as temperature, food supply, degree of maturity, etc. Racial differences in different localities may also enter as modifying factors.

The change brought about by migration is the more profound as is indicated by the fact that the rings of the intermediate growth are usually heavier and more widely spaced than those composing the new growth accomplished before migration. The difference between the two types of rapid growth is not, however, diagnostic, and it is usually impossible to distinguish in individual cases between intermediate bands and bands of new growth. Many of the fish taken in the upper part of the stream and which have begun the new growth could not be distinguished by the scales from fish taken in the estuary whose scales show the intermediate growth. From October on, therefore (and probably for some weeks previous to this time), one is likely to encounter fish in the estuary whose scales would be practically identical—having a marginal band of wider rings—but some of which will have formed the marginal band as a result of migration into brackish water, while others will have formed the marginal band in the upper parts of the stream previous to migration. Undoubtedly as the season advances the percentage of fish which have formed this band in response to the migration will decrease, while the percentage of fish which have started the new growth of the second

year will increase. Since there is no method of distinguishing with certainty between the two types, the marginal band of wider rings found on the scales of the fish taken in the estuary will be referred to as the "intermediate band." In the case of fish from the upper waters, however, where the interpretation is unquestioned, we shall designate the marginal widening as "new growth."

Such a marginal band of wider rings is not always formed on the scales of fish found in the estuary. It is not apparent on the scales of the smaller migrants owing to the fact that the first few rings formed on the scales are almost always wider than those normally succeeding. They are not, however, wider than the intermediate rings but are of approximately the same width, so that no break appears at the point where the intermediate growth actually begins. The absence of the intermediate band on the scales of some of the larger migrants is probably due to the fact that those fish have not been in the brackish water long enough for the wider rings to have developed. When the intermediate growth is not found on the scales of the adult fish, which show a nuclear area of true stream growth, it probably indicates that during the seaward migration the individual did not remain long in the brackish water but continued the migration so rapidly that typical ocean rings were formed immediately succeeding typical stream rings.

The following table (19) gives the data relative to the McKenzie River collection:

TABLE 19.—YOUNG CHINOOKS FROM MCKENZIE RIVER, NOV. 2 AND 3, 1915.

SPECIMENS WITHOUT NEW GROWTH.

Length.	Number—		Scale record.				Average estimated length of fish at time of formation of check.
			Average number of rings—		Average length of anterior radius—		
	Total.	With check.	To check.	Total.	To check.	Total.	
121 to 125 mm	1	1	8.0	22.0	28.0	58.0	58.0
116 to 120 mm	1	1	7.0	19.0	28.0	58.0	63.0
111 to 115 mm	9	4	7.7	19.4	23.0	55.2	49.2
106 to 110 mm	11	3	7.7	18.7	25.5	53.0	53.5
101 to 105 mm	7	2	8.5	18.3	23.0	52.3	48.0
96 to 100 mm	6	2	8.5	17.0	23.0	48.8	45.5
91 to 95 mm	1	1	10.0	15.0	33.0	48.0	63.0
86 to 90 mm	1	1	9.0	16.0	28.0	43.0	58.0
81 to 85 mm	1	0	.....	14.0	.....	38.0	.....
Total	38	20	.....	.....	.....	.....	.....
Av. 105.8 mm	.....	.....	8.0	18.5	25.2	52.2	53.7

SPECIMENS WITH NEW GROWTH.

Average length.	Number—		Scale record.						Average estimated length of fish at time of formation of—	
			Average number of rings—			Average length of anterior radius—				
	Total.	With check.	To check.	In first year.	Total.	To check.	In first year.	Total.	Check.	New growth.
108.0 mm	14	5	6.6	15.7	19.8	19.0	43.4	55.5	40.0	85.1

Six young chinooks were taken at Astoria, Oreg., November 7, 1914. These were captured by hook and line from under the Union Fishermens' Cooperative Cannery. Nothing of particular interest appeared in the study of this small collection, and the table (20) is therefore presented without comment.

TABLE 20.—YOUNG CHINOOKS FROM ASTORIA, OREG., NOV. 7, 1914.

Average length.	Number—		Scale record.						Average estimated length of fish at time of formation of—	
			Average number of rings—			Average length of anterior radius—				
	Total.	With check.	To check.	To intermediate growth.	Total.	To check.	To intermediate growth.	Total.	Check.	Intermediate growth.
135.0 mm.....	6	5	9.0	21.0	25.0	27.0	66.6	78.0	48.8	111.6

November 19, 1915, seven small chinooks were collected by means of a seine on a small sand bar near Warrendale, Oreg. (See Table 21.) This is on the Columbia River about 40 miles above the point where the Willamette River joins the Columbia. These fish average only 93 mm. in length, and it is worthy of note that the scales show no indication of the beginning of a period of rapid growth. The scales of one specimen show a primary check four rings from the center of the scales. Four specimens show the narrow, winter rings at the margins of the scales. The other three specimens have scales whose marginal rings are still of the summer type, no narrowing being apparent.

TABLE 21.—YOUNG CHINOOKS FROM WARRENDALE, OREG., NOV. 19, 1915.

Average length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
93 mm.....	7	15	45

Scales were taken December 4, 1914, from 52 specimens of young chinooks which had been reared at the hatchery of the U. S. Bureau of Fisheries at Clackamas, Oreg. These fish were measured but not sexed. The scales of these are no exception to the rule that the scales of hatchery fish exhibit uneven and abnormal growth and are seldom of much value in scale study. Since these are fish of known age, having been reared from eggs which were spawned in the fall of 1913, it will, however, be interesting to make a comparison between them and wild fish of the same approximate age. These hatchery fish are quite irregular in their growth, so much so, in fact, as to indicate a bimodal curve. The average length is, however, about the same as the average of other collections made at the same time of year, being less than some and greater than others. The scale growth is also, in spite of its irregularities, quite comparable with that observed in the wild fish in the number and the general arrangement of the rings. The data regarding these fish are collected in the following table (22).

TABLE 22.—YOUNG CHINOOKS FROM CLACKAMAS HATCHERY, OREG., DEC. 4, 1914.

Length.	Number—		Scale record.						Average estimated length of fish at time of formation of—	
			Average number of rings—			Average length of anterior radius—				
	Total.	With check.	To check.	To— New growth.	Of— New growth.	To check.	To new growth.	Total.	Check.	New growth.
151 to 155 mm	1	1	6.0	23.0	2	30.0	57.0	68.0	67.0	127.0
146 to 150 mm	2	2	8.0	24.5	2	29.0	72.0	[a] 70.0	55.5	127.0
141 to 145 mm	0	0	.....	.....	.....	.....	.....	.....	.....	.....
136 to 140 mm	2	2	7.5	21.5	.....	28.0	65.5	.....	60.5	.....
131 to 135 mm	6	6	9.3	22.0	2	28.0	68.0	81.0	54.5	115.0
126 to 130 mm	10	9	8.5	20.1	3	28.0	57.0	70.0	56.0	110.0
121 to 125 mm	3	3	8.3	20.6	.....	25.5	55.5	.....	48.0	.....
116 to 120 mm	8	8	8.6	19.0	.....	21.0	54.0	.....	50.0	.....
111 to 115 mm	12	12	8.9	19.4	.....	24.2	55.5	.....	51.0	.....
106 to 110 mm	3	3	8.6	17.3	.....	23.0	43.0	.....	46.0	.....
101 to 105 mm	4	4	8.2	19.4	.....	18.0	48.0	.....	50.5	.....
96 to 100 mm	0	0	.....	.....	.....	.....	.....	.....	.....	.....
91 to 95 mm	1	1	10.0	17.0	.....	23.0	53.0	.....	43.0	.....
Total	52	51	.....	.....	.....	.....	.....	.....	.....	.....
Av. 121.1 mm	.....	.....	8.6	20.1	2.2	24.8	57.3	72.2	52.3	119.7

[a] The fact that this is less than the length to the beginning of the new growth is due to the fact that the specimen not having the new growth had unusually large scales.

All but nine of the specimens have winter rings at the margins of the scales. Of these, four have a marginal band of wider rings, indicating that a period of more rapid growth has begun. This is probably the new growth of the second year. The remaining five specimens still show at the margins of the scales the wide rings of the first summer's growth.

December 3 to 8, 1915, several collections were made at different points on the Columbia River between the mouth of the Willamette River and Astoria. Collecting was rather difficult on account of inclement weather and unusually high water for this time of year. Collections were made in the following places: Upper Willow Bar, Lower Willow Bar, Deer Island, Mayger, Oreg., Wallace Island, and Seal Island. Unsuccessful attempts to collect were also made at several other places. The collections are all quite small, and the total number of fish taken was but 38. This represents the results of over 30 hauls with the 100-foot seine. One of the specimens collected is a small fry only 35 mm. in length. This is obviously a fish of the year, and therefore one year younger than the other individuals. No scales have been developed. This specimen is not included with the older fish in the following table. Fourteen of the older specimens are males averaging 95.5 mm. in length. Twenty-four females average 93.4 mm. The average length of all specimens is 94 mm. No significant differences have been observed in the several collections, and they are therefore cast together in the following table (23):

TABLE 23.—YOUNG CHINOOKS FROM LOWER COLUMBIA RIVER, DEC. 3 TO 8, 1915.

SEVENTEEN SPECIMENS WITHOUT INTERMEDIATE GROWTH.

Average length.	Scale record.	
	Average number of rings.	Average length of anterior radius.
92.3 mm	16.5	49.5

TABLE 23.—YOUNG CHINOOKS FROM LOWER COLUMBIA RIVER, DEC. 3 TO 8, 1915—Continued.

TWENTY-ONE SPECIMENS WITH INTERMEDIATE GROWTH.

Length.	Number.	Scale record.				Average estimated length of fish at beginning of intermediate growth.
		Average number of rings—		Average length of anterior radius—		
		To intermediate growth.	Total.	To intermediate growth.	Total.	
126 to 130 mm	1	19.0	25.0	53.0	68.0	93.0
121 to 125 mm	0					
116 to 120 mm	0					
111 to 115 mm	1	18.0	22.0	58.0	68.0	98.0
106 to 110 mm	3	14.7	18.7	43.0	58.0	81.3
101 to 105 mm	1	14.0	18.0	43.0	53.0	78.0
96 to 100 mm	4	14.5	18.5	36.7	50.5	71.7
91 to 95 mm	1	18.0	22.0	33.0	48.0	73.0
86 to 90 mm	4	14.2	18.2	36.7	46.7	68.0
81 to 85 mm	5	13.5	17.5	39.0	44.0	63.0
76 to 80 mm	1	13.0	14.0	33.0	38.0	68.0
Av. 95.1 mm		14.7	18.7	38.6	50.4	72.8

Owing to the unusual severity of the winter of 1915–16, no more collections were made after the one just considered until the following March and April. The fry taken during the spring and early summer have already been considered, and it remains now to discuss the yearlings which were taken during the second year after hatching.

During the course of the seining on the lower river in March and the early part of April, 1916, a total of 47 yearlings were captured. (See p. 7.) Although these were obtained from several different localities, separate tabulation shows no special difference in the fish from different places, and the entire collection is here tabulated together. There are 26 males in the collection averaging 97.6 mm. in length and 21 females averaging 93.2 mm. The average length of the entire collection is 95.6 mm. Thirteen of the specimens do not show the wider rings at the margins of the scales, but narrow, typically winter rings. The remaining 34 specimens have the wider marginal rings which are characteristic of the young migrating fish. It has been previously indicated that the marginal band of wider rings in these yearlings which were captured in the spring are probably in large measure indicative of the new growth of the second year. The term "intermediate growth" is retained, however, for the reasons given on page 25. The following table (24) presents the data for this collection:

TABLE 24.—CHINOOK YEARLINGS FROM LOWER COLUMBIA RIVER, MAR. 31 TO APR. 2, 1916.

SPECIMENS WITHOUT INTERMEDIATE GROWTH.

Average length.	Number—		Scale record.				Average estimated length of fish at time of formation of primary check.
	Total.	With primary check.	Average number of rings—		Average length of anterior radius—		
			To check.	Total.	To check.	Total.	
93.7 mm	13	3	7.6	18.7	16.0	35.7	43.0

TABLE 24.—CHINOOK YEARLINGS FROM LOWER COLUMBIA RIVER, MAR. 31 TO APR. 2, 1916—Contd.

SPECIMENS WITH INTERMEDIATE GROWTH.

Length.	Number—		Scale record.						Average estimated length of fish at time of formation of—	
			Average number of rings—			Average length of anterior radius—				
	Total.	With primary check.	To primary check.	To beginning of intermediate growth.	Total.	To primary check.	To beginning of intermediate growth.	Total.	Primary check.	Intermediate growth.
111 to 115 mm	2	0	.....	18.0	23.5	.....	33.0	45.5	.....	85.5
106 to 110 mm	0	0	.....	.....	.....	.....	.....	.....	.....	.....
101 to 105 mm	6	1	12.0	15.2	21.0	26.0	31.2	43.6	59.0	75.0
96 to 100 mm	9	0	.....	16.2	19.9	.....	31.2	39.9	.....	78.9
91 to 95 mm	11	2	11.0	15.9	19.7	23.6	28.8	37.0	61.0	73.8
86 to 90 mm	6	1	10.0	14.8	18.9	18.0	30.0	39.0	42.0	69.5
Total	34	4	.....	.....	.....	.....	.....	.....	.....	.....
Av. 96.4 mm	.....	.....	11.0	15.8	20.1	23.2	30.4	39.8	55.7	75.3

April 13, 1916, collections which contained specimens of yearlings were made on Deer Island and on Cottonwood Island. The total number of yearlings in these two collections is but 22. Of these, 10 are males and 12 females. The two sexes have the same average length, 107 mm. Five specimens have scales which terminate the growth in winter rings. The scales of the remaining 17 individuals show a distinct intermediate band. The following table (25) gives the data for these collections:

TABLE 25.—CHINOOK YEARLINGS FROM DEER AND COTTONWOOD ISLANDS, APR. 13, 1916.

FIVE SPECIMENS WITHOUT INTERMEDIATE GROWTH.

Average length.	Scale record.	
	Average number of rings.	Average length of anterior radius.
110 mm	19.6	42.0

SEVENTEEN SPECIMENS WITH INTERMEDIATE GROWTH.

Average length.	Scale record.				Average estimated length of fish at beginning of intermediate growth.
	Average number of rings—		Average length of anterior radius—		
	To intermediate growth.	Total.	To intermediate growth.	Total.	
105.7 mm	15.0	17.8	34.9	41.0	87.2

A somewhat larger collection of yearlings was made May 10, 1916, at Crandall's seining ground on Grims Island. Thirty-nine specimens were taken here—16 males and 23 females. The males average 106 mm. in length, and the females 101.1 mm. All of these fish have the characteristic marginal band of wider rings on the scales. The table (26) follows:

TABLE 26.—DATA FOR 39 CHINOOK YEARLINGS FROM CRANDALL'S SEINING GROUND, ON GRIMS ISLAND, MAY 10, 1916.

Length.	Number.	Scale record.				Average estimated length of fish at beginning of intermediate growth.
		Average number of rings—		Average length of anterior radius—		
		To intermediate growth.	Total.	To intermediate growth.	Total.	
121 to 125 mm	2	16.0	20.5	53.0	65.5	100.5
116 to 120 mm	3	16.6	21.9	46.3	68.0	74.6
111 to 115 mm	6	16.0	21.3	48.0	67.0	81.1
106 to 110 mm	6	14.1	19.2	42.0	57.0	76.1
101 to 105 mm	7	16.3	20.7	42.5	59.5	73.0
96 to 100 mm	4	15.2	19.9	41.7	55.5	75.5
91 to 95 mm	3	15.3	18.9	43.0	54.5	71.3
86 to 90 mm	7	12.9	17.6	33.0	49.5	62.3
81 to 85 mm	1	12.0	20.0	33.0	53.0	53.0
Av. 103 mm		15.0	19.9	41.7	58.5	74.0

Eight specimens of yearlings were taken May 11, 1916, at Point Ellice and two at Tenasillihee Island. (See Table 27.) These are quite similar to the fish contained in the collection from Crandall's seining ground, although they average somewhat larger in size.

TABLE 27.—CHINOOK YEARLINGS FROM POINT ELLICE AND TENASILLIHEE ISLAND, MAY 11, 1916.

Average length.	Number—		Scale record.						Average estimated length of fish at time of formation of—	
			Average number of rings—			Average length of anterior radius—				
	Total.	With check.	To primary check.	To intermediate growth.	Total.	To primary check.	To intermediate growth.	Total.	Check.	Intermediate growth.
108.7 mm	10	3	8.0	17.2	23.4	39.6	45.7	67.0	46.3	73.7

One yearling chinook was captured in the Columbia River just above the mouth of the Little White Salmon River on May 25, 1916. This specimen is a female, 98 mm. long. The scales show three rings of the new growth of the second year. The first year's growth comprises 15 rings. The anterior radius measures 45 mm. to the beginning of the new growth, and the total length is 59 mm. The estimated length at the time of beginning the new growth is 75 mm.

Fourteen yearlings were taken in the Clackamas River June 8, 1916, after which date no more yearlings were taken in any of the collections. Nine of these are males averaging 112 mm. in length. The 5 females average 112.6 mm. The scales of all these specimens show the wider rings of the new growth at the margins. The following table (28) gives the data for this collection:

TABLE 28.—CHINOOK YEARLINGS FROM CLACKAMAS RIVER, JUNE 8, 1916.

Average length.	Number—		Scale record.						Average estimated length of fish at time of formation of—	
			Average number of rings—			Average length of anterior radius—				
	Total.	With check.	To check.	To intermediate growth.	Total.	To check.	To intermediate growth.	Total.	Check.	Intermediate growth.
112.2 mm.....	14	2	12.5	15.5	22.6	40.0	49.1	72.6	63.0	78.3

FISH FROM THE SACRAMENTO RIVER.

The young Sacramento River chinooks available for study may be divided into two distinct groups. The first consists of young migrants which were collected by N. B. Scofield, of the California Fish and Game Commission, in the spring of 1911. This was done during the progress of an investigation into the loss of fish resulting from the overflow of the Sacramento during the spring floods. The second group consists of collections made from the McCloud River near the hatchery of the U. S. Bureau of Fisheries at Baird, Calif. These collections were made at the request of Dr. Gilbert during 1911 and 1912. The writer is indebted to both Dr. Gilbert and Mr. Scofield for the privilege of studying these collections.

The collections of young migrants from the lower part of the Sacramento were made under quite variable conditions and in several localities. Some were made from the river proper and others from the ponds formed by the overflow of the Sacramento during the spring floods. For the most part the collections were small and in several instances were so poorly preserved that many of the specimens had lost all of the scales. Very few of the collections were well enough preserved so that the individuals could be sexed.[a]

Most of these collections comprise so few individuals that a detailed consideration of each collection would be useless. No unusual results were obtained from a separate study of these smaller collections, and therefore the totals and averages for each have been collected in the following table (29). There are included also, for the purpose of comparison, three collections of young fry from the State hatcheries at Sisson and Brookdale. The few collections which are large enough to deserve more detailed study will be considered later.

[a] This poor preservation was in nowise the fault of the collector. The collections had been set aside as valueless several years before the writer found use for them and had received no care during the interval.

TABLE 29.—CHINOOK FRY FROM THE SACRAMENTO RIVER.

Date.	Locality.	Number.	Average length (mm.).	Scale record.	
				Average number of rings.	Average length of anterior radius.
1910.					
Mar. 5	Brookdale hatchery	26	36.3	(a)	(a)
1911.					
Mar. 8	Sisson hatchery	13	38.7	(b)	(b)
Apr. 3	.....do	12	41.2	(c)2.0	(c)17
Apr. 13	Sacramento River, 30 miles above Sacramento	9	57.5	4.4	23.6
Apr. 19	Cache Slough	2	67	6.0	28.2
Apr. 29	Prospect Slough	4	69	7.5	27.6
May 9	Pond near Butte Slough	13	81.5	9.2	37.5
May 15	Shag Slough	13	77	9.9	34.5
May 16	Hass Slough	4	75.2	9.5	32.2
May 27	Sausilito, Calif	8	81	10.9	37.5
May 28	Prospect Slough	16	68	7.5	28.3
June 8	Pond near Butte Slough	17	95.6	13.3	48.9
June 30	Ponds near Knights Landing, Calif	18	107.0	16.4	51.4
July 9	Pond near Butte Slough	5	92.2	14.8	47.9
1913.					
Jan. 4	Brookdale hatchery	55	[d] 95.7	17.5	38.9

[a] No scales formed.
[b] Only a few platelets present on the largest specimens.
[c] Average of six of the largest.
[d] 15 specimens without new growth. Four specimens with new growth show: Average number of rings to new growth, 16.7; of new growth, 3.7; average length of anterior radius to new growth, 37.4; total length of anterior radius, 44.9; and average estimated length at time of beginning new growth, 92.9.

The following tables (30, 31, and 32) contain the data for those collections of wild fish which are large enough for separation into the various size groups to be of value: It was not considered necessary to present in detail the data for the collections from the Brookdale hatchery, although these are as large as many of the collections of wild fish so considered. The fry preserved March 5, 1910, have no scales and present only a slight variation in length. The series of yearlings, preserved January 4, 1913, are so variable and the scale growth is so irregular that they can not be compared in detail with the wild fish.

TABLE 30.—DATA FOR 19 FRY FROM WALNUT GROVE, CALIF., APR. 9, 1911.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
71 to 75 mm	1	8	32.2
66 to 70 mm	3	7.3	26.5
61 to 65 mm	0	.....	.....
56 to 60 mm	2	4.5	23.6
51 to 55 mm	2	3.5	23.6
46 to 50 mm	2	3.0	14.9
41 to 45 mm	1	1.0	14.9
36 to 40 mm	6	.....	.....
31 to 35 mm	2	.....	.....
Av. 49.0 mm	.....	4.5	21.6

TABLE 31.—DATA FOR 22 FRY FROM BUTTE SLOUGH, MAY 8 AND 9, 1911.[a]

Length.	Number.
71 to 75 mm	4
66 to 70 mm	7
61 to 65 mm	5
56 to 60 mm	3
51 to 55 mm	2
46 to 50 mm	1
Av. 63.9 mm	

[a] The specimens in this collection had all lost the scales as a result of poor preservation.

TABLE 32.—DATA FOR 20 FRY FROM POND NEAR ELKHORN, CALIF., JUNE 3, 1911.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
81 to 85 mm	4	10.2	35.4
76 to 80 mm	10	10.0	35.3
71 to 75 mm	4	9.0	34.8
66 to 70 mm	2	8.5	27.6
Av. 77.0 mm		9.7	34.4

This collection contained 11 males averaging 77.1 mm. in length and 9 females averaging 76.9 mm. in length.

The largest collection from the lower Sacramento River was made at Woods Break, June 5 and 6, 1911. (See Table 33.) There is a total of 147 specimens. One hundred and fifteen of these were taken in a trap located at the point where the water was flowing through the break from the main river, and 32 were seined from an overflow pond near the break. The separate study of these two collections shows no essential difference, and the data are, therefore, placed together in the following table (33). This collection, undoubtedly, is a fair sample of the migrating fry in the Sacramento at this time of year. The average length is 71.7 mm. The average number of rings on the scales is 8.2, and the average length of the anterior radius is 30.5 on the arbitrary scale adopted. There are 77 males in the collection averaging 72.2 mm. in length. The 70 females average 71.0 mm.

TABLE 33.—DATA FOR 147 FRY FROM WOODS BREAK, JUNE 5 AND 6, 1911.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
91 to 95 mm	1	11.0	48.3
86 to 90 mm	5	11.6	43.0
81 to 85 mm	14	10.1	37.2
76 to 80 mm	20	9.0	33.4
71 to 75 mm	42	8.5	31.4
66 to 70 mm	34	7.6	27.9
61 to 65 mm	24	6.8	25.8
56 to 60 mm	5	5.6	23.0
51 to 55 mm	1	4.0	20.7
46 to 50 mm	1	4.0	20.7
Av. 71.7 mm		8.2	30.5

A collection of 44 specimens was made at Tisdale Wier, June 24 to 26, 1911. (See Table 34.) The average length is 78.8 mm. The average number of rings on the scales is 10.3, and the length of the anterior radius is 33.1. Twenty-one males average 78 mm. and 23 females 79.6 mm. in length.

TABLE 34.—DATA FOR 44 FRY FROM TISDALE WIER, JUNE 24 TO 26, 1911.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
101 to 105 mm	1	13.0	33.0
96 to 100 mm	2	11.5	35.5
91 to 95 mm	3	12.6	34.6
86 to 90 mm	8	10.9	29.9
81 to 85 mm	6	11.0	31.5
76 to 80 mm	5	10.2	29.0
71 to 75 mm	7	10.1	27.3
66 to 70 mm	7	9.0	25.9
61 to 65 mm	4	8.5	23.0
56 to 60 mm	1	8.0	23.0
Av. 78.8 mm		10.3	33.1

This completes the description of the young fry taken in the lower Sacramento River. The skewing of the curve of length toward the smaller sizes, which was noted in the collections from the Columbia River, is not apparent in this material. It is only slightly noticeable in Tables 30 and 33. This is, at least in part, due to the fact that there are few collections of any size which contain specimens of the smallest fish. The fact that these specimens from the Sacramento were not collected in the estuary, as were most of the Columbia River fry, would doubtless also have some such effect. In the estuary the fish hesitate for a time in the brackish water before completing the migration to the ocean. This gives an opportunity for the smaller fish from above to come in and form an abnormally large proportion of the collection.

The collections from the McCloud River include two made in July and September, 1909, and a series made during the fall and winter of 1911–12. A constant feature of the collections made from July to December is the presence of precociously matured males. These also have been noted among the fish from the Columbia River basin (p. 18). Such precociously mature males will not be included in the tables with the immature fish. None of these specimens show a well-defined primary check, as was met with in the Columbia River collections.

Thirty-eight specimens were taken July 24 and 25, 1909. Nine of these are mature males and average 124 mm. in length. The scales of the mature fish have an average of 18.5 rings, and the average length of the anterior radius is 63.9. Fourteen of the immature specimens are males averaging 85.5 mm. in length and fifteen are females averaging 91.5 mm. The data for the immature specimens, 29 in number, are given in the following table (35).

TABLE 35.—DATA FOR 29 YOUNG CHINOOKS FROM McCLOUD RIVER, BAIRD, CALIF., JULY 24 AND 25, 1909.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
111 to 115 mm	1	15.0	49.0
106 to 110 mm	1	14.0	55.0
101 to 105 mm	1	14.0	55.0
96 to 100 mm	6	13.3	51.1
91 to 95 mm	2	12.0	46.6
86 to 90 mm	6	11.3	43.7
81 to 85 mm	5	10.4	36.0
76 to 80 mm	3	9.3	36.0
71 to 75 mm	4	9.5	36.2
Av. 88.5 mm		11.5	43.1

A collection consisting of 82 specimens was made September 24, 1909. Seven of these are precociously mature males, averaging 109.5 mm. in length. The scales of one has a band of two wider rings at the margins. This undoubtedly represents the beginning of the new growth of the second year, since, as is presently shown, over one-half of the immature fish taken at this time have the new growth well developed. The average number of rings included within the first year's growth (extending to the periphery of the scales of all but the one specimen which shows new growth) is 15.3. The average length of the anterior radius is 43.

Seventy-five of the specimens included in this collection are immature fish, averaging 96.9 mm. in length. Forty individuals have definitely begun the new growth of the second year, as is indicated by a marginal band of wider rings. The scales of the remaining 35 individuals have marginal bands of the narrow, winter type. Thirty-two specimens are males averaging 97.9 mm. in length. Forty-three females average 96.3 mm. The data are presented in the following table (36):

TABLE 36.—YOUNG CHINOOKS FROM McCLOUD RIVER, BAIRD, CALIF., SEPT. 24, 1909.

THIRTY-FIVE SPECIMENS WITHOUT NEW GROWTH.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
121 to 125 mm	2	18.0	69.6
116 to 120 mm	0	.....	.....
111 to 115 mm	2	17.5	58.0
106 to 110 mm	3	16.7	49.5
101 to 105 mm	2	17.0	52.3
96 to 100 mm	6	14.3	47.5
91 to 95 mm	7	13.9	41.2
86 to 90 mm	8	13.2	40.8
81 to 85 mm	4	13.5	42.2
76 to 80 mm	0	.....	.....
71 to 75 mm	1	11.0	32.2
Av. 94.0 mm		14.5	46.0

TABLE 36.—YOUNG CHINOOKS FROM McCLOUD RIVER, BAIRD, CALIF., SEPT. 24, 1909—Continued.

FORTY SPECIMENS WITH NEW GROWTH.

Length.	Number.	Scale record.				Average estimated length of fish at beginning of new growth.
		Average number of rings—		Average length of anterior radius—		
		To new growth.	Of new growth.	To new growth.	Total.	
116 to 120 mm	1	15.0	4.0	49.5	61.0	93.0
111 to 115 mm	1	13.0	4.0	43.0	55.0	83.0
106 to 110 mm	7	13.2	3.1	43.7	56.0	86.0
101 to 105 mm	8	13.4	3.2	43.7	52.3	86.0
96 to 100 mm	13	12.9	3.3	40.3	50.2	78.0
91 to 95 mm	5	12.4	2.8	35.7	43.7	75.0
86 to 90 mm	5	11.8	2.4	36.8	44.9	73.0
Av. 99.5 mm		12.9	3.1	39.3	50.5	80.9

It is interesting to note that the scale records to the beginning of the new growth are approximately the same as the scale records of the fish which are equal in size to the estimated length at the time of beginning the new growth (80.9 mm.). Table 36 shows that the scales of fish 81 to 85 mm. in length have an average of 13.5 rings and an average length of 42.2. In the collection of specimens with new growth the average number of rings preceding the new growth is 12.9, and the average length of the anterior radius is 39.3.

September 18, 1911, 104 specimens were collected. Of these, 9 are mature males averaging 99.6 mm. in length. The scales of these males have an average of 14.2 rings, and the length of the anterior radius averages 50.7. None of the 95 immature fish had begun the new growth, the scales of all terminating in winter rings. This is in striking contrast to the condition found in 1909 when 53 per cent had started the new growth by September 24. Evidently the conditions in the same locality may vary from year to year in such a way as to materially alter the time for beginning the period of active growth. The possible results of such annual fluctuation may be of considerable importance in its effect on the future history of the fish. There are two possibilities: (1) The fish may tend to migrate earlier in those years when the new growth is started earlier; and (2) they may reach a greater size before migrating, but migrate at the same time of year. A detailed study of the fish in some one tributary extending over a series of years would be necessary to a solution to this problem. Careful attention should be paid to fluctuations in climatic conditions. Fifty-one of the immature specimens in this collection are males; 44, females. The males average 94.5 mm. in length; the females, 91.8 mm. The following table (37) presents the data regarding the immature specimens.

TABLE 37.—DATA FOR 95 YOUNG CHINOOKS FROM McCLOUD RIVER, BAIRD, CALIF., SEPT. 18, 1911.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
106 to 110 mm	1	17.0	61.0
101 to 105 mm	7	15.2	51.7
96 to 100 mm	25	14.0	49.5
91 to 95 mm	32	13.6	45.4
86 to 90 mm	24	12.9	42.6
81 to 85 mm	5	11.8	36.8
76 to 80 mm	1	11.0	38.0
Av. 93.2 mm	.....	13.6	46.6

The next collection was made October 18, 1911. One hundred and forty-six specimens were taken. Two of these are mature males 97 and 106 mm. in length. Their scales have an average of 15 rings, and the average length of the anterior radius is 53.2. One of the immature fish had started the new growth, as is indicated by two wider marginal rings. This specimen is 110 mm. long, and the scales have 15 rings belonging to the first year's growth. The length of the anterior radius is 36 to the end of the first year's growth and 45 to the periphery of the scales. Sixty-two males average 99.8 mm. and 81 females 98.9 mm. in length. The data for the immature fish which had not begun the new growth are given in the following table (38):

TABLE 38.—DATA FOR 143 YOUNG CHINOOKS FROM McCLOUD RIVER, BAIRD, CALIF., OCT. 18, 1911.

SPECIMENS WITHOUT NEW GROWTH.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
111 to 115 mm	2	17.5	58.0
106 to 110 mm	17	15.3	50.5
101 to 105 mm	42	15.1	49.3
96 to 100 mm	44	14.5	46.2
91 to 95 mm	30	14.0	44.6
86 to 90 mm	8	12.7	40.2
Av. 99.2 mm	.....	14.7	47.1

One hundred and thirty-six specimens were collected November 18, 1911. Six of these are mature males which average 110.5 mm. in length and whose scales have an average of 15.2 rings. The average length of the anterior radius of the scales is 53.2. Thirty-six of the remaining 130 specimens had begun the new growth of the second year. The scales of the other 94 individuals show marginal rings of the winter type. The collection contains 53 males and 77 females. The average lengths of the two sexes are the same, 101.2 mm. The table (39) follows:

TABLE 39.—YOUNG CHINOOKS FROM MCCLOUD RIVER, BAIRD, CALIF., NOV. 18, 1911.

NINETY-FOUR SPECIMENS WITHOUT NEW GROWTH.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
121 to 125 mm	2	17.5	59.8
116 to 120 mm	1	17.0	55.0
111 to 115 mm	2	15.5	55.2
106 to 110 mm	15	15.3	51.1
101 to 105 mm	27	15.3	48.9
96 to 100 mm	35	15.0	47.1
91 to 95 mm	12	14.3	46.0
Av. 101.5 mm		15.2	48.7

THIRTY-SIX SPECIMENS WITH NEW GROWTH.

Length.	Number.	Scale record.				Average estimated length of fish at time of beginning new growth.
		Average number of rings—		Average length of anterior radius—		
		To new growth.	Of new growth.	To new growth.	Total.	
111 to 115 mm	1	15.0	4.0	49.0	59.0	88.0
106 to 110 mm	8	14.6	1.8	50.0	58.0	92.5
101 to 105 mm	7	13.4	1.8	45.4	51.2	90.1
96 to 100 mm	14	13.4	1.8	41.4	51.4	83.0
91 to 95 mm	5	13.0	2.0	35.7	43.7	80.0
86 to 90 mm	1	12.0	2.0	32.2	43.0	73.0
Av. 100.5 mm		13.7	1.9	43.1	51.8	85.9

A collection made December 18, 1916, contains 92 specimens. Only one is a mature male, 108 mm. long. The scales of this individual show 16 rings, and the length of the anterior radius is 59.8. Fifty-one (56 per cent) of the 91 immature specimens had begun the rapid growth of the new year. The average length is 101.2 mm. Forty-five males average 101.9 mm. and 46 females 100.6 mm. The table (40) follows:

TABLE 40.—YOUNG CHINOOKS FROM MCCLOUD RIVER, BAIRD, CALIF., DEC. 18, 1911.

FORTY SPECIMENS WITHOUT NEW GROWTH.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
116 to 120 mm	1	18.0	55.0
111 to 115 mm	1	17.0	49.0
106 to 110 mm	7	16.5	53.4
101 to 105 mm	10	15.3	50.0
96 to 100 mm	15	14.8	46.3
91 to 95 mm	6	15.1	46.5
86 to 90 mm	1	13.0	38.0
Av. 100.5 mm		15.3	48.5

TABLE 40.—YOUNG CHINOOKS FROM MCCLOUD RIVER, BAIRD, CALIF., DEC. 18, 1911—Continued.

FIFTY-ONE SPECIMENS WITH NEW GROWTH.

Length.	Number.	Scale record.				Average estimated length of fish at time of beginning new growth.
		Average number of rings—		Average length of anterior radius—		
		To new growth.	Of new growth.	To new growth.	Total.	
116 to 120 mm	1	13.0	3.0	38.0	49.0	98.0
111 to 115 mm	3	13.6	3.0	47.1	52.0	96.3
106 to 110 mm	5	14.4	1.8	43.7	50.6	91.0
101 to 105 mm	20	13.6	2.0	42.0	48.3	88.5
96 to 100 mm	17	13.3	2.1	40.6	47.4	81.2
91 to 95 mm	5	12.4	2.0	36.8	44.8	79.0
Av. 101.7 mm		13.4	2.1	40.3	48.5	86.0

January 22, 1912, 75 specimens were collected. There were no mature males among them. One of the males, however, was of unusual size, 142 mm., and the testes of this specimen were found, upon dissection, to be slightly enlarged. It is shown later (p. 68) that precociously matured males may recover from the effects of ripening the sex products, and there is no doubt that this has occurred in the individual in question. No new growth is recorded on the scales, the terminal rings being of the winter type. The large size, enlarged testes, and delayed new growth all point to the interpretation given. The scales indicate clearly that the fish was a yearling, the same age as the other specimens. They show 20 rings, and the anterior radius measures 75 on the arbitrary scale. This specimen is not included in the tables. Forty-three (58 per cent) of the other specimens had begun the new growth. Thirty-one males average 104.1 mm. in length and 43 females 102.3 mm. The table (41) follows:

TABLE 41.—YOUNG CHINOOKS FROM MCCLOUD RIVER, BAIRD, CALIF., JAN. 22, 1912.

THIRTY-ONE SPECIMENS WITHOUT NEW GROWTH.

Length.	Number.	Scale record.	
		Average number of rings.	Average length of anterior radius.
111 to 115 mm	5	16.6	55.1
106 to 110 mm	2	16.5	49.5
101 to 105 mm	11	15.7	51.0
96 to 100 mm	7	14.7	48.5
91 to 95 mm	5	14.6	46.0
86 to 90 mm	1	14.0	38.0
Av. 101.7 mm		15.5	49.9

TABLE 41.—YOUNG CHINOOKS FROM MCCLOUD RIVER, BAIRD, CALIF., JAN. 22, 1912—Continued.

FORTY-THREE SPECIMENS WITH NEW GROWTH.

Length.	Number.	Scale record.				Average estimated length of fish at time of beginning new growth.
		Average number of rings—		Average length of anterior radius—		
		To new growth.	Of new growth.	To new growth.	Total.	
111 to 115 mm	6	13.7	3.5	44.3	55.2	90.5
106 to 110 mm	11	13.3	2.7	44.9	55.8	90.0
101 to 105 mm	13	13.2	2.6	40.2	49.5	85.5
96 to 100 mm	12	12.9	2.7	39.7	49.5	81.5
91 to 95 mm	1	11.0	3.0	32.0	43.0	73.0
Av. 104.0 mm	.....	13.2	2.8	41.5	51.7	86.0

February 27, 1912, 26 specimens were taken. One is a mature male, 127 mm. long. The scales of this individual show 18 rings in the first year's growth and 1 in the second year's growth. The length of the anterior radius is 51 to the beginning of the new growth and 57 to the periphery of the scale. The estimated length at the time of beginning the new growth is 114 mm. Twelve of the immature specimens show the new growth at the margins of the scales. The other 13 specimens terminate the scale growth in winter rings. The average length of the entire collection is 111.6 mm. Twelve males average 110.9 mm. in length; 13 females, 112.2 mm. The table (42) follows:

TABLE 42.—YOUNG CHINOOKS FROM MCCLOUD RIVER, BAIRD, CALIF., FEB. 27, 1912.

THIRTEEN SPECIMENS WITHOUT NEW GROWTH.

Average length.	Scale record.	
	Average number of rings.	Average length of anterior radius.
109.2 mm	16.9	52.2

TWELVE SPECIMENS WITH NEW GROWTH.

Average length.	Scale record.				Average estimated length of fish at time of beginning new growth.
	Average number of rings—		Average length of anterior radius—		
	To new growth.	Of new growth.	To new growth.	Total.	
114.2 mm	15.6	2.4	48.0	56.5	95.9

The last collection from Baird was made March 2, 1912. This contains 31 specimens averaging 109.6 mm. in length. There are no mature fish. Twelve males average 110.5 mm. and 19 females 109 mm. in length. Twenty-two (71 per cent) had begun the new growth. The table (43) follows:

TABLE 43.—YOUNG CHINOOKS FROM MCCLOUD RIVER, BAIRD, CALIF., MAR. 2, 1912.

NINE SPECIMENS WITHOUT NEW GROWTH.

Average length.	Scale record.	
	Average number of rings.	Average length of anterior radius.
105.8 mm	16.4	50.7

TWENTY-TWO SPECIMENS WITH NEW GROWTH.

Length.	Number.	Scale record.				Average estimated length of fish at time of beginning new growth.
		Average number of rings—		Average length of anterior radius—		
		To new growth.	Of new growth.	To new growth.	Total.	
121 to 125 mm	2	16.0	3.0	49.5	61.0	98.0
116 to 120 mm	1	17.0	2.0	49.0	55.0	103.0
111 to 115 mm	9	15.9	2.3	47.5	55.8	97.0
106 to 110 mm	7	15.1	2.1	48.5	57.0	93.5
101 to 105 mm	3	13.7	2.3	41.4	53.3	84.5
Av. 111.2 mm		15.4	2.5	47.3	56.2	94.8

MISCELLANEOUS COLLECTIONS.

With but two exceptions the miscellaneous collections were made by Prof. J. O. Snyder, of Stanford University, during the progress of biological investigations of the coastal streams of California and Oregon carried on during the summers of 1897 and 1899. One of the exceptions referred to is a collection, consisting of but three specimens, which was made by the writer in 1915 at Hope Island, Puget Sound, Wash. The other exception is one specimen which was collected in the ocean at Half Moon Bay, Calif., some 20 miles south of the mouth of the Sacramento River.

The collections from the coastal streams are for the most part small, and a detailed consideration of each collection will be unnecessary. Measurements of the scales were not made. The data are presented in the following table (44):

TABLE 44.—MISCELLANEOUS COLLECTIONS OF YOUNG CHINOOKS FROM COASTAL STREAMS OF CALIFORNIA AND OREGON.

Date.	Locality.	Length (mm.).	Number.			Scale record.		
						Number of rings—		
			Total.	With primary check.	With migratory check.	To primary check.	To migratory check.	Total.
1897.								
July 6	Bear River, Calif., not far from the mouth.	76 to 80	4	0	4	.....	9.5	14.5
		71 to 75	11	0	6	.....	8.5	12.9
		66 to 70	8	0	5	.....	7.4	11.5
		61 to 65	3	0	2	.....	7.5	12.0
		56 to 60	3	0	1	.....	8.0	12.3
Total		.....	29	0	18	.....	.....	.....
Average		69.5	.....	.....	.....	.....	8.3	12.6
July 8	Little River, Calif., from mouth up about 500 yards.	81 to 85	2	0	2	.....	9 0	14.5
		76 to 80	3	0	3	.....	8.6	12.6
		71 to 75	9	0	7	.....	6.8	11.9
		66 to 70	9	0	9	.....	7.5	11.9
		61 to 65	1	0	1	.....	7.0	11.0
Total		.....	24	0	22	.....	.....	.....
Average		72.1	.....	.....	.....	.....	7.6	12.2
July 19	Deer Creek, Oreg., 40 miles from the mouth.	[a] 68.0	7	6	.....	[a] 6.8	.....	[a] 11.0
July 24	Shasta River, Calif., tributary to the Klamath River.	[a] 75.8	[b] 6	5	.....	[a] 9.8	.....	[a] 13.5
1899.								
July 30	Flores Creek, Oreg., near tidewater.	76 to 80	1	0	0	.....	.....	14.0
		71 to 75	6	0	5	.....	10.0	13.8
		66 to 70	12	0	4	.....	8.2	13.3
		61 to 65	8	0	2	.....	7.0	13.1
		56 to 60	3	0	0	.....	.....	11.0
Total		.....	30	0	11	.....	.....	.....
Average		67.0	.....	.....	.....	.....	8.8	13.2
Aug. 5	Elk Creek, Curry County, Oreg., near tidewater.	91 to 95	2	0	1	.....	8.0	17.5
		86 to 90	3	0	3	.....	10.6	18.0
		81 to 85	4	0	2	.....	10.5	14.5
		76 to 80	12	0	12	.....	10.4	14.2
		71 to 75	4	0	4	.....	8.5	13.7
		66 to 70	2	0	1	.....	11.0	13.0
Total		.....	27	0	23	.....	.....	.....
Average		79.5	.....	.....	.....	.....	10.0	14.8
Aug. 6	Sixes River, Oreg., near tidewater.	[a] 77.6	6	0	2	.....	[a] 10.5	[a] 15.0
Sept. 6	Siletz River, Oreg., about 20 miles above mouth.	[a] 93.2	4	0	3	.....	[a] 7.0	[a] 17.5
Sept. 14	Nestucca River, Oreg., 10 miles above mouth.	[a] 115.5	4	3	4	[a] 3.6	[a] 15.0	[a] 21.2
Sept. 15	Trask River, Oreg., just above tidewater.	[a] 91.5	13	0	7	.....	[a] 15.2	[a] 18.5
Sept. 16	Nehalem River, Oreg., just ahead of incoming tide.	[a] 104.0	19	0	19	.....	[a] 15.8	[a] 20.5

[a] Average. [b] Two mature males.

The fish contained in these collections are obviously all fry, hatched from eggs laid down during the fall previous to the date of capture. No striking variation in size is noticeable, other than that which is apparently dependent on greater age, those fish collected later in the year averaging somewhat larger. The same uniformity is

characteristic of the scale growth. A more detailed study of much larger collections might, however, discover special characteristics of growth or of scale record in the different streams. The primary check appears in only one of the collections which were made close to tidewater, the one from the Nestucca River. The check observed on the scales of the specimens from Shasta River and Deer Creek (collected toward the headwaters of these streams) is undoubtedly the same as the primary check noted in upstream fish from the Columbia River basin. (See p. 18.) A band of intermediate rings is characteristic of varying proportions of the fish contained in all of the collections made near tidewater and is in every respect similar to the intermediate growth of the Columbia River migrants. Although the available data are meager, it seems safe to state that the history of the fish in these smaller streams is, in its general aspects, similar to the history of young fish collected in the Columbia River at the same time of year.

The three specimens taken near Hope Island, Puget Sound, were the only chinooks among some 70 specimens captured by hook and line in one of the fish traps located at this point. The remaining specimens were yearling silver salmon averaging about 100 mm. in length. There is no means of knowing whether this is the normal proportion existing between young silvers and young chinooks in this part of the sound at this time of year. It may be that the young chinooks do not lead into the traps as readily as the silvers; or they may be less willing to take the hook. These three chinooks were, respectively, 130, 97, and 94 mm. in length. All were males. On examining the scales it was surprising to find that, in spite of the negligible difference in size between the two smaller fish, the smallest individual was a fry and the two larger ones both yearlings. The record on the scales is perfectly clear, leaving no doubt as to the proper interpretation. The scales of the two smaller individuals, differing but 3 mm. in length, are reproduced in Plate IV, figures 6 and 7. The scales of the smallest individual show no indication of stream growth, and there is no doubt that this fish migrated as a young fry and that the scales represent a purely ocean type of nucleus in the process of formation. The scales of the fry show 13 rings, and the length of the anterior radius is 50. The scales of the smaller yearling have 13 rings to the end of the first year's growth and 5 in the intermediate growth. Those of the larger yearling have 19 rings to the end of the first year and 8 in the intermediate band. The scale measurements are as follows: 130 mm. specimen, 55 to beginning of the intermediate growth, total, 92; 97 mm. specimen, 28 to intermediate growth, total, 47.

The young chinook from Half Moon Bay, Calif., is of particular interest, since it is, so far as the author knows, the smallest individual which has been captured in the open ocean at any distance from the mouth of the parent stream. Unfortunately, there are no data as to the date of capture, except that it was previous to 1913. The specimen presumably came from the Sacramento River, since at the time this was captured no chinooks were known to spawn in the streams south of San Francisco.[a] This fish was approximately 100 mm. long. The scales (Pl. IV, fig. 8) indicate clearly a period of life spent in the stream followed by a sharply demarked area representing ocean growth. That part of the scale indicative of stream growth is precisely similar to the scales of young migrating fish taken in the spring and summer on the lower Sacramento River (Pl. III, fig. 6).

[a] Within the past six or seven years a run of chinook salmon has been established in the San Lorenzo River, Santa Cruz Co., Calif., by the late Supt. F. A. Shebley, of the California Fish and Game Commission.

CONCLUSIONS.

RATE OF GROWTH.

An analysis of the data from the Columbia River shows that all of the collections are not strictly comparable, since the rate of growth is markedly variable in different parts of the river. The environmental conditions in different regions of the watershed are so variable that this is not surprising. Therefore the collections have been separated into four groups, each group having been taken under approximately similar conditions. These four groups are as follows: (1) From the main river above the estuary (the estuary is considered as that part of the river below Tenasillihee Island, about 18 miles above Astoria); (2) from the estuary exclusive of the collections made under the canneries; (3) from under canneries in the estuary; (4) from Clackamas hatchery and the Clackamas River near the hatchery. In addition, there are the collections from the Little White Salmon River, from the McKenzie River, and from the lake at Seufert, Oreg.; but these are not included in this grouping.

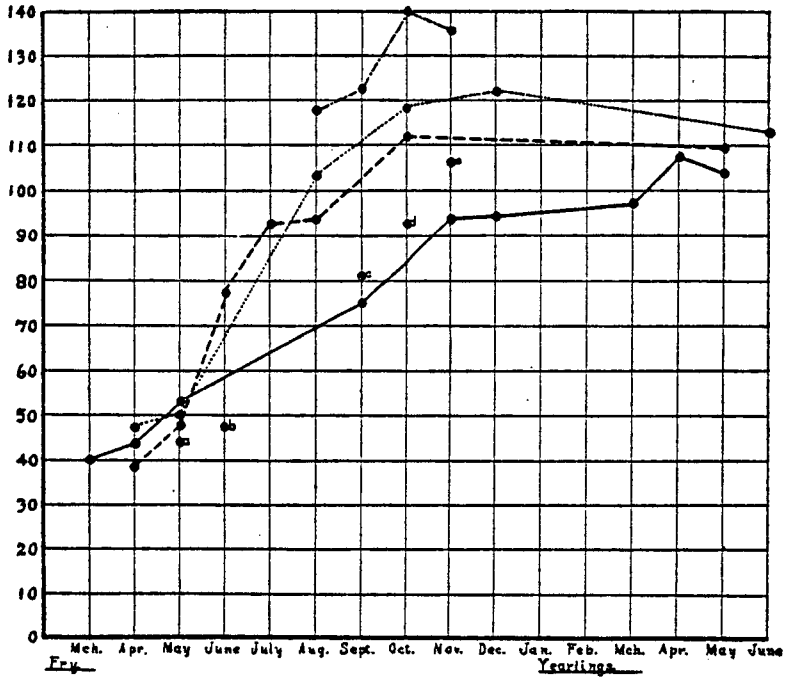
In the following table (45) the data which have been previously presented in separate tables are recombined, so as to show the average lengths, during each month of the year, of the fish captured in each of the four divisions of the river and in the Little White Salmon and McKenzie Rivers. These same data, with the addition of those for the collection from the lake at Seufert, Oreg., are presented in graph 1. In the graph, however, the collections from the mouth of the small creek near Point Ellice and from the Columbia River near the mouth of Little White Salmon River have been kept separate.

TABLE 45.—AVERAGE LENGTH OF SPECIMENS FROM THE COLUMBIA RIVER FOR EACH MONTH.

Month.	Group 1.		Group 2.		Group 3.		Group 4.	
	Locality.	Length.	Locality.	Length.	Locality.	Length.	Locality.	Length.
FRY.		*Mm.*		*Mm.*		*Mm.*		*Mm.*
March	Grims Island	40.0						
April	Cottonwood and Deer Islands.	43.2	Several points in estuary.	38.1			Clackamas hatchery.	46.5
May	Crandall's seining ground.	52.5	.....do	47.3			.....do	49.5
	Near mouth of Little White Salmon River.	44.6						
June			Small creek near Point Ellice.	47.7				
			Other points in estuary.	77.0				
July			Point Ellice	92.2				
August			.....do	94.0	Ilwaco, Wash	118.0	Clackamas River.	112.9
September	Crandall's seining ground.	74.5			.....do	122.0		
October			Point Ellice	112.7	Astoria, Oreg	127.5	Clackamas River.	118.0
					Ilwaco, Wash	146.7	[Little White Salmon River.	92.5]
November	Warrendale, Oreg	93.0			Astoria, Oreg	125.0	[McKenzie River.	105.8]
December	Several points on the lower river.	93.9					Clackamas hatchery.	121.1
YEARLINGS.								
March	.....do	95.9						
April	Cottonwood and Deer Islands.	107.0						
May	Crandall's seining ground.	103.0	Point Ellice and Tenasillihee Island.	108.7				
June							Clackamas River.	112.2

One of the most striking features of the growth as shown by this tabulation is the constant difference in average size maintained in different parts of the stream.

The smallest fish taken are those comprising group 1, from the main river above the estuary. The rate of increase in the size of these fish is quite regular, although there is a period from November until March when the growth is practically negligible. In April and May a second period of rapid growth is apparently started, although more data collected during subsequent months would be necessary to prove this. Since no yearlings are found in the river after June, it is impossible to get this information.



GRAPH 1.—Rate of growth of young chinook salmon from different regions of the Columbia River Basin. Figures at left of graph indicate length of fish in mm.; solid line, group 1; broken line, group 2; dots and dashes, group 3; dotted line, group 4; *a*, Columbia River near mouth of Little White Salmon River; *b*, small creek near Point Ellice; *c*, lake at Seufert, Oreg.; *d*, Little White Salmon River; and *e*, McKenzie River.

Until after May there is no particular difference in the size of the fry from different portions of the stream. However, in later collections it is seen that those composing group 1 are smallest, followed, in the order of increasing size, by those of group 2 (from the estuary), group 4 (from the Clackamas River), and group 3 (from under the canneries at Ilwaco and Astoria).

The greater size of the fish of group 2 as compared with those of group 1 is undoubtedly due to the more rapid rate of growth maintained in the estuary. In the same manner the greater size of the fish taken from under the canneries is due to the more rapid rate of growth of those fish which acquire the habit of feeding on the abundant offal. The fact that fish taken under canneries are so uniformly different from those taken but a short distance away indicates that the young salmon congregate at these

points and that individuals may remain here for some time feeding heavily on the offal and as a consequence growing with unusual rapidity. The greater size of the fish from the Clackamas River, as compared with those of groups 1 and 2, may be due to a racial difference characteristic of the fish in this tributary or to the fact that many of these fish have, in all probability, been reared for a part or all of their lives in the hatchery.

The rate of growth in the estuary, and especially under the canneries at Ilwaco and Astoria, is distinctly more rapid than in the higher waters. The increase in length is especially rapid during June, July, and August, by which time the fry in the estuary have far outstripped those in the upper part of the stream—in fact, have reached a greater size than will be attained during the remainder of the year by those individuals that do not migrate early. The growth in the estuary during September and October is positive, but much slower than that which took place during the three months just preceding. After the month of October the data pertaining to fish from the estuary is very scanty, but apparently a period during which little or no growth takes place follows, this coinciding with a similar condition in the regions upstream.

It will be noted on the graph that the final tendency of each of the curves is downward. This seems conclusive evidence that the larger individuals migrate earlier. Gilbert (1915) has found this to be true of young, seaward migrants of the sockeye salmon. The present author's conclusion that the young fish in the tributary streams tend to migrate shortly after beginning the new growth, if not before, also indicates that the larger specimens migrate earlier, since it has also been shown that the specimens which have begun the new growth invariably average larger than those which have not done so.

The single collections from Seufert, Little White Salmon River, and the McKenzie River do not offer any basis for estimation of the actual rate of growth during successive months, but it will be seen that they agree in general with the growth of fish in the main river, averaging somewhat more than the fish in group 1, but less than those of group 2.

In the case of fish taken from the Columbia River proper it may not be strictly correct to speak of the increasing size as growth. In all probability fish that have once entered the main river continue, more or less steadily, their migration to the ocean. We would thus be dealing, in successive months, with entirely different lots of fish. In a general way, however, our figures should show the main features of the growth.

At the time the fry become free swimming they are between 35 and 40 mm. in length. During March, April, and May the average length does not exceed 50 mm. Above the estuary the growth is quite regular from the time the fry first appear until October or November, by which time an average length of between 90 and 100 mm. has been attained. For the next several months no particular growth is recorded. The collections of yearlings made in April and May from the Clackamas River indicate that a new period of growth has been initiated, but because of the fact that about this time the last of the fish leave the tributary on their downward migration no further data are available. The rate of growth as indicated by these data has undoubtedly been modified by the migration of part of the fish. As has been shown, the larger fish tend to migrate earlier than the smaller ones. This would tend to slow up the growth curve and to obscure the sharp rise during the early summer so conspicuous for the curves for the other groups.

It has been shown that new growth is recorded on the scales of fish in tributary streams as early as October or November (p. 25). Since there is no conspicuous increase in the amount of new growth between this time and the following May or June, and since, also, it has been shown that the fish entering the estuary during the late fall or winter may show a marginal band identical with the "new growth" observed in the tributaries, it seems safe to conclude that the young fish start the downward migration soon after beginning the new growth, if not before. This matter is given further consideration in the sections dealing with scale development and with migration.

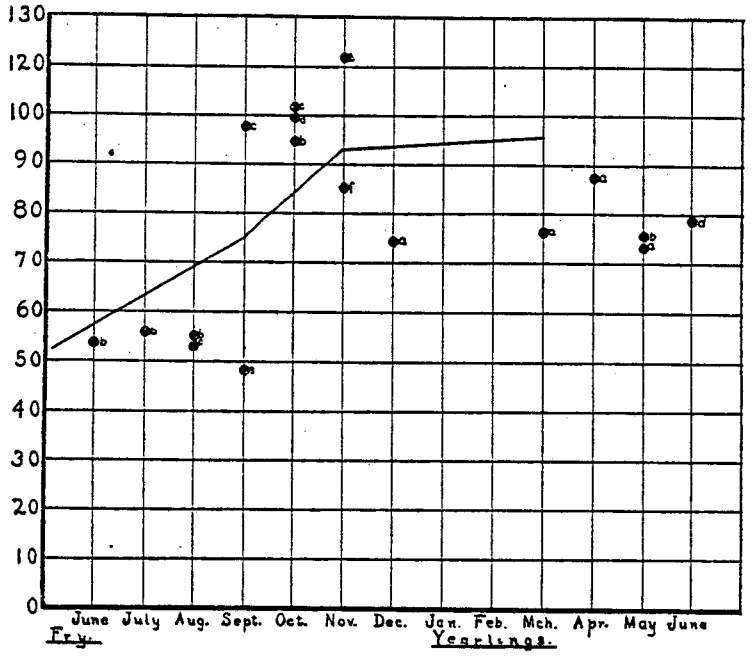
The estimated size at the time of beginning the new, or the intermediate, growth is given in the following table (46) and in graph 2. (Consideration of the collection made at Seufert, which has already been discussed, and of the one made at the Clackamas hatchery in December, 1914, is omitted here.)

TABLE 46.—AVERAGE ESTIMATED LENGTH AT TIME OF BEGINNING NEW GROWTH (GROUP 4) OR INTERMEDIATE GROWTH (GROUPS 1, 2, AND 3).

Month.	Group 1.		Group 2.		Group 3.		Group 4.	
	Locality.	Length.	Locality.	Length.	Locality.	Length.	Locality.	Length.
FRY.		*Mm.*		*Mm.*		*Mm.*		*Mm.*
June			Estuary, except from small creek near Point Ellice.	53.3				
July			Point Ellice	55.3				
August			do	54.5	Ilwaco	54.0		
September					do	97.5		
October			Point Ellice	94.7	Ilwaco and Astoria.	101.9	Clackamas River.	99.3
November					Astoria	111.6	[McKenzie River.	85.1]
December	Several points on lower Columbia.	73.7						
YEARLINGS.								
March	do	75.2						
April	Cottonwood and Deer Islands.	87.3						
May	Crandall's	74.0	Point Ellice and Tenasillihee Island.	74.8				
June							Clackamas River	78.3

There is a distinct grouping of the estimated lengths at the time of beginning the intermediate growth about three modes, as follows: During June, July, and August the mode is approximately 55 mm.; during September, October, and November, approximately 100 mm.; and during the remainder of the time in which the young are taken in the river, approximately 80 mm. This may be an accidental result due to insufficient data; but it is believed that there is something fundamental concerned. The mode at 55 mm. agrees fairly well with the length of the young chinooks planted in the pond at Seufert. (See p. 18.) It seems probable, therefore, that the check from which this estimate was made represents some incident in the early history of the fry comparable with the transfer from hatchery to more natural conditions. Therefore, this estimated length may represent either the size at the time of planting from the hatcheries, the size at the time the fish left the smaller streams on their downward migration, or the size at the time of entering the brackish water of the estuary. The mode at 80 mm. represents the size attained at the time of beginning the new growth of the second year.

This is shown by the close correspondence in estimated size of the yearlings at the time of beginning the more rapid growth of the second year. This correspondence also indicates that the yearlings migrating in the spring are a homogeneous lot and that the check preceding the intermediate growth (in Groups 1 and 2) is the same as that preceding the new growth (in Group 4); that is, that this check in both instances is in reality the winter band. (See discussion on p. 57.) The mode at 100 mm. undoubtedly represents, in the fall migrants, the size at the time of entering the estuary. It is possible that these differences in the estimated size at which the intermediate growth begins may be of value in determining, from the adult scales, the time at which migration took place.



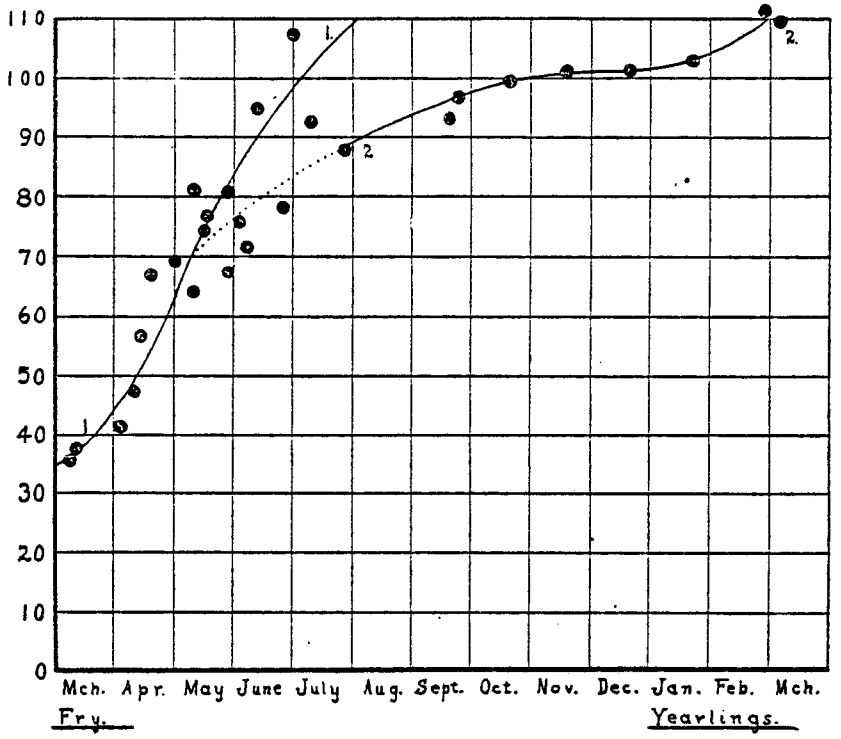
GRAPH 2.—Estimated length at time of beginning intermediate growth (groups 1, 2, and 3) and new growth (group 4). Figures at left of graph indicate length of fish in mm.; *a*, group 1; *b*, group 2; *c*, group 3; *d*, group 4; *e*, creek at Seufert, Oreg.; *f*, McKenzie River; and solid line, growth curve for group 1 (from fig. 1).

The rate of growth of the migrating fry in the Sacramento River is given in Table 47 and is shown in graph 3.

TABLE 47.—MIGRATING FRY FROM SACRAMENTO RIVER.

Date.	Locality.	Length.	Date.	Locality.	Length.
		Mm.			*Mm.*
Mar. 5	Brookdale	36.3	May 15	Shag Slough	77.0
Mar. 8	Sisson	38.7	May 16	Hass Slough	75.2
Apr. 3	do	41.2	May 27	Sausalito	81.0
Apr. 9	Walnut Grove	48.1	May 28	Prospect Slough	68.0
Apr. 13	Sacramento River 30 miles above Sacramento.	57.5	June 3	Elkhorn	76.8
			June 5 and 6	Woods Break	71.0
Apr. 19	Cache Slough	67.0	June 8	Pond near Butte Slough	95.6
Apr. 29	Prospect Slough	69.0	June 24 to 26	Tisdale wier	78.8
May 8 and 9	Butte Slough	64.1	June 30	Ponds near Knights Landing	107.0
May 9	Pond near Butte Slough	81.5	July 9	Pond near Butte Slough	92.2

The average length of the fry at the time of hatching is the same as for the Columbia River fish, 35 to 40 mm. The data here presented give only the earlier part of the growth. The rapid rise of the curve during April, May, and June is conspicuous. In comparison with the rate of growth in the Columbia River it is seen that, while the rate itself is approximately the same, the time at which the most rapid growth takes place is fully a month earlier. This is, in all probability, due to the fact that, as a whole, the water in the Sacramento Basin is warmer than that in the Columbia River Basin. As a consequence, the eggs hatch sooner and the growth is somewhat more rapid.



GRAPH 3.—Rate of growth of young chinook salmon in the Sacramento River Basin. Figures at left of graph indicate length of fish in mm.; dotted line represents probable growth of McCloud River fish, May to July; 1, lower part of river; 2, McCloud River.

The rate of growth in the McCloud River is shown in the following statement and in graph 3.

GROWTH OF YOUNG CHINOOKS IN MCCLOUD RIVER AT BAIRD.	Length, Mm.
July 24, 1909	88.5
September 24, 1909	96.9
September 18, 1911	93.2
October 18, 1911	99.2
November 18, 1911	101.3
December 18, 1911	101.2
January 22, 1912	103.0
February 27, 1912	111.6
March 2, 1912	109.6

There is here merely the upper end of a curve of growth which began in the early months of the year, when the fry were 35 to 40 mm. in length. The earlier part of the curve is undoubtedly represented quite accurately by the data obtained from the collections from the lower part of the river.

In graph 3 the lines give a generalized curve combining the data from the two regions of the Sacramento. The dotted line represents the probable growth of McCloud River fish during May, June, and July. This curve represents approximately the normal rate of growth in the Sacramento Basin. It is interesting to note that the indications are quite clear that the growth of the migrating fish does not slow up during June and July, as is the case with the fish from the McCloud River. It is more than likely that the yearlings in the McCloud River would begin to show the slower growth in May if data were available.

The single collections from the coastal streams offer no basis for the analysis of growth. The collections from the Siletz, Trask, Nehalem, and Nestucca Rivers average about the same as those taken at the same time of year from the Sacramento and Columbia Rivers. The rate of growth in these streams is, therefore, probably about the same as in the larger rivers. The collections from the Bear, Little, Shasta, and Sixes Rivers and from Deer, Flores, and Elk Creeks average smaller in size than the collections from the Sacramento and Columbia Rivers. It may be concluded that the rate of growth in these streams is slower than in the others studied. Any conclusions, however, based on such scanty material must necessarily be merely tentative.

It may be stated in a general way that the growth of young chinook salmon in fresh water is most rapid during the first three or four months after the appearance of the fry. The time of year during which this rapid growth takes place varies in different streams, according to the time at which the fry make their appearance. The prevailing temperature of the water is also an important factor. After this first period of rapid growth the rate rapidly decreases during another period of about three months, until finally growth practically ceases for the year. A new period of rapid growth is apparently begun during the early months of the second year in case the fish remain in fresh water.

At the time the yolk sac is absorbed and the fry become free-swimming the average length is between 35 and 40 mm. By the end of the first period of most active growth a length of 80 or 90 mm. has been attained. The average length attained during the entire first year is approximately 100 mm.

The effect of migration into the brackish water of the estuary is to decidedly stimulate the growth.

DEVELOPMENT OF SCALES.

This section, dealing with the development of the scales, is, in certain respects, the most important part of this study. The work on the young fish was undertaken primarily, as has been previously mentioned, in order to supply an established basis for the interpretation of the nuclear portion of the adult scales. The especial need was data sufficient to permit a reasonably accurate determination, from the adult scales, of the time of migration. To this end are recorded here in detail the data bearing both on ring counts and the length of the anterior radii. The data for the Columbia River fish are given in Table 48 and in graphs 4 to 7.

TABLE 48.—FISH FROM THE COLUMBIA RIVER: AVERAGE LENGTH AND SCALE DEVELOPMENT FOR EACH MONTH.

GROUP 1.

Month.	Locality.	Specimens.			Scale record.			
					Number of rings—		Length of anterior radius—	
		Length.	With scales with rings.	With new or intermediate growth.	To beginning of rapid growth.	Total.	To beginning of rapid growth.	Total.
FRY.		*Mm.*	*Per cent.*	*Per cent.*				
March	Grims Island	40.0	38.0	0.0	.....	1.4	.....	7.0
April	Cottonwood and Deer Islands	43.2	96.0	.0	.....	3.3	.....	17.1
May	Crandall's seining ground	52.5	88.0	.0	.....	4.9	.....	22.4
	Near the mouth of Little White Salmon River	44.6	78.0	.0	.....	3.1	.....	16.5
September	Crandall's	74.5	100.0	5.0	[a]	13.1	.....	40.1
					[b] 7.0	16.0	21.3	47.3
November	Warrendale	93.0	100.0	.0	.....	15.0	.....	45.0
December	Several points on the lower river	93.9	100.0	55.0	[a]	16.5	.....	49.5
					[b] 14.7	18.7	38.6	50.4
YEARLINGS.								
March	Several points on the lower river	95.9	100.0	72.0	[c]	18.7	.....	35.7
					[d] 15.8	20.0	30.3	39.8
April	Cottonwood and Deer Islands	107.0	100.0	77.0	[c]	19.6	.....	42.0
					[d] 15.0	17.8	34.9	41.0
May	Crandall's	103.0	100.0	100.0	15.0	19.9	41.7	58.5

GROUP 2.

FRY.								
April	Several points in estuary	38.0	13.0	0.0	.....	1.7	.....	6.3
May	.....do	47.3	86.0	.0	.....	4.2	.....	20.6
June	Small creek near Point Ellice	47.7	97.0	.0	.....	4.1	.....	20.5
	Other points in estuary	77.0	100.0	17.0	[c]	9.5	.....	38.1
					[d] 11.6	16.2	26.7	42.4
July	Point Ellice	92.2	100.0	70.0	[c]	11.9	.....	46.4
					[d] 7.6	13.1	28.5	49.8
August	.....do	93.9	100.0	58.0	[c]	13.5	.....	45.7
					[d] 8.5	16.1	28.2	52.3
October	.....do	112.7	100.0	24.0	[c]	22.1	.....	59.8
					[d] 20.3	23.4	50.7	60.6
YEARLINGS.								
May	Point Ellice and Tenasillihee Island	108.7	100.0	100.0	17.2	23.4	45.7	67.0

GROUP 3.

FRY.								
August	Ilwaco	118.0	100.0	0.0	.....	21.3	.....	61.3
September	.....do	123.0	100.0	80.0	[c]	20.2	.....	59.4
					[d] 17.2	22.4	48.1	62.0
October	Astoria	127.5	100.0	70.0	[c]	23.2	.....	64.5
					[d] 21.8	26.0	58.0	73.0
	Ilwaco	146.7	100.0	94.0	[c]	21.5	.....	61.3
					[d] 19.5	26.6	54.6	77.1
November	Astoria	135.0	100.0	84.0	[c]	33.0	.....	73.0
					[d] 18.6	22.6	65.4	78.0

[a] Without new growth.
[b] With new growth.
[c] Without intermediate growth.
[d] With intermediate growth.

TABLE 48.—FISH FROM THE COLUMBIA RIVER: AVERAGE LENGTH AND SCALE DEVELOPMENT FOR EACH MONTH—Continued.

GROUP 4.

Month.	Locality.	Specimens.			Scale record.			
		Length.	With scales with rings.	With new or intermediate growth.	Number of rings—		Length of anterior radius—	
					To beginning of rapid growth.	Total.	To beginning of rapid growth.	Total.
FRY.		*Mm.*	*Per cent.*	*Per cent.*				
April	Clackamas hatchery	46.5	100.0	0.0	.....	5.4	.....	18.8
May	do	49.5	100.0	0.0	.....	5.9	.....	29.1
August	Clackamas River	112.9	100.0	0.0	.....	20.7	.....	58.2
October	do	118.0	100.0	14.0	(a)	20.6	.....	64.6
					[b] 20.0	25.0	58.0	77.0
	Little White Salmon River [c]	92.5	100.0	0.0	.....	15.8	.....	52.5
November	McKenzie River [c]	106.4	100.0	27.0	(a)	18.5	.....	52.2
					[b] 15.7	19.8	43.4	55.5
December	Clackamas hatchery	121.1	100.0	8.0	(a)	20.0	.....	56.0
					[b] 21.7	24.0	62.7	73.0
YEARLINGS.								
June	Clackamas River	112.2	100.0	100.0	15.5	21.6	49.2	72.6

[a] Without new growth.
[b] With new growth.
[c] These collections are given with the Clackamas series for the purpose of comparison.

The chief generalizations derived from the data recorded here are:

1. The increase in the number of rings on the scales and the increase in the length of the anterior radii are proportionate to the increase in length of the fish.

2. Hatchery-reared fish develop scales with rings earlier than do wild fish.

3. The length of those fish whose scales show a marginal band of wider rings (intermediate or new growth) is usually greater than that of fish taken at the same time and place, but whose scales do not present such a marginal band. As a corollary to this, the length of the scales and the total number of rings are greater in those fish which have started a period of active growth than in those, taken at the same time, which have not done so.

4. The number of rings in the intermediate band (or the band of new growth in Group 4) and the width of this band are somewhat greater in the spring yearling migrants than in the fall fry migrants.

5. This increase in the size of the intermediate (or new) band is not due to an increase in the size of the fish, which is not apparent, but to the fact that the part of the scales central to the beginning of the intermediate band is smaller in the spring than in the fall fish. This indicates that the fall migrants are larger before beginning the intermediate growth than are the spring migrants and is indicative of the earlier migration of the larger fish noted elsewhere.

6. In collections which contain both specimens whose scales show the intermediate growth and those which do not, the number of rings and the length of the anterior radius are less to the beginning of the intermediate growth than to the periphery of the scales on which such growth is not present. Since the fish which have not begun the intermediate growth have, in all probability, entered the estuary more recently than those

which have begun such growth, this would seem to indicate that the later migrants reach actually a greater size before migrating than do the earlier migrants. It is possible, however, that the scales are larger proportionately in the later migrants, the fish themselves being the same size, or even smaller. In such a large river as the Columbia, where the young migrants are coming from numerous tributaries, such generalizations require careful confirmation.

The author has been unable to see any systematic arrangement in the occurrence of the primary check. The cause of the formation of such a check has been traced in the collection from Seufert; but it is not to be inferred that the change from the hatchery environment to one approximating normal, wild conditions is the only cause behind the formation of such a check. Other somewhat similar environmental changes early in the life of the fish would undoubtedly result in a similar check.

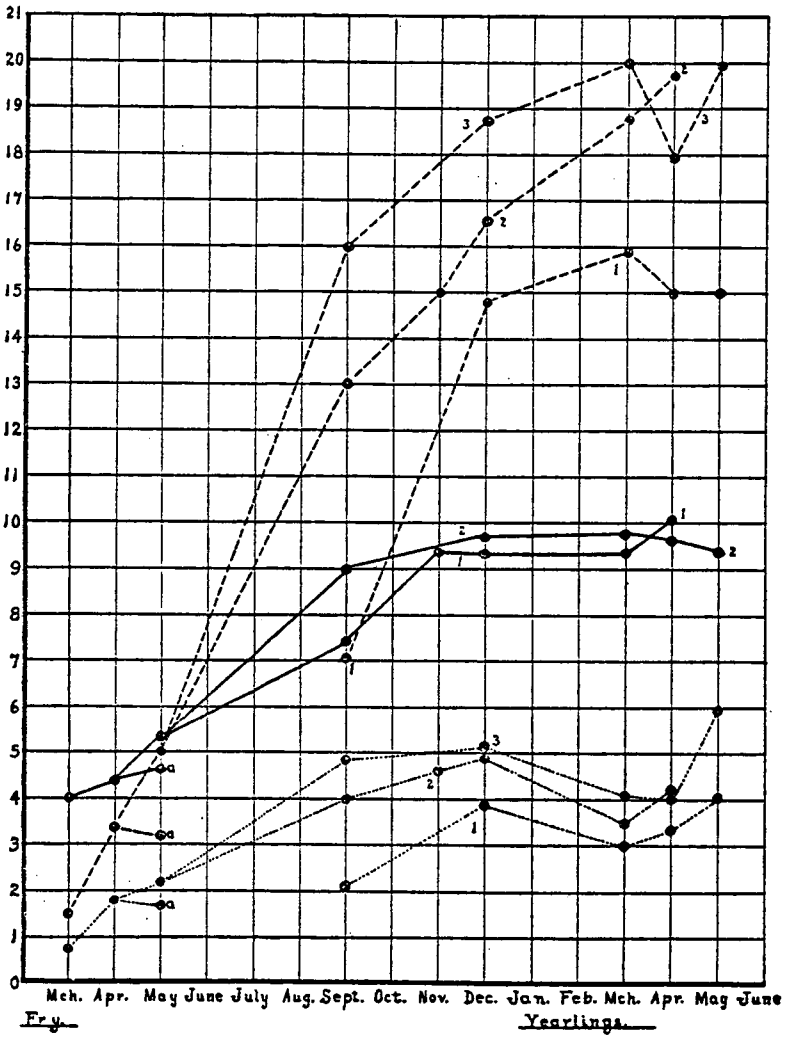
In Table 49 are presented in percentages the data regarding the type of marginal rings found on the scales during successive months on the Columbia River. During the early months the marginal rings of the fry are always of the summer type [type (1) in the table]; that is, are not conspicuously narrowed. In August is encountered the first development of narrow, winter rings [type (2)], and from this time on until April varying proportions of the specimens have marginal rings of this type. After the time when the marginal winter rings begin to be a feature of the scale growth it may be expected that the intermediate band, when formed, will be preceded, in some instances, at least, by a distinct band of narrower rings. After the winter bands begin to appear there is a constantly decreasing percentage of specimens whose scales show marginal rings belonging to the growth of the first summer in fresh water.

TABLE 49.—PERCENTAGE OF FISH WHOSE SCALES SHOW MARGINAL RINGS OF (1) SUMMER TYPE NOT ASSOCIATED WITH INTERMEDIATE OR NEW GROWTH, (2) WINTER TYPE, (3) SUMMER RINGS OF NEW OR INTERMEDIATE GROWTH.

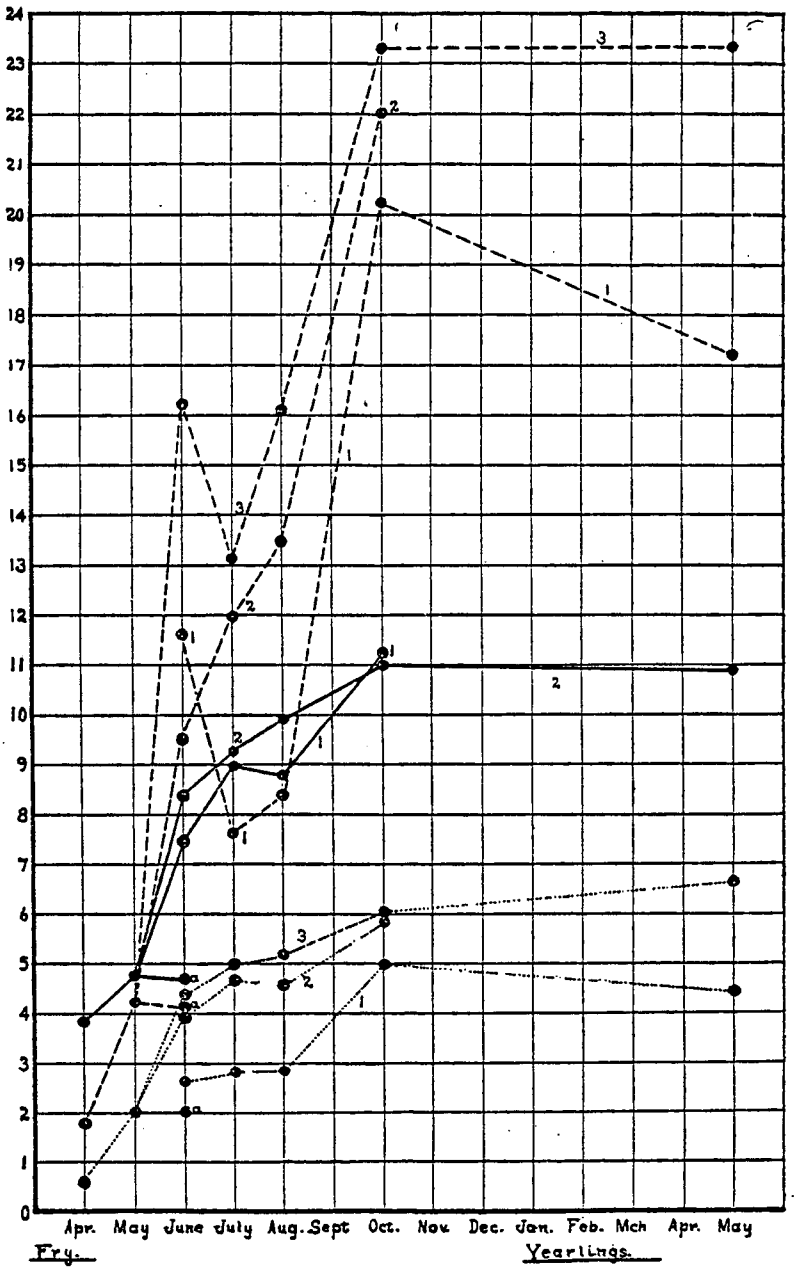
Month.	Group 1.			Group 2.			Group 3.			Group 4.		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
FRY.												
March	100	0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....
April	100	0	0	100	0	0	.....	.....	.....	100	0	0
May	100	0	0	100	0	0	.....	.....	.....	100	0	0
June	.....	.....	.....	83	0	17	.....	.....	.....	.....	.....	.....
July	.....	.....	.....	30	0	70	.....	.....	.....	.....	.....	.....
August	.....	.....	.....	40	2	58	0	67	33	20	80	0
September	21	74	5	.....	.....	.....	6	14	80	[a]65	35	0
October	[b]100	0	0	0	76	24	0	15	85	0	86	14
November	[c]43	57	0	.....	.....	.....	0	16	84	[d]25	48	27
December	0	45	55	.....	.....	.....	.....	.....	.....	[e]9	83	8
YEARLINGS.												
March	0	28	72	.....	.....	.....	.....	.....	.....	.....	.....	.....
April	0	23	77	.....	.....	.....	.....	.....	.....	.....	.....	.....
May	0	0	100	0	0	100	.....	.....	.....	.....	.....	.....
June	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	100

[a] Seufert.
[b] Little White Salmon River.
[c] Warrendale.
[d] McKenzie River.
[e] Clackamas hatchery.

With the exception of the collection from Clackamas hatchery none of the fish taken after November shows marginal rings belonging to the first summer's growth. Such changes as these, combined with the development of an intermediate band, will result

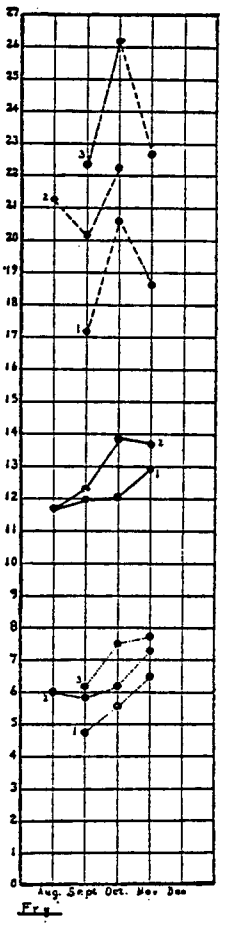


GRAPH 4.—Columbia River (group 1): Rate of growth, increase in number of rings, and increase in length of anterior radii of scales. Figures at left of graph indicate ordinate values for the three types of curves, as follows: (1) For curve of length, *centimeters;* (2) for number of rings, *ordinary numerical values;* (3) for length of anterior radii, *arbitrary units* (*actual value, 0.00834 mm.*). Solid line indicates length of—1, specimens without intermediate growth; and 2, specimens with intermediate growth. Broken line indicates number of rings on the scales—1, to intermediate growth; 2, total for specimens without intermediate growth; and 3, total for specimens with intermediate growth. Dotted line indicates length of anterior radii—1, to intermediate growth; 2, total for specimens without intermediate growth: and 3, total for specimens with intermediate growth. *a* indicates collection from Columbia River near mouth of Little White Salmon River.



GRAPH 5.—Columbia River (group 2): Rate of growth, increase in number of rings, and increase in length of anterior radii of scales. Significance of curves is same as in graph 4, with the following exception: *a* indicates collection from mouth of small creek near Point Ellice.

in a constantly increasing percentage of fish whose scales show an intermediate band preceded by a band of distinctly narrowed rings. The fry migrating in August and September will contain a relatively small percentage of specimens whose scales are of this type. As the season advances this percentage gradually increases, as the percentage of fish entering the estuary from above and having begun the slower winter growth, increases. When fish which have not begun the slower growth enter the estuary, the vigorous intermediate growth may begin immediately, so that no distinctly narrow rings will intervene between the growth of the first summer and the intermediate growth. All possible gradations between these two types of scales may be seen among the fall migrants. The migrating yearlings taken in the spring all have the band of narrow winter rings preceding the intermediate growth.



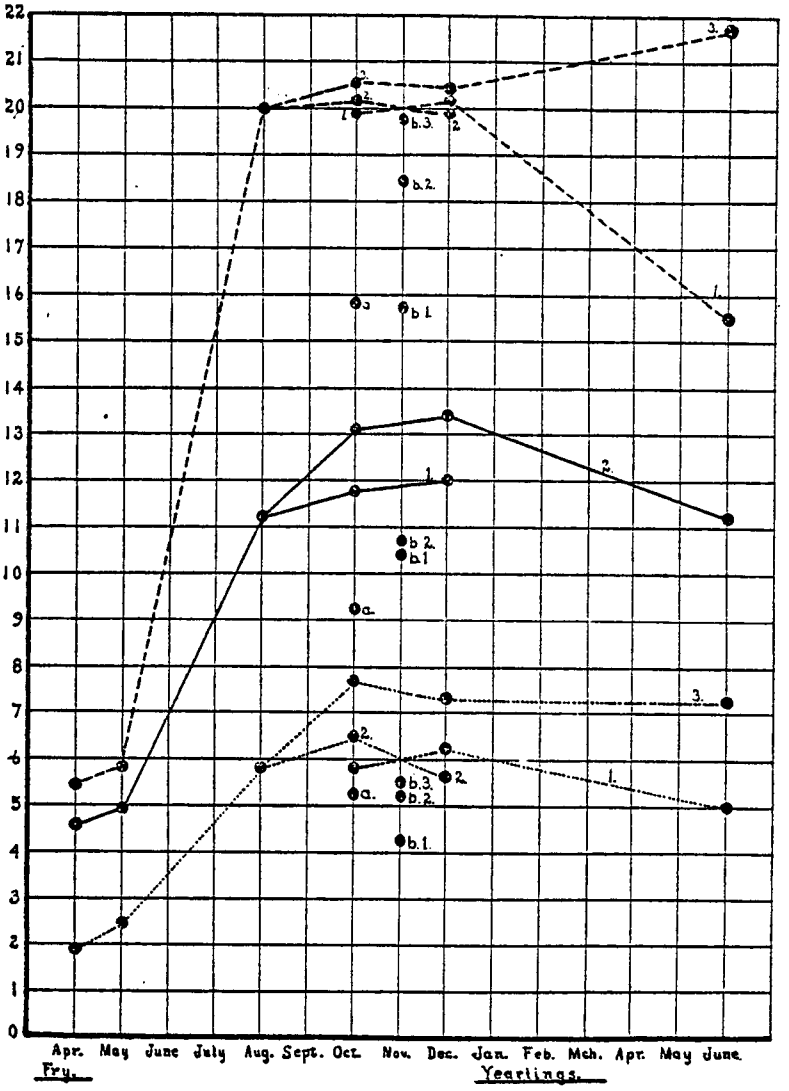
GRAPH 6.—Columbia River (group 3): Rate of growth, increase in number of rings, and increase in length of anterior radii of scales. Significance of curves is same as in graph 4.

The question arises: Is there any criterion whereby fry migrating seaward in the fall and yearlings migrating seaward in the spring can be distinguished? It has been shown that there is an average difference in the following respects: (1) Spring yearling migrants show a larger average amount of intermediate growth, both on the basis of ring counts and scale measurements; and (2) the intermediate band in the case of fall migrants is less frequently preceded by a band of narrower rings. Although these average differences in the scale growth of the fall fry and the spring yearling migrants are well enough established they are not diagnostic, and it would be impossible in many cases to determine from the scales the time at which migration took place.

Owing to the practical importance of determining, if possible, any discernible difference between the scales of fish migrating at such widely separated times, a series of each group was photographed in order to see whether some criterion, independent of the data presented in the tables, might be established by means of which the fish could be identified. The necessity for such series of photographs was discussed on page 6. For this purpose there were selected, at random, 50 specimens collected at Point Ellice, October 16, 1915, as representative of the fall migrants, and 50 specimens of the spring, yearling migrants collected on the lower Columbia River during March and April, 1916. A careful study of these series of photographs has disclosed no such criterion as was sought, and the conclusion is forced that, so far as the nuclear growth alone is concerned, it can not be hoped to distinguish in all cases adult fish which have migrated as fry in the fall from those which have migrated as yearlings in the spring. Plate II, figures 1 to 4, and Plate III, figures 1 to 4, were selected from these photographs as examples of the scales of the fall and spring migrants.

The available data regarding the scale growth of the Sacramento River fish do not indicate that there is as much variation as has been shown to exist in the case of the

Columbia River fry and yearlings. With the exception of the three earliest collections, made at hatcheries, all of the fish possess scales with rings. Very few of the wild fish taken on the lower river show the marginal band of wider rings, the intermediate band, which is so characteristic of the young migrants on the Columbia River. This may be



GRAPH 7.—Columbia River (group 4): Rate of growth, increase in number of rings, and increase in length of anterior radii of scales. Significance of curves is same as in graph 4, with the following exceptions: *a* indicates collection from Little White Salmon River; *b*, collection from McKenzie River; and "new growth" takes the place of "intermediate growth."

accounted for by the fact that none of these collections from the Sacramento was made in San Francisco Bay, which corresponds to the estuary of the Columbia, where intermediate growth was found most commonly. The collections of yearlings made at Brookdale and the majority of the collections made in the McCloud River contain

specimens whose scales show the marginal band of wider rings indicative of the new growth of the second year.

The "primary check" which has been noted on the scales of the Columbia River fish does not appear conspicuously in the Sacramento series. In the case of the fish from the lower part of the river this is not surprising, since such a primary check has not been found on the scales of specimens from the lower part of the Columbia until autumn, considerably later in the year than the last collection from the lower Sacramento. The absence of the primary check in the collections from the McCloud may well be a racial characteristic, just as the presence of such a check is a racial characteristic of the young fish in the McKenzie River. (Compare Pl. I, fig. 8, a scale from one of the McKenzie River fish, with Pl. III, fig. 9, a scale from one of the McCloud River specimens.)

Table 50 gives the data, averaged for each month, for the collections from the lower part of the river. Table 51 gives the data for the collections from the McCloud River. Graph 8 gives the data regarding scale growth based on all the available data from the Sacramento River system. In this graph the line representing the growth of the fish is the same as the generalized curve developed in graph 3.

TABLE 50.—RATE OF GROWTH AND SCALE DEVELOPMENT IN LOWER SACRAMENTO RIVER.

Month.	Length.	Average number of rings.	Average length of anterior radii.
	Mm.		
March	37.2	.....	.....
April	50.8	4.5	22.3
May	72.7	9.1	33.7
June	77.3	9.6	34.1
July	92.2	14.8	47.9

TABLE 51.—MCCLOUD RIVER: AVERAGE LENGTH AND SCALE DEVELOPMENT FOR EACH MONTH.

Month.	Specimens.		Scale record.			
			Number of rings—		Length of anterior radius—	
	Length.	With new growth.	To beginning of new growth.	Total.	To beginning of new growth.	Total.
FRY.	*Mm.*	*Per cent.*				
July	88.5	0.0	.....	11.5	.....	43.1
September:						
1909	96.9	53.0	(c)	14.5	.....	46.0
			[b] 12.9	16.0	39.3	50.5
1911	93.3	0.0	.....	13.6	.....	46.6
October	99.2	0.7	(c)	14.6	.....	47.1
			[b] 15.0	17.0	36.0	45.0
November	101.3	28.0	(a)	15.2	.....	48.7
			[b] 13.7	15.6	43.1	51.8
December	101.2	56.0	(a)	15.3	.....	48.5
			[b] 13.4	15.5	40.3	48.5
YEARLINGS.						
January	103.0	58.0	(a)	15.5	.....	49.9
			[b] 13.2	16.0	41.5	51.7
February	111.6	48.0	(a)	16.9	.....	52.2
			[b] 15.6	18.0	48.0	56.5
March	109.6	71.0	(a)	16.4	.....	50.7
			[b] 15.4	17.9	47.3	56.2

[a] Without new growth. [b] With new growth.

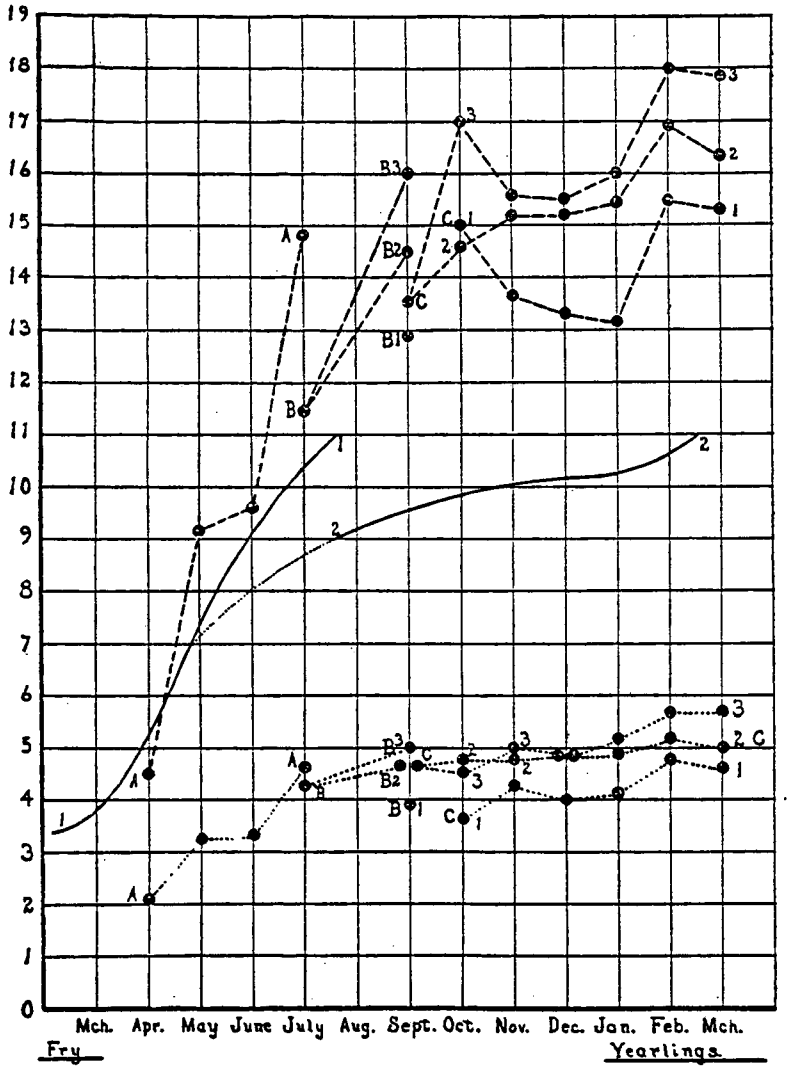
Tables 50 and 51 and graph 8 show that, as in the case of the rate of growth, the general features of scale development are not conspicuously different in the Sacramento River from those found in the Columbia River. As a result of the earlier beginning of the growth (noted on p. 50) the scale development also starts earlier.

So far as can be judged by the available data, none of the fry migrating in the spring will show a distinct narrowing preceding the intermediate growth. Inasmuch as the water of the Sacramento River becomes so warm during the summer that young salmon can not survive in it, it seems probable that the collections studied represent quite completely the migrating fry, and therefore it may be concluded that few, if any, of these will show a band of narrow rings preceding the intermediate band. There is very little evidence to show when the yearlings migrate, if at all, or whether there is any migration of fry during the late fall or winter. It would be logical to expect to find that fish older than the fry migrating in their first spring do migrate, and it seems probable that many, if not all, of such older migrants would show a band of narrower winter rings preceding the intermediate band. The evidence for this is given in Table 52, in which it is seen that none of the fish taken later than August has scales whose marginal rings belong to the first summer's growth. None of the fry collected in the lower part of the Sacramento shows scales whose marginal rings are of the winter type. There have been entered, therefore, in the following table (52) only the data on the collections from the McCloud River:

TABLE 52.—PERCENTAGE OF FISH FROM MCCLOUD RIVER WHOSE SCALES SHOW MARGINAL RINGS OF (1) SUMMER TYPE BELONGING TO THE FIRST SUMMER'S GROWTH, (2) WINTER TYPE, (3) SUMMER RINGS OF NEW OR INTERMEDIATE GROWTH, ASSOCIATED WITH THE SECOND PERIOD OF RAPID GROWTH.

Month.	(1)	(2)	(3)
1909: FRY.			
July	45.0	55.0	0.0
September	.0	47.0	53.0
1911:			
September	.0	100.0	.0
October	.0	99.3	.7
November	.0	72.0	28.0
December	.0	44.0	56.0
1912: YEARLINGS.			
January	.0	42.0	58.0
February	.0	52.0	48.0
March	.0	29.0	71.0

If the author's supposition is correct that there is a migration of older fish sharply separated from the spring migration of fry, it would be expected that there would be two distinct types of nuclei found on the scales of the adults—one characteristic of fish which had migrated as fry in the spring and which shows no particular narrowing preceding the intermediate or ocean growth, and the other type showing a narrowing preceding the intermediate or ocean growth representative of fish which had migrated either in the fall as fry or as yearlings in the spring. A more detailed study of the young migrants in the Sacramento, involving collections made throughout the year, would be necessary to firmly establish this hypothesis. The spring and fall runs of adult fish in the Sacramento River are sharply separated, and a study of the scales of adults belonging to these two runs would seem to offer interesting possibilities.



GRAPH 8.—Sacramento River: Rate of growth, increase in number of rings on scales, and increase in length of anterior radii of scales. Significance of curves is same as in graph 4, with the following exceptions: Solid line indicates the generalized curve of length developed on graph 3. Broken line indicates number of rings on scales—1, to beginning of new growth; 2, total for specimens not showing new growth; and 3, total for specimens showing new growth. Dotted line indicates length of anterior radii—1, to beginning of new growth; 2, total for specimens not showing new growth; and 3, total for specimens showing new growth. A indicates collections from lower part of river; B, McCloud River, 1909; and C, McCloud River, 1911–12.

The scale growth of the fish from the coastal streams presents nothing unusual or of particular value because of the scarcity of data. Certain racial characters are suggested by the data from one or two of the streams, but the evidence does not warrant drawing even tentative conclusions.

MIGRATION.

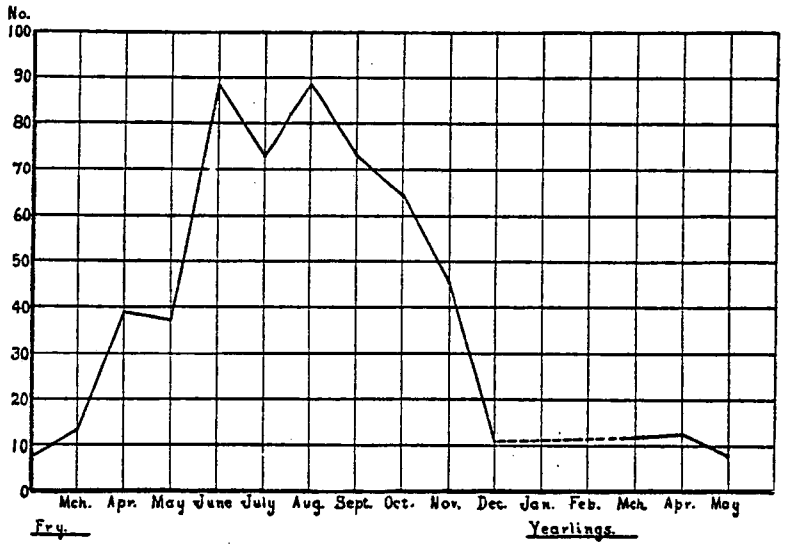
In the preceding sections the matter of migration has been dealt with in only a general way, and an attempt will now be made to summarize the available facts.

In the Columbia River migration takes place throughout the year. The fry hatched during the fall and winter may migrate immediately after the yolk sac is absorbed or even before this process is entirely completed, since occasionally specimens which still retained part of the yolk have been found in the estuary. The earliest hatched fry may migrate as early as December, and by March the migration is well under way. The data regarding the time at which the greater proportion migrate are not especially satisfactory, as the accurate determination of this would involve collecting either with some form of stationary gear or by frequent and uniform hauls with a seine at some one point. Such collecting would need to be continued during each month of the year. The nearest approach that can be made with the present data to a determination of the time of most frequent migration is by finding the average number of fish contained in each collection made in the lower part of the main river (exclusive of the collections made under canneries). This method is subject to considerable error, especially owing to the fact that at the times when the young fish were relatively scarce the collecting was more persistent and more seine hauls were made, on the average, at each point where collections were made, in order to get as large a representation of the migrants as possible. Obviously, such a source of error will tend to broaden the mean time of migration over more time than is actually the case. The data are presented in Table 53. The process of "smoothing," by which the figures in the fifth column were obtained, is the one commonly used. The smoothed figure for each month is obtained by taking the average of the actual figures for the month in question, plus those for both the preceding and succeeding months. Graph 9 gives the smoothed curve.

TABLE 53.—COLUMBIA RIVER: AVERAGE NUMBER OF FISH IN EACH COLLECTION.

Month.	Number of specimens.	Number of collections.	Average number of specimens to each collection.	Preceding column smoothed.
FRY.				
March	102	4	25.2	19.1
April	26	2	13.0	39.4
May	321	4	80.2	37.8
June	80	3	20.2	89.0
July	166	1	166.0	72.6
August	64	2	32.0	89.0
September	69	1	69.0	73.3
October	119	1	119.0	65.0
November	7	1	7.0	46.6
December	38	3	12.6	10.6
YEARLINGS.				
March	47	4	12.0	11.9
April	22	2	11.0	12.3
May	57	4	14.0	12.2

As stated above, migration in the Columbia River takes place throughout the year, but the data here presented indicate clearly that the chief period of migration for the fry is during the months from June to October, inclusive. On account of the source of error mentioned above it seems probable that the main period of migration is actually somewhat shorter than is here indicated. The mode of the curve, showing the height of the migration, would not necessarily be affected by error of this sort. The migration of yearlings is completed by June. This wide range in the time of migration is not surprising in such a large river system as that of the Columbia, where a great diversity of climatic conditions obtains in different regions. There are two possible explanations for the wide extension of the migration period: (1) Fish from each tributary may migrate gradually, a few at a time, through the year; (2) fish from each tributary may all migrate at about the same time, but migration from different tributaries takes place at different times of the year.



GRAPH 9.—"Smoothed" curve showing average number of specimens taken in each collection in the main Columbia River and the estuary for each month.

There is some evidence to show that the young fish from particular tributaries tend to migrate at the same time and, moreover, that they tend to school together during the seaward migration. The collection made at Crandall's seining ground, September 15, 1916, especially suggests this interpretation, as the fish are noticeably smaller and the character of the scale growth different from other collections made during the same time of year under approximately similar conditions. (See p. 19.)

The time at which the fry leave the tributary streams for the main river and the rate of downward migration have not been determined. Undoubtedly, the time of leaving the tributary streams is subject to great variation. On purely a priori grounds it seems certain that the earliest fry to migrate—such, for example, as those taken in March and April—must have come from the lower tributaries. The spawning season in the different tributaries does not differ more than a few weeks over the entire Columbia system, but the much colder water of the higher streams delays development so markedly

that there may be a difference of several months in the time at which the yolk sac will be fully absorbed and the fish begin an active existence. It can not well be doubted, then, that the earliest fry to migrate have been hatched in the lower tributaries, and it seems reasonable to assume that, in a general way, at least, the successively later migrants have come from successively higher tributaries.

The abnormally large proportion of smaller fish found in the lower part of the river during the spring and early summer, which causes the "skewing" of the frequency curve of length noted on page 8, may also indicate that the height of the migration has not been passed and that the smaller fish entering from above are doing so in constantly increasing numbers. After the height of the migration the skewing effect of the constantly decreasing numbers of smaller fish would not be noticeable. This skewing of the curves of length is not found to any noticeable degree after the early part of the summer, a fact which seems to give additional evidence that the height of migration comes, in the lower part of the Columbia River, during the latter half of the summer or early in autumn.

The migration of fry in the Sacramento River has been given in detail by Rutter (1903). He found that fry were migrating in the lower part of the river during the months from January to May, inclusive, and that they started the migration from the streams in which they were hatched as soon as the yolk sac was absorbed, as early as October. This migration is much earlier than that observed by the author in the Columbia River, a fact associated with the earlier hatching of the eggs and the more rapid development of the fry in the warmer water of the southern stream. The data presented in this study add nothing to Rutter's conclusions on this point. No migrating yearlings were taken by Rutter (1903) nor by Scofield (1898) in their work on the lower river, but, as no collections were made during the fall and early winter, it is quite possible that there is a migration of the older fish at this time of the year. It is possible that yearlings migrating in the spring are so scarce that none were captured. It has been shown (p. 36) that the new growth of the second year may begin in the case of the young chinooks in the McCloud River as early as September, varying, however, in different years. It has also been shown (p. 48) that in some cases, at least, there is a tendency for the older fry or yearlings to migrate soon after beginning the new growth of the second year. Consideration of these two facts lends considerable probability to the theory that there is a fall migration of older fry in the Sacramento River. An investigation of this matter would be pertinent, since a distinct difference in the scale growth between fry migrating in the spring and those migrating in the fall would be expected. The relation between the young migrating at these two periods (granting that such a later migration takes place) and the adults comprising the sharply separated spring and fall runs of spawning fish might well prove to be of considerable practical importance.

VARIATIONS DUE TO SEX.

SEX PROPORTIONS.

The proportions of males and females in the collections from the Columbia River, while subject to considerable variation in different collections, are on the whole remarkably even. The data for each collection are presented in Table 54. There seems to be no regularity to the variations noted, and the conclusion that males and females migrate seaward in equal numbers throughout the year seems justified.

TABLE 54.—COLUMBIA RIVER: PROPORTION OF MALES AND FEMALES, AVERAGE LENGTH OF MALES AND FEMALES, AND LENGTH OF FEMALES AS PERCENTAGE OF THE LENGTH OF MALES.

Date.	Locality.	Males.		Females.		
		Percentage.	Length in millimeters.	Percentage.	Length—	
					In millimeters.	As percentage of the male length.
FRY.						
1916:						
Apr. 13	Cottonwood and Deer Islands	50	42.3	50	44.1	104
May 2	Clackamas hatchery	53	46.5	47	46.9	101
May 10	Lower Columbia	54	52.3	46	52.8	101
May 11	Estuary	50	46.7	50	48.8	105
May 25	Columbia River near Little White Salmon River	50	44.6	50	44.6	100
May 27	Clackamas hatchery	50	53.0	50	59.0	111
June 13	Small creek near Point Ellice	53	47.5	47	48.0	101
Do	Estuary	44	78.5	56	74.9	95
July 19	Point Ellice	46	90.1	54	93.6	104
Aug. 12	do	62	92.0	38	97.2	106
Aug. 30 and 31	Clackamas River	50	113.8	50	112.0	99
1915:						
Sept. 2	Seufert	48	81.5	52	80.3	99
1916:						
Sept. 15	Crandall's	52	74.2	48	74.8	101
1914:						
Sept. 17	Ilwaco	51	121.3	49	124.7	102
1915:						
Oct. 16	Point Ellice	51	112.2	49	113.3	101
Oct. 17	Astoria	54	127.9	46	127.0	99+
Nov. 2 and 3	McKenzie River	46	107.1	54	106.0	99
Dec. 3 to 8	Lower Columbia	37	95.5	63	93.4	98
YEARLINGS.						
1916:						
Mar. 31 to Apr. 2	Lower Columbia	55	97.6	45	93.2	96
Apr. 13	Cottonwood and Deer Islands	45	107.0	55	107.0	100
May 10	Crandall's	41	106.0	59	101.0	95
June 3	Clackamas River	64	112.0	36	112.6	100+

The only collections from the lower Sacramento River which were large enough to give significant data and in which the specimens were sexed are those from Woods Break, June 5 and 6, 1911, and from Tisdale wier, June 24–26, 1911. The sexes were quite evenly balanced in both of these collections, 52 per cent males in the first and 48 per cent males in the second.

The situation in the McCloud River is somewhat complicated by the presence of precociously matured males. Table 55 gives the percentages of males, both mature and immature, and of females for each collection made in the McCloud River. The sexes are present in approximately equal numbers, although there is a slight preponderance of females. Five and eight-tenths per cent of the total number of specimens are mature males. This signifies that between 10 and 12 per cent of the males which do not migrate during their first spring mature precociously during the following summer and fall.

TABLE 55.—PERCENTAGES OF MALES AND FEMALES IN MCCLOUD RIVER COLLECTIONS.

Date.	Females.	Males.		
		Total.	Immature.	Mature.
1909: FRY.				
July	39	61	37	24
September	53	47	39	8
1911:				
September	42	58	49	9
October	56	44	43	1
November	57	43	39	4
December	50	50	49	1
1912: YEARLINGS.				
January	57	43	42	1
February	50	50	46	4
March	61	39	39	0
Average	51.6	48.4	42.6	5.8

RELATIVE SIZES OF MALES AND FEMALES.

Table 54 gives, for each Columbia River collection in which the specimens were sexed and which was large enough so that conclusions seem warranted, the average length of the females as a percentage of the average length of the males. Dividing this series roughly into quartiles, it is found that the average for the first six collections is 103.6; for the next five, 101; for the next five, 100.4; and for the last six, 98. The cumulative evidence seems conclusive that among the younger fish the females average slightly larger. In the case of the fish taken during and subsequent to September, however, this condition is reversed, and the males are slightly larger than the females. No explanation for this is offered, but the facts seem undoubted and worthy of record.

The males and females from the two collections from the lower Sacramento are approximately the same size. The length of the females in the collection from Woods Break averages 98.3 per cent of that of the males. In the collection from Tisdale wier the percentage is 102.4.

Table 56 gives for each collection made on the McCloud River the length of the females and of the mature males as percentages of the length of the immature males.

TABLE 56.—MCCLOUD RIVER: LENGTH OF FEMALES AND OF MATURE MALES AS PERCENTAGES OF THE LENGTH OF IMMATURE MALES.

Date.	Males.		Females.
	Immature.	Mature.	
1909: FRY.			
July	100	145	107
September	100	112	98.3
1911:			
September	100	105	97.5
October	100	101.5	98.9
November	100	109	100
December	100	106	99.7
1912: YEARLINGS.			
January	100	136	98.2
February	100	115	101.2
March	100	.....	98.6

There is apparently no significant difference in the length of immature males and females, but the mature males are distinctly larger than the immature specimens. This indicates either that they are slightly older or that they have, for some unknown reason, grown more rapidly than the other individuals of the same brood.

PRECOCIOUSLY MATURE MALES.

The precocious maturing of young chinooks has been noted by Rutter and is a phenomenon well known to many hatchery men. Most of these precocious males are, without question, the same age as the immature fish taken at the same time, but, as we have just shown, average distinctly larger (about 16 per cent). The time for maturing corresponds with the normal spawning time for the adult fish, late summer and autumn, although, as shall presently be shown, they may be found during the winter and spring, long after the normal spawning season is past. In addition to the precocious males from the McCloud River they have been also found in various collections from the Columbia River system, as follows:

1. Clackamas River, August 30 and 31, 1916: Four out of 10 specimens. Length of the mature males is 105 per cent that of the immature specimens.

2. Seufert, Oreg., September 2, 1915: Three out of 52 specimens. Length of mature males is 116 per cent that of immature specimens.

3. McKenzie River, September, 1916: Eight out of 11 specimens. Length of mature males is 122 per cent that of immature specimens. (These were collected from a pond used for holding spawning fish and have not previously been considered because of the small size of the collection and the great irregularities in size and scale growth.)

4. Hatchery ponds at Bonneville, Oreg.: Specimens of mature males were not infrequently found here during the spring of 1915, while the author was engaged in marking a series of yearling fish.

It will be noticed that the mature males are only recorded in collections from tributaries fairly well upstream.

In appearance these precocious fish are, when fully mature, strikingly different from the immature specimens. In addition to the greater size, the head is relatively larger, the body is deeper and thicker, the skin covering the entire body and fins is thickened so that the scales appear smaller, and the coloration is distinctly modified. The general color is a dark yellowish brown, becoming distinctly yellow ventrally. The color of the spots is deepened so that they are conspicuous even against the darkened background. There is also a tendency toward the development of bright yellow or rose-colored borders to the fins. The testes are large and white, in every respect resembling the testes of normal, mature, sea-run males. The scales are normal and show no absorption along the edges, as is so characteristic of the scales of spawning sea-run adults.

The habits of these fish do not apparently differ greatly from the habits of the immature fish with which they are associated. They feed regularly and are, to all appearances, fully as well conditioned as the others. This probably accounts for the fact that the scales are not absorbed at the margins. Rutter (1903) reports that they do not seem to be attracted by the females as are the sea-run adult males. Our observations are, however, to the contrary. The fish contained in the collection from the McKenzie River, made in September, 1916, were taken from a pond used for empounding spawning fish and the percentage of mature males is much higher than in any of the other collections. Rutter reports that the milt from such males will fertilize eggs normally.

The fate of these precociously matured males has been a matter of some speculation. It has been both claimed and denied that these died as do the sea-run adults after the spawning season. The writer had an opportunity in the spring of 1915 of testing this. He was at this time marking series of young blueback (sockeye) and chinook yearlings at the Bonneville (Oreg.) hatchery. Mature male chinooks, with fluid milt which could be expressed, were frequently encountered. A number of these were marked and held in a tank at the hatchery until July. Some had died in the meanwhile, but in some of those which remained the testes had practically recovered the normal immature appearance, and the characteristic coloration above described was much less conspicuous than it had been at the time the fish were marked and placed in the tank. The fish were apparently in perfect condition, and the scales show that they were growing actively at the time they were preserved. It is not known whether young males which have thus recovered from the effects of ripening the sex products will migrate to the sea.

PRACTICAL SUGGESTIONS.

Although information of still greater practical value may be expected to come from the study of the adult fish, some of the conclusions reached in this study appear to offer important suggestions, which may be applied in practical fish culture, as to the proper time for planting fry from the hatcheries.

In the early days of the artificial propagation of salmon it was an almost universal practice to "plant" the fry as soon as they were hatched. The mortality among the helpless alevins, encumbered by the heavy yolk sac, must have been enormous, and the hatcheries probably inflicted as much, or more, damage to the salmon runs as they did service of value. More recently the tendency among the more intelligent and scientific hatchery men has been to abandon the practice of planting alevins and to hold the fry at least until the yolk sac is absorbed. The system of holding and feeding fry after the yolk is absorbed has followed and with this, a not unnatural idea, that the longer the fish are held and fed the greater the chance of their surviving. The validity of this assumption is, however, dependent upon several factors which have not been sufficiently considered. The following more important ones may be mentioned here: (1) The possibility of an increasing percentage of loss among fish so held which would ultimately seriously reduce the number of fish planted; and (2) the effect of holding fish beyond the normal time of migration on (*a*) their chances for survival and return as adults, (*b*) the time of return as adults and whether they will return as spring or as fall fish,[a] and (*c*) the development of the normal feeding and protective reactions (instincts) which are essential to their survival after planting.

It is a well-known fact among hatchery men that salmon fry held and fed in hatchery ponds will, after a time, "go bad." At such times the fish usually refuse to eat well and show a distinct tendency to collect toward the lower end of the trough, tank, or pond in which they are held. If persistently held the loss rapidly increases but finally lessens as the critical period is passed, after which there is usually no more serious difficulty experienced in holding the fish. This critical period usually comes after the fish have been held and fed from 6 to 12 weeks—on the Columbia River in May or June

[a] The greater value of fish composing the spring run has been noted above (p. 5).

and on the Sacramento River a month or two earlier, the exact time varying at different hatcheries and even in different ponds and tanks at the same hatchery. It has been shown above that the most normal time for migration on the Sacramento River is during the latter part of the spring, and on the Columbia River during the latter part of the summer. Therefore, it seems quite probable that these critical periods occur at times when the fry would normally quit the stream in which they were hatched and begin the seaward migration. There may or may not be a causal connection between these two phenomena, but even though the fry were allowed to leave the streams at these times—as the majority will, if permitted to do so—their time of migration would coincide well with the normal time observed, and the certain loss resulting from holding them over this critical period would be prevented. There is, of course, the possibility that this loss will occur under any circumstances, but such a conclusion is unwarranted from any data at present available.

Suggestions, then, as to the care of fry are as follows:

1. The practice of planting alevins before the complete absorption of the yolk can not be too strongly condemned. No hatchery should be allowed to take a larger number of eggs than can be hatched and reared until the fry are at least ready to feed. Rather than plant the alevins before the yolk has been absorbed it would be infinitely better to allow the eggs which can not be properly accommodated in hatcheries to be deposited normally by the parent fish, and to thus rely upon natural propagation for the outcome.

2. The liberation of chinook fry at such a time as will enable them to migrate seaward at the normal migrating season for the stream in question is advised. This, on the Columbia and Sacramento Rivers, will ordinarily come within about three months after the fry have absorbed the yolk sac and begun feeding. Within this limit it would seem that the longer the fish are held and continue to feed well and grow normally (a point which should be carefully watched) the greater would be their chance for survival. If after several weeks' feeding the symptoms indicative of the approach of the critical period mentioned above appear, it would seem advisable to allow the fish to migrate. Where practicable the fry should not be liberated all at once, but should be allowed to begin the migration gradually and naturally, each fish leaving the parent tributary as the "instinct" to migrate develops. These conditions will be fulfilled if, at the proper time, the screens be removed from the retaining tanks or ponds so as to leave the way clear for the fry to enter the open stream.

These suggestions are of a general nature only. It is possible that in particular tributaries or in particular regions of a large watershed the conditions and habits of the fish are so different that these suggestions will not apply. In the absence, however, of definite information on these points the practical application of the above suggestions will, as a rule, be found advantageous.

SUMMARY.

1. Chinook fry first appear in the Columbia River as early as December of the same year in which the eggs are deposited. By March and April they are fairly numerous in the lower part of the river. Fry appear about two months earlier in the Sacramento River.

2. The average length of the youngest fry is between 35 and 40 mm. The rate of growth is especially rapid during the first five or six months, by which time the average stature for the first year has been attained. The average length of yearlings is approximately 100 mm. (4 inches), both in the Columbia and Sacramento Rivers.

3. The length of the scales and also the number of rings formed on the scales parallel quite closely the increasing length of the fish. Many of the youngest and smallest fry have not developed scales before migrating seaward.

4. Migration into the brackish water of the estuary is usually accompanied by an increase in the rate of growth, which is recorded on the scales as a marginal band of wide rings—the intermediate band. No intermediate band has been demonstrated on the migrating fry of the Sacramento River, but this is undoubtedly due to the lack of material collected at the right time and place.

5. The scales of fry remaining in fresh water develop a marginal band of narrow, winter rings during the latter part of the summer. The new growth of the second year begins soon thereafter.

6. The normal time for seaward migration among Columbia River chinooks is during the summer next succeeding the fall in which the eggs are laid. Seaward migrating chinook fry are, however, found throughout the year in the Columbia River, and the collections taken in March, April, and May include also migrating yearlings. There is, therefore, for each brood of fish, a period extending over about 18 months, during which the young may migrate seaward.

7. In the Sacramento River there is a distinct migration of fry lasting from January to June, inclusive. Although definite proof is lacking, it is probable that there is another period of seaward migration during the late autumn.

8. In the younger migrants of the Columbia, including practically all the fish migrating previous to June, the intermediate band is not to be distinguished from the preceding scale growth, due to the fact that the first few rings formed on the scales are always somewhat wider than the latter ones. After the first of June the intermediate band may be (but not always) distinguished as a marginal band of distinctly wider rings. Beginning in August or September this intermediate band may be preceded by a more or less distinct band of narrow rings that correspond to the winter band forming on the scales of upstream fish. The percentage of fish, whose scales show such a narrowing preceding the intermediate band, increases through the autumn and winter, so that by the following spring this narrowing becomes characteristic of the scales of all the yearling migrants. Although there is this average difference in the scales of fish migrating as fry during the fall and those migrating as yearlings in the spring, it is impossible, with our present knowledge, to distinguish in many individual cases between fish migrating at these two periods.

9. A sudden change in environmental conditions, such as removal from hatchery to wild conditions, may result in modified growth, recorded on the scales as a distinct break or check in the scale growth. This we have designated as the "primary check." Characteristically this appears as a more or less distinct narrowing of the rings succeeded by a series of wider rings.

10. There is apparently a distinct tendency for the larger specimens among the fish of any particular tributary to migrate earlier than the smaller specimens. It is

also apparent that the fish from the lower tributaries of a river system will, in a general way at least, migrate earlier than those from the higher tributaries.

11. Among the male fry which remain in fresh water over their first summer, about 10 per cent will mature precociously during the fall, the normal spawning period for adult sea-run chinooks. The proportion of male fry thus maturing presumably differs in different streams. These precociously mature males may recover from the effects of ripening the sex products, in this respect differing markedly from the known habits of the sea-run fish.

12. The suggestion is made that chinook fry be liberated from the hatcheries at such a time as will enable them to migrate at the normal period for seaward migration for the stream in question.

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EXPLANATION OF PLATES.

[The magnification of all photographs is the same, × 35. Abbreviations: *l* indicates lateral line; *c*, primary check; *g*, point distal to which is intermediate growth; *x*, check indicative of time of planting; *1st yr.*, first year of growth; and *2d yr.*, second year of growth.]

PLATE I.

FIG. 1.—Fry from Deer Island, Columbia River. April 13, 1916. Female, 51 mm. Part of skin from near center of body, showing scales with from one to five rings.

FIG. 2.—Isolated scale from the same specimen from which the skin shown in figure 1 was taken.

FIG. 3.—Fry from Point Ellice, Columbia River. June 12, 1916. Male, 68 mm.

FIG. 4.—Fry from Point Ellice, Columbia River. August 12, 1916. Female, 113 mm. Showing a weakly differentiated intermediate band not preceded by a band of narrow rings.

FIG. 5.—Fry from Crandall's seining ground, Grims Island, Columbia River. September 15, 1916. Male, 76 mm. Showing winter rings at the margin of the scale.

FIG. 6.—Fry from lake at Seufert, Oreg. September 2, 1915. Male, 83 mm. Showing check at *x* indicative of the time of planting.

FIG. 7.—Fry from Clackamas River. August 30, 1915. Female, 114 mm. Showing primary check and marginal winter rings.

FIG. 8.—Fry from McKenzie River. November 3, 1915. Male, 107 mm. Showing primary check and well-developed winter band at the margin.

FIG. 9.—Fry reared at Clackamas hatchery, Oreg. December 15, 1911. Male, 125 mm. A scale with but slight differentiation, characteristic of hatchery fish.

PLATE II.

FIG. 1.—Fry from Point Ellice, Columbia River. October 16, 1915. Female, 116 mm. Typical fall migrant, showing marginal winter band. No primary check.

FIG. 2.—Fry from same collection as figure 1. Male, 117 mm. Showing primary check and marginal winter band.

FIG. 3.—Fry from same collection as figure 1. Female, 110 mm. The intermediate band is preceded by a distinct band of narrow rings. No primary check.

FIG. 4.—Fry from same collection as figure 1. Female, 118 mm. Similar to figure 3, except that the primary check is present.

FIG. 5.—Fry from under cannery at Ilwaco, Wash. October 26, 1914. Sex not determined. 141 mm. The intermediate band is composed of unusually wide rings, characteristic of fish found under the canneries. The band of narrow rings preceding the intermediate band is conspicuous.

FIG. 6.—Fry from same collection as figure 5. Sex not determined. 166 mm. Similar to figure 5, except that the intermediate band is not preceded by a distinct band of narrow rings.

FIG. 7.—Fry from same collection as figure 5. Female, 145 mm. The check preceding the intermediate band (which is not strongly differentiated) is intermediate between the conditions illustrated in figures 5 and 6.

PLATE III.

FIG. 1.—Yearling from Deer Island, Columbia River. April 13, 1916. Female, 103 mm. Showing marginal winter band and no primary check.

FIG. 2.—Yearling from Crandall's seining ground, Grims Island, Columbia River. March 31, 1916. Male, 92 mm. Similar to figure 1, except for the primary check.

FIG. 3.—Yearling from same collection as figure 1. Female, 99 mm. A typical scale characteristic of the spring yearling migrants, showing an intermediate band preceded by a distinct winter band of narrow rings. No primary check present.

FIG. 4.—Yearling from same collection as figure 1. Male, 113 mm. Showing intermediate band and also primary check.

FIG. 5.—Yearling from Clackamas River. June 3, 1916. Male, 105 mm. Showing well developed new growth of the second year.

FIG. 6.—Sacramento River fry from Walnut Grove, Calif. April 9, 1911. Male, 75 mm.

FIG. 7.—Sacramento River fry from Butte Slough. June 8, 1911. Male, 97 mm.

FIG. 8.—Sacramento River fry from near Butte Slough. May 9, 1911. Male, 103 mm. Showing intermediate growth.

FIG. 9.—Fry from McCloud River. July 24, 1909. Mature male, 128 mm. Showing marginal winter rings.

PLATE IV.

FIG. 1.—Yearling from McCloud River. January 22, 1912. Male, 142 mm. Showing marginal winter band.

FIG. 2.—Yearling from same collection as figure 1. Male, 110 mm. Showing two wide marginal rings of the new growth of the second year.

FIG. 3.—Yearling from Brookdale hatchery, Calif. January 4, 1913. Female, 127 mm. Showing irregularities of growth characteristic of the scales of hatchery fish.

FIG. 4.—Yearling from Bonneville hatchery, Oreg. March 2, 1915. Male, 162 mm. The winter band is not strongly defined, but the new growth is well started.

FIG. 5.—Yearling from Bonneville hatchery, Oreg. July 7, 1916. Male, 150 mm. This fish was one of the mature males marked in March or April and held until July. The new growth of the second year has begun, but is somewhat irregular.

FIG. 6.—Fry from Hope Island, Puget Sound. May 28, 1915. Male, 94 mm.

FIG. 7.—Yearling from same collection as figure 6. Male, 97 mm.

FIG. 8.—Young chinook taken in Half Moon Bay, Calif.

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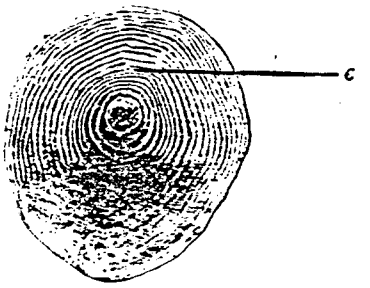

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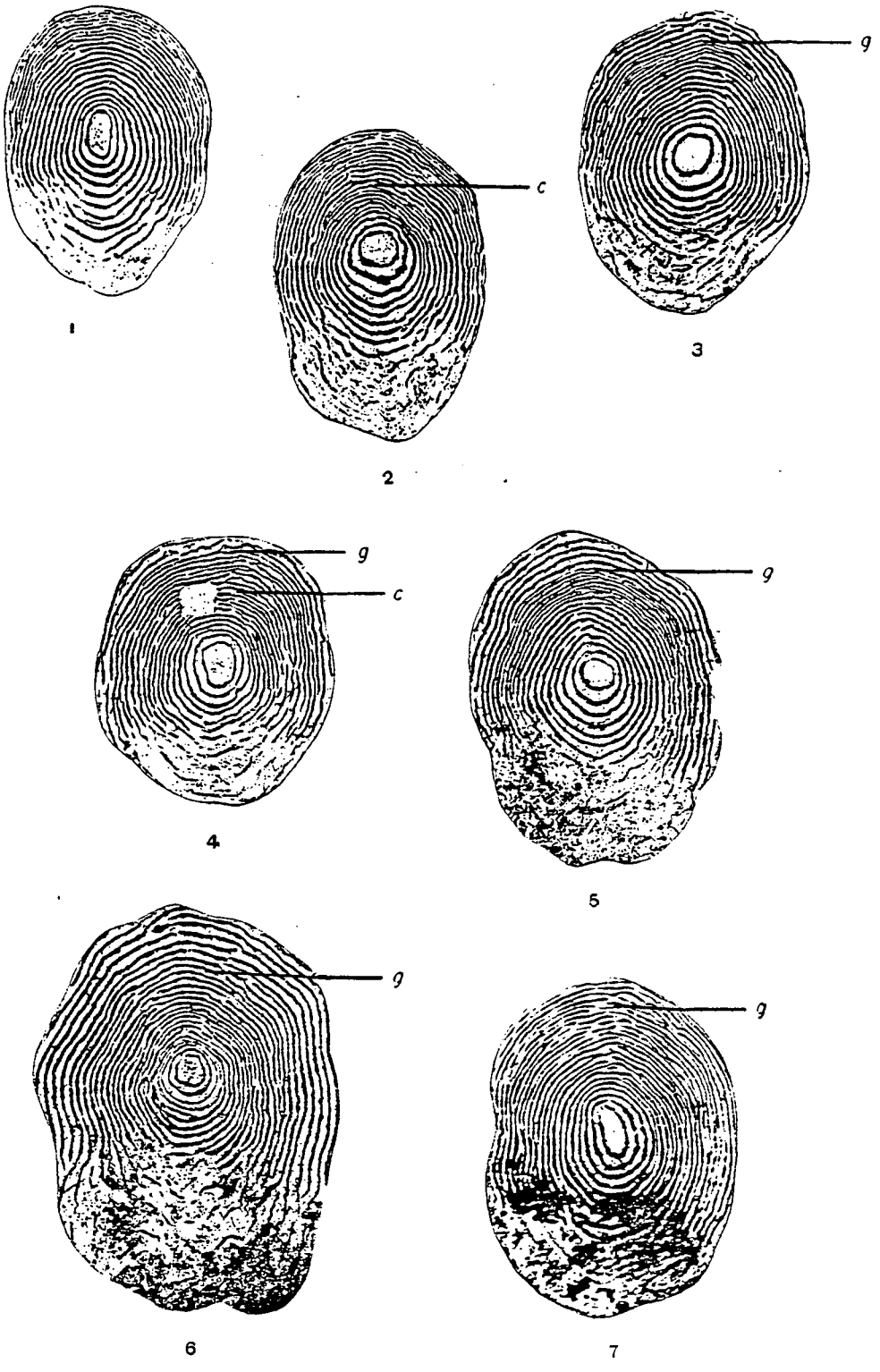
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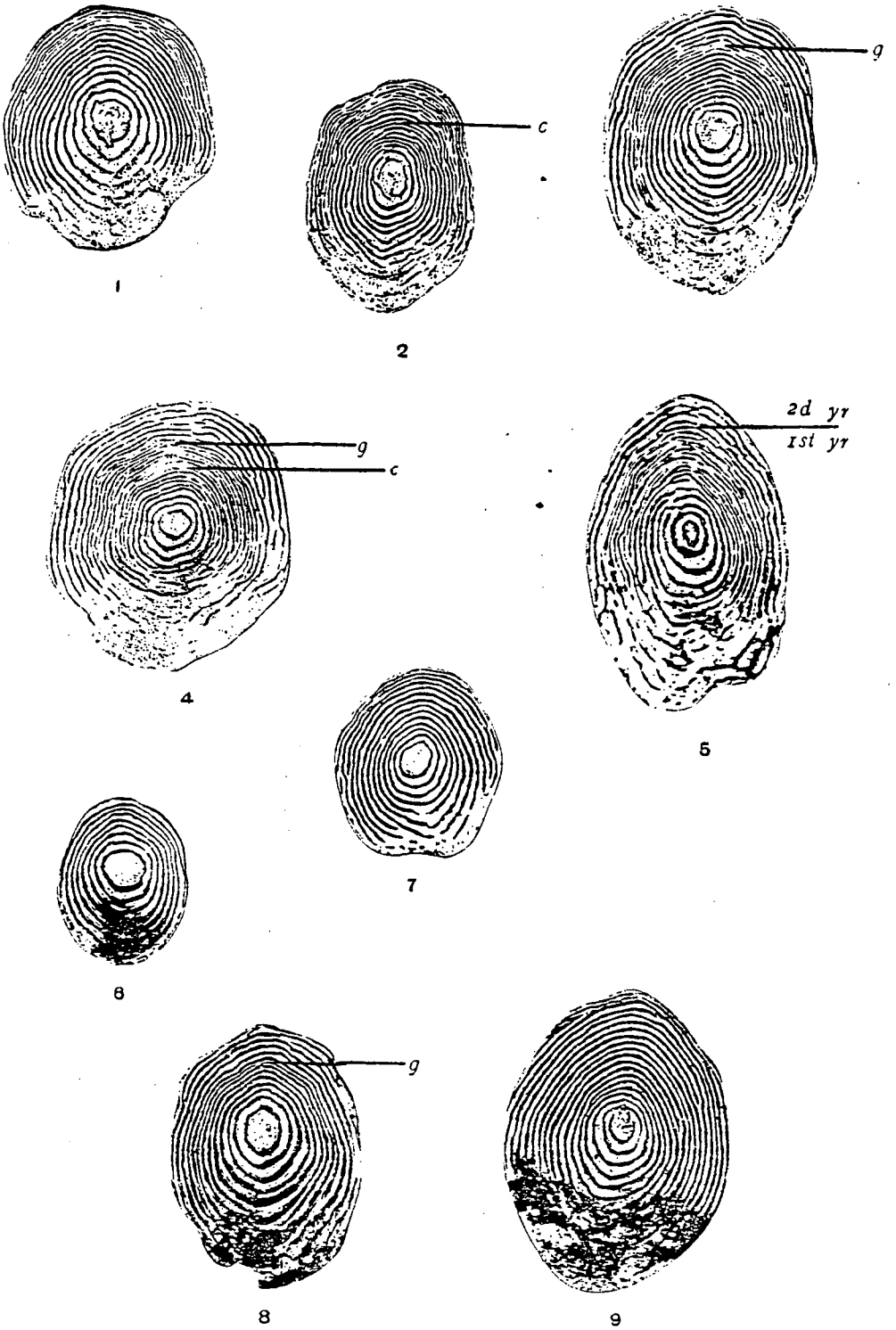

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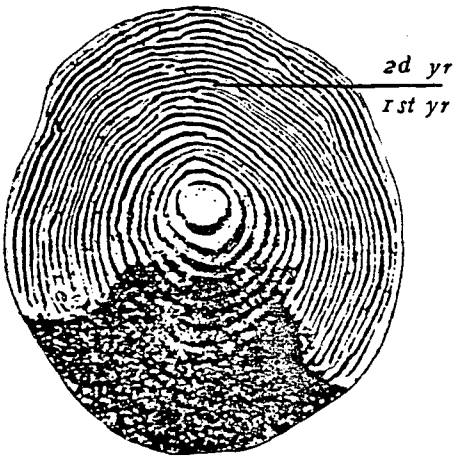

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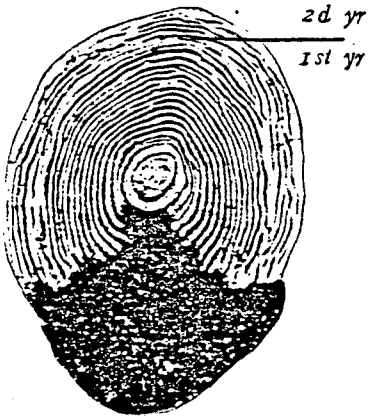

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