GROWTH AND DEGREE OF MATURITY OF CHINOOK SALMON IN THE OCEAN

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CONTENTS

	Page
Introduction	15
Methods	18
Determination of age	18
Determination of relative maturity	20
Correlation between size of eggs and size of fish	27
Fish taken in the Columbia River and in the ocean off the mouth of the river	28
Relative maturity of chinook salmon taken in the ocean	29
Age of immature fish	39
Percentages of immature fish at different times	40
Percentages of fish more than one year from maturity	42
Abundance of the various age groups	43
Growth	48
Fish taken in Monterey Bay	63
Size	63
Percentages of the various age groups	64
Relative maturity	66
Fish from Drakes Bay and Fort Bragg	67
Summary and conclusions	69
Supplementary tables	75
Bibliography	89

INTRODUCTION

The rapid increase in the amount of trolling and purse seining for salmon which has taken place along the Pacific coast during the past few years has directed attention toward this phase of the salmon industry. The general consensus of opinion of those interested in conservation is to the effect that these methods of taking salmon are, under certain circumstances at least, destructive and undesirable. The fishing on Swiftsure Bank, off the coast of Washington, was reported on a number of years ago by Dr. C. H. Gilbert (1915), who found that the silver salmon (cohoes) taken by purse seines on the bank, "especially in the first part of the season, are far from having attained their full growth, although maturity is but a few months distant." Of the spring salmon (the chinook) he makes the following statement:

> The spring salmon is taken in large numbers and furnishes a somewhat inferior product, with soft flesh, little oil, and poor color. Several thousand young of this species are captured during the season, 2-year-olds about a foot long with white, soft flesh—a total waste. The numbers of these are relatively small, as the great majority of the salmon on the bank are in their last season, but the loss is nevertheless serious and deplorable.

In 1920 Smith and Kincaid reported on the immature salmon taken off the mouth of the Columbia River, Grays Harbor, and Neah Bay during 1918. Later in the same year (1920) a more complete report by Smith gave the results of his investigations during 1918 and 1919. In both of these reports Smith gives the results of chemical analyses, which show that the product resulting from the canning of the immature fish is decidedly inferior to the standard grades in fat and protein content. He also presents figures that show something of the extent of the operations of both the purse seine and the trolling fleets, and concludes that "the taking of immature salmon in the Puget Sound and on the banks along the coasts of Oregon, Washington, and Vancouver Island is responsible for a great loss in one of the important food products of the region."

The "outside fishing," as it is commonly termed, has been increased by the addition of both purse seines and trolling boats, but the exact amount of this increase in the different regions where such fishing is carried on is difficult to determine. The purse seiners frequently move from one location to another, fishing wherever the greatest returns can be obtained. The trollers not infrequently (at least in Oregon and Washington) fail to take out licenses. Much of the trolling is carried on outside the 3-mile limit, and some of the trollers argue that it is not necessary for them to take out licenses to fish except in territorial waters. Furthermore, one fisherman often takes out licenses for more than one kind of gear—as for trolling and gill netting, or trolling and trapping—and trolls only a small part of the season. These factors make it practically impossible to determine with any accuracy the amount of increase in this outside fishing, but there can be no doubt that it has developed within the past few years into a very important factor and represents an increased drain on the resources of the fishery which may easily result in serious depletion. The number of trollers operating off the mouth of the Columbia River during the three seasons, 1919 to 1921, inclusive, was estimated at between two and three thousand, and the Columbia River District Troller's Union alone contained some 1,500 members. At the same time there were probably not less than 40 purse seines operating in the same region. This is in strong contrast to the condition in 1914, when there were only a few dozen trollers and possibly three or four purse seines operating off the mouth of the river.

One of the chief objections that has been raised to this "outside fishing" has been that it was destructive of immature salmon. The most casual observation shows that a considerable percentage of the fish taken outside are relatively immature. They average decidedly smaller than the fish taken inside, are feeding heavily, and observation of the gonads discloses the fact that these organs are relatively undeveloped in many of the individuals. The taking of fish one or more years before they will become mature reduces the population that will form the basis of the fishery one or more years later, at which time fishing operations of dangerous intensity will be brought to bear upon the reduced numbers. Such an increase in the intensity of fishing that will affect the abundance of salmon previous to maturity, when they are comparatively small and of poor quality, and acting on a resource already showing evidence of depletion, is unquestionably a dangerous development.

In a preliminary report dealing with the subject of this paper (Rich, 1921a) the writer made the following statement:

> The determination of the age by means of scale studies will not alone give a sufficient index to the degree of immaturity since there is such a wide range in the age at which these fish reach the spawning stage—from 2 to 6 years. If the percentage of individuals of different ages among the mature fish were constant, it would be possible, from a determination of the percentage of fish of different ages taken by troll and purse seine in the ocean, to estimate the percentage of fish of different degrees of maturity. This, however, is not the case. The percentage of fish of the various age groups varies greatly at different times among the mature fish and also among those taken in the ocean. Presumably these variations, at least among the mature fish, are due quite largely to racial differences, but our present knowledge of the various races of chinook salmon is far too limited to aid in segregating the races from mixed lots. Even if our knowledge of the races were complete it might well be that they could not be identified and segregated accurately and fully enough to serve this purpose. It is apparent that some other means than the determination of the age is necessary in order to learn the percentages of mature and immature fish taken in the ocean and their relative maturity.

It has been found, as will be subsequently shown in detail, that the size of the eggs gives a fairly accurate means for determining how soon the females will mature. During a field trip to Monterey, in 1915, it was noted that there was considerable variation in the size of the ova, and a series of egg samples was collected. It was thought that from a study of the eggs something might be learned of the percentage of mature and immature fish taken by troll in Monterey Bay. These eggs were collected from the cleaning tables and no attempt was made to collect data and scales from the fish from which the eggs were taken. Nothing was done with this collection until the summer of 1918, when the matter was again brought up for consideration. On examining the samples, the fact became apparent that several reasonably distinct sizes of eggs were to be found, which presumably represented different degrees of maturity. (See Table 23, p. 86.) In order to secure more complete data, another collection was made at Monterey in the summer of 1918, and in this case measurements and scales were secured along with the egg samples. The study of this collection confirmed the earlier observations as to the presence of fairly distinct size groups of eggs, and the examination of the scales showed a high degree of correlation between age and the size of the eggs. (Table 25, p. 87.) Extensive collections have since been made from the fish taken by troll off the mouth of the Columbia River, and it has been found that, while the determination of maturity is not as simple a matter as it had first appeared, the general features will hold good.

It is obvious that this method is applicable only to the females and no method has yet been devised for accurately determining the relative maturity of the males. It was thought at first that the percentage of males of various degrees of maturity could be calculated with reasonable accuracy from the percentages of males and females found among the mature fish in the stream if once the percentage of mature and immature females taken outside was known. If it were not for disturbing factors this could easily be determined, *for each separate age group*, by means of the following proportion: Percentage of males taken inside : percentage of females taken inside :: percentage of males taken outside which are mature : percentage of females taken outside which are mature. It has been found, however, that the proportions of males and females found among the mature fish taken inside the river at different times during the season is so variable as to make a calculation of this nature very unsatisfactory on the basis of the data at present available. No attempt has been made, therefore, to do this. The males undoubtedly show a decided tendency to mature younger than the females, and for this reason the total percentage of immature fish taken outside is somewhat less than the percentage of immature females. Just how much allowance should be made for this factor it is impossible to say, but in any event it would not alter materially the general conclusions arrived at from a study of the females alone. It may be mentioned that, from the standpoint of conservation, a knowledge of the effect of a fishery upon the supply of females is of much more importance than a similar knowledge of the effect upon the supply of males.

In the preliminary report mentioned above an outline of the method used in determining the relative maturity was given, together with a brief summary of the more important results that had been obtained at that time. The following report embodies the results of more recent studies and gives in detail the data on which the conclusions are based.

The writer wishes to acknowledge his indebtedness to Dr. C. H. Gilbert, of Stanford University, whose advice has been constantly available throughout the preparation of this report. Many helpful suggestions have been obtained from Dr. F. W. Weymouth, of the physiology department at Stanford University. Some of the earlier work was done at the Hopkins Marine Station at Pacific Grove, Calif., but most of it was done in the laboratories of the zoology department of Stanford University.

METHODS

DETERMINATION OF AGE

Although a detailed study of the life history and scale growth of the chinook salmon still remains to be made, the main features are sufficiently known to permit of a reasonably accurate determination of age by the usual examination of the scales.

The determination of the age of fish by means of a microscopic examination of their scales has been used so extensively during the past two decades that a detailed description of the method seems unnecessary. It depends upon the fact that the rate of growth of the fish varies materially at different times of the year. During the spring and summer, in general, growth is more rapid, and during the fall and winter it is slower. The scales of many fish, including the salmon and trout, bear series of concentrically arranged ridges on their outer surface. On account of their concentric arrangement these are known as rings or circuli. The scales increase in size with the growth of the fish, and circuli are added at the margins. The scales are never normally shed, but increase in diameter by these accretions to their margins, and in thickness by additions to the inner surfaces. The markings formed by the circuli are therefore persistent throughout the life of the fish. The arrangement of these circuli is characteristically modified by variations in the rate of growth of the fish. During the more rapid growth of the spring and summer the rings are spaced relatively widely, but during the period of slow or of perhaps no growth, which obtains during the fall and winter, the rings are crowded together closely and are frequently more or less broken and imperfect. The complete year's growth, therefore, consists in a "summer" band of relatively wide rings followed by a "winter" band of narrow rings. By counting the number of "summer" or "winter" bands the age can readily be determined.

Weymouth (1923) has given a brief though admirable discussion of the various methods of determining age. In answering certain criticisms that have been made of the method of age determination of fishes by means of scales, he makes the following pertinent observations:

> These objections are not valid, however, in the case of a number of species of fish, where the annual nature of the marks rests on no assumption of any kind, but on direct observation. In some a study of the scales throughout the year has clearly shown that the ring is formed during the winter and only once each year. In others it has been shown that the number of rings agrees with the known age of fish kept in captivity or of marked fish recaptured after known periods. The soundness of these conclusions is not affected by the fact that in certain species the rings are less distinct and hence in these cases may be an unreliable guide to age, nor that incompetent or hasty workers may have reached incorrect conclusions in any species.

Although this method of determining the age of fishes appears to be simple and of easy application, in practice serious difficulties are frequently encountered. The relative approximation of the rings is merely a reflection of the rate of growth prevailing at the time the rings were formed. Not infrequently factors cause variations in the rate of growth which are unassociated with the seasonal variations responsible for the formation of "summer" and "winter" bands. As a rule, the cause of these incidental variations is unknown, although the present writer has suggested causes for some of the minor variations observed in the scale growth of chinook salmon previous to or during their seaward migration (Rich, 1920). Snyder (1922 and 1923) has also discussed the causes responsible for unusual checks on the scales of chinook salmon in the Klamath River. In the case of the chinook salmon the determination of age is further complicated by the fact that the young fish, at least in the Columbia River, may migrate seaward at any time after they emerge from the gravel of the spawning beds up to an age of 18 months or more. There are, therefore, many difficult and puzzling characters in the scale growth which must be worked out before a completely satisfactory analysis can be made, but a full consideration of the problems connected with age determination in the chinook salmon lies outside the scope of the present paper. The age determinations will, therefore, be presented without further discussion of the details. It may be remarked that the author, in the course of an intensive study of the scales of several thousands of chinook salmon from the Columbia River, has found nothing that conflicts with the main conclusions reached by Gilbert in his initial paper dealing with scale studies (Gilbert, 1913). In all cases where the interpretation of the scales was in doubt the individuals have been omitted from the tables. This procedure may have eliminated some few small categories, but these would not materially affect the main conclusions that have been reached.

The lack of data bearing on the types of scale growth presented by the fish of the various coastal streams and of the various tributaries of the Columbia has made the study of the scales of the fish taken in the ocean an extremely difficult matter. Numerous more or less distinct types of scale growth could be described, but the description alone would have little bearing on the subject matter of this report, in view of the fact that it is at present impossible to assign the various types to particular streams or tributaries. It has been necessary, therefore, to omit a detailed segregation of individuals on the basis of racial differences and to segregate only into the main age groups. With the exception of age, the only other feature of the life history which has been used as a basis of segregation has been the general type of the early growth. Gilbert has shown in the report above cited (1913) that the chinooks of the Columbia River exhibit two distinct types of "nuclear growth" (the growth of the first year), forming what he terms the "ocean type" and the "stream type" of nuclei. The ocean type of nucleus is large, with rings that are relatively widely separated (figs. 27 to 33), and indicates that the fish migrated to the ocean early in its first year. The stream type of nucleus, on the other hand, is small, of closely crowded and more delicate rings (figs. 34 to 40), and characterizes the scales of those fish that have spent the entire first year in fresh water. An age group, in the sense in which the term is employed in this paper, comprises all of the individuals in a collection that are of the same age and that have the same general type of nuclear growth. Thus there are fish with ocean nuclei from 2 to 6 years old, and also fish with stream nuclei from 2 to 6 years old—a total of 10 age groups in all. Illustrations of typical scales of each group will be found in Figures 27 to 42.

DETERMINATION OF RELATIVE MATURITY

Mention has already been made of the fact that the determination of the relative maturity has been based upon variation in the size of the eggs.

The egg samples, as collected in the field, consisted in a small portion of the ovary. When the eggs were relatively small and the ovary but half an inch or so in diameter, a section of the ovary about 1 inch long was taken for a sample. When the eggs were larger, as in the nearly mature fish, a section of the ovary approximating 1 cubic inch in volume was taken. These egg samples were tagged with serially numbered tin tags and the number of the egg sample added to the other data recorded in the book in which the scales were preserved. The samples were preserved in 10 per cent formalin.

The size of the eggs has been determined by measuring 10 of each sample and taking the average. The larger eggs—those over 1 mm. in diameter—were measured in a simple device, which consists essentially of a small trough, V-shaped in cross section and with closed ends, which is graduated in millimeters. In use this is partially filled with water, the eggs are placed in a row in the bottom of the trough, and then are carefully pushed up to the zero end of the scale by means of a small piece that fits the bottom of the trough and on which is graduated a vernier, enabling one to read accurately to tenths of a millimeter. The reading is made when the first egg is in contact with the zero end of the trough and the eggs are all just in contact with one another. If too great pressure is applied, one or more of the eggs will be pushed above the others, so that the error in procedure is readily detected. When this happens it is necessary to push back the vernier, readjust the eggs, and repeat the operation. The measurement of 10 eggs by this scale gives, by simply moving the decimal point one place to the left, the average size of the eggs to hundredths of a millimeter, a degree of accuracy which is unnecessary in the great majority of cases. In preparing eggs for this measurement it is necessary to free them very carefully from the ovarian membranes, so as not to break the delicate egg membrane and yet to clear them of all shreds of tissue which might tend to affect the measurement. The smaller eggs—those less than 1 mm. in diameter—were measured by means of a microscope fitted with an eyepiece micrometer, carefully calibrated against a stage micrometer. In using this method it was necessary, of course, to measure the 10 eggs separately, and then the average of these measurements was found.

If one examines the eggs of chinook salmon taken in fresh water during their spawning migration, it is found that the eggs of different individuals vary only slightly in size. A similar examination of the eggs of females taken in the ocean discloses that there are wide variations in size. A group with eggs approximately the same size as those of the fish taken at the same time of year in the river can readily be selected. In addition to this group, however, many of the females have eggs distinctly smaller than any found among the spawning run in the river, and it is possible many times to separate these smaller eggs into two or more groups, even without careful measurement. When this observation was first made it seemed probable that each size group of eggs indicated a different degree of maturity, so that an analysis of the relative maturity of the fish in a given catch could be accomplished merely from an examination of a series of the ovaries. The assumption was that the fish with the largest eggs would mature and spawn during the year in which they were captured, that those with eggs falling within the next smaller group would mature during the next year, and so on. It has been found, on closer analysis, that while the size of the eggs alone forms a very satisfactory diagnostic character for distinguishing between fish that will mature during the year in which they are captured and those that will not mature for at least one more year, it can not be depended upon to distinguish between those that will mature in one year from those that will mature in two or more years. It has been found that the eggs grow in proportion to the rest of the fish until, approximately, the beginning of the growing season, which is destined to end in the maturing and spawning of the individual. With the onset of this last growing period, however, the rate of growth of the eggs is relatively accelerated and a differential growth sets in, so that the eggs gradually increase in size relative to the size of the fish. As a result, the eggs of the maturing fish are relatively larger than those of the immature specimens. This fact makes it possible to distinguish between those individuals that are maturing and those that will not mature for at least one year.

The observed differences in the size of the eggs of the immature fish taken in the ocean are due only to corresponding differences in the size of the fish. As will be shown later, there is a high degree of correlation between the size of the eggs and the size of the fish. The observation that the eggs may be grouped on the basis of size is dependent upon the fact that the differences in size between the younger age groups of chinook salmon, as in many other animals, is often so marked that the fish themselves fall into fairly distinct size groups corresponding to different ages, and the size groups of eggs is merely a reflection of this condition.

The acceleration of the growth of the eggs during the last growing season is shown clearly in Figure 1. This graph shows the proportional changes in the size of the eggs of fish with ocean nuclei during their third year—first, for those mature fish taken inside the river; second, for the mature fish taken outside; and third, for the immature fish taken outside. The points on this graph indicate the position of the weighted arithmetic means of the logarithms of the egg sizes.[1]

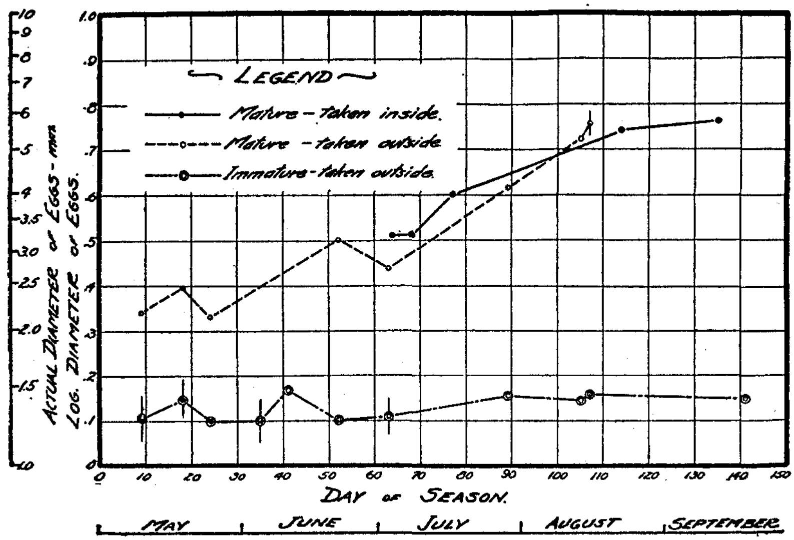


FIG. 1.—Changes in the sizes of the eggs of females in their third year, ocean nuclei, during the course of the fishing season. Columbia River and the ocean off the mouth of the Columbia

In addition to the fact that the eggs of the immature fish are distinctly smaller, it is apparent from Figure 1 that the slope of the curve for the mature fish is much steeper than that for the immature fish, indicating unmistakably that the eggs of the maturing fish are increasing in size, not only actually, but relatively, at the more rapid rate. If the two curves were projected back into the months preceding the opening of the fishing season, they would evidently meet some time in March or early in April, which would indicate that the differential growth probably begins at about that time.

This differential growth of the eggs of the maturing fish is shown in another way in the following table, which gives the proportional size of the eggs in relation to the length of the fish in a few selected groups chosen largely because they were better represented than the others.

[1] See pages 24 and 25 for an explanation of the use of logarithms in this connection.

TABLE 1.—*Relation between diameter of eggs and size of fish (Columbia River chinook salmon)*

Age group	Date taken	Number of specimens	Average length in centimeters (L)	Average logarithm of egg diameter	Geometric mean of diameters of eggs (D) in millimeters [1]	$\frac{D\times100}{L}$
In third year, stream nuclei, immature	May 8 to 10	18	48.11	$\bar{1}$.9588	0.909	1.890
	June 4	11	50.40	$\bar{1}$.9480	.889	1.763
	July 2	7	55.00	.0214	1.050	1.909
	July 28	7	59.00	.0756	1.190	2.017
	August and September	4	66.00	.1150	1.303	1.975
In third year, ocean nuclei, immature	May 8 to 10	100	61.00	.1043	1.272	2.085
	June 4	32	61.61	.0981	1.254	2.035
	July 2	26	66.50	.1085	1.284	1.930
	Aug. 13	6	70.33	.1430	1.390	1.977
	Sept. 18 to 19	7	70.72	.1500	1.412	1.998
In fourth year, ocean nuclei, mature	May 10	18	79.56	.3174	2.075	2.610
	June 21	10	86.40	.5100	3.230	3.740
	July 2	22	84.19	.5336	3.415	4.055
	July 28	49	89.33	.6406	4.370	4.890
	Aug. 13	63	93.50	.7243	5.300	5.670
In fifth year, ocean nuclei, mature	May 18	13	96.15	.4054	2.542	2.645
	July 2	11	95.40	.5792	3.796	3.978
	July 28	18	96.22	.6733	4.712	4.900
	Aug. 13 to 17	19	100.16	.7553	5.695	5.680

[1] The geometric mean of a series of measures is the number corresponding to the arithmetic mean of the logarithms of the original measures. Since the data on egg sizes has been handled in the logarithmic form (see pp. 24 and 25), it is convenient to use here the geometric rather than the arithmetic mean.

The ratio, $\frac{D\times100}{L}$, given in the last column of this table, is 10 times the percentage of the length of the fish represented by the diameter of the eggs. The actual percentages are so small that it is more convenient to handle the values in this way.

The table shows that among the immature fish there is little variation in the relative size of the eggs as compared with the size of the fish. The ratio is practically the same in immature fish of the different age groups, and within a single age group there are no significant changes in the ratio during the season. This signifies that the size of the eggs and their growth is closely proportional to the size and growth of the fish. In the case of the mature groups, however, a constant and marked increase in the ratio $\frac{D\times100}{L}$ is clearly shown as the season advances—an increase which is indicative of a distinct differential growth, resulting in the rapid increase in the relative size of the eggs as maturity approaches.

In May there is comparatively little difference in the relative size of the eggs of the mature fish and those of the immature fish. The value of the ratio for immature fish is very close to 2.0, and in May the ratio for mature fish is only about 2.6. During the season, however, the value of the ratio in the case of the maturing fish steadily increases until it is nearly three times as large as that for the immature fish. Evidently the differential growth of the eggs, which takes place during the last year, has not progressed far by May. Scale examinations show that the new growth of the year, if apparent at all, is at this time just beginning to show as a distinct band of wider rings at the margins of the scales. (See figs. 38, 39, and 40.) It seems altogether probable that the differential growth of the eggs is begun simultaneously with the onset of the growth period of the last year.

Another disturbing factor, which undoubtedly makes the accurate determination of the relative maturity from the size of the eggs more difficult, is the fact that the various collections contain a mixture of races, which, as has already been mentioned, have not been segregated, and it is known that there is considerable variation among different races in the size of the fully mature eggs.

In determining the relative maturity it has been found necessary to compare the size of the eggs of the fish taken in the ocean with the size of the eggs of the undoubtedly mature fish taken in the river at about the same time. Moreover, it has been found necessary to consider the entire distribution of egg sizes as exhibited in each collection in determining whether any particular group of fish was mature or immature. The tables have been carefully scrutinized and the size of the eggs in the particular group under consideration compared with the size of the eggs of the other fish taken in the same collection. If necessary, comparison has also been made with the size of the eggs of the undoubtedly mature fish taken in the river. In making these comparisons, not only the mean, but the range of the distribution as well, has been kept in mind. If a frequency distribution of egg sizes was found to be unimodal, the position of the mode and the extent of the dispersion were considered in relation to the position of the mode and the dispersion of other groups—especially those known to be mature. If the given distribution were bimodal or multimodal, the position of each of the modes and the distribution of individuals about these modes has been considered separately and compared with the mode and dispersion of other groups. It has proved impracticable to publish all of the detailed tables, but representative examples will be found on pages 81 to 88. The interpretations of the degrees of maturity have all been made through a study of such detailed tables.

In this study the logarithms of the observed egg diameters instead of the actual measurements have been tabulated and plotted. This has been done as a simple mechanical means of reducing all measurements to a strictly proportional basis. As has already been stated, it was thought during the early stages of the investigation that the egg size would indicate whether the immature fish were destined to mature during the year following their capture or not for two or more years. With this in mind it seemed essential to emphasize not the actual but the proportional variations, since a difference that would be relatively insignificant in the case of the larger eggs might be decidedly significant in the case of smaller eggs. For example, a difference of 0.5 mm. in eggs averaging 7 mm. in diameter would be of no great significance, while with eggs averaging only 0.7 mm. the same difference might be of decided importance. Therefore the logarithms of all measurements were found and the tables prepared from them. Although the final results of the study do not entirely justify the use of this method, the labor involved in retabulating the data, recalculating the constants, and redrawing the graphs is so great that it has not been attempted, particularly in view of the fact that such modification would in no way affect the conclusions that have been drawn. If it be remembered that this use of logarithms is only a means for showing *percentage* variation rather than *actual* variation in the size of the eggs, any confusion will be avoided.[2]

The tables and text figures have been arranged with class intervals of 0.02 in the logarithm of the diameter of the eggs. This is the same as saying that the mid-value of each class has been made 4.713 per cent greater than the mid-value of the next preceding class.

If the variations in the sizes of the eggs are such that the relative maturity of the fish can be determined from their study, several consequences will naturally follow, which may be used as criteria in determining the validity of the method. First, it must be possible to separate the fish taken in the ocean into at least two

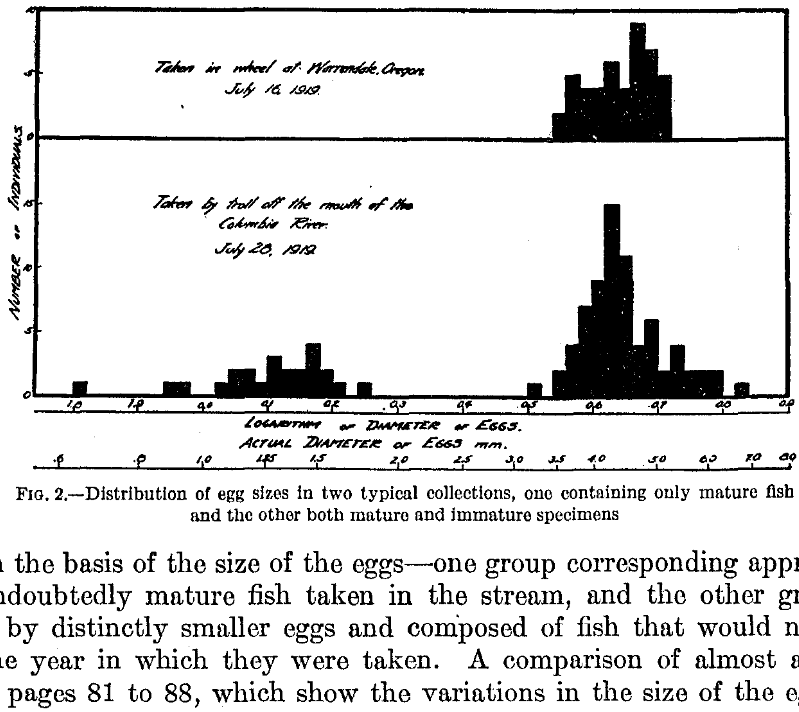


FIG. 2.—Distribution of egg sizes in two typical collections, one containing only mature fish and the other both mature and immature specimens

groups on the basis of the size of the eggs—one group corresponding approximately to the undoubtedly mature fish taken in the stream, and the other group characterized by distinctly smaller eggs and composed of fish that would not mature during the year in which they were taken. A comparison of almost any of the tables on pages 81 to 88, which show the variations in the size of the eggs of fish taken in the ocean, with a similar table of fish taken within the river at about the same time, will show that this is the case. One such example is shown in Figure 2, which shows the distribution of egg sizes in a collection made just outside the Columbia River, July 28, 1919, and also the similar distribution in a collection made inside, at Warrendale, Oreg., on July 16, 1919.

Figure 2 shows clearly that the fish taken outside the mouth of the river are sharply separated into two main groups—one with larger eggs, which closely agree

[2]For the benefit of those unfamiliar with the use of logarithms it may be stated that the logarithm of 1 is 0, that the logarithms of all values lying between 1 and 10 are less than 1 and greater than 0, and that the logarithms of all values lying between 1 and 0.1 lie between 0 and −1. The logarithms of values intermediate between 1 and 10 appear, therefore, as simple decimal fractions. Those of values intermediate between 0.1 and 1 are customarily shown as a decimal fraction preceded by the figure 1 over which is placed the minus sign, thus: $\bar{1}$. The logarithm of 0.9 is therefore written $\bar{1}.9542$ and the logarithm of 1.1 is written 0.0414. It is also customary to abbreviate the phrase "logarithm of" to "log"; thus, in this paper "log D" has frequently been used to indicate "the logarithm of the diameter."

in size with the fish taken inside the river at Warrendale and which are undoubtedly mature. There can be no question that the fish with the smaller eggs would not have matured during the year in which they were caught. The details of the distribution of egg sizes among the various age groups in these two collections can be seen by referring to Tables 17 and 18, on page 81.

Secondly, if it be true that the variations in egg size form a valid criterion of the degree of maturity, it should be found that among the fish taken in the ocean some of the age groups will contain both individuals with large eggs and others with small eggs. Those with large eggs are destined to mature during the year in which they were caught and those with small eggs would not have matured for at least one more year. This condition will inevitably result from the fact that the fish do not all mature at the same age. Considering the fish of a single age group,

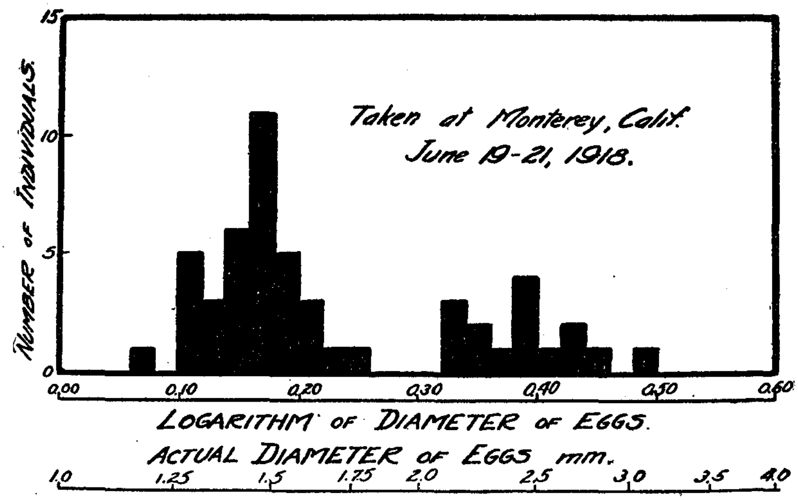


FIG. 3.—Distribution of egg sizes among females in their third year, ocean nuclei, taken at Monterey, June 19 to 21, 1918

say three years with ocean nuclei, which may be found together in the ocean, some of them will mature during the year as 3-year fish while others will not mature for another year, as 4-year fish. If the size of the eggs forms such a criterion as is claimed, it should be possible to segregate these two categories on the basis of egg sizes. It has been found possible to do this more or less clearly in a number of the collections that have been studied. For example, in Table 18 (p. 81) it may be seen that individuals with large eggs (maturing) and those with smaller eggs (immature) are to be found among the fish in their third year with scales having nuclei of the ocean type. The same thing is true of the fish in their fourth year with scales having nuclei of the stream type, given in the same table. Similarly, in the collection at Monterey (June 19 to 21, 1918) the 3-year fish with ocean nuclei are well separated into two groups on the basis of egg size (Table 25, p. 87). The frequency distribution in this last-mentioned collection is shown in Figure 3.

CORRELATION BETWEEN SIZE OF EGGS AND SIZE OF FISH

A careful examination of the data has been made in order to determine to what extent the size of the eggs is correlated with the size of the fish, and, further, the extent to which this factor may tend to produce the observed differences in egg sizes.

A very definite positive correlation is found to exist between the size of the eggs and the size of the fish when fish of the same age group and the same degree of maturity are considered. The coefficient of correlation (r) has been computed for two typical distributions—one of mature and the other of immature fish. Table 2 shows the correlation between the size of fish and the size of eggs in 66 females in their fourth year, ocean nuclei, which were taken by troll off the mouth of the Columbia River, August 13, 1919. There are obviously two distinct groups represented in this tabulation, which are readily distinguishable on the basis of egg size. One group of 63 individuals, in which the logarithm of the diameter of the eggs is greater than 0.55, and another containing only three individuals, in which the logarithm is less then 0.35. The group with the larger eggs is mature and the coefficient of correlation between size of eggs and length of fish was found to be 0.6210 ± 0.0531, a high positive correlation.

TABLE 2.—*Chinook salmon taken by troll off the mouth of the Columbia River, August 13, 1919*

Females in their fourth year and which migrated as fry (scales with ocean nuclei) tabulated to show correlation between length and size of eggs

Logarithms of diameter of eggs (mid-value of class)	Centimeter length (mid-value of class)																Total
	77	79	81	83	85	87	89	91	93	95	97	99	101	103	105	107	
0.29			1	1													2
.33*								1									1
.57**		1				1											2
.59	1								1								2
.61	1																1
.63					1			1	1								3
.65	1							2	2	1	1						7
.67		1	1	1		1					2						6
.69							1	1									2
.71										1	1						2
.73							1	4			1	1			1		8
.75		1		1						1						1	4
.77							1			2	2	2					7
.79									2		3	1	2	1	1	1	11
.81									2		1	1	1	1			6
.83											1		1				2
Total	3	3	2	3	1	2	3	9	8	5	12	5	4	2	2	2	66

NOTE.—In this and all other tables of this report an asterisk (*) has been used to mark a break in the continuity of the table. It indicates that one or more classes have been omitted from the natural sequence just preceding the class marked. A double asterisk (**) is used to mark such breaks as are of particular significance.

The coefficient of correlation between size of eggs and size of fish has likewise been determined for a group of 36 immature females in their third year, ocean nuclei, taken in Monterey Bay, June 19 to 21, 1918. The data showing the distribution according to size of eggs and length of fish of all the females of this age group contained in the collections are given in Table 3. Two distinct groups, which are well separated on the basis of egg size but overlap almost completely in length, are also shown in this tabulation. The coefficient of correlation for the immature group is 0.7680 ± 0.0461.

TABLE 3.—*Chinook salmon taken by troll in Monterey Bay, Calif., June 19 to 21, 1918*

Females in third year, and which migrated as fry (scales with ocean nuclei), tabulated to show correlation between size of fish and size of eggs

Logarithm of diameter of eggs (mid-value of class)	Centimeter length (mid-value of class)																	Total	
	57	59	61	63	65	67	69	71	73	75	77	79	81	83	85	87	89		
0.07	1																	1	
.11*		1			1	1	2											5	
.13				1		2												3	
.15				1		3		1		1								6	
.17					1	3	1	2	1	2	1							11	Group 1 (36 individuals).
.19							1	1		2	1							5	
.21										1	2							3	
.23													1					1	
.25												1						1	
.33**											1	1	1					3	
.35										1			1					2	
.37									1									1	
.39								1		1	1		1					4	Group 2 (15 individuals).
.41														1				1	
.43												1		1				2	
.45													1					1	
.49*														1				1	
Total	1	1		2	2	9	4	5	2	8	6	3	5	3				51	
Group 1	1	1		2	2	9	4	4	1	6	4	1	1					36	
Group 2								1	1	2	2	2	4	3				15	

These examples indicate clearly that within a single category (that is, among females of a similar degree of maturity and of the same age group) the size of the eggs is dependent to a considerable extent upon the size of the fish. The regression coefficients have been calculated for the two groups for which the coefficients of correlation were determined. From these it was found that in the first group (mature fish taken off the Columbia River in August) the logarithm of the diameter of the eggs was, on the average, increased by 0.005850 for each increase of 1 cm. in the length of the fish. In the second group (immature fish taken at Monterey in June) an increase of 1 cm. in the length of the fish was accompanied, on the average, by an increase of 0.005535 in the logarithm of the diameter of the eggs.

It may readily be seen, however, from an examination of Tables 2 and 3, that the groups distinguished as mature and immature are sharply and widely separated on the basis of egg sizes but overlap almost completely in so far as length is concerned. Within each group there is the distinct tendency for the larger fish to have larger eggs, but this is quite inadequate to account for the greater difference observed between the mature and immature groups. These can only be explained as the result of the differential growth of the eggs during the last year.

FISH TAKEN IN THE COLUMBIA RIVER AND IN THE OCEAN OFF THE MOUTH OF THE RIVER

In discussing the various features of the life history, which will be treated in this paper, the data on the fish from the Columbia River, from near Fort Bragg and Point Reyes on the northern coast of California, and from Monterey Bay will be handled separately. Each age group will also be given separate consideration. The oldest fish will be treated first, since the results of their study will aid in interpreting the data from the younger age groups.

RELATIVE MATURITY OF CHINOOK SALMON TAKEN IN THE OCEAN

It has been shown above that the determination of the degree of maturity is accomplished primarily by comparing the distribution of the egg sizes of a group of fish with the similar distribution of fish known to be mature. It has been pointed out that the size of the eggs changes during the season; that there are differences in the size of eggs of fish of different ages, due to the difference in the size of the fish; and also there are racial differences in the size of the eggs. It is obvious that these factors will make it impossible to draw a sharp line of distinction, which will hold good throughout the season, between the size of the eggs of mature and immature fish, and that the determination of the relative maturity of the fish taken in the ocean must depend upon a comparison of the distribution of egg sizes in the various age groups with the distribution of egg sizes of unquestionably mature fish taken in the river at about the same time of the year. This has been done in the determination of relative maturity given below.

FISH IN THEIR SIXTH YEAR, OCEAN NUCLEI

Only two females of this age group were taken in the collection studied. One was taken on July 28, 1919, and the other September 18 or 19, 1919. Both were undoubtedly mature. The logarithm of the diameter of the eggs (log D) was 0.69 in the first specimen and 0.77 in the second. No fish of this age group appear in the collections taken inside the river near these dates, but four specimens are found in a collection made June 24 and 25, 1919, and three in one made July 3. The average log D in these collections was, respectively, 0.55 and 0.657. The maximum age attained by the chinooks of the Columbia River is 6 years, and comparatively few fish of this age are found. It is, therefore, quite to be expected that any fish of this age group which might be taken in the ocean would be maturing.

FISH IN THEIR FIFTH YEAR, OCEAN NUCLEI

As has just been indicated, very few fish with ocean nuclei older than 5 years are found in the Columbia River run. It was, therefore, to be expected that nearly, if not quite all, of the fish of this age group which are taken outside would be maturing, and such was found to be the case. No immature fish of this age group were found. Figure 4 shows the average log D for the collections of fish taken outside and also for those taken inside throughout the season. The figure shows clearly that there are only negligible differences in the sizes of the eggs of the fish taken in the two localities.

FISH IN THEIR FOURTH YEAR, OCEAN NUCLEI

The determination of the relative maturity of the fish of this age group has proved more difficult and the results are less satisfactory than with any other category. The number of fish belonging to this age group, which were taken in the ocean and which were with certainty immature, is small. There must, however, be a considerable proportion of the 4-year fish with ocean nuclei that do not mature during their fourth year, since there is a rather high percentage of fish in their fifth year, with ocean nuclei, found both in the ocean and within the stream. No satisfactory explanation of this can be given, although the possibility of some sort of a selective migration naturally suggests itself. Figure 5 shows the distribution of egg sizes for this age group during the season, and it may readily be seen that, with the exception of the groups marked by a double circle, the range of egg sizes shown by the fish taken outside is quite comparable with the range shown by those taken inside the river. The groups indicated by a double circle are those that

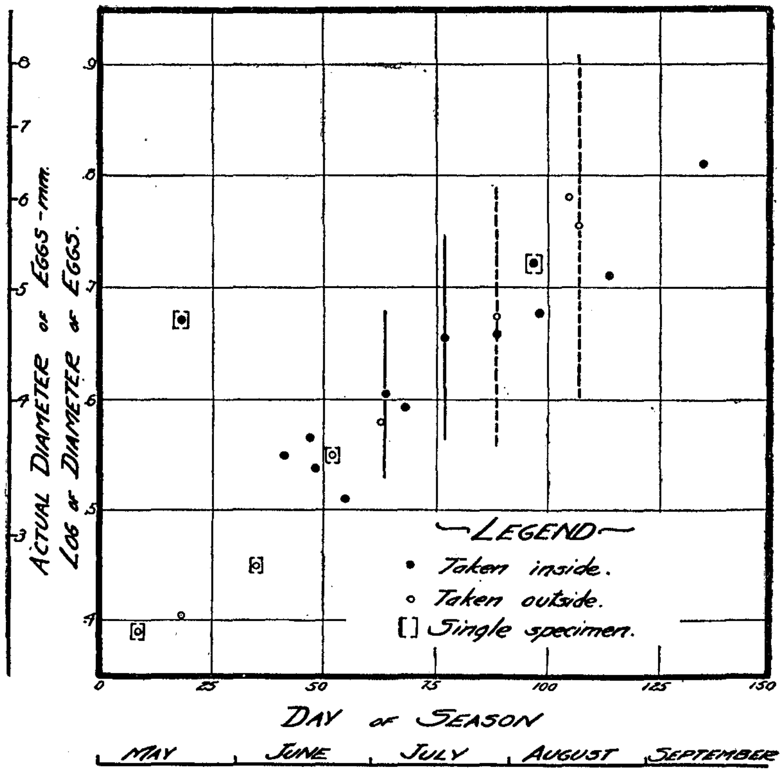


FIG. 4.—Sizes of eggs of females in their fifth year, ocean nuclei, from the Columbia River and the ocean off the mouth of the river. In this and other similar illustrations the average size of the eggs is indicated by the circles or dots; the vertical lines extending from these points show the limits of twice the standard deviation ($\pm 2\sigma$). Ninety-five per cent of the cases will fall within the upper and lower limits indicated by these lines. The standard deviation has, with a few exceptions, been calculated only for these cases in which at least 20 individuals of the particular age group in question were contained in the collection

may be considered as immature, although the interpretation, especially in the case of those collections made during May, is somewhat doubtful.

A correlation table has been prepared (Table 4), giving the sizes of the eggs found in the fish of this age group contained in a collection of troll fish taken off the mouth of the Columbia River, May 17 and 18, 1920. Reference to this table will show that the fish are quite distinctly separated into two groups on the basis of egg sizes. The log D of one group is greater than 0.30, averaging 0.4254, and of the other group is less, averaging 0.2486. The modes of the two distributions are distinct, and it seems probable that two categories are represented—one of mature and the other of immature fish. This interpretation is further indicated by the fact, apparent from Figure 5, that the size of the smaller eggs agrees with the size of eggs in other later collections, in which there is no question as to the correct interpretation. Reference to Figure 9 shows also that these small eggs are approximately the same size as those of the immature fish taken at the same time, which were in their fourth year, stream nuclei—a group fairly comparable with the one under

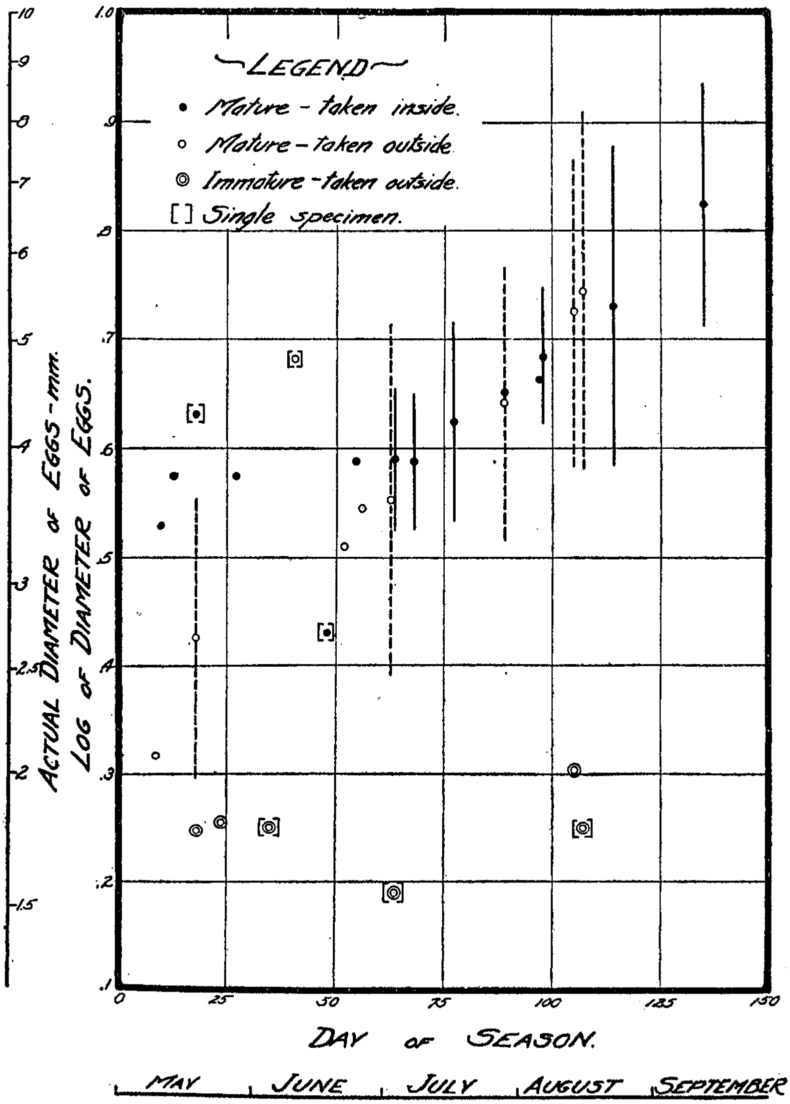


FIG. 5.—Sizes of eggs of females in their fourth year, ocean nuclei. Columbia River and the ocean off the mouth of the Columbia

discussion. The distribution of egg sizes in the case of these 4-year fish with stream nuclei is similar to that of the 4-year fish with ocean nuclei in that it does not seem sharply to separate the two groups of mature and immature fish. The factor $\frac{D \times 100}{L}$, described above and illustrated in Table 1, has been calculated for that group of 4-year fish with ocean nuclei that had the smaller eggs, and was found to be 2.24.[3] This is somewhat larger than is characteristic of immature fish (about 2.0), but it is nearer this figure than that which is characteristic of mature fish taken in May (2.6).

TABLE 4.—*Chinook salmon taken by troll off the mouth of the Columbia River, May 17 and 18, 1920*

[Females in their fourth year, ocean nuclei, tabulated to show correlation between length and size of eggs]

Logarithms of diameter of eggs (mid-value of class)	Centimeter length (mid-value of class)														Total
	73	75	77	79	81	83	85	87	89	91	93	95	97	99	
0.21		1													1
.23		1	1		1	1									4
.25	1				3	1									5
.27			2			1									3
.29					1										1
.33**								1							1
.35					1		1								2
.37			1		1		1		2						5
.39					2										2
.41			1												1
.43								1	1						2
.45						1	1					1			3
.47								2							2
.49							1								1
.55*			1									1	1		3
Total	1	2	6		9	4	4	4	3			2	1		36

The relatively slight differences noted between the size of the eggs of the mature and those of the immature fish in this collection are probably associated with the fact that the collection was made in 1920, while most of the collections that have been made the basis for this study were made in 1919. It is not improbable that the differential growth of the eggs, which takes place during the last year (and which has been shown to be mainly responsible for the observed difference in the sizes of the eggs of mature and immature fish), may begin at different times in different years. It should also be noted that the fish taken in the ocean during 1920, which were available for study, were selected, very few being under 8 pounds in weight. Laws passed by the Washington and Oregon Legislatures prevented the sale of immature salmon under this weight, so that few of the smaller fish found their way to the canneries. This factor alone, by tending toward a selection of gear that would take the larger fish, might well be responsible for the difficulty encountered in determining the relative maturity of the fish found in this collection.

In most of the other collections no particular difficulty has been encountered in determining the relative maturity, but the percentage of immature fish is, as has already been mentioned, much lower than would naturally be expected. Figure 30 shows a scale from one of the immature fish of this age group taken on August 13, 1919, and Figure 31 a scale from one of the mature fish taken at the same time.

FISH IN THEIR THIRD YEAR, OCEAN NUCLEI

The distribution of egg sizes during the season for the fish that are in their third year, with ocean nuclei, is shown in Figure 6. The difficulties encountered in

[3] Average log D=0.2485. Geometrical mean of the diameters=1.772 mm. Average length=79 cm. $\frac{177.2}{79}$=2.24.

the interpretation of the data in the case of the 4-year fish with ocean nuclei are entirely lacking here. Two distinct distributions are clearly shown. In one the eggs are small, the average log D being in every case less than 0.20, and the increase in size observed as the season advances is very slight. It has already been shown

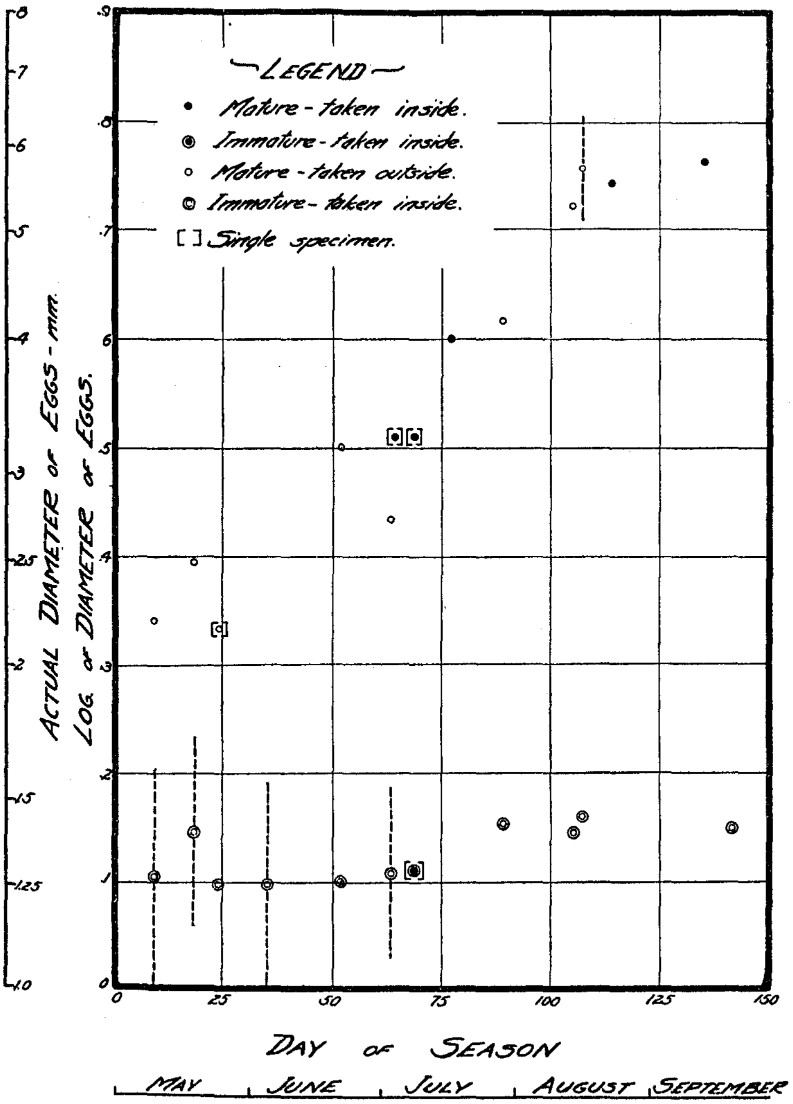


FIG. 6.—Sizes of eggs of females in their third year, ocean nuclei. Columbia River and the ocean off the mouth of the Columbia

in Table 1 that the factor $\frac{D \times 100}{L}$, for fish of this age group contained in several of the larger and typical collections, is close to 2, which is characteristic of other groups of undoubtedly immature fish.

In the other distribution the eggs are distinctly larger, the log D ranging from about 0.34 at the beginning of the season to about 0.80 by the end of the season. This increase in size during the season is conspicuous and is in marked contrast to the condition observed in the group of immature fish. So far as the available data show, the segregation of the fish of this age group into mature and immature groups may be accomplished with very satisfactory accuracy by means of a study of the egg sizes. The percentage of mature and immature fish taken at different times during the season is treated on page 40 ff. Figure 28 shows a scale from one of the immature fish of this age group, which was taken on July 2, and Figure 29 one of the mature fish taken on the same date.

It will be noticed in the collection made inside the river on July 7, 1919, that one immature fish of this age group was taken. It will presently be shown that there were other immature fish taken at the same time which belonged to other age groups—2-year fish with ocean nuclei and 3-year fish with stream nuclei. The explanation of this occurrence and other associated facts is interesting in its possible bearing on the habits of the chinook salmon.

These immature fish observed inside the river were taken by seine on Sand Island, a low, level, sandy island several miles in length and about 1 mile in width, which is situated in the estuary of the Columbia River, only a mile or so inside the mouth of the river. The seining grounds are toward the upper end of the island, approximately 5 miles from the river's mouth. On the Washington side of Sand Island is Baker Bay, a broad, shallow stretch of water in which are situated most of the salmon traps in use on the Columbia River—about 200 in number. Under ordinary circumstances the water of this lower part of the Columbia estuary is fresh or only slightly brackish, depending upon the tides and the flow of the river. At the time of the "spring" tides, however, especially when the river is at a low stage, the lower part of the estuary, up for a distance of several miles, becomes very brackish, approximating the salinity of pure sea water. On such occasions it frequently happens that small, immature fish are taken, both in the seines operating on Sand Island and in the traps in Baker Bay. It is generally believed among the fishermen of the lower Columbia River, and some statistical evidence is available which would indicate that the belief is well founded, that the salmon enter the river in greater numbers on the spring than on the neap tides. Apparently the immature fish to some extent join those that are maturing in a general movement into the river on these high tides, but do not pass beyond the upper limit of the approximately pure sea water. It is at these times that immature fish are taken on Sand Island and in Baker Bay. Presumably the immature fish return to the ocean again as the water freshens with the receding of the tide, while the mature individuals remain, in large measure, to continue their spawning migration.

In this connection it is interesting to note that the stomachs of the immature fish thus taken inside the river are frequently filled with food, usually in an advanced stage of digestion. This is in contrast to the condition in the mature fish, the stomachs of which have never been observed to contain any food.[4]

[4] The writer has described (Rich, 1921) an instance, apparently unique, in which the stomachs of mature salmon taken in fresh water contained food. In the case described chinook salmon were found feeding on eulachon (*Thaleichthys pacificus*) in the Cowlitz River, a tributary of the Columbia, some 70 miles above the ocean.

FISH IN THEIR SECOND YEAR, OCEAN NUCLEI

All of the females of this age group taken in the ocean have been found to be immature. This was to be expected, since it is known that no mature females of this age are found among the spawning runs within the river. Figure 7 shows the distribution of egg sizes during the season. Comparison with Figure 6, which shows the size of eggs of the 3-year fish with ocean nuclei, will show that the eggs are distinctly smaller in the case of the 2-year-old fish. This would be expected from the fact, previously demonstrated, that the size of the eggs is correlated to a high degree with the size of the fish.

The question arises as to the relative maturity of these 2-year-old fish as compared to those that are 3 years old. It has been shown above that the method used for

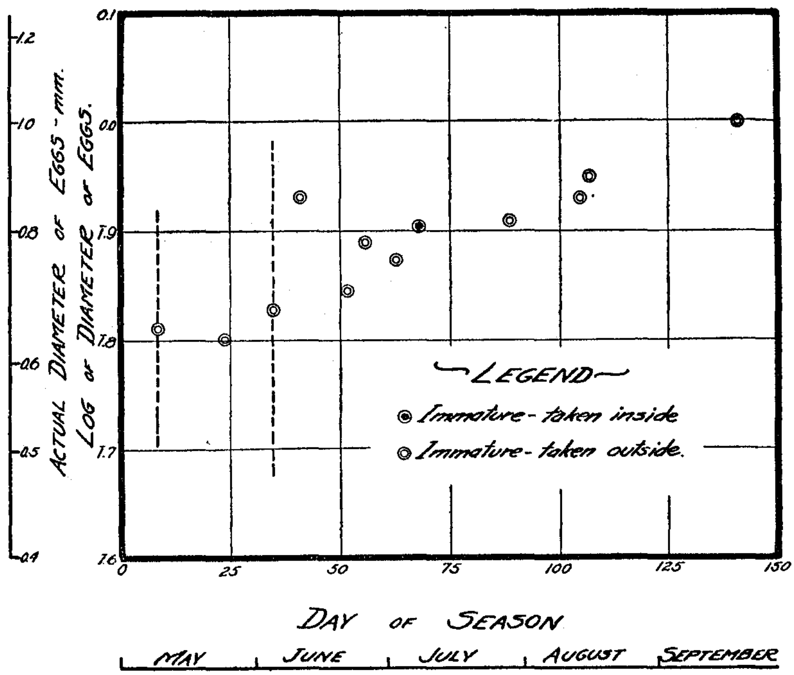


FIG. 7.—Sizes of eggs of females in their second year, ocean nuclei. Columbia River and the ocean off the mouth of the Columbia

determining relative maturity is inadequate to differentiate between degrees of immaturity, although it is, in most cases, an entirely adequate and reliable means for distinguishing between fish that will mature during the year in which they are taken and those that will not mature for at least one more year. Although it is impossible to establish the fact with certainty, the probabilities are all in favor of considering the 2-year fish as, on the whole, one year further from maturity than the 3-year fish taken at the same time. Certain obvious possibilities for error are inherent in such a treatment, especially when comparatively few data are available, as in the present case, but it is felt that the picture presented by this means will be much nearer the true state of affairs than can be arrived at by any other method. This allowance will, therefore, be made in the later discussion of the percentages of mature and immature fish taken at different times of the year.

FISH IN THEIR SIXTH YEAR, STREAM NUCLEI

Only three specimens of this age group were found among the troll fish included in this study. Two of these were taken May 8 to 10, 1919, and one August 13 to 17, 1918. In the discussion of the 6-year-old fish with ocean nuclei, it was mentioned that 6 years is the maximum age of chinook salmon in the Columbia River, and it follows that fish of this age could only be mature. The size of the eggs indicated

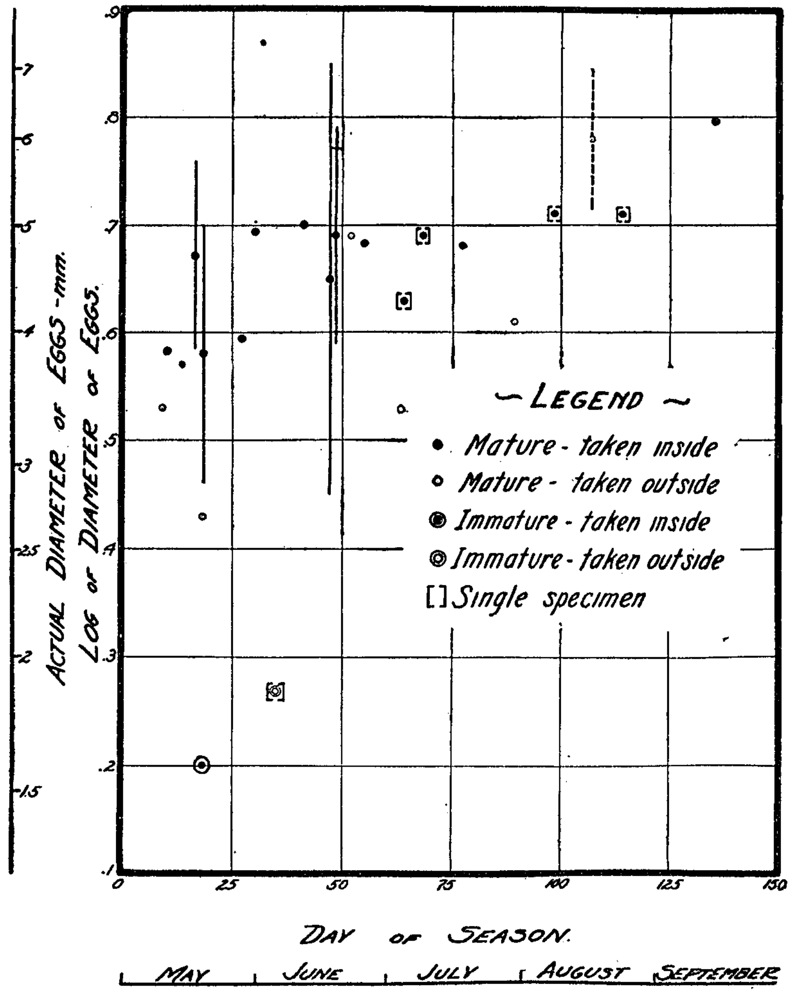


FIG. 8.—Sizes of eggs of females in their fifth year, stream nuclei. Columbia River and the ocean off the mouth of the Columbia]

beyond question that such was the case. The eggs of the two specimens taken in May had an average log D of 0.58, and the log D of the specimen taken in August was 0.75. The log D of the fish of this age group taken inside the river, of which there were 7 specimens, ranged from 0.51 to 0.75.

FISH IN THEIR FIFTH YEAR, STREAM NUCLEI

Figure 8 shows the distribution of egg sizes for fish of this age group during the season. Only three immature fish were found. Two of these were taken in the lower part of the Columbia River estuary, May 17 and 18, 1920, one in a trap in Baker Bay, and another by gill net. The other immature fish was taken by troll, June 4, 1919, The figure shows how distinctly these immature specimens are separated from the maturing fish on the basis of egg size. There can be no doubt of their immaturity. Figure 38 shows a scale of one of the immature fish taken inside the river in May, and Figure 39 one from a mature fish of the same age group taken at the same time.

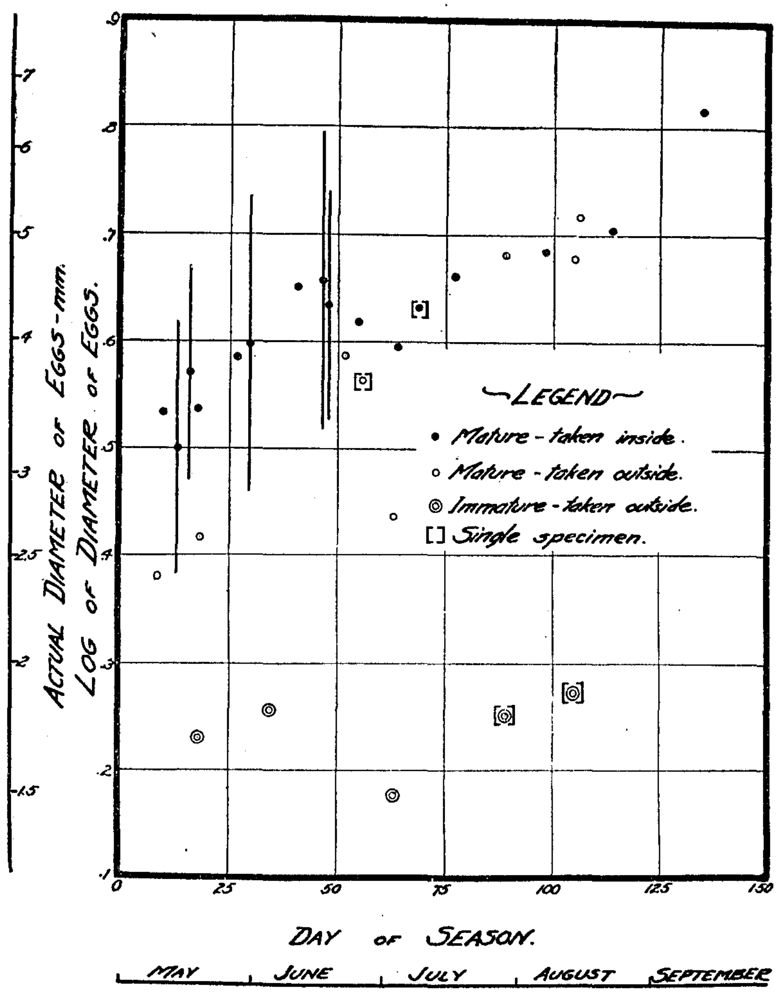


FIG. 9.—Sizes of eggs of females in their fourth year, stream nuclei. Columbia River and the ocean off the mouth of the Columbia

FISH IN THEIR FOURTH YEAR, STREAM NUCLEI

The distribution of egg sizes found among the females of this age group are shown in Figure 9. Two distinct groups are apparent, in one of which the average log D is less than 0.30. In the other group, the log D ranges from 0.40 or 0.50 in the early part of the season and to about 0.80 at the end of the season. The first group is composed of immature individuals and the second of those that are maturing. Figures 36 and 37 show scales of immature and mature fish, respectively, taken by troll on July 28, 1919.

FISH IN THEIR THIRD YEAR, STREAM NUCLEI

The fish of this age group resemble the 2-year-old fish with ocean nuclei in that mature females have never been reported. None of these fish taken outside was mature, as is apparent from Figure 10. The question of the percentages of these fish that will mature during the following year as 4-year fish, and during the second subsequent year as 5-year fish, arises here as in the case of the 2-year fish with ocean nuclei. As in the case previously considered, it seems probable that these 3-year fish with stream nuclei are, on the whole, one year further from maturity

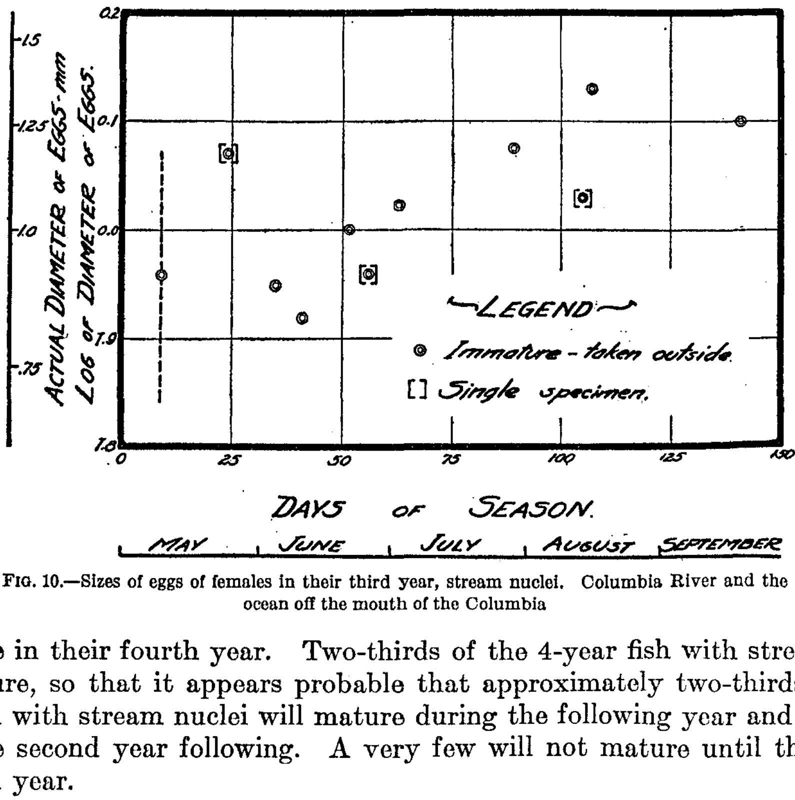


FIG. 10.—Sizes of eggs of females in their third year, stream nuclei. Columbia River and the ocean off the mouth of the Columbia

than those in their fourth year. Two-thirds of the 4-year fish with stream nuclei were mature, so that it appears probable that approximately two-thirds of these 3-year fish with stream nuclei will mature during the following year and one-third during the second year following. A very few will not mature until they are in their sixth year.

FISH IN THEIR SECOND YEAR, STREAM NUCLEI

No females of this age group were found in any of the collections, although a very few males were discovered. One was taken inside and three outside. Among these three, however, two were contained in a special collection, made in 1914, of fish selected for their small size—the "grilse." Mature males of this age group are extremely rare in the Columbia River and apparently are seldom taken by troll. In so far as their maturity is concerned, it seems fair to assume that they will mature one year later than the 3-year fish with stream nuclei and two years later than the 4-year fish.

In the preceding discussion of the various age groups, no attempt has been made to show the percentage of mature and immature fish in each, nor the percentage which the immature fish formed of the total number in the different collections. These data have been compiled in separate tables for ease in making comparisons. Table 5 shows, for each collection of fish taken inside the river, the percentages of the total number of females which are composed of the mature and immature fish of the different age groups. Table 6 gives similar data for the collections of fish caught in the ocean. A discussion of the composition of the entire collections as regards age groups will be given later, but attention is first directed to a discussion of the age groups most commonly represented among the immature fish.

AGE OF IMMATURE FISH

Reference to Table 5 shows, as would be expected, that very few immature fish are taken inside the river. It has already been explained (page 34) that a few immature fish are occasionally taken in the lower part of the Columbia River estuary. The collections of May 17 and 18, July 3, and July 7 were all made in this part of the river and are the only ones to contain immature fish. Such immature fish as were taken belong to the 2 and 3 year groups with ocean nuclei and to 3 and 5 year fish with stream nuclei.

TABLE 5.—*Percentages of females of different age groups and different degrees of maturity taken in the river at different times during the season* [1]

Date	Ocean nuclei in—						Stream nuclei in—				
	Second year	Third year		Fourth year	Fifth year	Sixth year	Third year	Fourth year	Fifth year		Sixth year
	I.	I.	M.	M.	M.	M.	I.	M.	I.	M.	M.
May 10				4.5				72.8		22.7	
May 13				11.1				62.2		26.7	
May 16								77.8		22.2	
May 17 and 18				2.9	2.9			8.8	5.9	79.5	
May 27				44.5				14.8		33.4	7.4
May 30 and 31								84.0		16.0	
June 10					45.5			18.2		36.3	
June 16					8.0	2.0		52.0		36.0	2.0
June 16 and 17				2.1	20.8			35.4		41.7	
June 24 and 25				40.8	11.1	14.8		18.5		11.1	3.7
July 3			2.0	47.0	33.3	5.9	2.0	7.8		2.0	
July 7	12.2	2.4	2.4	48.8	19.5		9.8	2.4		2.4	
July 16			4.3	41.3	39.2			8.7		4.3	2.2
July 28				34.8	65.2						
Aug. 5				80.0	20.0						
Aug. 6				55.3	34.2			7.9		2.6	
Aug. 22			19.5	61.1	7.3			7.3		2.4	2.4
Sept. 12			16.7	57.2	9.5			7.1		7.1	2.4

[1] The initials I. and M. stand for immature and mature, respectively.

Among the fish taken in the ocean (Table 6), it is seen that by far the greater part of the immature fish are in their third year, with ocean nuclei. Fish in their second year, ocean nuclei, are the next most important component. Fish in their third year, stream nuclei, come next in importance. In addition to these age groups, which include the greater part of the immature fish taken, a few immature fish in their fourth year with ocean nuclei, fourth year with stream nuclei, and fifth year with stream nuclei, are taken.

TABLE 6.—*Percentages of females of different age groups and different degrees of maturity taken in the ocean at different times during the season* [1]

Date	Ocean nuclei in—							Stream nuclei in—					
	Second year	Third year		Fourth year		Fifth year	Sixth year	Third year	Fourth year		Fifth year		Sixth year
	I.	I.	M.	I.	M.	M.	M.	I.	I.	M.	I.	M.	M.
May 8 to 10	11.5	60.6	1.2		10.9	0.6		10.9		1.2		1.8	1.2
May 18, 1920		29.0	7.5	13.1	20.5	12.2			6.5	5.6		5.6	
May 24	25.0	43.7	6.3	18.7				6.3					
June 4	26.4	47.0		1.5		1.5		16.2	5.9		1.5		
June 10	33.3	33.3			11.1			22.2					
June 21	19.3	6.5	6.5		32.3	3.2		12.9		16.1		3.2	
June 25	42.8				28.6			14.3		14.3			
July 2	14.1	26.3	5.1	1.0	22.2	11.1		7.1	3.0	7.1		3.0	
July 28	3.1	13.2	3.1		50.0	18.4	1.0	7.1	1.0	2.0		1.0	
Aug. 13	2.1	6.3	9.5	3.2	66.4	4.2		1.0	1.0	6.3			
Aug. 13 to 17	4.9	3.9	20.6	1.0	18.6	18.6		1.9		2.9		26.5	1.0
Sept. 18 and 19	16.7	58.3					8.3	16.7					

[1] The initials I. and M. stand for immature and mature, respectively.

PERCENTAGES OF IMMATURE FISH AT DIFFERENT TIMES

The composition of the various collections as regards mature and immature fish is best shown in Tables 7 and 8, which give the percentages of mature and immature fish found in each collection taken inside and outside, respectively. In Table 8 is also given the estimated percentage of fish that would not mature for two or more years. This has been derived by assuming that in any one collection the 2-year fish with either ocean or stream nuclei would, the next year, show a similar percentage of mature and immature fish as did the 3-year fish with the same type of nucleus at the time the collection was made. As has been mentioned above, this assumption is not necessarily justified, but it is believed that the general results of the application of such an assumption will approximate more closely the true state of affairs than could otherwise be reached.

TABLE 7.—*Percentage of mature and immature females taken inside the river at different times during the season*

Date	Percentage		Date	Percentage	
	Immature	Mature		Immature	Mature
May 10		100	July 3	2	98
May 13		100	July 7	25	75
May 16		100	July 16		100
May 17 and 18	5	95	July 28		100
May 27		100			
May 30 and 31		100	Aug. 5		100
			Aug. 6		100
June 10		100	Aug. 22		100
June 16		100			
June 16 and 17		100	Sept. 12		100
June 24 and 25		100			

TABLE 8.—*Percentage of mature and immature females taken outside the river at different times during the season*

Date	Percentage due to mature during—			Total percentage of immature fish	Date	Percentage due to mature during—			Total percentage of immature fish
	Year taken (mature)	Next year	Second year			Year taken (mature)	Next year	Second year	
May 8 to 10	16.9	71.7	11.3	83.1	July 2	48.5	37.6	13.9	51.5
May 24	6.3	71.9	21.8	93.7	July 28	75.5	19.6	4.9	24.4
June 4	1.5	55.9	42.6	98.5	Aug. 13	86.4	12.7	.9	13.6
June 10	11.1	55.5	33.3	88.9	Aug. 13 to 17	88.2	10.9	.8	11.7
June 21	61.3	29.1	9.6	38.7					
June 25	42.9	57.1		57.1	Sept. 18 and 19	8.3	75.0	16.7	91.7

Reference to these tables shows that, with the exception again of the three collections made in the lower part of the Columbia estuary, the fish found inside the river are all mature. This is so obviously in accord with the familiar facts of the life history of the chinook salmon that it would be quite unnecessary to present the data given in Table 7 were it not for the unusual presence of immature fish in those collections made in the estuary and the desirability of presenting a table that may be compared with the similar table for the fish taken in the ocean. In the case of the fish taken outside the river, it is apparent that during May and the first half of June the percentage of immature fish is high. This percentage gradually falls during the latter part of June, July, and August, until by the middle of August only about 10 per cent of the fish taken outside are immature. The one collection made in September shows a high percentage of immature fish again. The number of fish included in this September collection is too small to be reliable (12), but it would not be surprising to find that at this time of year most of the fish taken outside are immature, since the height of the run of chinooks in the Columbia comes during August, and the result of the entrance into the river of most of the maturing fish would be to leave mainly immature fish outside. At the time these collections were made there was little outside fishing done during the fall months, so that it was impractical to gather adequate data.

The percentages of mature fish taken outside are shown in Figure 11. It is evident that, with the exception of the last record (that made in September), there is a fairly steady increase in the percentage of mature fish in the collections. The trend of this increase has been calculated, omitting the record for September and that for May 18, 1920, which has previously been shown to be unreliable for this purpose, and assuming that a straight line will approximate the most probable change in the percentage of mature fish taken. The trend has been calculated by the method of averages, [5] weighting the various points by the number of individuals contained in the collections that established the points. The trend, shown on the graph by the broken line, fits the later part of the data remarkably well, but it fails to fit accurately the data for the early part of the season. It is probable, however, that this trend represents the true tendency as accurately as could be done by any such generalization of the observed data. It is quite conclusively

[5] For a description of this method see Lipka, Graphical and Mechanical Computation, Wiley, 1918.

shown that during May less than 20 per cent of the fish taken in the ocean are mature; during July, between 50 and 75 per cent; and during August, between 75 and 90 per cent. It has already been mentioned that few data are available for September, but those that are available indicate a return to the low percentage of mature fish found during the early part of the season.

PERCENTAGES OF FISH MORE THAN ONE YEAR FROM MATURITY

Table 8 shows that the percentage of fish taken in the ocean which would not mature for two or more years is considerably less than the percentage that would mature in one more year. The data are not reliable enough to serve as a basis for definite conclusions, but in general it appears that fully two-thirds of the imma-

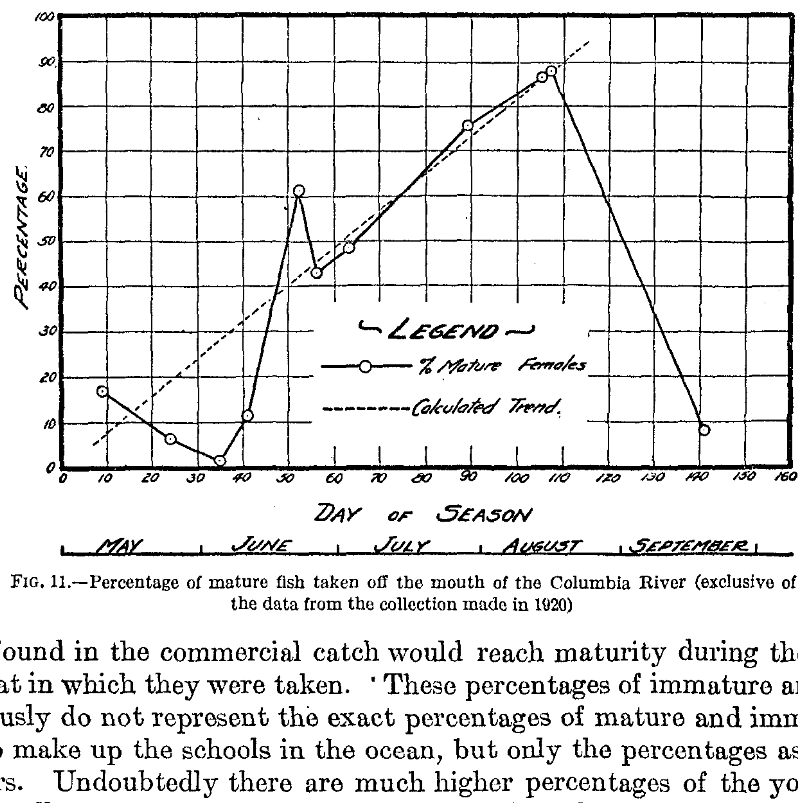


FIG. 11.—Percentage of mature fish taken off the mouth of the Columbia River (exclusive of the data from the collection made in 1920)

ture fish found in the commercial catch would reach maturity during the year following that in which they were taken. These percentages of immature and mature fish obviously do not represent the exact percentages of mature and immature fish that go to make up the schools in the ocean, but only the percentages as taken by the trollers. Undoubtedly there are much higher percentages of the younger age groups actually present outside the mouth of the river than would appear from this study of the catch. The taking of the small fish is relatively unprofitable to the fishermen if larger ones can be caught, and this would inevitably lead to such a selection of gear or of the locality in which the fishing is carried on as would make it possible to take more of the larger fish.

It should be noted that, in designating as "mature" fish taken in the ocean, it is not implied that such fish are ready to spawn or even to enter the river. The term is used merely to indicate that the individuals would mature and spawn during the year in which they were taken. There are many individuals especially during the early part of the season that are not ready to begin the spawning migration, even though they would have matured during the year in which they were taken. For instance, many of the fish with ocean nuclei captured during May and June, and which have been considered as mature, would, in all probability, not be ready to enter the river until August or September, and would be feeding and growing at a rapid rate during the interval. Gilbert has shown, in his paper on the salmon of Swiftsure Bank, that maturing cohoes taken at that point increased nearly 100 per cent in weight during July and August, just prior to their entry into fresh water for the purpose of spawning. On account of the range in the age at maturity of the chinook salmon, it is impossible to get as reliable figures for this species. It will presently be shown, however, that there is a distinct increase in length of the chinooks taken outside the mouth of the Columbia during the season. In the case of the 4-year fish with ocean nuclei—the age group that contains the greatest number of maturing individuals—the length increases from about 80 cm. at the opening of the season to over 90 cm. by the close of the summer season on August 25. Since the weights vary as the cubes of the linear dimensions, this increase in length indicated an increase of nearly 50 per cent in weight during the summer. At this rate a fish weighing 16 pounds at the opening of the season on May 1 would weigh 24 pounds by the end of August. The 3-year fish with ocean nuclei increase in length from about 60 cm. to about 75 cm. during the season. This indicates an increase of approximately 95 per cent in weight, a figure quite similar to that given by Gilbert for the cohoes, which are also 3-year fish.

In résumé, this inquiry into the relative maturity of the chinook salmon taken in and near the Columbia River has established the following facts: (1) The fish found in the river are, with very few exceptions, mature; that is to say, they have definitely left the ocean and entered upon their spawning migration. A very few fish taken in the extreme lower end of the Columbia River estuary, and only under exceptional tidal conditions, are immature; that is, they will not mature and spawn during the year in which they are taken. (2) In contrast with this condition it has been shown that the fish taken in the ocean near the mouth of the Columbia River contain varying proportions of fish that will not mature for at least one more year. (3) These immature fish taken in the ocean belong mainly to the following age groups, arranged in the order of relative abundance: Third year, ocean nuclei; second year, ocean nuclei; third year, stream nuclei; fourth year, ocean nuclei; fourth year, stream nuclei; and fifth year, stream nuclei. (4) The percentages of mature and immature fish taken at different times during the fishing season have been determined, and it has been shown that a very high percentage (approximately 90 per cent) of the fish taken in the ocean during the early part of the season are immature. The proportion of immature fish gradually lessens as the season advances, until in August nearly 90 per cent of the fish taken are maturing. There is some indication that in September there is a return to the conditions found in May—a high percentage of immature individuals.

ABUNDANCE OF THE VARIOUS AGE GROUPS

The variations in the percentages of the various age groups taken inside the river at different times during the season are striking, especially when compared with similar data for the fish taken in the ocean. Table 9 gives for each collection of fish taken inside the percentage of fish belonging to each age group, and in the last two columns the percentage of fish with ocean and stream nuclei. The data on the percentage of fish with ocean nuclei and with stream nuclei are also shown in Figure 12. In the figure the trend, as shown by the broken line, was determined by twice smoothing the original data by threes,[6] and then further smoothing "by eye." A high percentage of fish with stream nuclei is found during the first month and a half of the season, but during the latter part of June the percentage of fish with stream nuclei decreases rapidly and fish with ocean nuclei constitute from 80 to 90 per cent of the take after the first of July. The percentages of fish with ocean nuclei are not shown in the figure, as they are merely complementary to those for the fish with stream nuclei.

TABLE 9.—*Composition of collections of fish taken inside the river as regards age groups*

Date	Percentage with—										Total percentage with—	
	Ocean nuclei in—					Stream nuclei in—					Ocean nuclei	Stream nuclei
	Second year	Third year	Fourth year	Fifth year	Sixth year	Second year	Third year	Fourth year	Fifth year	Sixth year		
May 10			2.4					80.5	17.1		2.4	97.6
May 13	4.3	1.4	5.0				25.9	49.7	13.0	0.7	10.7	89.3
May 16								82.5	17.5			100.0
May 17 and 18			5.6	3.7				11.1	79.6		9.3	90.7
May 27	2.3		34.1		2.3		2.3	34.1	20.4	4.5	38.7	61.3
May 30 and 31	4.8	1.2					13.3	72.3	7.2	1.2	6.0	94.0
June 10				25.0	10.0			25.0	35.0	5.0	35.0	65.0
June 16				7.1	2.0		10.2	48.0	28.6	4.1	9.1	90.1
June 16 and 17		.8	.8	15.7			8.7	52.7	20.5	.8	17.3	82.7
June 24 and 25	3.7	14.8	25.9	9.3	9.3		5.6	24.1	5.6	1.8	63.0	37.0
July 3		2.0	47.1	33.3	5.9		2.0	7.8	2.0		88.0	12.0
July 7	30.6	5.9	25.9	21.2	2.3		10.6	2.3	1.2		85.9	14.1
July 16	19.7	17.0	24.0	15.3	1.6		15.3	5.5	1.1	.5	77.6	22.4
July 28		4.0	42.0	50.0	2.0			2.0			98.0	2.0
Aug. 5	20.8		33.3	16.7	4.2	4.2	12.5	4.2	4.2		72.0	28.0
Aug. 6	10.5	6.3	46.3	29.5			3.2	3.2	1.0		92.6	7.4
Aug. 22	1.0	22.4	66.0	3.2				5.3	1.0	1.0	92.7	7.3
Sept. 12		22.1	59.0	6.3				3.2	4.2	5.3	87.3	12.7

Although it appears from these data that stream nuclei predominate during about half of the season, it must not be inferred that approximately half of the total number of fish taken during the season are of this type. The fish taken during May and June form a comparatively small part of the total pack, although an important part, owing to their fine quality. The great bulk of the run occurs during July and August. Reliable statistics are not available, but it is probable that, in most years, not more than 25 per cent of the total pack on the Columbia River is taken during May and June. On this account the percentage of the total pack formed by fish with stream nuclei will be much less than the percentage formed by fish

[6] This smoothing was accomplished by smoothing independently the series of time values (10, 13, 16, 18, 27, etc.), and the series of percentage values (97.6, 89.3, 100.0, 90.7, etc.). The resulting smoothed time values were then paired with the corresponding percentage values and the pairs used as coordinates for the determination of the "smoothed" points.

with ocean nuclei, even though the two types are predominant for approximately equal times.

Among the fish with stream nuclei, those in their fourth and fifth years are most common. A few in their sixth year are taken, but constitute a relatively small part of the total catch. Three-year-old fish are quite common, but this age group contains only precociously mature males. Two-year-old fish with stream nuclei are very rarely found.

The fish with ocean nuclei are likewise predominantly 4 and 5 years old. Fish in their sixth year are comparatively rare, but those in their third and second years are fairly common, especially during the last half of the season. It has been shown

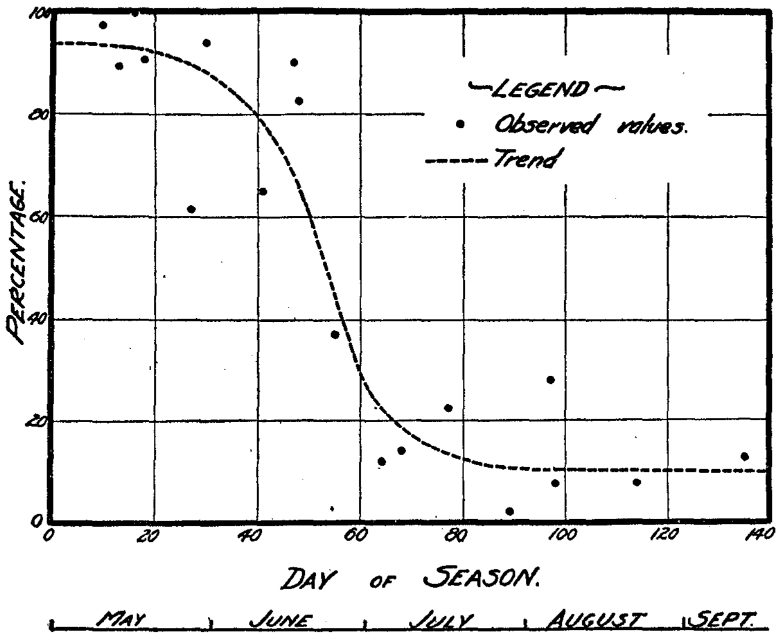


FIG. 12.—Percentage of fish with stream nuclei taken inside

above that some of the 3-year fish with ocean nuclei are mature females, but most of the fish of this age group are males, and all of those in their second year are the precociously mature males locally known as "grilse" or "jack salmon."

The variations in the percentages of fish of the different age groups found among the fish taken in the ocean is strikingly different from those observed among the fish taken inside the river. The data are presented in Table 10 and Figure 13. The trends shown on the graph represent the position of the averages given at the bottom of the last two columns in Table 10. In view of the fact that there were no consistent changes in the percentages of fish with ocean and with stream nuclei, it appeared that the averages would represent the trends as accurately as could be done by any other means.

TABLE 10.—*Composition of collections of fish taken outside the river as regards age groups*

Date	Percentage with— Ocean nuclei in— Second year	Third year	Fourth year	Fifth year	Sixth year	Stream nuclei in— Second year	Third year	Fourth year	Fifth year	Sixth year	Total percentage with— Ocean nuclei	Stream nuclei
May 8 to 10	13.2	56.2	7.8	0.4			19.1	1.5	1.1	0.7	77.6	22.4
May 18		42.4	26.8	13.6				11.5	5.8		82.7	17.3
May 24	23.3	43.3	20.0				13.3				86.7	13.3
June 4	24.2	47.5	3.3	.8		0.8	18.3	3.3	1.7		75.9	24.1
June 10	41.7	25.0	8.3				25.0				75.0	25.0
June 21	14.9	22.4	29.8	3.0			17.9	10.4	1.5		70.2	29.8
June 25	27.3	9.1	27.3				18.1	18.1			63.8	36.2
July 2	14.1	31.4	23.3	11.1			7.0	10.1	3.0		79.9	20.1
July 28	3.0	16.4	50.0	18.5	1.0		7.1	3.0	1.0		88.9	11.1
Aug. 13	2.1	15.8	69.5	4.2			1.0	7.4			91.6	8.4
Aug. 13 to 17	4.9	24.5	19.6	18.6			1.9	2.9	26.5	1.0	67.7	32.3
Sept. 18 and 19	23.3	46.7			6.7		10.0	10.0	3.3		76.7	23.3
Average	16.00	31.80	23.80	5.85	.64	.07	11.55	6.52	3.66	.14	78.0	22.0

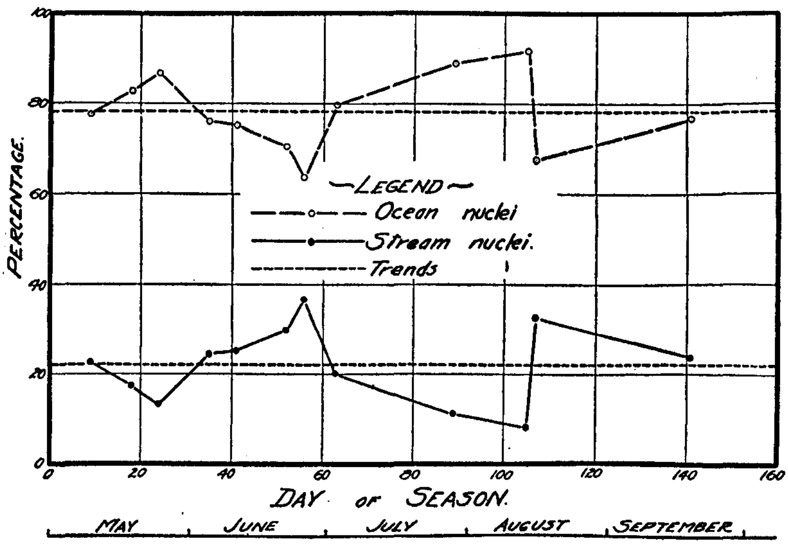


FIG. 13.—Percentages of fish with stream and ocean nuclei taken outside

One of the most notable differences between the collections of fish taken in the ocean and those of fish taken in the river is the fact just mentioned, that in the former there is no such decided and consistent change in the percentage of fish with ocean and with stream nuclei as has been described for the collections of fish taken inside. The percentage of fish with ocean nuclei taken outside varies from 63.8 to 91.6, averaging 78 per cent, and of fish with stream nuclei from 8.4 to 36.2, averaging 22 per cent. These figures are somewhat different from those given by Fraser (1920) for the chinook salmon taken during 1915 and 1916 in the Straits of Georgia, near Vancouver Island, British Columbia. Fraser found 34.6 per cent of fish with the stream type of nuclear growth and 65.4 per cent with the ocean type. In 1917, however, the same author (Fraser, 1921) found exactly the same percentage of fish with the ocean type of nucleus which we have recorded here—78 per cent.

Contrasted with this condition of relative stability in the percentages of fish with ocean and with stream nuclei, which is found among the fish taken in the ocean, are the marked variations found among the fish taken in the river and which are illustrated in Figure 12. There would seem to be but one possible explanation of these facts, namely, that the fish taken outside the mouth of the river represent a fairly accurate sample of the entire population of Columbia River chinooks contained in the ocean, and that these average percentages of fish with ocean and with stream nuclei represent, approximately, the percentage of fish with stream and with ocean nuclei that would go to make up the total of the run in the Columbia River. It is, of course, possible that races other than those belonging to the Columbia River Basin are taken off the mouth of the Columbia River, but since the Columbia is by far the most important chinook salmon stream on the coast it can hardly be doubted that the great majority of fish found just outside are native to this river. The fish found outside therefore represent the supply of fish from which the runs of mature fish found in the river are drawn. It would be expected that the removal from this supply of considerable numbers of fish with stream nuclei during the early part of the run, and of greater numbers of fish with ocean nuclei during the later part of the run, would tend to upset these ratios in a systematic manner, but this effect is not noticeable. The high percentages of immature fish taken outside would tend to obscure this effect, since the migration of mature fish would affect only the percentages of fish with ocean and with stream nuclei among the maturing fish. It seems probable, however, that with many more data than are available, some systematic fluctuations in the proportions of fish with ocean and stream nuclei might be shown.

On account of the fact that the variations in the percentages of fish with ocean and with stream nuclei among the fish taken in the ocean are practically negligible, the average percentages of fish of the different age groups taken throughout the season is significant. (This, as mentioned above, was not true of the data from the fish taken inside the river, on account of the great variations in the percentages of fish with ocean and with stream nuclei and the differences in the relative importance of the different parts of the run. See page 44.) These data are given in the bottom line of Table 10, and from them it is evident that among the fish with ocean nuclei the 3-year group is most abundantly represented, forming 31.8 per cent of the total take. The 4-year group comes next and forms 23.8 per cent of the total. Fish in their second year with ocean nuclei form the next most important group, with an average of 16 per cent. A few 5-year fish and a very few 6-year fish appear in the collections. In the case of the fish with stream nuclei it is seen that 3-year-old fish are most numerous, followed by 4, 5, 6, and 2 year fish, in the order of importance. Fraser (1920, p. 172) gives the percentages of fish of different ages of "sea type;" that is, those whose scales show the ocean type of nuclear growth, as observed in the Straits of Georgia. The figures are very similar to those obtained in this study of the fish taken off the mouth of the Columbia River, as may be seen from the following table:

TABLE 11.—*Percentages of fish with ocean nuclei in the various age groups*

Locality	Age				
	Second year	Third year	Fourth year	Fifth year	Sixth year
Off mouth of Columbia River	20.5	40.7	30.5	7.50	0.8
Straits of Georgia (from Fraser)	28.1	42.9	27.8	1.2	----------

The correspondence is remarkably close, considering the fact that the data were taken at different places, in different years, and were handled by different observers.

It is interesting to compare these data with those obtained from a study of the collections made of fish taken inside the river. Among the fish with ocean nuclei taken in the river, 4 or 5 year old fish were found to be the most numerous. Among the fish taken in the ocean, 3-year fish were most abundant. Also, in the case of the fish with stream nuclei, it was found that 4 and 5 year fish were most numerous in the river, while 3 and 4 year fish were more common in the catches made outside. It has already been pointed out that the data bearing on the proportions of fish of the different age groups present in the ocean can not be compared in detail with the similar data for the fish taken in the river, but in a general way it may be stated that the fish taken outside tend, on the whole, to be about 1 year younger than those taken inside.

GROWTH

A study has been made of the increase in length of fish of different age groups taken during the season of 1919, both outside and inside of the river. The study was confined to the collections made during a single season in order that any yearly fluctuations in growth rate might be excluded. It must be emphasized that an observed increase in the average size of the individuals contained in a series of collections is not necessarily due to growth, particularly in the case of fish taken inside the river. The constant migration upstream after fish have entered fresh water results in a constant change in the content of the run passing any given point along the river. Gilbert (1914, 1915, 1916, 1918, 1919, 1920, 1922, and 1923), in his intensive study of the sockeye salmon of British Columbia, has conclusively demonstrated the existence of distinct races characterized, among other things, by very different sizes at maturity. Considerable unpublished evidence is in the hands of the writer, which indicates that similar races are to be found among the chinook salmon of the Columbia River. The result of such differences in size of the races running in the river at various times will necessarily be to mask, more or less completely, the results of growth. The extent to which the effect of growth will be thus masked will depend upon a number of factors, such as the relative sizes and numbers of the various races found together within the river. If large races were running early in the season and smaller races later, the observed changes in size during the season would be less than the actual growth occurring within a single race. It might even occur that fish of the same age group taken late in the season would be actually smaller than others taken earlier in the season, although they had had several additional months of life in the ocean during which time they were feeding and growing rapidly. The reverse condition might also be found, in which smaller races were running early in the season and larger ones later. The effect of this would be to augment the true effect of growth.

In the case of fish taken outside, however, it seems probable that the observed changes in length quite truly represent the effect of growth, since fish of the same race presumably remain within the fishing area over the entire fishing season. That this in general is true is indicated by the fact, demonstrated above, that there is comparatively little change in the composition of the outside schools as regards age groups, and particularly the main types of nuclear growth, while at the same time very conspicuous changes are taking place in the composition of the runs in the river. The details of the growth process are necessarily lost unless they can be worked out for single races. A mixture of several races, such as we have in the collections available, will show only certain of the general features of growth that are common to at least the majority of the races represented in the collections. The results of the study of such mixed material give a composite picture, which may not exactly represent the true condition in any one of the races represented. Fraser (1920) has made an intensive study of the growth of all five species of salmon as found in the Straits of Georgia, where, as in the present study, it was impossible to segregate accurately the various races. The results of his study are interesting as showing the general trend of the growth, but it would seem that such material can not be relied upon to show the finer details of the growth process.

In order to reduce to the simplest terms the observed changes in length, the trend of these changes during the fishing season, from the 1st of May to the end of September, have been calculated. The data on fish taken in the ocean have been kept separate from those relating to fish taken in the river, and separate trends have been calculated. An examination of the data showed that the rate of change in length was, in most age groups (and by inference in others), practically constant during the season, and it was therefore assumed that the trend would be best shown as a straight line. The trends were therefore calculated on the basis of the formula $y=a+bx$, in which y is the observed length (the average of all individuals of a single age group found in any one collection), x is the day of the fishing season on which the collection was made (beginning with the opening of the fishing season on May 1), and a and b are constants. a represents the most probable average length of the age group in question on the 1st day of May, and b the most probable daily increment in length. The calculations were made by the method of least squares,[7] and the "observation equations" were weighted according to the number of individuals found in each age group in the various collections. This method of direct weighting is recommended in some of the texts on the method of least squares. The mathematical work of calculating these trends was accomplished in most cases by the use of logarithms, and the results were checked by means of a 20-inch

[7] See any of the numerous texts on the method of least squares.

slide rule. In the case of a few of the age groups in which the numbers involved were small, the calculations as far as the determination of the constants from the "normal equations" were done entirely on the slide rule, which gave exact figures to a sufficient number of places. The calculation of the constants from the "normal equations" was in all cases done by the use of logarithms. The following table (Table 12) gives the values of the constants a and b and the values of y when x is 100 (the most probable average length on the one-hundredth day of the season—August 8), for each age group, both for fish taken in the ocean and in the river.

Figures 14 to 21 show, for each age group, the average length observed in each collection and the calculated trend of the growth during the season, calculated separately for the collections made in the ocean and in the river. The upper and lower limits of twice the standard deviation is also indicated in the same manner as in the previous figures showing the variations in the size of the eggs. For the purpose of this study, both males and females have been included. The various age groups will be discussed separately.

TABLE 12.—*Data for the trends in length of chinook salmon taken during 1919*

Age group	Number of specimens	a	b	Value of y when x equals 100
FISH TAKEN IN THE OCEAN				
Ocean nuclei				
Second year	121	42.97	0.0888	51.85
Third year	322	60.20	.1193	72.14
Fourth year	194	77.65	.1410	91.75
Fifth year	37	92.02	.0610	98.12
Stream nuclei				
Third year	117	48.57	.0979	58.36
Fourth year	40	72.10	.1169	83.79
Fifth year	11	83.50	.1064	94.14
FISH TAKEN IN THE RIVER				
Ocean nuclei				
Second year	90	44.54	−.0252	42.02
Third year	99	48.98	.1989	68.87
Fourth year	319	79.10	.0771	86.81
Fifth year	166	111.10	−.1051	[1] 100.59
Sixth year	19	104.70	.1546	120.16
Stream nuclei				
Third year	115	47.30	.0956	56.86
Fourth year	489	75.00	.0671	81.71
Fifth year	147	92.30	.0832	104.98
Sixth year	17	112.05	−.0600	106.05

[1] The fish of this age group taken on June 16 and June 16 and 17, 1919, were unusually large. Both collections were taken well up the river, one at Seufert and the other at Warrendale, and it is difficult to escape the conclusion that these fish are representative of a large race. Omitting these two collections the constants become: $a=100.5$, $b=0.0015$, and the value of y when x is 100 is 100.65.

FISH IN THEIR SECOND YEAR, OCEAN NUCLEI

Figure 14 shows the variations in the length of fish of this age group. The differences between the fish taken outside and those taken inside are conspicuous. The trend of those taken outside is upward, from nearly 43 cm. on the 1st of May to nearly 52 cm. on August 8, 100 days after the opening of the season. The change in length during the first 100 days of the season has been used simply as a matter of convenience in calculation and discussion. In the text figures the trend is extended beyond this point. The points that show the average size of the fish of this age group taken in the various collections are distributed quite closely about the trend. The fish that were taken in the river, however, tend to be smaller toward the end of the season than at the beginning, as is shown by the downward slope of the line of

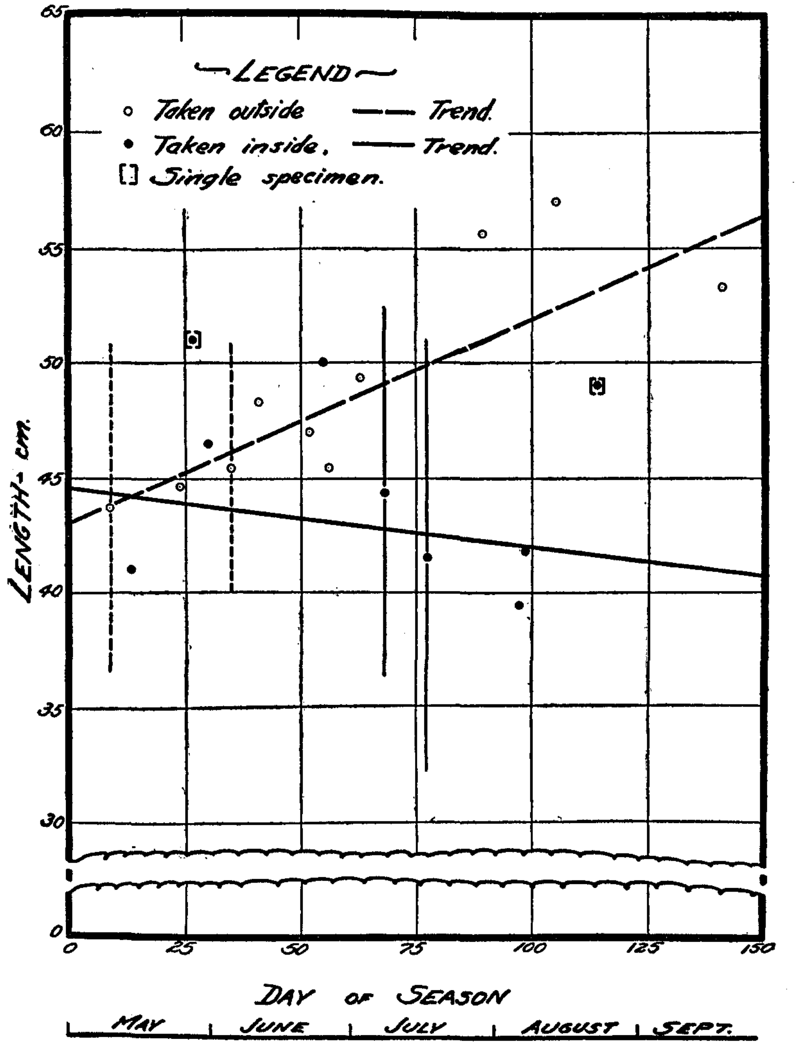


FIG. 14.—Length of fish in their second year, ocean nuclei. As in the illustrations showing sizes of eggs, the upper and lower limits of twice the standard deviation ($\pm 2\sigma$) are shown by the vertical lines extending from the points that indicate the position of the mean. The same conventions have been used in the other illustrations of length

trend, and the deviation of the points from the trend is distinctly greater than in the case of the fish taken outside.

FISH IN THEIR THIRD YEAR, OCEAN NUCLEI

Figure 15 shows the variations in the length of the fish in their third year, ocean nuclei. The trends for the fish of the two groups—those taken outside and those taken inside—differ materially, although in quite another manner than was noted in the fish with ocean nuclei in their second year. In the 3-year-old fish, the trend for the individuals taken inside is much steeper than that for those taken outside, indicating a more rapid increase in size during the season. The trend for the fish taken outside starts at about 60 cm. on the 1st of May and is increased to a little over 72 cm. by the 8th of August. As in the case of the 2-year-old fish, the variation about

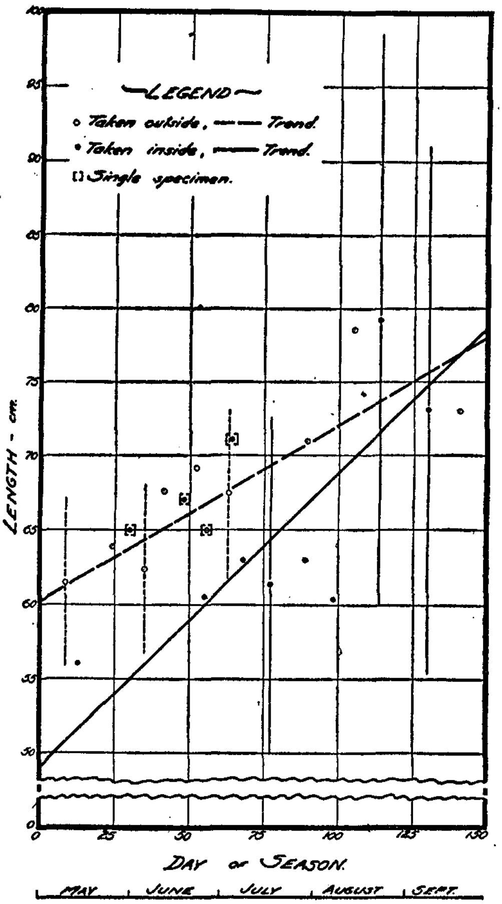


FIG. 15.—Length of fish in third year, ocean nuclei

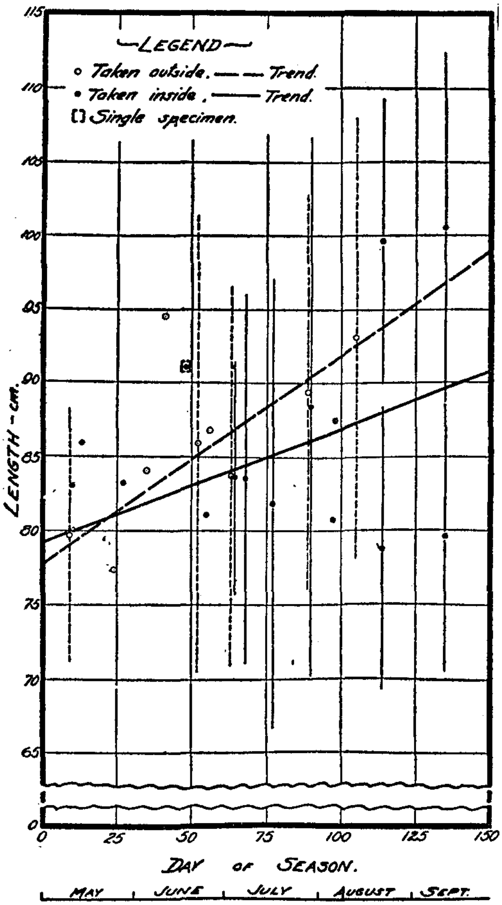


FIG. 16.—Length of fish in fourth year, ocean nuclei

the trend of the points indicating the average size found in the various collections is less in the case of the fish taken in the ocean than among the fish taken in the river.

FISH IN THEIR FOURTH YEAR, OCEAN NUCLEI

The data and the trends for the fish of this age group are shown in Figure 16. The trend for the fish taken outside starts at 77.7 cm. and increases to 91.7 cm. by the 8th of August. The corresponding trend for the fish taken inside is much less steep, starting at 79.1 cm. and reaching a value of only 86.8 by the same date. As in the two age groups previously discussed, the deviation of the points from the trends is greater in the case of the fish taken inside.

The study of the fish of this age group taken in the river is complicated by the fact that two quite distinct races are found running simultaneously during the latter part of August and September. A discussion of the racial differences observed among the chinook salmon has not been attempted in this paper, but in this particular case the differences are so striking that a failure to segregate the two races would be misleading. Tables 19 and 20 on pages 82 and 83 give the length-frequency distributions in detail for two large collections made, respectively, on August 22 and September 12, 1919. An examination of these tables will show that the length-frequency distributions of the 4-year fish with ocean nuclei are distinctly bimodal. The bimodality is apparent, not only in both collections but also in the two sexes of each collection, as well as in the distribution in which males and females are combined. The cumulative evidence of these facts points strongly to the fact that two distinct races are present. Additional evidence of a very satisfactory nature, which supports this interpretation, is available from the scales. Two quite different types of scales are found among the fish of this age group: One, typical of the smaller fish, is characterized by a comparatively small ocean nucleus, which is usually not sharply defined from the succeeding growth of the second year, and the winter bands of the second and third years are relatively close together. The type that is associated with the larger fish has a distinctly larger nucleus, which is usually well set off from the rest of the scale. The second and third winter bands are more widely separated and are frequently less sharply marked than those of the other type. Figure 41 illustrates the scales of the first type—associated with the smaller sized fish—and Figure 42 illustrates the scales of the second type. The evidence given by the length-frequency distributions and by a careful study of the scales indicated that there was very little overlapping in the sizes of these two races, and consequently the line of separation has, somewhat arbitrarily, been set at 90 cm. All of the fish above this size have been considered as belonging to the larger race, and all below it as belonging to the smaller race. The overlapping of the two races is quite obviously so slight that there will be little error in making this assumption. In the text figure the two races have been shown separately in the last two collections. Both races were included in the calculation of the trend.

FISH IN THEIR FIFTH YEAR, OCEAN NUCLEI

It has been shown above that there were comparatively few fish of this age group taken outside the river, although it is well represented among the fish taken inside. It is significant, therefore, that the trend, as determined from these relatively inadequate data from outside, is quite similar to the trends as determined for the other age groups found among the fish taken outside, which were much more adequately represented. On the other hand, the trend for the fish taken inside is reversed, the larger fish occurring during the early part of the season, although the group is well represented both as regards number of individuals and number of collections. The deviations from the line of the trend are again greater in the case of the fish taken inside the river. These features are shown in Figure 17.

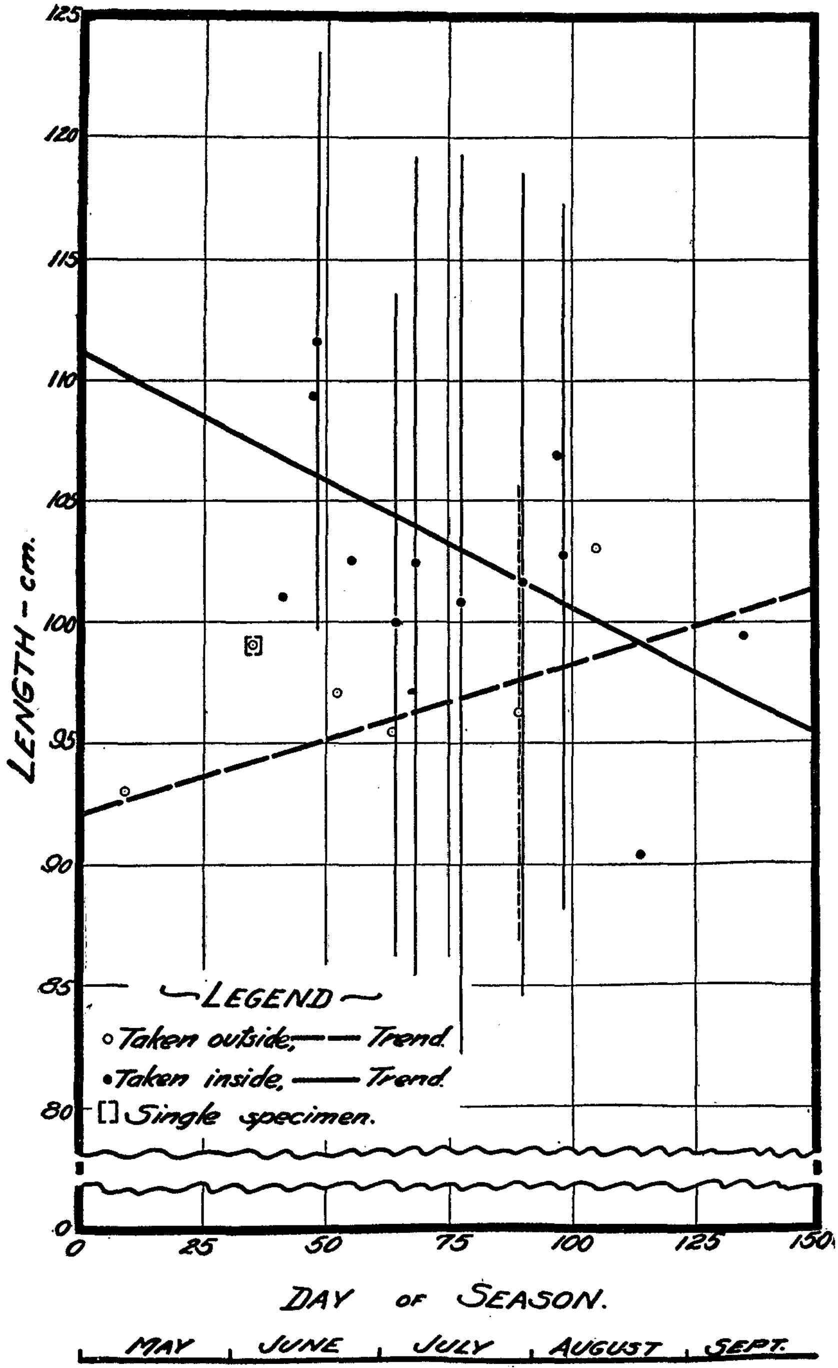


FIG. 17.—Length of fish in their fifth year, ocean nuclei

FISH IN THEIR SIXTH YEAR, OCEAN NUCLEI

This age group is so poorly represented among the fish taken outside that it is impossible to learn anything of the general trend of the growth. The group is by no means adequately represented among the fish taken inside, but for the sake of completeness the trend has been calculated and is shown in Figure 18. It can not, however, be considered as reliable.

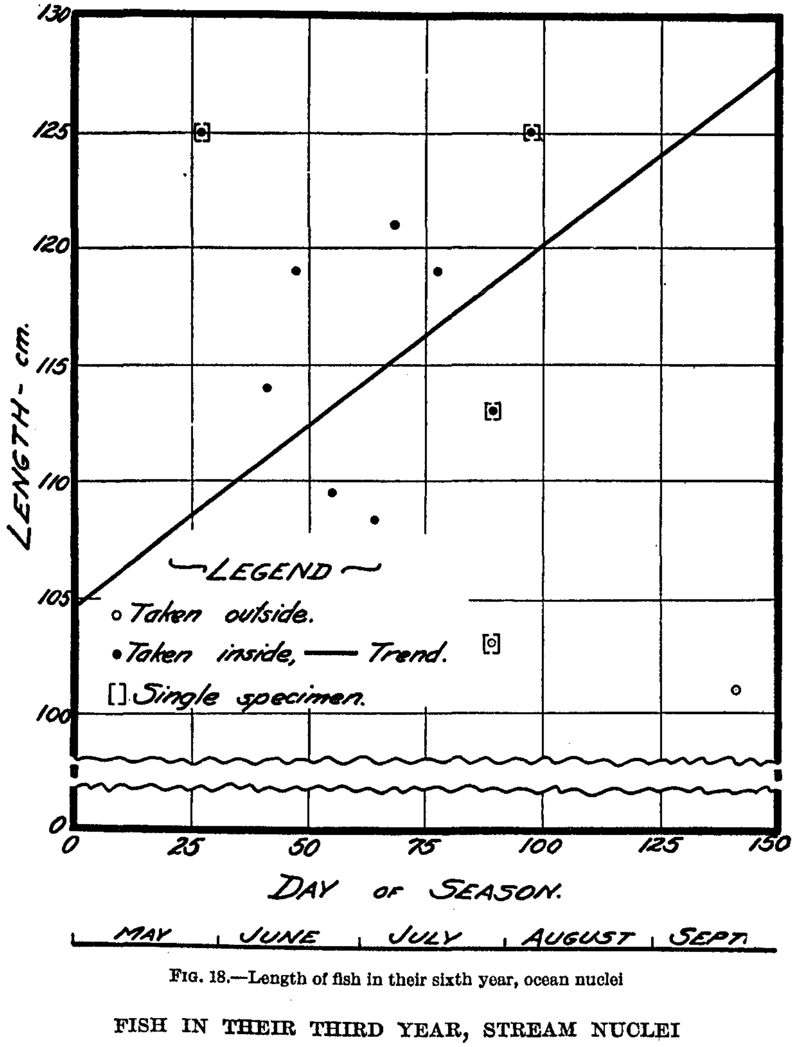


FIG. 18.—Length of fish in their sixth year, ocean nuclei

FISH IN THEIR THIRD YEAR, STREAM NUCLEI

The data for this age group are shown in Figure 19. The trends for the fish taken inside and those taken outside run close together and almost parallel—the only example among all of the age groups in which this is the case, although it might well be expected that this would happen in the majority of instances, were it not for the influence of factors other than growth, such as the presence of a succession of various races. As shown by these trends, the fish of this age group averaged about 48 cm. in length at the beginning of the season in 1919, and increased approximately 10 cm. between that time and August 8. The greater variability of the fish taken inside is not as clearly shown in this group of fish as in many of the others, but a consideration of the actual deviations of the observed average lengths from the calculated lengths (the residuals) shows that even in this instance the fish taken inside are distinctly more variable. The average deviation from the trend among the collections taken inside is 1.8 cm., and among the fish taken outside is only 0.9 cm.

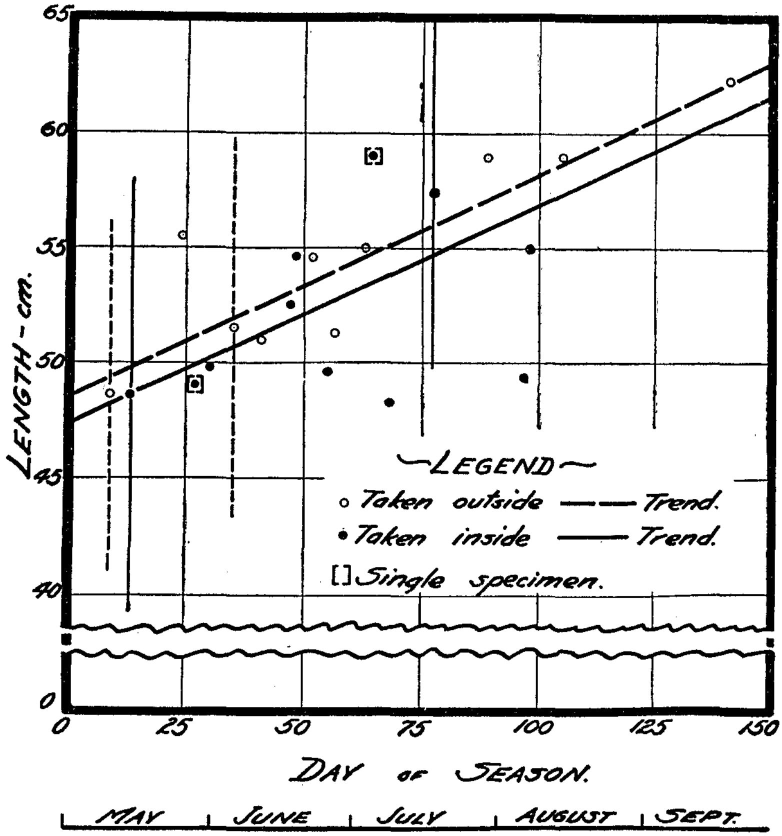


FIG. 19.—Length of fish in their third year, stream nuclei

FISH IN THEIR FOURTH YEAR, STREAM NUCLEI

Figure 20 shows the data for the fish of this age group. As in the last group considered, the trends of the fish taken inside and outside are in fair agreement, although the agreement is by no means as close as in the 3-year fish. Only 40 individuals, scattered through 8 collections, represent this age group among the fish taken outside, while there were 489 individuals in 16 collections taken inside. Yet the average deviation of the points from the trends is distinctly less in the case of the fish taken outside.

FISH IN THEIR FIFTH YEAR, STREAM NUCLEI

Only 11 fish of this age group appear in the collections of fish taken in the ocean during 1919. These were scattered through six collections and yet give a trend similar to the other trends shown by the fish taken outside. The trend for

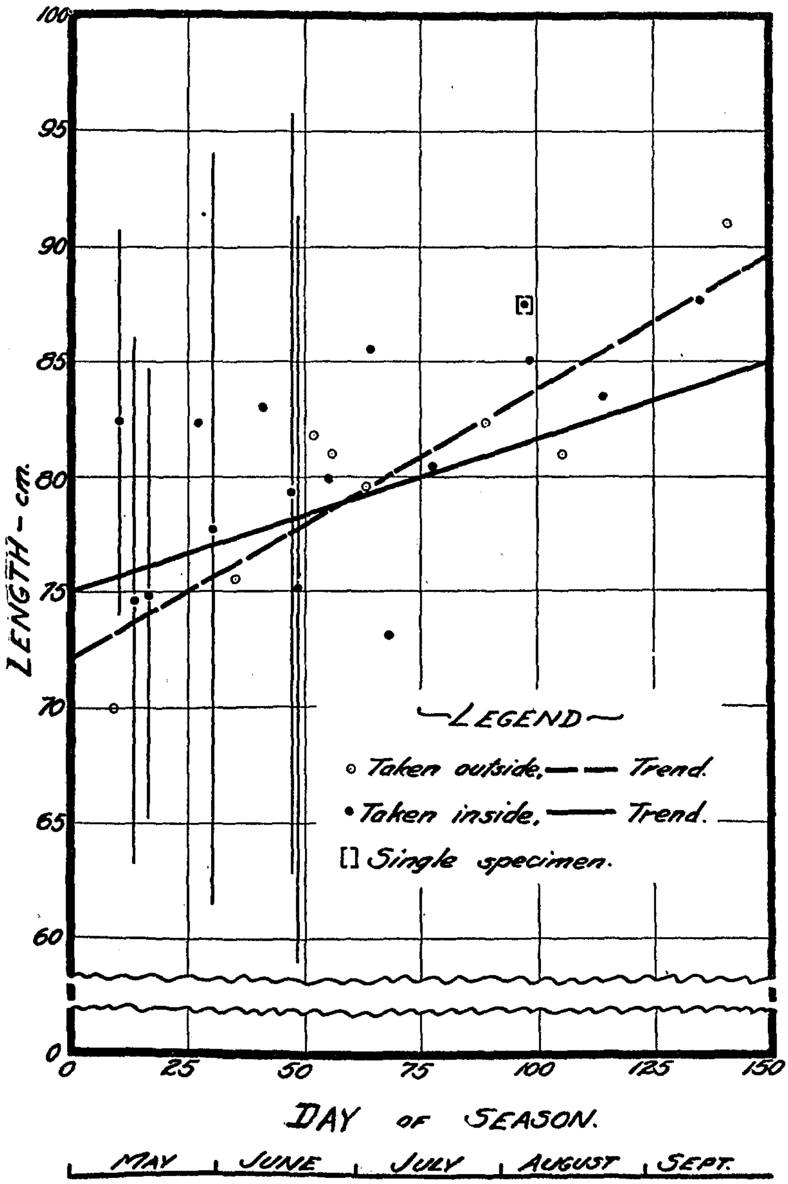


FIG. 20.—Length of fish in their fourth year, stream nuclei

the fish taken inside is quite similar, but runs considerably higher. The data are shown in Figure 21, and an inspection of this graph shows again the greater variability of the average sizes of the fish taken inside.

FISH IN THEIR SIXTH YEAR, STREAM NUCLEI

No fish of this age group were taken outside of the river, and only 17 inside. A text figure, therefore, has not been prepared to show these data, although the values of the constants determining the trend have been given in Table 12. That the trend would be reversed is indicated by the negative value for b as given in

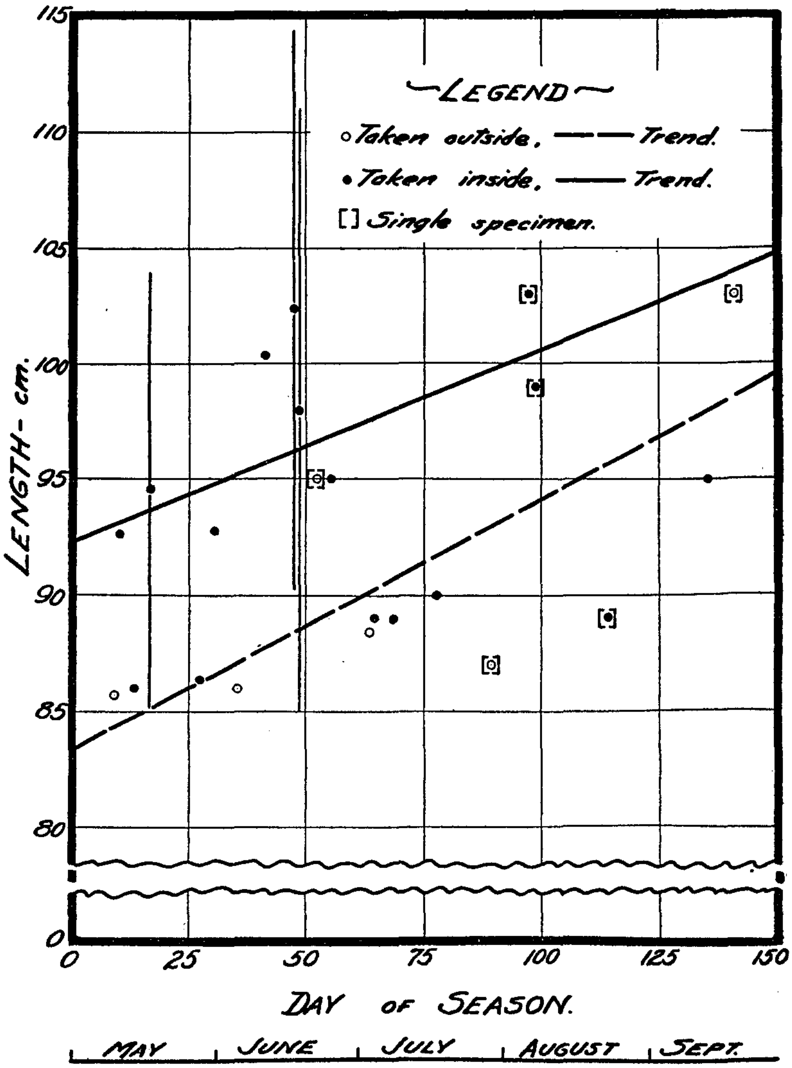


FIG. 21.—Length of fish in their fifth year, stream nuclei

the table. Although, with so few individuals, such a trend can not be considered very reliable, it is worthy of some consideration in view of the fact that, among the fish taken inside the river, there were two other age groups, both of which were well represented but which showed a similar negative trend.

Several important facts are shown by these data on the length of the fish.

An examination of the tables and text figures given above shows clearly that in all of the age groups represented among the fish taken in the ocean a marked increase in length occurs during the fishing season, from May to September, inclusive. Similar increases in length are shown in five of the age groups taken inside the river, but in three of the age groups—the 2-year and the 5-year fish with ocean nuclei and the 6-year fish with stream nuclei—the trend is reversed and the fish belonging to these age groups are smaller toward the end of the season than earlier. It is also noticeable that, even excluding these age groups in which the trend is reversed, the trends for the fish taken inside are more variable than for the fish taken outside. The average daily increment (b in Table 12) for the fish taken outside varies from 0.0888 to 0.1410 cm., while that for the groups taken inside, omitting those age groups in which the trend is downward, is much greater, ranging from 0.0671 to 0.1989. This is over two and one-half times that shown by the fish taken outside. Attention has also been called repeatedly to the fact that in each age group the deviations of the average lengths for each collection (shown as the points in the figures) from the trend (as determined from the series of collections taken over the whole season) is greater among the fish taken in the river than among those taken in the ocean. All of the evidence available indicates a decidedly greater variability among the fish taken inside. A few instances of this sort might be attributed to chance, but the uniformity of the evidence demands some other explanation.

It seems very probable, if not, indeed, certain, that this greater variability in the rate of increase in length among the fish taken in the river is due to the fact (which has been mentioned above) that there are more profound changes in the racial constitution of the fish found migrating up the river than in those found schooled outside, and that these different races vary sufficiently in their average size so that the effect of growth may be masked more or less completely by these racial changes. Evidence has been presented which shows that both of these factors are present in the migrating fish within the river. It seems hardly necessary to argue that there is a succession of races during the season among the migrating fish. Granting the existence of such races it follows that there must be a succession of them in the river during the season, so that at one time the run contains a conspicuously large percentage of fish from one or at most a few races, while at other times other races will predominate. This would be particularly true in the case of such a large river system as the Columbia with its numerous tributaries, which probably have, as Gilbert has shown for the sockeye salmon, each its individual race. It has been shown in one specific instance—that of the 4-year fish with ocean nuclei taken during August and September, 1919—that distinct races are to be found among the chinook salmon of the Columbia River, and, moreover, that these races may vary sufficiently in size so that the predominance of one of them at one time and another at another time would undoubtedly greatly modify the true effect of growth.

The reversed, downward trend of the fish belonging to some of the age groups—the fish in their second and fifth years with ocean nuclei and those in their sixth year with stream nuclei—may be explained, then, by supposing that the races that predominate in these age groups early in the season are large and those running late are small. Such characters might, however, fluctuate from year to year, so that samples collected in other seasons might not show exactly the same effect. It is not necessarily to be expected that the trends of the fish of different age groups taken inside will run parallel with each other, even though they do not run parallel with the trends for the fish taken outside. It may well happen that at any given time one race of fish will predominate among the fish of one age group, and that an entirely different race will be predominant in another age group. The evidence is not available to prove this for the Columbia River chinook salmon, but Gilbert has shown, in his extensive studies of the sockeye salmon, that different races may show quite different distributions among the different age groups. It may be inferred that similar conditions would be found among the chinook salmon if sufficient evidence were available. The possible effect of such a succession of different races should be carefully considered in any detailed study of growth in which this factor may have an opportunity to operate.

It has been shown that there are probably no radical changes in the racial constitution of the fish found in the ocean outside the mouth of the river. It has also been shown that the fish taken in the ocean are, in varying measure, immature, and that many of them are not destined to enter the river during the year in which they are taken. In consideration of these facts, it seems reasonable to suppose that the increase in size of the fish taken in the ocean reflects, with reasonable accuracy, the true effect of growth. If this be true, it is evident that most of the growth of the year takes place during the fishing season—that is, during the late spring and summer. This is shown by the fact that the fish of any one of the age groups are, at the end of the season, nearly equal in size to the fish of the next older age group at the beginning of the season. This is quite to be expected since it has been shown by numerous studies on various fish and other marine and fresh-water organisms that the main growth occurs during this part of the year. Fraser (1917) has shown that the chinook salmon found in the Straits of Georgia make their most rapid growth during this season—80 per cent of the total growth of the year taking place during the months from April to September, inclusive. These figures must, however, be considered as very general, since in computing them Fraser made use of the yearly increment of growth in fish of all age groups. In his investigation of the growth of the Pismo clam, Weymouth (1923) found that the period of most rapid growth usually came during May to September, inclusive. The writer (Rich, 1920) has shown that the period of most active growth in young chinook salmon previous to or during their seaward migration occurs during the spring and summer but varies somewhat with the locality. In the Columbia River, the most rapid growth occurs between May and September, inclusive, and in the Sacramento River from March to July, inclusive. Weymouth points out that the rate of growth is profoundly affected by variations in temperature, being induced and accelerated by higher temperatures. The earlier occurrence of the period of most rapid growth in the young salmon of the Sacramento River, when compared with those in the Columbia River, is undoubtedly due to the earlier warming of the Sacramento water. Numerous other examples, showing that the most rapid growth occurs during the spring and summer, might be cited, and it seems certain that for most organisms the more rapid growth occurs during the warmer part of the year.

Since the data on which this paper is based were taken entirely during the months from May to September, inclusive, the trends that have been calculated for the fish taken in the ocean represent the average slope of the growth curve during the period of most rapid growth. In order to show the general appearance of the total growth curve for chinook salmon, these trends have been used in preparing Figures 22 and 23, showing growth curves for fish with the ocean type of nucleus and with the stream type of nucleus, respectively. Such a use of these data is not strictly justified, as the data were all taken during a single year (1919), so that the individuals belonging to each separate age group came from different broods. The fish in their second year came from eggs deposited in 1917, those in

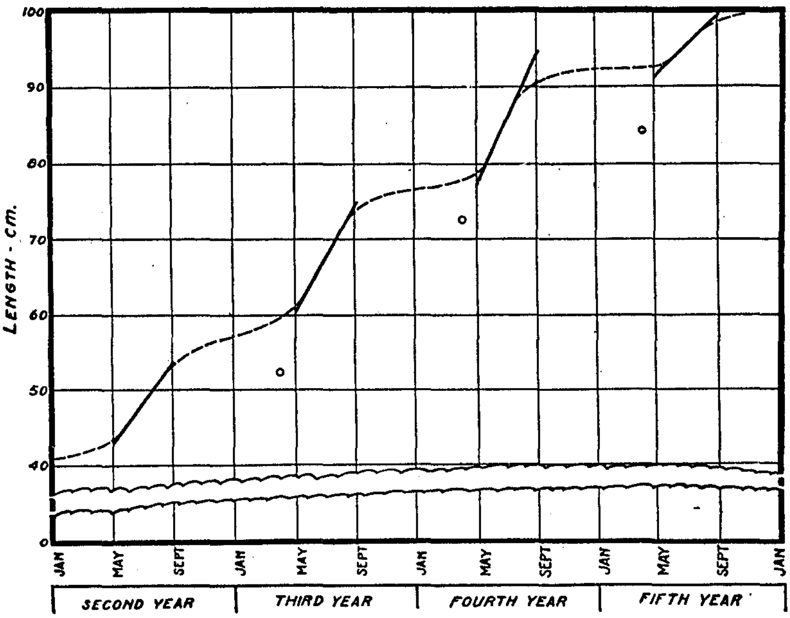


FIG. 22.—Growth curve of chinook salmon that migrated seaward as fry (scales with ocean type of nuclei). Data from fish taken in the ocean near the mouth of the Columbia River. Solid lines show the trends of growth during the fishing season; broken lines indicate roughly the probable course of growth during the remainder of the year; circles show the size of chinook salmon taken in the Straits of Georgia, as given by Fraser. Fraser's measurements did not include the caudal rays, while our's did

their third year from the brood of 1916, and so on. The most logical method for preparing such a growth curve would be to have data over a series of years so that the growth of the fish derived from a single brood year could be obtained. Lacking this, it has seemed desirable to present in this form such data as are available.

In the illustrations the calculated trends are shown by the solid lines, and the trends for successive years have been connected by dotted lines. No data are available upon which to base the form of these connecting lines. They have therefore been drawn in "by eye." The resulting growth curve probably represents fairly well the average size of these fish at different ages and at different seasons. Some error is doubtless due to the use of a straight-line trend as showing the size during the period of rapid growth. The growth during the first and the last parts of each growth period is probably slower than indicated, while that at the height of the growing season is somewhat more rapid. The data available, however, do not lend themselves to a more detailed analysis.

The general form of the growth curve thus obtained is typical and consists of a series of steps, rising rapidly during the summer season and more gradually during the rest of the year. Similar growth curves have been presented by a number of authors and have been obtained by the writer in an unpublished study of young steelhead trout. For the sake of comparison, the data given by Fraser (1917) for the size of chinook salmon taken in the Straits of Georgia have been indicated

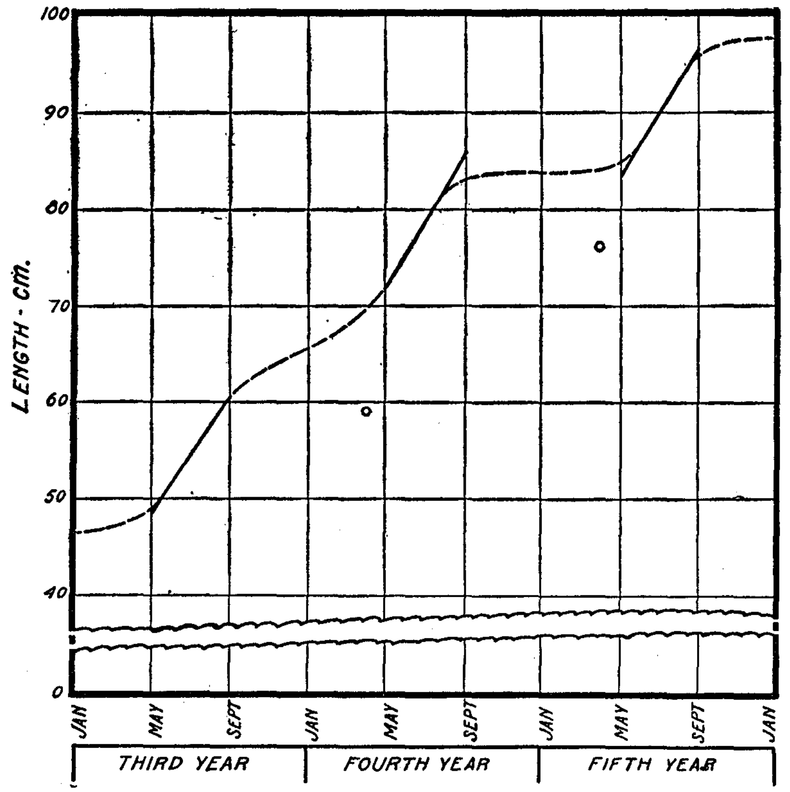


FIG. 23.—Growth curve of chinook salmon that migrated seaward after spending one year in fresh water (scales with stream type of nuclei). For explanation see Figure 22

on the figures. Fraser gives the size of fish of the different age groups at the end of each year as calculated from scale measurements. Since he has considered April 1 as marking the beginning of the new growth period, his data for the length of fish at the end of each year have been placed on the ordinate corresponding to this date. His data are not exactly comparable with ours, since his measurements do not include the caudal rays, while ours do so. On this account his figures fall consistently below those for the Columbia River fish but near enough so that it seems probable that the differences are due almost entirely to the different measurements used. There is very little variation in these differences, Fraser's figures being 6 to 10 cm. lower than ours.

The agreement in the data from the Straits of Georgia and from the ocean near the mouth of the Columbia River is remarkably close, considering the different conditions under which the data were collected. The growth is apparently nearly identical in the two localities. It seems evident that the growth curves given in Figures 22 and 23 represent quite accurately the average size of chinook salmon during their life in the ocean.

The results of this study of growth may be summarized as follows:

1. Examination of the trends of the variations in size of the different age groups during the season has shown that the variations are much more irregular among the fish taken in the river than among those taken in the ocean. Evidence is presented to show that these irregularities are due to variations in the racial constitution of the fish taken in the river. On this account the data from this source are not suitable as a basis for a study of growth. The data obtained from fish taken in the ocean is, however, suitable for such a study.

2. A growth curve has been based on the trends obtained from the study of the fish taken in the ocean. It has the form typical of organisms the growth of which continues over a series of years and shows seasonal fluctuations in rate. The agreement with similar data obtained by Fraser in his investigation of the salmon of the Straits of Georgia is very close—a fact which indicates that the growth curve presented in this paper may be relied upon to show the average size of chinook salmon in the general region of the Columbia River and Puget Sound during the greater part of their life in the ocean.

FISH TAKEN IN MONTEREY BAY

A few data are available from the chinook salmon taken by troll in Monterey Bay, Calif. A collection of scales was made during the summer of 1915, and at the same time a collection of egg samples was made. The egg samples were merely taken from the cleaning tables and, since the value of the size of the eggs in determining the relative maturity had not then been established, no attempt was made to take data and scales from the fish from which the eggs came. In fact, this value first became apparent through the study of this collection. In the summer of 1918 (June 19 to 21), a small collection of females was made and egg samples taken and tagged so that they could be identified with the corresponding scales and data. At the time this collection was made it was the intention to obtain many more data, but the fishing happened to be unusually poor and only 63 females could be obtained in the time available. The study of these few data has proved interesting, although they form an inadequate basis for final conclusions. More extensive studies of the fish taken in Monterey Bay are being made by the California Fish and Game Commission under the direction of Prof. J. O. Snyder, assisted by E. A. McGregor, to whom the writer is indebted for the privilege of examining some of their unpublished data.

SIZE

The length-frequency distributions for the various age groups found in the collections made in 1915 and 1918 are given in Tables 22 and 24 on pages 84 and 86. The number of individuals belonging to each age group and the average lengths are given in Table 13.

TABLE 13.—*Number of specimens and average length of salmon of each age group taken at Monterey*

	June 16, 1915		June 19 to 21, 1918			June 16, 1915		June 19 to 21, 1918	
	Number	Average length, centimeters	Number	Average length, centimeters		Number	Average length, centimeters	Number	Average length, centimeters
Ocean nuclei:					Stream nuclei:				
Second year	30	53.27	2	47.00	Third year	1	59.00	1	57.00
Third year	28	76.07	51	72.64	Fourth year	6	81.33	3	80.30
Fourth year	25	87.72	6	91.30	Fifth year	2	93.00		
Fifth year	14	96.60							

A comparison shows that these figures are, in the main, in fair agreement with the data from the Columbia River. A slight tendency is apparent, especially among the fish of the younger age groups, for the fish taken at Monterey to run larger than did the Columbia River fish in 1919, but many more data than are at present available will be necessary before this can be asserted with any certainty.

PERCENTAGES OF THE VARIOUS AGE GROUPS

The collection made in 1915 can not be considered as showing the proper percentages of fish of the various age groups. It was taken at a time when the fish were so segregated at the cannery that a random sampling was impossible. Individuals were sorted into three lots, according to size. One contained fish less than 5 pounds in weight, which was, at the time, the legal limit below which the fish could not be sold. Many fish of this size were taken by the fishermen and were brought to the canneries, only to be discarded. The second group contained fish between 5 and 15 pounds in weight, and the third group those above 15 pounds. In collecting these data it was necessary to handle the various sizes separately, and it was, therefore, impossible to get a fair sample of the take as a whole. The collection made in 1918 contains practically all of the females that were brought to one of the large canneries and to several of the smaller fish dealers during the period of three days in which the collection was made. It therefore represents a fair random sample of the take at that time. The percentages of fish of the different age groups are given in Table 14. The table also gives the percentages of fish of the different age groups as found by Mr. McGregor of the California Fish and Game Commission. His collection contained over 200 specimens taken between June 4 and June 22, 1921.

TABLE 14.—*Percentages of fish of different age groups in Monterey Bay*

Date	Age group							
	Ocean nuclei					Stream nuclei		
	Second year	Third year	Fourth year	Fifth year	Sixth year	Third year	Fourth year	Fifth year
June 19 to 21, 1918	3.2	81.0	9.5			1.6	4.7	
June 4 to 22, 1921	1.9	70.8	13.6	6.6	0.5	1.9	3.3	1.4

There is a remarkably close agreement between the figures for these two collections, when it is considered that they represent different years and the work of two entirely independent observers. The proportion of fish with ocean and with stream nuclei is almost identical—6.3 per cent of the 1918 collection and 6.7 of the 1921 collection having scales with the stream type of nuclei.

It was shown above that the percentage of fish with stream nuclei among the schools off the mouth of the Columbia River was close to 22 per cent, and the fact was mentioned that Fraser has found that 34.6 per cent of the chinook salmon taken during 1915 and 1916 in the straits of Georgia showed the stream type of nucleus. Although in 1917 Fraser found that the percentage of fish with the ocean type of nuclear growth was 78 per cent, identical with our findings in the fish taken near the mouth of the Columbia, it would seem probable that the salmon in the Straits of Georgia tend to contain a larger percentage of individuals that have remained an entire year in fresh water before migrating seaward. Gilbert (1922a) has found that the chinook or king salmon of the Yukon River invariably have scales with the stream type of nucleus.

These data indicate with considerable certainty that latitude, or more properly the differences in climatic conditions obtaining in different latitudes, has a definite effect upon the early history of the chinook salmon. In the more southerly latitudes the tendency is for the young fish to migrate soon after they become free-swimming, early in their first year. Under the influence of the more severe climatic conditions of the north, which cause later hatching and slower growth, the tendency is for greater and greater percentages of the fish to remain in the home stream during the first year.

A similar condition has been found to exist among the salmon of Norway. Dahl (1910) gives tables showing for three localities and for two years the percentages of these salmon that migrate seaward after spending 2, 3, 4, and 5 winters in fresh water. He concludes:

> A close examination of these tables shows that the age of the smolts at migration varies between 2 and 5 winters. In the south the smolts are generally young, but the farther north we go the more pronounced is the tendency for the fish to remain longer in the river before migration.

In this connection it is interesting to note that in a large river basin such as that of the Columbia River a distribution of races is found which is suggestive of this distribution in latitude. It is certain, from unpublished data in the hands of the writer, that as a rule the races in the Columbia which spawn in the higher tributaries are predominantly those which have the habit of remaining in fresh water during the first year and whose scales, therefore, show the stream type of nucleus. The races in the lower tributaries, on the other hand, migrate, as a rule, during the first year, and as a result the scales of the adults show the ocean type of nuclear growth. It is evident, therefore, that the effect of altitude on the early history of the chinook salmon is very similar to the effect of latitude—an increase in either altitude or latitude resulting in an increase in the number of young that remain in the stream during the entire first year. This similar influence of altitude and latitude is well known from the numerous studies of the geographical distribution of land animals and plants, and it is interesting to note the parallel effect on racial habit in such an anadromous form as the chinook salmon.

RELATIVE MATURITY

In the matter of relative maturity the salmon of Monterey Bay do not differ greatly from those taken off the mouth of the Columbia River. The distribution of egg sizes, as found in the collection of eggs made in 1915, is given in Table 23. In this table the egg sizes are given separately for the three size groups mentioned above—that is, for the fish less than 5 pounds in weight (Group 1), for those between 5 and 15 pounds (Group 2), and for those over 15 pounds (Group 3). Group 2 is composed largely of fish in their third year with ocean nuclei, and the distribution of egg sizes in this age group has been shown separately in Figure 3. Table 25 gives the distribution of egg sizes as found in the 1918 collection. Figure 24 shows

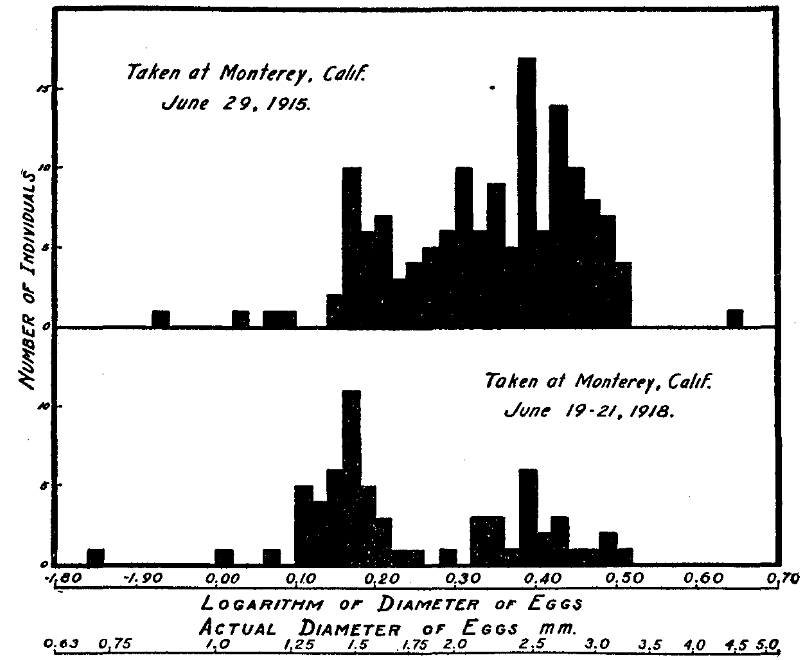


FIG. 24.—Distribution of egg sizes as found in two collections made at Monterey, Calif.

the distribution of egg sizes for both the 1915 and the 1918 collections. The general appearance of the two distributions is quite similar, although many more mature fish were taken in 1915 than in 1918, probably due to the selection involved in making the first collection, which has been mentioned above. A distinct bimodality is apparent in both collections. One mode appears in both at log D 0.17 and another at log D 0.39. The two modes in the distribution of egg sizes in the fish in their third year with ocean nuclei, as shown in Figure 3, are at the same points. Of the two groups shown in Figure 24 the fish with the larger eggs would undoubtedly have matured during the year in which they were taken, while the others would not have matured for at least one more year. There is obviously a certain amount of overlapping, which is especially evident in the 1915 collection. An examination of Table 23 on page 86 shows that the overlapping is entirely within the group of fish weighing from 5 to 15 pounds. The distribution of egg sizes within this group is quite irregular but is obviously bimodal. It has been possible, by the application of statistical methods, to separate the two component curves with some degree of satisfaction, but in view of the fact that the material is selected and therefore not representative it seems unnecessary to discuss this in detail. It is apparent from the table that all of the fish contained in the group weighing less than 5 pounds were immature and that all above 15 pounds in weight were destined to mature during the year in which they were taken.

The percentage of mature and immature fish can not be determined from the data available for 1915 on account of the selection involved in making the collection. The 1918 collection, although inadequate, gives some indication of the relative number of mature and immature fish present in Monterey Bay at the time the collection was made. In Table 25 (p. 87) and Figure 24 it is shown that the lines separating the two distinctive egg sizes comes at approximately log D 0.30. With the exception of one individual, for which the log D is 0.29, the two groups are well separated. If we include this doubtful individual with the group having the larger eggs, this group will include 24 individuals and the group with smaller eggs will contain 39 individuals. On a percentage basis, then, this collection contains 38.1 per cent mature and 61.9 per cent immature individuals. This agrees very closely with the data from the Columbia River. In Figure 11 the trend of the percentage of mature fish taken in the ocean near the mouth of the Columbia River shows that on the fiftieth day of the season, June 19, the catch contained 40 per cent of mature fish. Such a close agreement as this is doubtless accidental, but it indicates strongly that the relative maturity of the chinook salmon in Monterey Bay is, during the latter part of June at least, approximately the same as that of the salmon found in the ocean near the mouth of the Columbia River.

FISH FROM DRAKES BAY AND FORT BRAGG

A small collection of scales and eggs was made on August 15 and 16, 1918, by representatives of the California Fish and Game Commission from fish taken by troll in the region of Drakes Bay. This bay is located about 30 miles north of the Golden Gate and is one of the centers from which trolling is conducted. Scales and eggs from 12 chinook salmon taken near Fort Bragg were also taken on July 17. Since both collections were small, and separate study has disclosed no marked differences, they have been combined in the tables presented. Unfortunately serial numbers were not given to both scale and egg samples, and it is impossible to refer the scales to the corresponding eggs. The length of the fish was recorded with the scale samples, and a tag attached to the egg samples also gives the length of the fish from which the sample was taken, but except in a few extreme instances this does not serve to identify the corresponding samples. Furthermore, the number of egg samples does not agree with the number of females. On account of this confusion of the records, a satisfactory analysis is impossible, and it has been necessary to handle the data for size of fish and size of eggs separately.

Table 26 (p. 87) gives the length-frequency distributions for the fish with ocean nuclei. In addition to these there were four fish with stream nuclei, all in their third year and averaging 64.5 cm. in length. Three of these were females.

Comparison with the data from the Columbia River and from Monterey shows that the average lengths of the various age groups, as found near Fort Bragg and Drakes Bay, is substantially in agreement with the data from other sources, although, as at Monterey, the fish are somewhat longer than Columbia River fish of the same age groups. The data are too few, however, to give accurate results.

Table 27 (p. 88) and Figure 25 give the egg sizes found in these collections. Sixty-four females are available, and the table shows that they are divided, on the basis of the size of the eggs, into three well-marked groups—the group with the largest eggs destined to mature during the year in which they were captured and the others composed of immature individuals. Sixty-seven per cent were mature. This is a somewhat smaller percentage of mature fish than was found off the mouth of the Columbia River at the same time of year. Since most of the individuals contained in this collection from the northern coast of California were taken in Drakes Bay, August 15 and 16, the comparison has been made with the Columbia River fish taken August 15. Reference to Figure 11 shows that on this

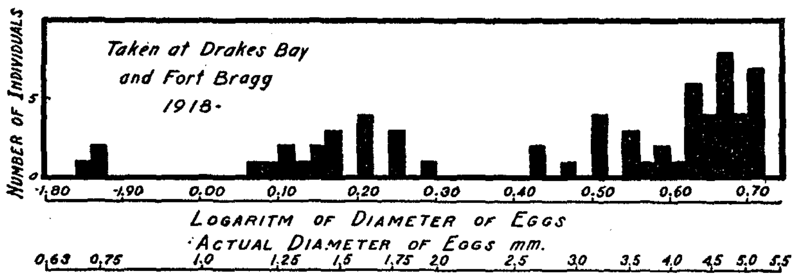


FIG. 25.—Distribution of egg sizes as found in a collection from Fort Bragg and Drakes Bay, Calif.

date (the one hundred and seventh day of the season) about 87 per cent of the fish taken near the mouth of the Columbia were mature. The discrepancy can hardly be considered as significant, however, on account of the inadequate number of data from Drakes Bay and Fort Bragg.

Since the egg samples were accompanied by data giving the length of the fish from which they were taken, and presumably, in the main, came from the same individuals from which scale samples were taken, an attempt has been made to determine which age groups were represented among the immature fish. A table has been prepared (Table 15) showing the correlation between length of fish and size of eggs, and also the range in the size of the fish composing the three groups distinguished by egg size. For the sake of comparison there is shown, in the same table, the range in size of the females found in the various age groups. From this table it is apparent that the fish with the smallest eggs were all in their second year. They were all between 40 and 50 cm. in length, and the only individuals of this size represented in the collection of scales were 2-year fish. The second group of fish (those with log D between 0.00 and 0.30) agree in length with those in their third year. There are 18 individuals in group 2, and in the scale collection 19 females were 3-year fish. The agreement between the two categories makes it seem practically certain that group 2 is composed largely, if not entirely, of fish in their third year with ocean nuclei. Group 3 (the mature individuals) is evidently composed mainly of fish in their fourth and fifth years.

TABLE 15.—*Chinook salmon taken by troll near Drakes Bay and Fort Bragg, Calif., July and August, 1918, tabulated to show correlation between size of eggs and length of fish*

Logarithm of diameter of eggs (mid-value of class)	Centimeter length (mid-value of class)							Total
	45	55	65	75	85	95	105	
1.85	3							3 (Group 1; 3 individuals).
.05			1	1				2
.15		1	4	2	1			8 (Group 2; 18 individuals).
.25			4		4			8
.45					3			3
.55				1	4	3	2	10 (Group 3; 43 individuals).
.65					5	10	8	23
.75						5	2	7
Total	3	1	9	4	17	18	12	64.
Group 1	3							3.
Group 2		1	9	3	5			18.
Group 3				1	12	18	12	43.

Females of scale collection tabulated according to length and age

	45	55	65	75	85	95	105	Total
Second year	3							3.
Third year			8	3	8			19.
Fourth year				1	2	17	10	30.
Fifth year							1	1.
Total	3		8	4	10	17	11	53.

SUMMARY AND CONCLUSIONS

1. It has been shown that the eggs of female chinook salmon undergo a well-marked differential growth during the growing period just preceding and terminating in the migration. As a result, those females which are destined to spawn during the year in which they are captured may be distinguished by the size of their eggs from those which will not mature for at least one more year.

2. Using the size of the eggs as a criterion, the commercial catch of salmon taken in the ocean near the mouth of the Columbia River has been analyzed and the percentage of mature and immature fish determined. It has been found that the percentage of mature fish taken in the ocean varies greatly during the season, being relatively small (from 10 to 20 per cent) in May but increasing gradually, until in August nearly 90 per cent are mature. While in general, as would be expected, fish taken within the Columbia River are mature, there are times when a few immature fish are taken by seines and traps in the extreme lower part of the estuary. The few data from Monterey and the northern coast of California are in substantial agreement with those from the region of the Columbia.

3. The immature fish taken in the ocean comprise, in the order of relative abundance, the following age groups: Third year, ocean nuclei; second year, ocean nuclei; third year, stream nuclei; fourth year, ocean nuclei; fourth year, stream nuclei; and fifth year, stream nuclei.

4. The relative abundance of fish with stream and with ocean nuclei has been considered, and it has been shown that about 22 per cent of the fish taken off the mouth of the Columbia River have scales with the stream type of nucleus. Since these fish are predominately from the Columbia River, this probably represents closely the percentage of fish of this category contained in the entire population.

5. Evidence is presented which shows that the more rigorous climatic conditions associated with higher latitudes and greater altitudes tend to increase the percentage of fish with stream nuclei—that is to say, more of the young fish remain in their home stream for at least one year after hatching.

6. Variations in size within the various age groups have been studied and a growth curve constructed. It has been found that the variations in the size of different races successively passing up the river on the spawning migration are such that data from this source can not be relied upon to show the growth. Similar variations among the fish taken in the ocean are, however, consistent, and may be depended upon to show the growth of the various age groups. Only this data has been used in constructing the growth curve.

7. The growth is typical of nearly all organisms in that it progresses at a maximum rate during the warmer part of the year—from May to September—and slows materially, if it does not stop entirely, during the colder months.

The undesirable features of the fishing for chinook salmon, which is carried on in the ocean by trolling and purse seining, are more or less obvious. A large percentage of immature fish are taken, which are far from having attained their maximum size and of relatively poor quality. They are feeding heavily, and the presence of large quantities of food in the stomach and intestines causes rapid spoiling. In many cases these immature fish are unfit for canning. On the other hand, the fish found in the river are, with very few exceptions, mature, and have definitely left their ocean feeding grounds and begun the long journey to the spawning beds. They have ceased feeding, and therefore growing, and the deterioration in the quality of flesh known to occur in salmon during their spawning migration will soon begin. Since the fish taken in the river have thus reached their maximum size and an optimum condition for commercial use, it seems logical that the commercial catch should be restricted to this stage in the life history.

From a business standpoint, the development of this ocean fishery would seem to be most undesirable. The poor quality of the outside fish, when canned, can not be questioned, and to continue to pack and market them as Columbia River chinook salmon can not fail to react unfavorably on the reputation of the Columbia River product. Many of the packers now place most of the fish taken outside in the inferior grades, marketing them as chums, but there is certain to be a constant tendency to place inferior fish with the better grades.

A much more important phase of the development of this outside fishery has to do with its effect on the conservation of the salmon run in the Columbia River. In order to understand this, however, it will be necessary to review briefly the recent history of the salmon industry in this district.

With slight fluctuations, which can not be referred definitely to any cause, the pack of chinook salmon on the Columbia River has remained fairly constant for the past 15 or 20 years. The opinion is current, however, that the run of salmon was low for the few years just preceding 1914, but in that year the run suddenly rose to normal again and was maintained at this higher level for a number of years. This erroneous opinion is the result of a common practice which considers only the canned product in discussing the trend of the productivity of the Columbia River. The figures for the canned pack alone support this contention but do not take into consideration the mild-curing industry, the development of which has had a marked effect on the production of canned salmon. Much of the mild-cured salmon was marketed in Europe and this market was suddenly closed by the opening of the

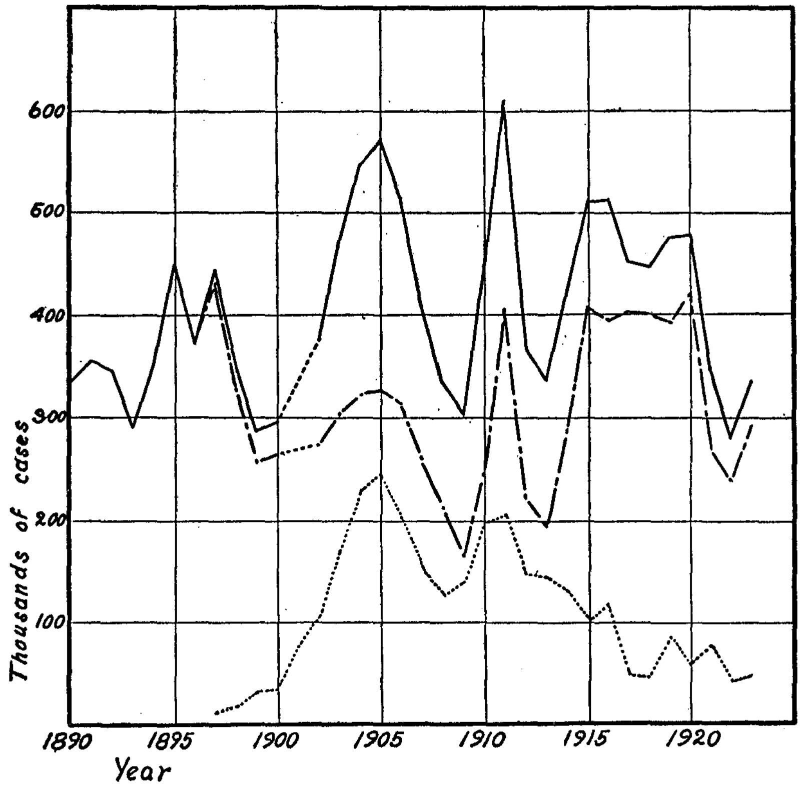


FIG. 26.—Pack of chinook salmon on the Columbia River, 1890 to 1923, inclusive. The mild-cured pack has been reduced to a basis of cases, one tierce being considered equal to 25 cases. Data from Cobb (1921) and Pacific Fisherman Year Book, 1924. Dotted line shows the mild-cure pack; broken line, the canned pack; and solid line, the total

World War in August, 1914. If this pack is calculated on the basis of cases of canned salmon and is added to the canned pack, the totals do not show a marked depression preceding 1914 nor a sudden rise in that year. There are fluctuations, of course, but there is nothing to show that they are systematic or other than "chance" variations.

This is apparent from Figure 26, which shows the number of cases of chinook salmon packed on the Columbia River from 1890 to 1923, both inclusive. The pack of mild-cured salmon is also shown, reduced to a basis of cases, and the total pack when these last data are added to the pack of canned salmon. The reduction of mild-cured salmon to a basis of cases has been made by considering that one tierce is the equivalent of 25 cases of canned fish. Published data are not available to show that this is a fair procedure, but it is believed that it gives a very close approximation to the truth. It is stated by Cobb (1921) that the loss in weight of mild-cured salmon "during the 2 or 3 weeks in which the fish lie in the first packing may be reckoned at 30 per cent." Packers on the Columbia River usually estimate that chinooks lose about 25 per cent of the round weight in cleaning preparatory to canning. Although the loss is probably a little more in the case of the fish that are mild cured, on account of the removal of the backbone, the figure is close enough for practical purposes. If, then, the weight of the cured fish is 70 per cent of the cleaned weight, and the cleaned weight is 75 per cent of the round weight, the total loss in weight during the entire process is 52.5 per cent of the round weight. It would therefore require 1,600 pounds of round fish to produce a tierce containing 830 pounds of mild-cured salmon. Canners on the Columbia River consider that it usually requires about 65 pounds of round fish to produce a case of canned fish, and on this basis 1,600 pounds would produce very close to 25 cases.

The Columbia River salmon fishery has for years been prosecuted with an intensity that makes it seem remarkable that a run of commercial value still remains. Figures, unfortunately, are not available to show how this intensity has increased since the beginning of the industry, but there can be no doubt that there has been a tremendous increase in the total fishing effort within the river. There has been not only an increase in the number of men, boats, and various units of gear, but a marked increase in the effectiveness with which the gear is employed. The motor boat has, within the last 20 years, replaced the slower sailboat, and the length of gill nets and seines and the size and effectiveness of fish wheels has increased. The fishing inside the river was, at the time the outside fishing first began, about as intensive as possible. Practically all good trap and wheel sites, seining grounds, and "drifts" in which gill nets could be operated were occupied. The discovery that salmon could be caught profitably outside the mouth of the river by trolling and in purse seines offered, therefore, a new avenue of expansion in which the fishermen so engaged did not come into direct and immediate competition with those already established on the fishing grounds in the river. It was found that the area in which such fishing could be carried on was wide, trollers ranging 20 to 30 miles in all directions from the mouth of the river. Such a broad region offered large possibilities for expansion and, since the outside fishing proved lucrative, it is not surprising that fishermen flocked to the new fields. Since this has not been accompanied by any appreciable reduction in the fishing effort within the river, it has meant a sudden and great increase in the total fishing effort directed against the salmon run of the Columbia River. Since a considerable portion of the total pack of salmon in the river has come from fish caught in the ocean, it means, further, that a correspondingly smaller percentage of the total pack has come from inside the mouth of the river from gill nets, seines, traps, and wheels.

From the evidence given above it is apparent that the immediate effect of the introduction of fishing methods that attack the immature fish found just off the mouth of the river is to increase the intensity of fishing, not only upon those salmon that are destined to mature and spawn during the year but also upon those that will form the spawning run the following year, and, to a more limited extent, the second year later. The full effect of the increased fishing effort during a given year will not, therefore, fall entirely upon that year but will be distributed over at least 3 years. Thus the outside fishing conducted in 1920 affected the run of mature fish into the river not only in 1920 but also in 1921 and 1922. Entirely apart from the fact that the young, immature fish produce an inferior product, this encroachment upon the runs of future years seems an especially vicious phase of this newly developed fishery. The full effect of the outside fishing is partially hidden; it is not immediately apparent in a decreased run into the river. It might, therefore, easily cause a very serious depletion before it became apparent that there was any danger of such an outcome.

At the same time other factors that have undoubtedly tended to reduce the supply of salmon have been at work. Many of the tributary streams that were once used as spawning beds by thousands of salmon are now blocked by dams of one sort or another, and other streams are made barren by the removal of quantities of water during the irrigation season. Large numbers of young salmon on their seaward migration become lost in the irrigation ditches or impounded in the pools left in the main stream as the water is drawn off for irrigation—where they die as the water warms and evaporates. On the whole, there is no question that the available spawning area in the Columbia River Basin has been materially reduced by such factors as these, and it seems probable that the encroachment on the spawning area will continue for some years to come. We have, then, a situation in which the continuance of the salmon is menaced on the one hand by a diminishing spawning area and on the other by an increased intensity of fishing. The various industrial and agricultural projects that are responsible for the erection of dams and irrigation ditches are of such importance that it is idle to suppose that they can long be opposed successfully by the interest of the salmon fishery. Regardless of right or wrong, it is inevitable that sooner or later the fisheries must disappear wherever they are directly and unavoidably opposed by the requirements of industrial and agricultural expansion.

Efforts to counteract the effect of these various agencies, all of which tend toward the destruction of the salmon, fall into three general categories: (1) Legal restrictions. These may affect the type or amount of gear used, the area open to fishing, and the time during which fishing may be conducted. (2) Construction of fishways over dams and of screens to irrigation ditches. (3) Artificial propagation.

The first of these is obviously designed to reduce the intensity of fishing. It is the oldest and still the most effective and indispensable of all means for conserving fishery resources. Unless a sufficient number of mature fish are permitted to ascend the rivers to the spawning areas, depletion is certain to occur regardless of any efforts that may be made in maintaining spawning areas or in reducing the mortality of the young fish by means of artificial propagation.

The construction and maintenance of fishways and screens to irrigation ditches is purely a palliative measure designed to offset in some measure the effect of encroaching civilization and development. They merely lessen to some extent the effect which the building of dams and irrigation ditches has in destroying spawning areas, and can not be expected fully to counteract the effect of this one destructive agency.

In artificial propagation we have a method designed to offset the work of destructive agencies, which is at once the hope and the despair of the scientific conservationist—the hope, in that it is so eminently logical to protect the young of the salmon during the early part of their life when the rate of mortality is high, and the despair, in that the evidence of its efficiency is inadequate and conflicting. Many instances can be adduced showing, apparently, the beneficial results of artificial propagation, but there are other instances in which no such results are to be observed. And if the extravagant claims of some of the proponents of artificial propagation were true we would long since have ceased to worry about the future of our salmon resources. The difficulty apparently lies in the fact that, as at present conducted, the procedure of artificial propagation is not based on scientific knowledge. With a gradual increase in the efficiency of hatchery procedure, which will come with placing it more and more on a truly scientific basis, we may hope that artificial propagation will come to be one of the most important factors in the preservation of our fishery resources. Noteworthy progress is being made by the Bureau of Fisheries toward this end, and it seems certain that the future development of artificial propagation is most promising. At the present time, however, it must be admitted that the importance of artificial propagation as a means of conserving the supply of salmon can not be accurately evaluated.

We are left, then, with the single alternative of maintaining the intensity of fishing below the danger point if the salmon run is to be preserved. Just what this point is no one can tell, and for that very reason it is essential to see that the intensity of fishing is kept down so as to provide what may be reasonably supposed to be a margin of safety. It is the duty of all who are interested in conservation to see that this is done—especially those officials whose duty it is so to administer the fisheries that depletion may not occur.

Just where do these facts fit into our discussion of the effect of the development of outside fishing on the supply of fish in the Columbia River? We have seen that the pack on the river has remained practically stationary for a number of years, during which time the intensity of fishing has been increased, especially by the addition of trolling and purse seining; that the spawning area is being gradually reduced; and finally, that a restriction of the amount of total fishing effort is essential to the maintenance of the run in the Columbia River.

It must always be an indication of danger if an appreciable increase in the intensity of fishing does not provide a corresponding increase in output. It must inevitably indicate that the productivity of a fishery is being maintained at a given level only by drawing to some extent upon the reserve stock needed for breeding if the race is to be maintained. Evidently a surplus of breeding adults is normally provided in nature, and it is only from this surplus that man can draw without immediately endangering the continuance of the supply. Any infringement upon the necessary breeding reserve is dangerous. A slight infringement may show no immediate effect, but if continued over a period of years the effect will be cumulative and is certain to end in disaster. The increase in fishing effort on the Columbia River by the development of trolling and purse seining has shown no corresponding increase in the total pack, and we may assume, therefore, that the present intensity of fishing is too great and is resulting in a dangerous reduction of the reserve of breeding adults. It may well, indeed, have been too great even before the outside fishing developed, in which case the new fishery is especially dangerous.

The intensity of fishing could, of course, be reduced by increasing restrictions on the gear used in the river, but this is hardly reasonable, since the outside fishery was the last to develop. It has further been shown that the outside fishing is uneconomical in that it takes the fish at a time when they are of poor quality and are much smaller than they would be at maturity, and that it is especially and subtly dangerous because it not only increases greatly the intensity of fishing but attacks the supply of fish one or two years before they become mature.

It is quite possible that these reasons are insufficient ones on which to base a legal restriction of this newly developed fishery, but if the run in the Columbia River is to be maintained we may be certain of one thing—if the outside fishing is not restricted, it will be a matter of a relatively short time only before the fishing in the river itself will have to be limited proportionally so as to supply the deficiency of spawning fish which is certain to result from the increased intensity of fishing caused by the development of trolling and purse seining. Efforts have been made to have restrictive legislation passed by the State legislatures of Oregon and Washington, but so far these efforts have met with only partial success. If it should prove impossible to prevent outside fishing entirely, it would seem desirable to limit such fishing to the latter part of the fishing season. This, at least, would reduce the number of immature fish taken, would tend to improve the quality of the pack, and would minimize to some extent the danger of seriously depleting the supply of fish before some indication of the imminence of such depletion has become apparent.

SUPPLEMENTARY TABLES

TABLE 16.—*Constants for each frequency distribution, Columbia River collections*

[F, female; M, male; S.D, standard deviation]

COLLECTIONS MADE INSIDE THE RIVER

Locality and date	Type of nucleus	Year class	Sex	Number	Length in centimeters		Logarithm of egg diameter	
					Mean	S. D.	Mean	S. D.
1. Ilwaco, May 10, 1919	Ocean	4	F	1	83.00		0.53	
	Stream	4	M	17	83.95			
			F	16	80.87		.531	
			Both	33	82.45±0.49	4.15±0.34		
		5	M	2	95.00			
			F	5	91.80		.582	
			Both	7	92.70			
2. Astoria, May 13, 1919	Ocean	2	M	6	41.00			
		3	M	2	56.00			
		4	M	2	83.00			
			F	5	87.00		.574	
			Both	7	85.86			
	Stream	3	M	36	48.67± .53	4.70± .37		
		4	M	41	73.73± .61	5.80± .43		
			F	28	75.85± .60	4.74± .43	.498±0.0075	0.0598±0.0054
			Both	69	74.59± .46	5.64± .32		
		5	M	6	82.66			
			F	12	87.64		.57	
			Both	18	86.00			
		6	M	1	105.00			
3. Seufert, Oreg., May 16, 1919	Stream	4	M	74	75.00± .41	5.28± .29		
			F	77	74.74± .34	4.40± .24	.5713±.0039	.0502± .0027
			Both	151	74.87± .27	4.86± .19		
		5	M	10	96.80			
			F	22	93.64± .61	4.24± .43	.6718±.0062	.0430± .0044
			Both	32	94.62± .56	4.72± .40		

TABLE 16.—*Constants for each frequency distribution, Columbia River collections*—Continued

COLLECTIONS MADE INSIDE THE RIVER—Continued

Locality and date	Type of nucleus	Year class	Sex	Number	Length in centimeters		Logarithm of egg diameter	
					Mean	S. D.	Mean	S. D.
4. Ilwaco, May 17 and 18, 1920 (from gill nets and traps).	Ocean	4	M	2	84.00			
			F	1	97.00		0.63	
			Both	3	88.33			
		5	M	1	111.00			
			F	1	93.00		.67	
			Both	2	102.00			
	Stream	4	M	3	66.33			
			F	3	78.33		.5366	
			Both	6	72.33			
		5	M	14	101.28			
			F	29	94.45±1.03	8.25±0.73	[1] .5804±0.0078	0.0600±0.0055
			Both	43	96.67±.87	8.48±.62		
5. Chinook, May 27, 1919 (from traps in Baker Bay).	Ocean	2	M	1	51.00			
		4	M	3	82.30			
			F	12	83.30		.572	
			Both	15	83.10			
			M	1	125.00			
	Stream	3	M	1	49.00			
		4	M	11	81.60			
			F	4	83.50		.584	
			Both	15	82.30			
		5	F	9	86.40		.595	
		6	F	2	93.00		.620	
6. Dodson, May 30 and 31, 1919 (from wheels and seines).	Ocean	2	M	4	46.50			
		3	M	1	65.00			
	Stream	3	M	11	49.90			
		4	M	34	77.29±1.01	8.78±.72		
			F	26	78.23±.96	7.30±.68	.5977±.0092	.0693±.0065
			Both	60	77.70±.71	8.18±.50		
		5	M	1	101.00			
			F	5	97.00		.6930	
			Both	6	97.80			
		6	M	1	111.00			
7. Ilwaco, June 10, 1919 (from gill nets).	Ocean	5	F	5	101.00		.550	
		6	M	2	114.00			
	Stream	4	M	3	82.33			
			F	2	84.00		.650	
			Both	5	83.00			
		5	M	3	108.00			
			F	4	94.50		.700	
			Both	7	100.30			
		6	M	1	123.00			
8. Seufert, June 16, 1919	Ocean	3	M	1	61.00			
		5	M	3	111.00			
			F	4	108.00		.565	
			Both	7	109.30			
		6	M	1	123.00			
			F	1	115.00		.53	
			Both	2	119.00			
	Stream	3	M	10	52.60			
		4	M	21	76.52±1.16	7.86±.82		
			F	26	81.54±1.03	7.76±.73	.6569±.0093	.0696±.0065
			Both	47	79.30±.81	8.20±.57		
		5	M	10	103.80			
			F	18	101.56±.96	6.06±.68	.6500±.0160	.1010±.0113
			Both	28	102.36±.76	6.00±.54		
		6	M	3	115.60			
			F	1	109.00		.51	
			Both	4	114.00			
9. Warrendale, June 16 and 17, 1919 (wheels and seines).	Ocean	3	M	1	67.00			
		4	F	1	91.00		.43	
		5	M	10	114.60			
			F	10	108.80		.538	
			Both	20	111.70±.89	5.9 ±.63		
	Stream	3	M	11	54.64			
		4	M	50	72.92±.72	7.5 ±.51		
			F	17	81.35±1.03	6.3 ±.73	.6324±.0087	.0530±.0061
			Both	67	75.06±.66	8.08±.47		
		5	M	6	102.00			
			F	20	96.00±.76	5.02±.54	.6910±.0075	.0496±.0053
			Both	26	98.00±.86	6.50±.61		
		6	M	1	123.00			

[1] Calculated for 27 mature specimens. For one other log *D* was 0.11; for another, 0.29.

TABLE 16.—*Constants for each frequency distribution, Columbia River collections*—Continued

COLLECTIONS MADE INSIDE THE RIVER—Continued

Locality and date	Type of nucleus	Year class	Sex	Number	Length in centimeters		Logarithm of egg diameter	
					Mean	S. D.	Mean	S. D.
10. Astoria, June 24 and 25, 1919 (seines).	Ocean	2	M	2	50.00			
		3	M	8	60.50			
		4	M	3	79.60			
			F	11	81.50		0.588	
			Both	14	81.10			
		5	M	2	112.00			
			F	3	96.20		.510	
			Both	5	102.50			
		6	M	1	123.00			
			F	4	106.00		.550	
			Both	5	109.50			
	Stream	3	M	3	49.60			
		4	M	8	77.30			
			F	5	84.20		.618	
			Both	13	79.90			
		5	F	3	95.00		.683	
		6	F	1	101.00		.550	
11. Ilwaco, July 3, 1919 (traps).	Ocean	3	F	1	71.00		.5100	
		4	F	24	83.58±0.54	3.93±0.38	.5900±0.0046	.0332±0.0032
		5	F	17	99.94±1.12	6.82± .79	.6029± .0062	.0381± .0044
		6	F	3	108.30		.6570	
	Stream	3	F	1	59.00		.0100	
		4	F	4	85.50		.5950	
		5	F	1	89.00		.6300	
12. Sand Island, July 7, 1919 (seines).	Ocean	2	M	21	43.38± .51	3.46± .36		
			F	5	48.60		$\bar{1}$.902	
			Both	26	44.38± .53	4.04± .38		
		3	M	3	57.67			
			F	2	71.00		One 0.11 and another 0.51	
			Both	5	63.00			
		4	M	2	87.00			
			F	20	83.30± .92	6.10± .65	0.5880± .0047	.0309± .0033
			Both	22	83.54± .90	6.24± .63		
		5	M	10	104.20			
			F	8	100.00		.5925	
			Both	18	102.33±1.34	8.42± .95		
		6	M	2	121.00			
	Stream	3	M	5	48.60			
			F	4	48.00		$\bar{1}$.850	
			Both	9	48.30			
		4	M	1	63.00			
			F	1	83.00		0.63	
			Both	2	73.00			
		5	F	1	89.00		.69	
13. Warrendale, July 16, 1919 (wheels).	Ocean	2	M	36	41.55± .53	4.72± .37		
		3	M	29	60.58± .63	5.04± .45		
			F	2	72.00		.60	
			Both	31	61.32± .68	5.63± .48		
		4	M	25	83.24±1.15	8.50± .81		
			F	19	79.95± .89	5.79± .63	.6247± .0072	.0466± .0051
			Both	44	81.82± .78	7.63± .55		
		5	M	10	106.40			
			F	18	97.67±1.10	6.95± .78	.6555± .0074	.0466± .0052
			Both	28	100.78±1.19	9.33± .84		
		6	M	3	119.00			
	Stream	3	M	28	57.50± .48	3.8 ± .34		
		4	M	6	79.40			
			F	4	82.00		.66	
			Both	10	80.40			
		5	F	2	90.00		.68	
		6	F	1	103.00		.67	
14. Ilwaco, July 28, 1919 (traps)	Ocean	3	M	2	63.00			
		4	M	13	87.48			
			F	8	89.74		.65	
			Both	21	88.33±1.33	9.12± .95		
		5	M	10	108.80			
			F	15	96.88		.658	
			Both	25	101.64±1.14	8.48± .81		
		6	M	1	113.00			
	Stream	4	M	1	72.50			

TABLE 16.—*Constants for each frequency distribution, Columbia River collections*—Continued

COLLECTIONS MADE INSIDE THE RIVER—Continued

Locality and date	Type of nucleus	Year class	Sex	Number	Length in centimeters		Logarithm of egg diameter	
					Mean	S. D.	Mean	S. D.
15. Seufert, Aug. 5, 1919 (wheels).	Ocean	2	M	5	39.30			
		4	M	4	84.00			
			F	4	77.50		0.662	
			Both	8	80.75			
		5	M	3	109.50			
			F	1	99.00		.721	
			Both	4	106.90			
		6	M	1	125.00			
	Stream	2	M	1	26.50			
		3	M	3	49.50			
		4	M	1	87.50			
		5	M	1	103.00			
16. Dodson, Aug. 6, 1919 (seines).	Ocean	2	M	10	41.80			
		3	M	6	60.34			
		4	M	23	[2] 90.04			
			F	21	[2] 84.72		.6824±0.0047	0.0323±0.0033
			Both	44	[2] 87.44			
		5	M	15	107.26			
			F	13	97.46		.6778	
			Both	28	102.71±0.93	7.28±0.66		
	Stream	3	M	3	55.00			
		4	F	3	85.00		.6833	
		5	F	1	99.00		.7100	
17. Astoria, Aug. 22, 1919 (seines).	Ocean	2	M	1	49.00			
		3	M	13	77.30			
			F	8	82.50		.7426	
			Both	21	79.28±1.42	9.66±1.00		
		4	M	37	See text, p. 53, and Table 19.			
			F	25			.7316± .0098	.0730± .0069
			Both	62				
		5	F	3	90.33		.7100	
	Stream	4	M	2	77.00			
			F	3	87.67		.7033	
			Both	5	83.50			
		5	F	1	89.00		.71	
		6	F	1	103.00		.59	
18. Astoria, Sept. 12, 1919 (seines).	Ocean	3	M	14	70.29			
			F	7	78.80		.7614	
			Both	21	73.10±1.31	8.94± .93		
		4	M	35	See text, p. 53, and Table 20.			
			F	21			.8233± .0076	.0550± .0053
			Both	56				
		5	M	2	112.00			
			F	4	93.00		.8100	
			Both	6	99.30			
	Stream	4	F	3	87.70		.8167	
		5	M	1	103.00			
			F	3	92.30		.7967	
			Both	4	95.00			
		6	M	4	105.00			
			F	1	103.00		.7500	
			Both	5	104.60			
COLLECTIONS OF FISH TAKEN IN THE OCEAN BY TROLL UNLESS OTHERWISE STATED								
19. May 8 to 10, 1919	Ocean	2	M	17	44.53±0.61	3.72±0.43		
			F	19	43.10± .50	3.26± .36	$\bar{1}.8100$±0.0085	0.0548±0.0060
			Both	36	43.78± .40	3.57± .27		
		3	M	51	62.41± .51	5.43± .36		
			F	102	61.00± .38	5.68± .27	[3] 0.1042± .0034	.0500± .0024
			Both	153	61.46± .31	5.64± .22		
		4	M	3	80.33			
			F	18	79.56± .71	4.46± .50	.3174	
			Both	21	79.67± .63	4.25± .44		
		5	F	1	93.00		.3900	
	Stream	3	M	34	49.06± .43	3.74± .31		
			F	18	48.11± .59	3.72± .42	$\bar{1}.9588$± .0092	.0580± .0065
			Both	52	48.73± .35	3.76± .25		
		4	M	2	66.00			
			F	2	74.00		0.3800	
			Both	4	70.00			
		5	F	3	85.67		.5300	
		6	F	2	95.00		.5800	

[2] The distributions were so irregular and, especially in the case of the males, suggestive of bimodality, that it seemed useless to calculate the standard deviation and the probable errors until a more detailed study can be made.

[3] Excluding 2 individuals with log D greater than 0.30. (See p. 34.)

TABLE 16.—*Constants for each frequency distribution, Columbia River collections*—Continued

COLLECTIONS OF FISH TAKEN IN THE OCEAN BY TROLL UNLESS OTHERWISE STATED—Contd

Locality and date	Type of nucleus	Year class	Sex	Number	Length in centimeters		Logarithm of egg diameter	
					Mean	S. D.	Mean	S. D.
20. May 18, 1920	Ocean	3	M	64	71.16±0.40	4.74±0.28		
			F	39	70.74± .57	5.25± .40	(See Table 21.)	
			Both	103	71.00± .33	4.95± .23		
		4	M	29	84.52± .97	7.73± .68		
			F	36	83.00± .63	5.66± .45	(See Table 21.)	
			Both	65	83.68± .56	6.70± .40		
		5	M	20	99.60±1.22	8.12± .87		
			F	13	96.15		0.4054	
			Both	33	98.09± .92	7.84± .65		
	Stream	4	M	15	73.80			
			F	13	76.54		(See Table 21.)	
			Both	28	75.07± .79	6.18± .56		
		5	M	8	87.40			
			F	6	89.70		.4333	
			Both	14	88.40			
21. May 24, 1919	Ocean	2	M	3	46.30			
			F	4	43.50		$\bar{1}.8000$	
			Both	7	44.70			
		3	M	5	66.20			
			F	8	62.50		[4] 0.0980	
			Both	13	63.90			
		4	M	3	77.00			
			F	3	77.70		.2567	
			Both	6	77.30			
	Stream	3	M	3	53.60			
			F	1	61.00		.0700	
			Both	4	55.50			
22. June 4, 1919	Ocean	2	M	11	46.45			
			F	18	44.78± .45	2.81± .32	$\bar{1}.8280$±0.0178	0.0756±0.0137
			Both	29	45.41± .34	2.69± .24		
		3	M	25	63.40± .82	6.09± .58		
			F	32	61.61± .59	5.05± .42	0.0981± .0056	.0474± .0040
			Both	57	62.38± .49	5.60± .37		
		4	M	3	84.30			
			F	1	83.00		.25	
			Both	4	84.00			
		5	F	1	99.00		.45	
	Stream	2	M	1	37.00			
		3	M	11	52.80			
			F	11	50.40		$\bar{1}.948$	
			Both	22	51.66± .60	4.10± .43		
		4	F	4	75.50		0.255	
		5	M	1	91.00			
			F	1	81.00		.270	
			Both	2	86.00			
23. June 10, 1919	Ocean	2	M	7	47.20			
			F	3	50.60		$\bar{1}.931$	
			Both	10	48.22			
		3	M	3	63.30			
			F	3	72.00		0.169	
			Both	6	67.70			
		4	M	1	97.00			
			F	1	92.00		.681	
			Both	2	94.50			
	Stream	3	M	4	53.00			
			F	2	47.00		$\bar{1}.919$	
			Both	6	51.00			
24. June 21, 1919	Ocean	2	M	4	48.00			
			F	6	46.30		$\bar{1}.845$	
			Both	10	47.00			
		3	M	11	67.80			
			F	4	72.50		[5]	
			Both	15	69.12			
		4	M	10	85.40			
			F	10	86.40		0.510	
			Both	20	58.90±1.16	7.72± .82		
		5	F	2	97.00		.550	
	Stream	3	M	8	54.70			
			F	4	54.50		.000	
			Both	12	54.60			
		4	M	2	82.00			
			F	5	81.80		.586	
			Both	7	81.86			
		5	F	1	95.00		.690	

[4] Exclusive of 1 individual with large eggs; log D greater than 0.30.
[5] Two individuals had small eggs, log D 0.10, and two had large eggs, log D 0.50.

TABLE 16.—*Constants for each frequency distribution, Columbia River collections*—Continued

COLLECTIONS OF FISH TAKEN IN THE OCEAN BY TROLL UNLESS OTHERWISE STATED—Contd.

Locality and date	Type of nucleus	Year class	Sex	Number	Length in centimeters		Logarithm of egg diameter	
					Mean	S. D.	Mean	S. D.
25. June 25, 1919 (purse seines)	Ocean	2	F	3	45.50		$\bar{1}$.8990	
		3	M	1	65.00			
		4	M	1	88.50			
			F	2	83.50		0.5430	
			Both	3	85.20			
	Stream	3	M	1	56.50			
			F	1	46.00		$\bar{1}$.9590	
			Both	2	51.20			
		4	M	1	83.00			
			F	1	79.00		0.5610	
			Both	2	81.00			
26. July 2, 1919	Ocean	2	F	14	49.30		$\bar{1}$.8730	
		3	F	31	67.45± .69	5.72±0.49	[6] 0.1085±0.0052	0.0396±0.0037
		4	F	23	83.78± .90	6.37± .63	[7] .5336± .0116	.0805± .0082
		5	F	11	95.40		.5792	
	Stream	3	F	7	55.00		.0214	
		4	F	10	79.60		[8] .4340	
		5	F	3	88.40		.5300	
27. July 28, 1919	Ocean	2	F	3	55.67		$\bar{1}$.9100	
		3	F	16	71.01		[9] 0.1531	
		4	F	49	89.33± .64	6.64± .45	.6406± .0059	.0618± .0042
		5	F	18	96.22± .75	4.72± .53	.6733± .0094	.0594± .0067
		6	F	1	103.00		.6900	
	Stream	3	F	7	59.00		.0756	
		4	F	3	82.33		[10] .6800	
		5	F	1	87.00		.6100	
28. Aug. 3-5 and 25, 1914 (selected as "grilse").	Ocean	2	M	35	51.91± .51	4.47± .36		
			F	38	51.37± .36	3.35± .25		
			Both	73	51.63± .30	3.80± .21		
		3	F	2	62.00			
	Stream	2	M	2	40.00			
		3	M	4	56.50			
			F	12	57.50			
			Both	16	57.25			
29. Aug. 13, 1919	Ocean	2	F	2	57.00		$\bar{1}$.9300	
		3	F	15	78.60		[11] 0.7210	
		4	F	66	93.00± .62	7.48± .43	[12] .7243± .0060	.0706± .0042
		5	F	4	103.00		.7800	
	Stream	3	F	1	59.00		.0300	
		4	F	7	81.00		[13] .6767	
30. Aug. 13-17, 1918 (five taken in September).	Ocean	2	F	5	53.00		$\bar{1}$.9500	
		3	F	25	86.60±1.04	7.70± .74	[14] 0.7580± .0035	.0235± .0024
		4	F	20	95.30± .98	6.50± .69	[15] .7426± .0127	.0820± .0090
		5	F	10	100.16± .99	6.40± .70	.7553± .0121	.0784± .0086
	Stream	3	F	2	66.00		.1300	
		4	F	3	87.00		.7170	
		5	F	27	95.59± .77	5.96± .55	.7811± .0043	.0332± .0030
		6	F	1	95.00		.7500	
31. Sept. 18 and 19, 1919	Ocean	2	M	5	52.20			
			F	2	56.00		.0000	
			Both	7	53.30			
		3	M	7	75.28			
			F	7	70.72		.1500	
			Both	14	73.00			
		6	M	1	103.00			
			F	1	99.00		.7700	
			Both	2	101.00			
		3	M	1	55.00			
			F	2	66.00		.1000	
			Both	3	62.33			
		4	M	3	91.00			
		5	M	1	103.00			

[6] Exclusive of 5 individuals, for which log *D* was 0.4340.
[7] Exclusive of 1 individual, for which log *D* was 0.1900.
[8] Exclusive of 3 individuals, for which log *D* was 0.1766.
[9] Exclusive of 3 individuals, for which log *D* was 0.6167.
[10] Exclusive of 1 individual, for which log *D* was 0.2500.
[11] Exclusive of 6 individuals, for which log *D* was 0.1430.
[12] Exclusive of 3 individuals, for which log *D* was 0.3030.
[13] Exclusive of 1 individual, for which log *D* was 0.2700.
[14] Exclusive of 4 individuals, for which log *D* was 0.1600.
[15] Exclusive of 1 individual, for which log *D* was 0.2500.

TABLE 17.—*Chinooks taken in wheels in the Columbia River near Warrendale, Oreg., July 16, 1919*

Females tabulated according to size of eggs, type of nucleus, and age

Logarithm of diameter of eggs (mid-value of class)	Ocean nuclei			Stream nuclei			Total
	Third year	Fourth year	Fifth year	Fourth year	Fifth year	Sixth year	
0.55		1	1				2
.57		4	1				5
.59	1	2		1			4
.61	1	2	1				4
.63		2	4				6
.65		2	2				4
.67		4	2	1	1	1	9
.69		1	3	2	1		7
.71		1	4				5
Total	2	19	18	4	2	1	46
Mean	0.60	0.6247±0.0072	0.6555±0.0074	0.66	0.68	0.67	
Standard deviation		.0466± .0051	.0466± .0052				

TABLE 18.—*Chinooks taken by troll off the mouth of the Columbia River, July 28, 1919, collected at Ilwaco, Wash. Females only*

Tabulated according to size of eggs, type of nucleus, and age[1]

Logarithm of diameter of eggs (mid-value of class)	Ocean nuclei				Stream nuclei		Total
	Second year	Third year	Fourth year	Fifth year	Third year	Fourth year	
$\bar{1}.81$	1						1
.95*	1						1
.97	1						1
0.03*					1		1
.05		1			1		2
.07					2		2
.09					1		1
.11		1			2		3
.13		2					2
.15		2					2
.17		4					4
.19		2					2
.21		1					1
.25*						1	1
.51**			1				1
.53							
.55			2				2
.57		1	3				4
.59			6	1			7
.61			6	3			9
.63		1	11	3			15
.65		1	6	3		1	11
.67			4				4
.69			4	2			6
.71				1		1	2
.73			2	2			4
.75			1	1			2
.77			1	1			2
.79			1	1			2
.81							
.83			1				1
Total	3	16	49	18	7	3	96
Mean	$\bar{1}.91$	Immature 0.1531 Mature .6167	0.6406±0.0059	0.6733±0.0094	0.0756	Immature 0.25 Mature .68	
Standard deviation			.0618± .0042	.0594± .0067			

[1] Two specimens, one a 5-year fish with the stream type of nucleus and one a 6-year fish with the ocean type of nucleus, are omitted from the table. The logarithm of the diameter of the eggs in the case of the 5-year fish was 0.61, and for the 6-year fish 0.69.

TABLE 19.—*Chinook salmon taken by seines on the lower Columbia River, collected at Astoria, Oreg., August 22, 1919*

Tabulated according to length, type of nucleus, age and sex[1]

Centimeter length (mid-value of class)	Ocean nuclei								Stream nuclei				Total
	Second year	Third year			Fourth year			Fifth year	Fourth year			Fifth year	
	Male	Male	Female	Total	Male	Female	Total	Female	Male	Female	Total	Female	
49	1												1
53*		1		1									1
65*		1		1									1
67					1		1						1
69		2		2	1		1						3
71					1		1						1
73		2		2	1		1						3
75			1	1	4		4		1		1		6
77		1	1	2	4		4						6
79			1	1	2	3	5		1		1		7
81		1		1	2	4	6						7
83		1	1	2	1	1	2						4
85			1	1	1	3	4						5
87			3	3	1		1	1		2	2		7
89		1		1				1		1	1	1	4
91		3		3	2	1	3						6
93						1	1						1
95						3	3	1					4
97					2	3	5						5
99					2	2	4						4
101					3	4	7						7
103					4		4						4
105					1		1						1
107					2		2						2
109					2		2						2
Total	1	13	8	21	37	25	62	3	2	3	5	1	93
Mean	49.0	77.30	82.50	79.28±1.42	(2)	(2)	(2)	90.33	77.00	87.67	83.50	89.00	
Standard deviation				9.66±1.00									

[1] In addition to the specimens tabulated above there was 1 female 103 cm. long, in its sixth year, stream nucleus.

[2] The apparent bimodality of the distributions of the 4-year fish has been discussed on page 53. The various averages and standard deviations are as follows: (1) Fish less than 90 cm. in length—males (19 specimens), mean, 77.00±0.77, standard deviation, 4.98±0.55; females (11 specimens), mean, 81.73; total (30 sepcimens), mean, 78.74±0.59, standard deviation, 4.78±0.43. (2) Fish greater than 90 cm. in length—males (18 specimens), mean, 101.44±0.81; standard deviation, 5.10±0.57; females (14 specimens), mean, 97.30; total (32 specimens), mean, 99.62±0.57, standard deviation, 4.80±0.41.

TABLE 20.—*Chinook salmon taken in beach seines on the lower Columbia River collected at Astoria, Oreg., September 12, 1919*

Tabulated according to length, type of nucleus, age, and sex

Centimeter length (mid-value of class)	Ocean nuclei									Stream nuclei							Total
	Third year			Fourth year			Fifth year			Fourth year	Fifth year			Sixth year			
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Female	Male	Female	Total	Male	Female	Total	Total
57	1		1														1
61*	1		1														1
63		1	1														1
65	3		3														3
69*	4		4		1	1											5
71	1	1	2														2
73				3		3											3
75	1		1	4		4											5
77				4		4											4
79	1	1	2	3	1	4											6
81		1	1	1	3	4											5
83	1		1	2	1	3											4
85		2	2	2	4	6		2	2	1							11
87	1	1	2							1		1	1				4
89				1		1											1
91				1		1				1							2
93					3	3											3
95				3	2	5						2	2	1		1	8
97					1	1											1
99					2	2											2
101				1	2	3		2	2								5
103				2		2					1		1	1	1	2	5
105				5	1	6								1		1	7
109*				2		2											2
111							1		1								1
113							1		1								1
115				1		1											1
117														1		1	1
Total	14	7	21	35	21	56	2	4	6	3	1	3	4	4	1	5	95
Mean	70.29	78.80	73.10±1.31	(1)	(1)	(1)	112.00	93.00	99.30	87.7	103.00	92.30	95.00	105.00	103.00	104.60	
Standard deviation			8.94± .93														

[1] The two types (small and large) of 4-year fish with ocean nuclei have been separated, as was done in Table 19. (See p. 53.) The means and standard deviations are as follows: (1) Fish less than 90 cm. in length—males (20 specimens), mean, 78.50±0.66, standard deviation, 4.42±0.47; females (10 specimens), mean, 81.40; total (30 specimens), mean, 79.53±0.56, standard deviation, 4.55±0.41. (2) Fish greater than 90 cm. in length—males (15 specimens), mean, 102.76; females (11 specimens), mean, 97.37; total (26 specimens), mean, 100.46±0.78, standard deviation, 5.94±0.55.

TABLE 21.—*Chinooks taken by troll near the mouth of the Columbia River, collected at Ilwaco, Wash., May 18, 1920*

Females tabulated according to size of eggs, type of nucleus, and age

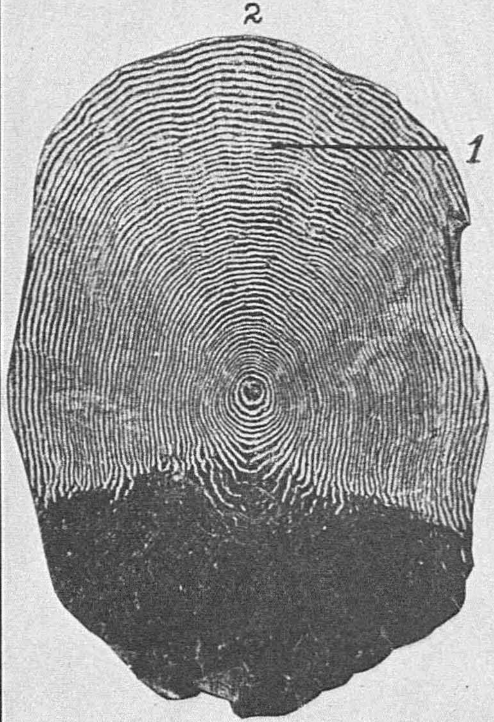
Logarithm of diameter of eggs (mid-value of class)	Ocean nuclei			Stream nuclei		Total
	Third year	Fourth year	Fifth year	Fourth year	Fifth year	
0.05	1					1
.07	2					2
.11*	3					3
.13	8					8
.15	7					7
.17	4			1		5
.19	3					3
.21	1	1		1		3
.23	1	4		3		8
.25		5	1	1		7
.27	1	3				4
.29		1		1	1	3
.31			1			1
.33	1	1				2
.35	1	2	1	1		5
.37	1	5	1			7
.39	1	2	1	2		6
.41	1	1	4		1	7
.43	2	2		1	3	8
.45	1	3	2	1		7
.47		2				2
.49		1		1		2
.51			1			1
.55*		3	1			4
.61*					1	1
Total	39	36	13	13	6	107
Mean	(1)	(2)	0.4054	(3)	0.4333	

[1] Group with log D less than 0.30, mean is 0.1474 ± 0.0053; standard deviation is 0.0444 ± 0.0038. Group with log D greater than 0.30, mean is 0.395.
[2] Group with log D less than 0.30, mean is 0.2486. Group with log D greater than 0.30, mean is 0.4254 ± 0.0095; standard deviation is 0.0658 ± 0.0067.
[3] Group with log D less than 0.30, mean is 0.2300. Group with log D greater than 0.30, mean is 0.4167.

TABLE 22.—*Chinook salmon taken by troll in Monterey Bay, Calif., June 16, 1915*

Tabulated according to length, type of nucleus, age, and sex

Centimeter length (mid-value of class)	Ocean nuclei								
	Second year			Third year			Fourth year		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
47	1	1	2						
49	2	1	3						
51	7	2	9						
53	2	2	4						
55	3	1	4						
57	5		5						
59	2		2						
63*	1		1						
67*					1	1			
69				2		2			
71				2	1	3			
73				3	4	7			
75				3		3			
77				2		2	1		1
79				1	3	4			



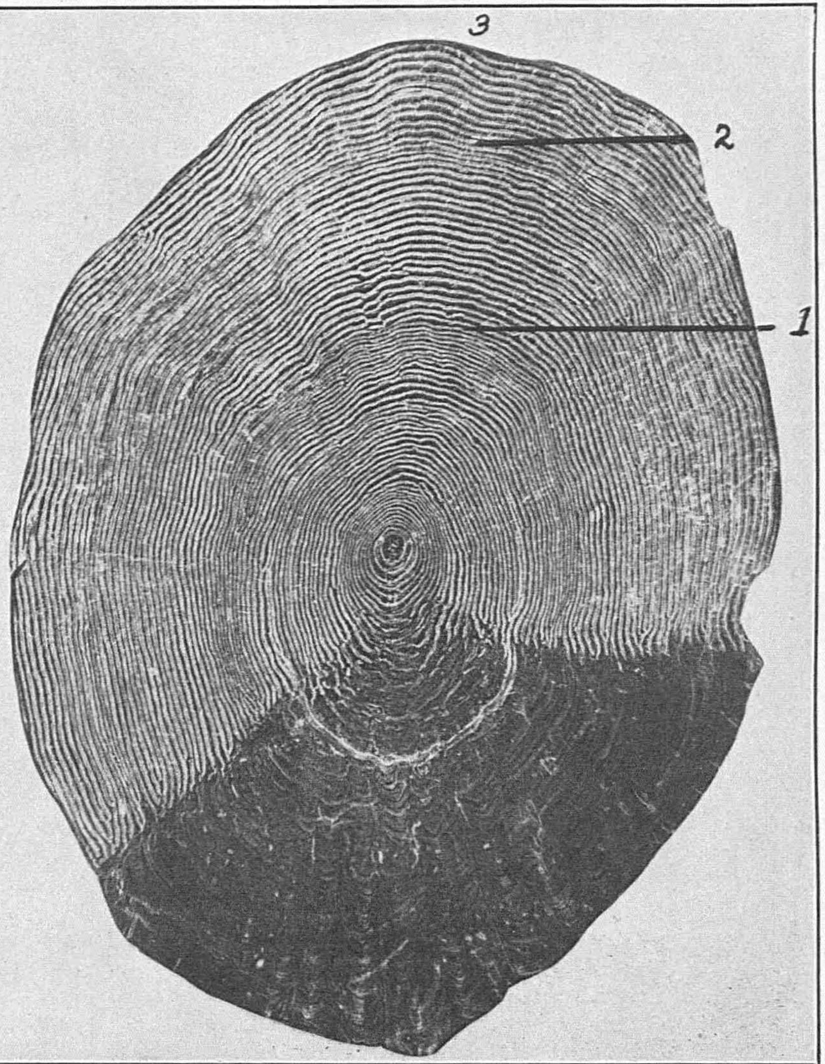


FIG. 27.—Chinook salmon in its second year, ocean nucleus, immature. Female, 51 cm., log. *D* 1.91. Taken by troll off the mouth of the Columbia River, June 4, 1919. ×20

FIG. 28.—Chinook salmon in its third year, ocean nucleus, immature. Female, 67 cm., log. *D* 0.113. Taken by troll off the mouth of the Columbia River, July 2, 1919. ×20

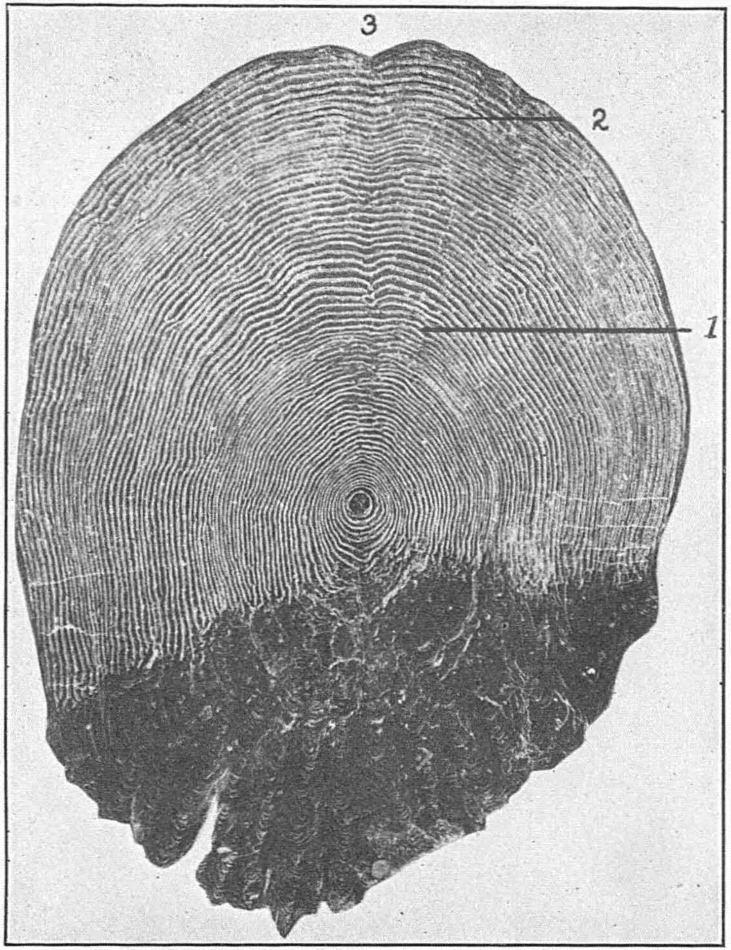


FIG. 29.—Chinook salmon in its third year, ocean nucleus, mature. Female, 66 cm., log. *D* 0.431. Taken by troll off the mouth of the Columbia River, July 2, 1919. ×20

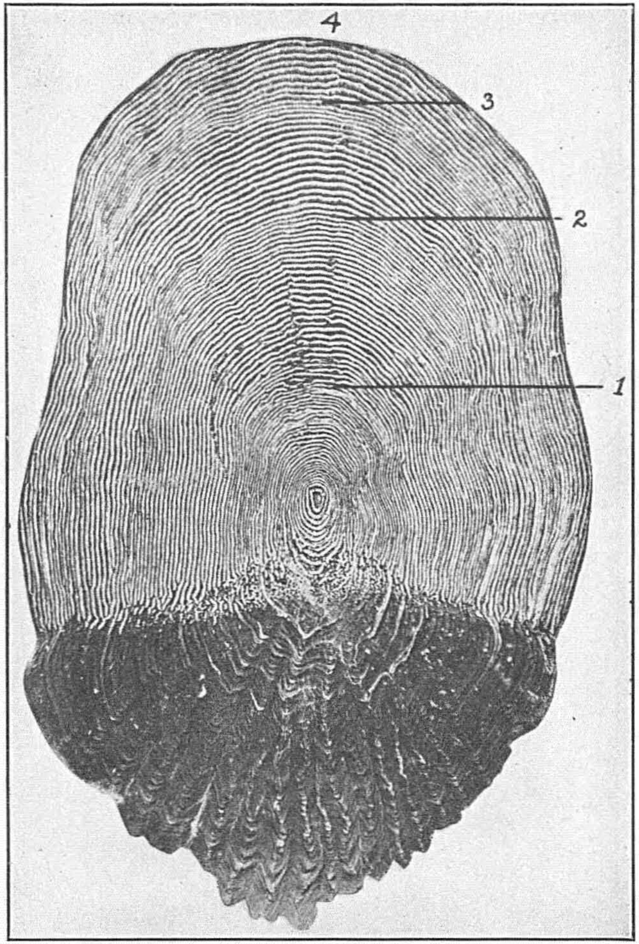


FIG. 30.—Chinook salmon in its fourth year, ocean nucleus, immature. Female, 80 cm., log. *D* 0.281. Taken by troll off the mouth of the Columbia River, August 13, 1919. ×20

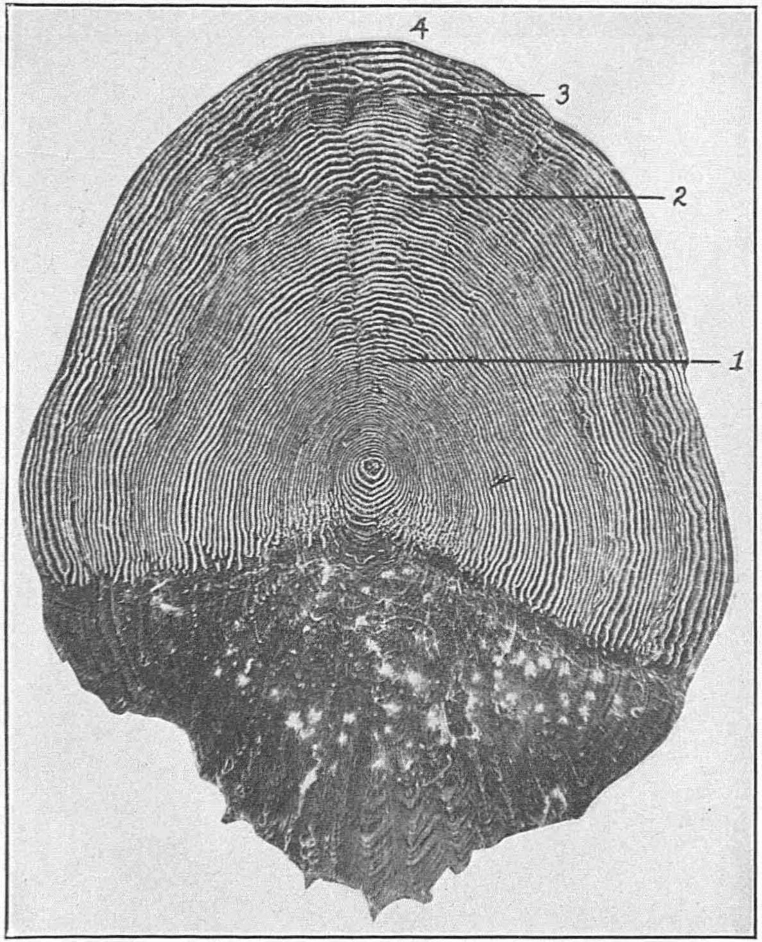


FIG. 31.—Chinook salmon in its fourth year, ocean nucleus, mature. Female, 77 cm., log. D 0.643. Taken by troll off the mouth of the Columbia River, August 13, 1919. ×20

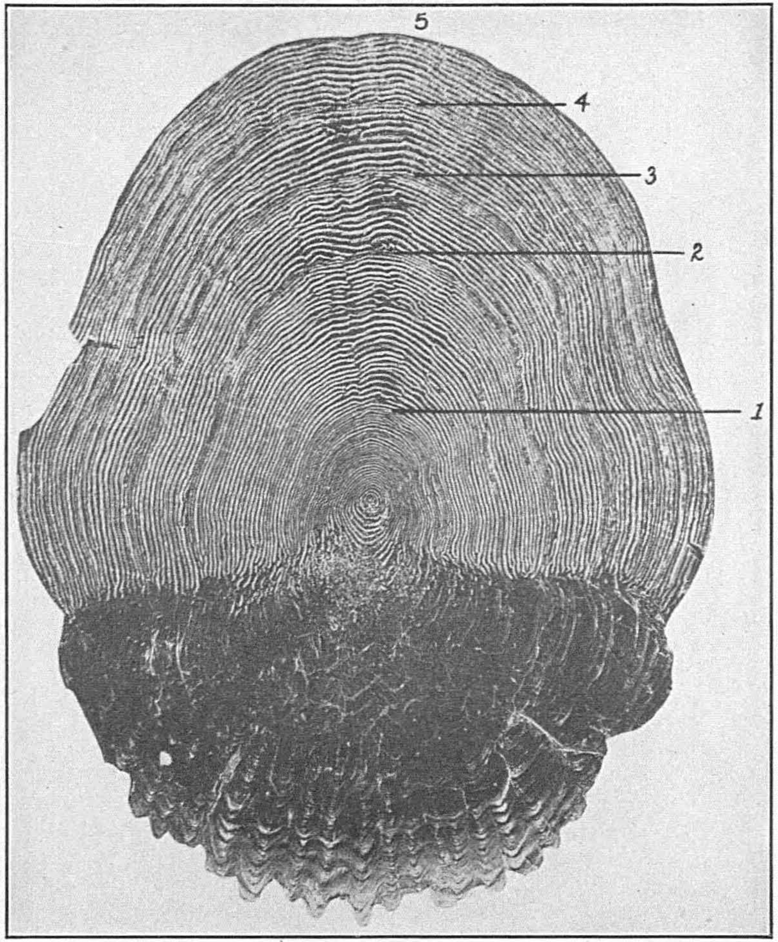


FIG. 32.—Chinook salmon in its fifth year, ocean nucleus, mature. Female, 90.5 cm., log. D 0.690. Taken by troll off the mouth of the Columbia River, July 28, 1919. ×20

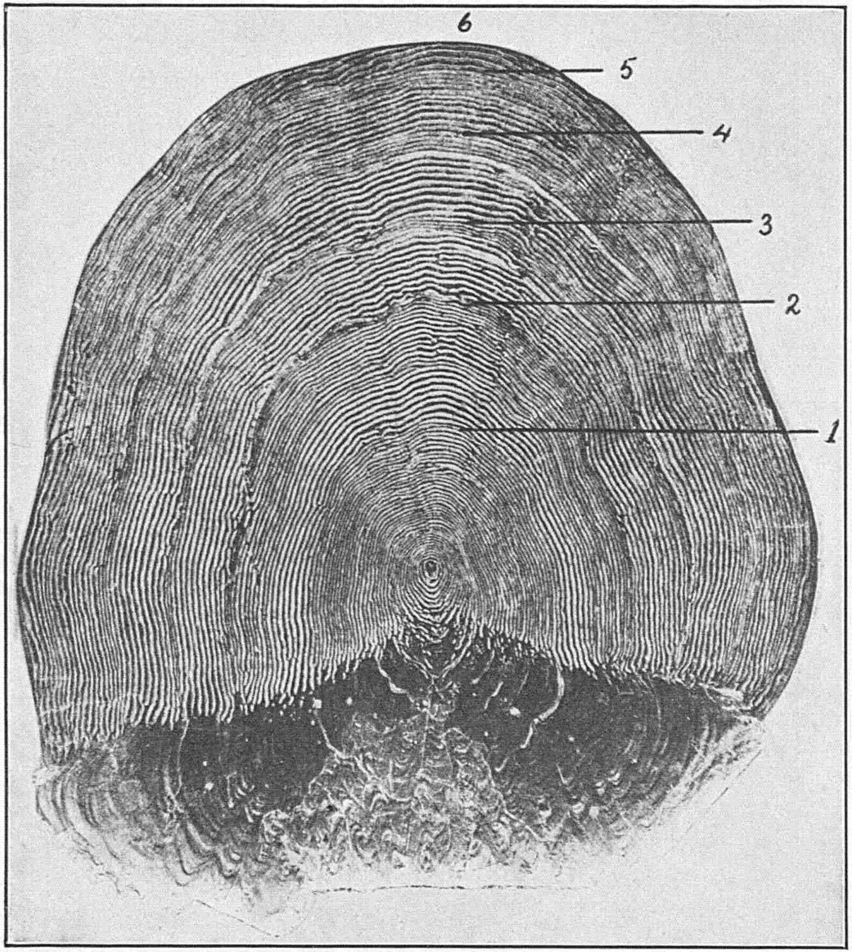


FIG. 33.—Chinook salmon in its sixth year, ocean nucleus, mature. Female, 103 cm., log. *D* 0.681. Taken by troll off the mouth of the Columbia River, July 28, 1919. ×20

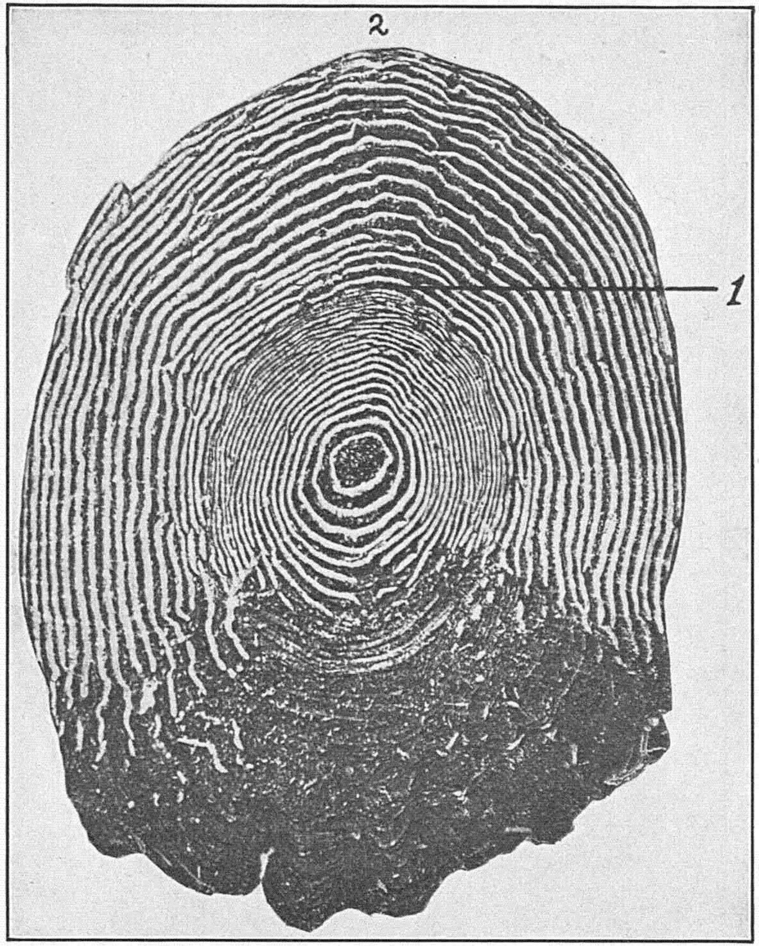


FIG. 34.—Chinook salmon in its second year, stream nucleus, mature. Male, 26 cm. Taken in wheel near Seuferts, Oreg., August 5, 1919. ×35

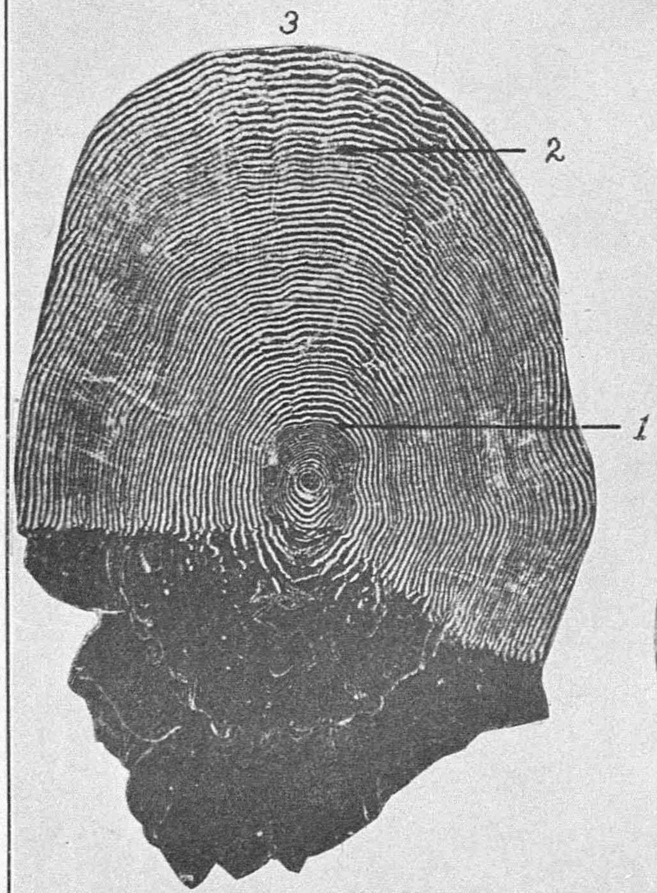


Fig. 35.—Chinook salmon in its third year, stream nucleus, maturity unknown. Male, 50 cm. Taken by troll off the mouth of the Columbia River, June 4, 1919. ×20

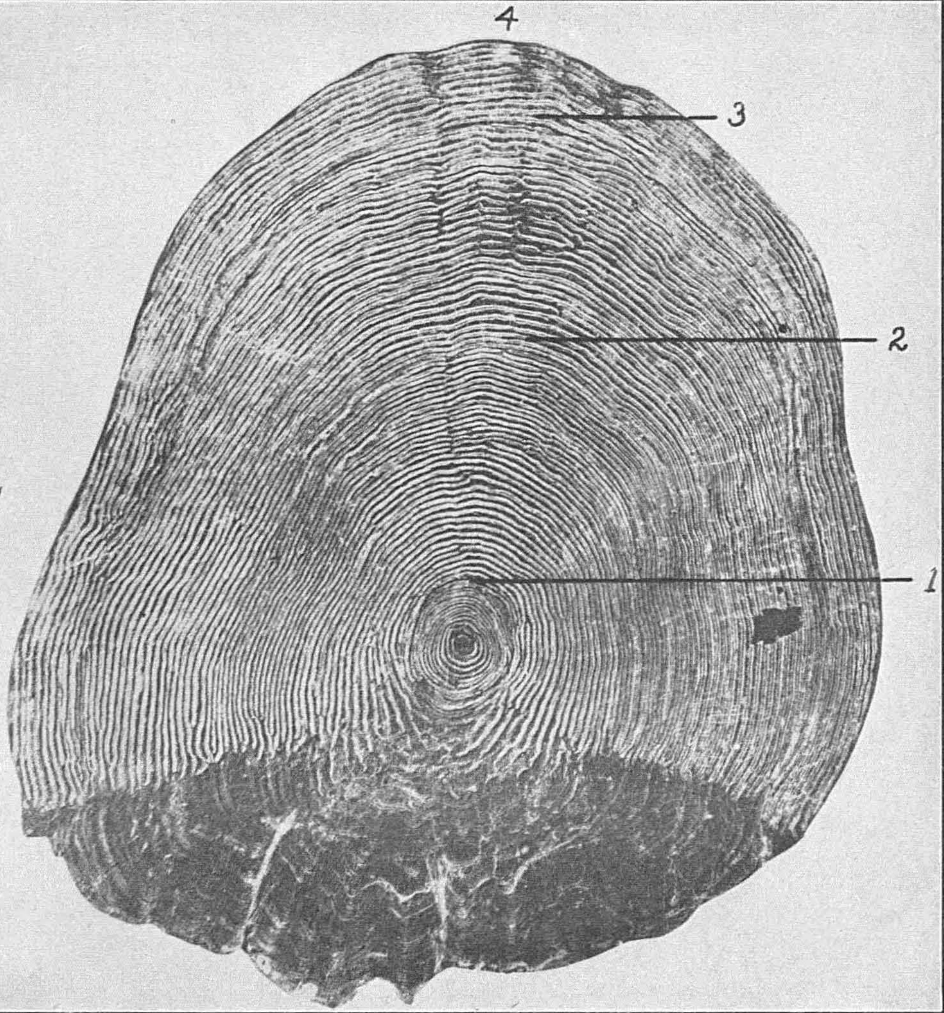


Fig. 36.—Chinook salmon in its fourth year, stream nucleus, immature. Female, 82 cm., log. *D* 0.257. Taken by troll off the mouth of the Columbia River, July 28, 1919. ×20

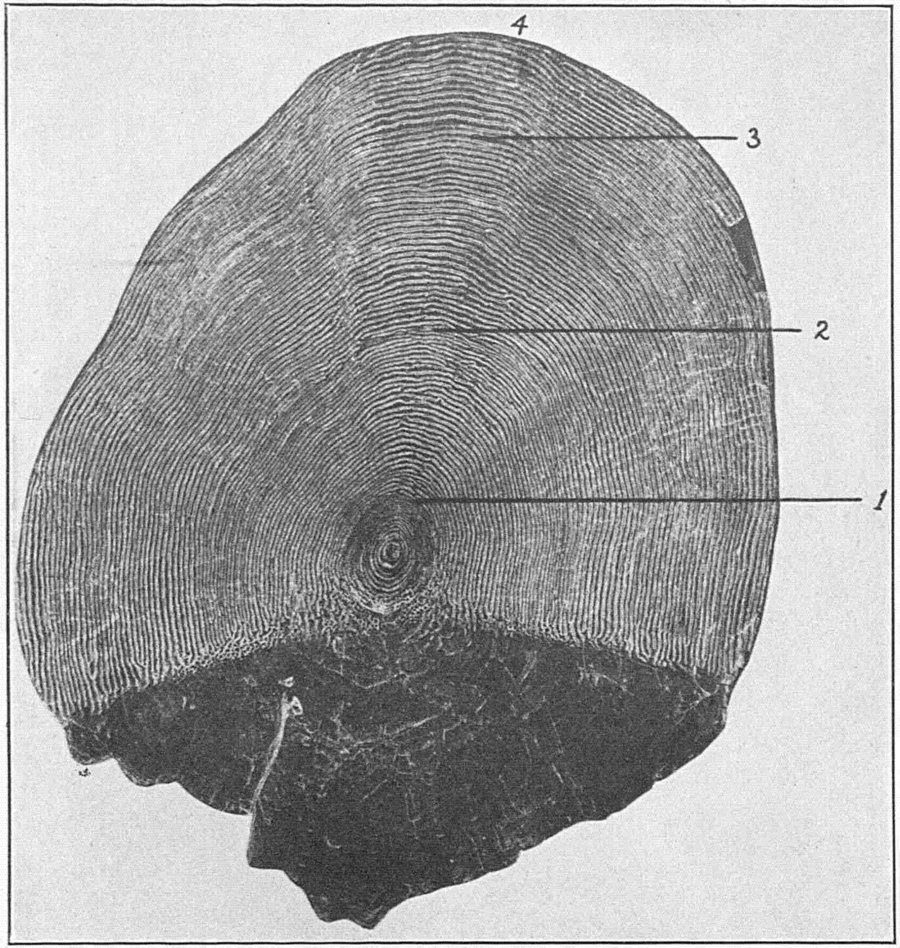


FIG. 37.—Chinook salmon in its fourth year, stream nucleus, mature. Female, 84 cm., log. *D* 0.647. Taken by troll off the mouth of the Columbia River, July 28, 1919. ×20

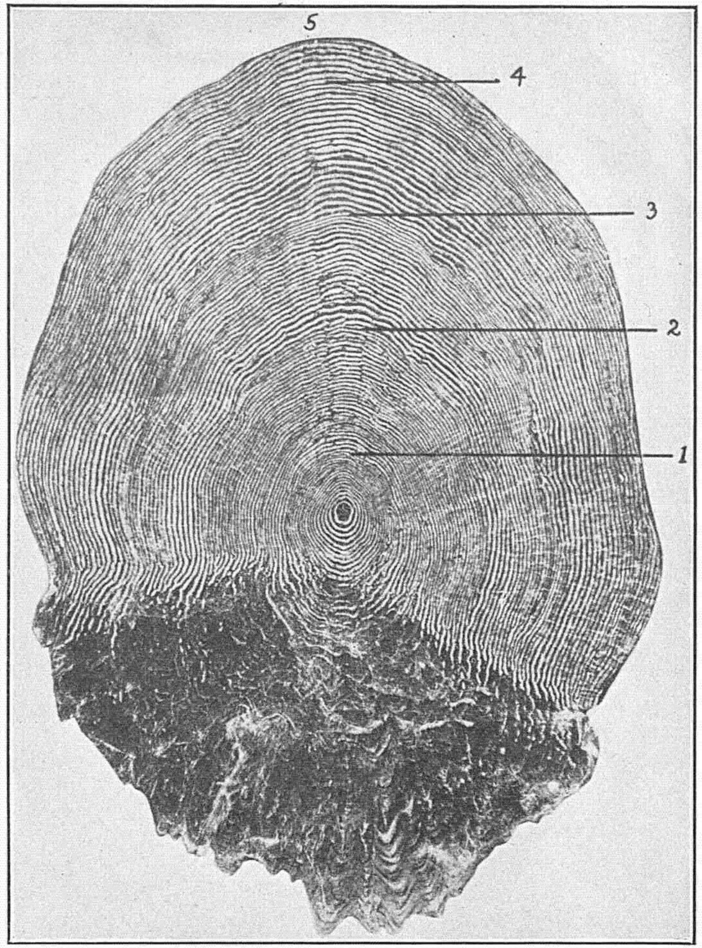


FIG. 38.—Chinook salmon in the fifth year, stream nucleus, immature. Female, 80 cm., log. *D* 0.117. Taken in traps in Baker Bay, Columbia River, May 18, 1920. ×20

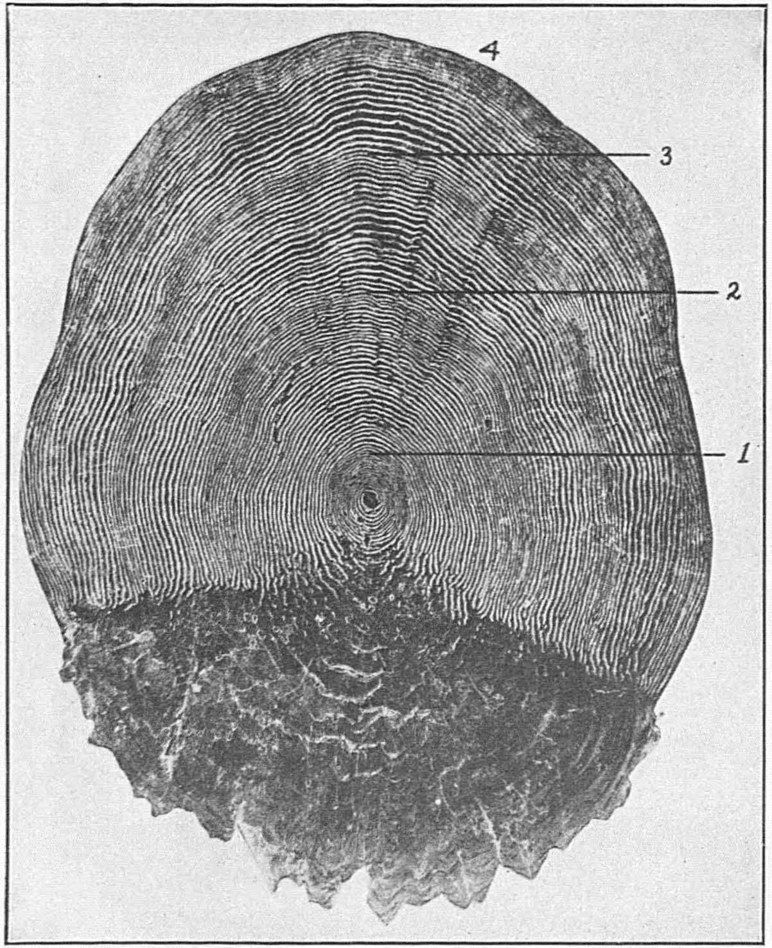


FIG. 39.—Chinook salmon in the fifth year, stream nucleus, mature. Female, 85 cm., log. *D* 0.607. Taken in traps in Baker Bay, Columbia River, May 18, 1920. The new growth of the fifth year had not begun, so that the winter band of the fourth year is at the margin of the scale. ×20

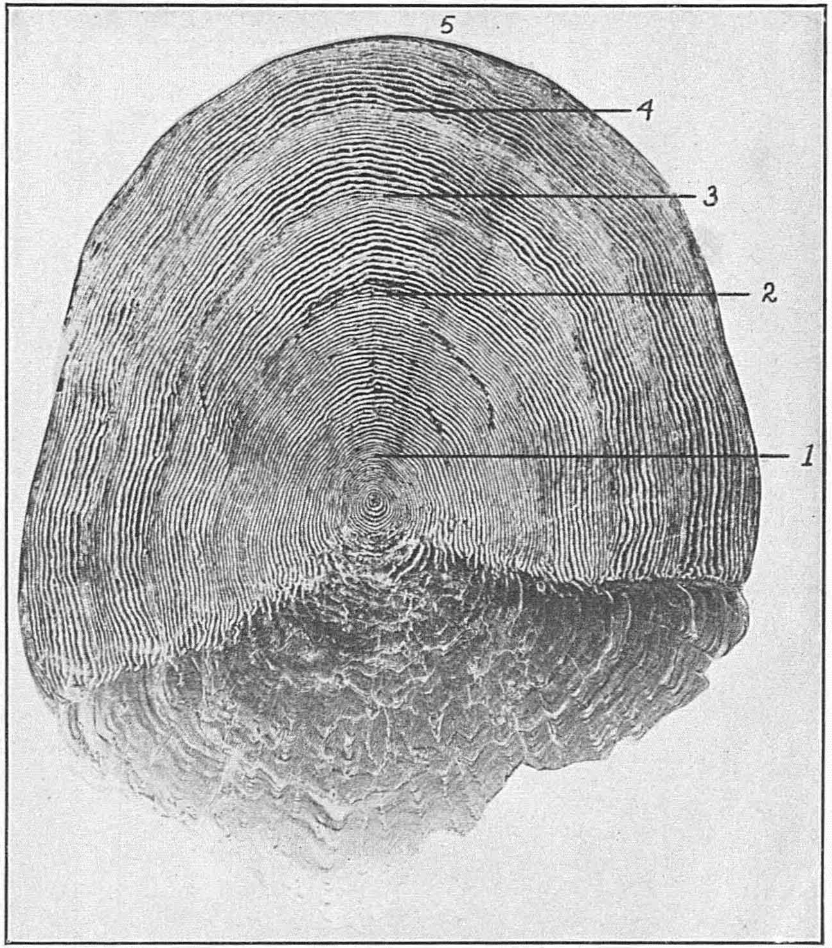


FIG. 40.—Chinook salmon in the sixth year, stream nucleus, mature. Female, 92 cm., log. *D* 0.626. Taken by troll off the mouth of the Columbia River, May 10, 1919. The new growth of the sixth year had not started, so that the marginal rings are those of the fifth winter band. ×20

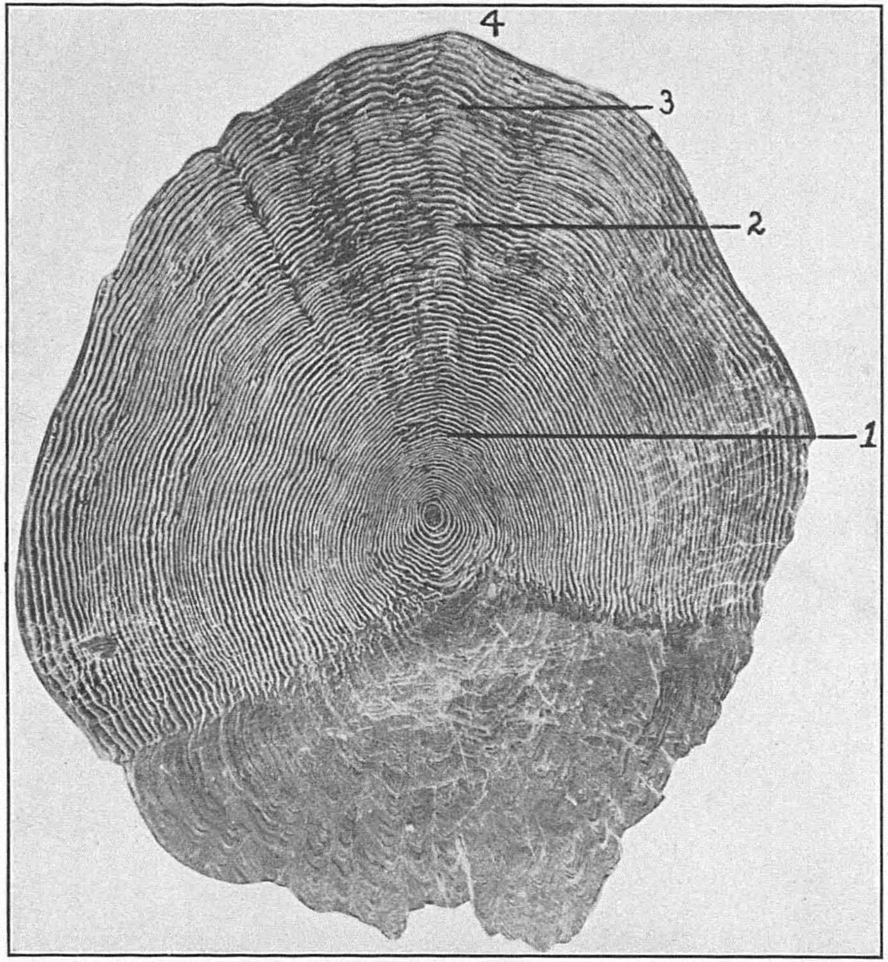


FIG. 41.—Chinook salmon in the fourth year, ocean nucleus. Taken by seine in the Columbia River near Astoria, Oreg., August 22, 1919. This is a representative of the race, having the small type of nucleus, and should be compared with Figure 16. Female, 81 cm. ×20

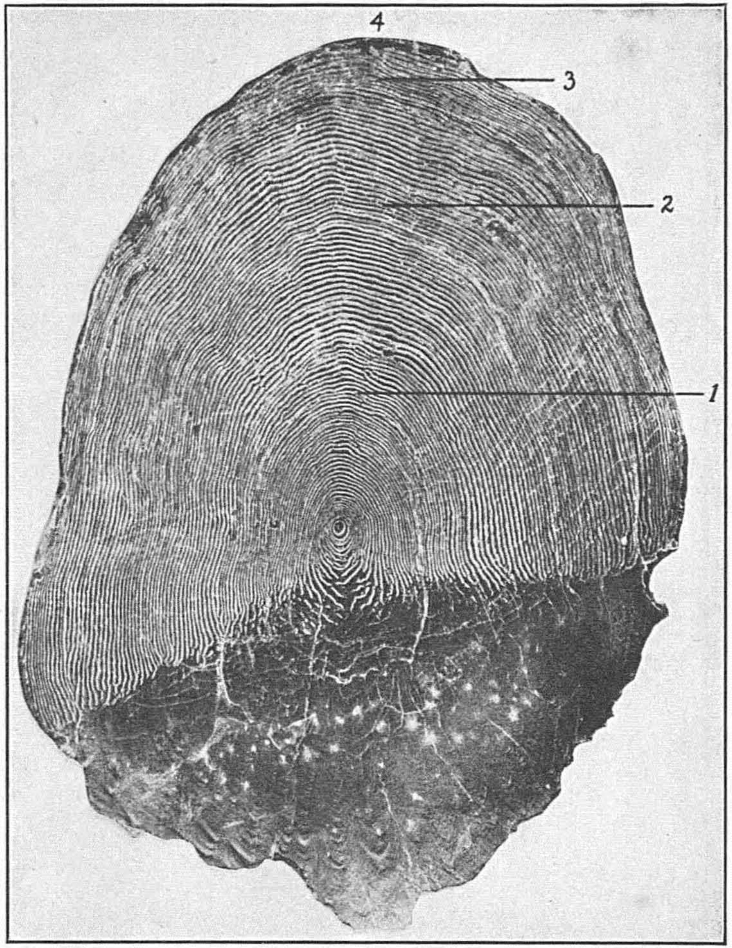


FIG. 42.—Chinook salmon in the fourth year, ocean nucleus. Taken by seine in the Columbia River near Astoria, Oreg., August 22, 1919. This is a representative of the race, having the large type of nucleus, and should be compared with Figure 15. Male, 101.5 cm. ×20

TABLE 22.—*Chinook salmon taken by troll in Monterey Bay, Calif., June 16, 1915*—Continued.

Tabulated according to length, type of nucleus, age, and sex

Centimeter length (mid-value of class)	Ocean nuclei								
	Second year			Third year			Fourth year		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
81				1	1	2			
83					1	1		5	5
85				1		1		5	5
87				1		1	1	3	4
89				1		1		2	2
91							2	1	3
93							1	1	2
95							1		1
97								1	1
99							1		1
Total	23	7	30	17	11	28	7	18	25
Mean	53.87±0.54	51.3	53.27±0.46	76.41±0.96	75.54	76.07±0.69	90.48	86.67±0.60	87.72±0.67
Standard deviation	3.86± .38		3.75± .33	5.86± .68		5.44± .49		3.78± .43	5.00± .48

Centimeter length (mid-value of class)	Ocean nuclei—Continued			Stream nuclei					Total
	Fifth year			Third year	Fourth year			Fifth year	
	Male	Female	Total	Male	Male	Female	Total	Female	
47									2
49									3
51									9
53									4
55									4
57									5
59				1					3
63*									1
67*									1
69									2
71									3
73									7
75									3
77					1		1		4
79						1	1		5
81					1	1	2		4
83									6
85					1	1	2		8
87									5
89		2	2						5
91		2	2						5
93		2	2					2	6
95	1	1	2						3
97		2	2						3
99									1
101	1		1						1
105*	1		1						1
107		1	1						1
109	1		1						1
Total	4	10	14	1	3	3	6	2	106
Mean	102.5	94.2	96.6	59.0	81.0	81.66	81.33	93.0	

TABLE 23.—*Eggs from chinook salmon taken by troll in Monterey Bay, Calif., June 29, 1915*

Tabulated according to size of eggs and approximate size of fish

Logarithm of diameter of eggs (mid-value of class)	Group 1 [1]	Group 2 [2]	Group 3 [3]	Total	Logarithm of diameter of eggs (mid-value of class)	Group 1 [1]	Group 2 [2]	Group 3 [3]	Total
$\bar{1}$.93	1			1	0.37		2	3	5
0.03*	1			1	.39		10	7	17
.07*		1		1	.41		2	4	6
.09	1			1	.43		6	8	14
.15*		2		2	.45			10	10
.17		10		10	.47		1	7	8
.19		6		6	.49		1	6	7
.21		7		7	.51		2	2	4
.23		3		3	.65*			1	1
.25		4		4					
.27		4	1	5	Total	3	86	55	144
.29		4	2	6	Mean	0.0100	(4)	0.4264±0.0059	
.31		7	3	10	Standard deviation			0.0653± .0042	
.33		6		6					
.35		8	1	9					

[1] Fish under 5 pounds. [2] Fish between 5 and 15 pounds. [3] Fish over 15 pounds. [4] See page 66.

TABLE 24.—*Chinook salmon taken by troll in Monterey Bay, Calif., June 19 to 21, 1918*

Tabulated according to length, type of nucleus, and age

Centimeter length (mid-value of class)	Ocean nuclei			Stream nuclei		Total
	Second year	Third year	Fourth year	Third year	Fourth year	
43	1					1
51*	1					1
57*		1		1		2
59		1				1
63*		2				2
65		2				2
67		9				9
69		4				4
71		5				5
73		2				2
75		8			1	9
77		6				6
79		3				3
81		5			1	6
83		3				3
85					1	1
87			1			1
89			1			1
91			1			1
93			2			2
95			1			1
Total	2	51	6	1	3	63
Mean	47.0	72.64±0.59	91.3	57.0	80.3	
Standard deviation		6.32± .42				

TABLE 25.—*Chinook salmon taken by troll in Monterey Bay, Calif., June 19 to 21, 1918. Females only*

Tabulated according to size of eggs, type of nucleus, and age

Logarithm of diameter of eggs (mid-value of class)	Ocean nuclei			Stream nuclei		Total
	Second year	Third year	Fourth year	Third year	Fourth year	
$\bar{1}$.85	1					1
0.01*	1					1
.07*		1				1
.11*		5				5
.13		3		1		4
.15		6				6
.17		11				11
.19		5				5
.21		3				3
.23		1				1
.25		1				1
.29*					1	1
.33*		3				3
.35		2			1	3
.37		1				1
.39		4	1		1	6
.41		1	1			2
.43		2	1			3
.45		1				1
.47			1			1
.49		1	1			2
.51			1			1
Total	2	51	6	1	3	63
Mean	$\bar{1}$.93	(1)	0.45	0.13	0.343	

[1] Group with log D less than 0.30, mean equals 0.1622±0.0042; standard deviation equals 0.0372±0.0029. Group with log D greater than 0.30, mean equals 0.3887±0.0080; standard deviation equals 0.0458±0.0056.

TABLE 26.—*Chinook salmon taken by troll near Drakes Bay and Fort Bragg, Calif., July and August, 1918*

Fish that migrated as fry (scales with ocean nuclei) tabulated according to length, age, and sex

Centimeter length (mid-value of class)	Second year			Third year		
	Male	Female	Total	Male	Female	Total
43	1		1			
45	5	1	6			
47		1	1			
49	1	1	2			
51	1		1			
53	4		4			
61*				2	1	3
63				1	1	2
65				1	1	2
67					3	3
69					2	2
71				1	2	3
73				2		2
75				2		2
79*				3	1	4
81				1	2	3
83				2	2	4
85					2	2
87				1	1	2
89					1	1
91				1		1
Total	12	3	15	17	19	36
Mean	48.33	47.00	48.00	75.23±1.41	74.89±1.37	75.05±0.98
Standard deviation				8.64±1.00	8.84± .97	8.74± .69

TABLE 26.—*Chinook salmon taken by troll near Drakes Bay and Fort Bragg, Calif., July and August, 1918*—Continued

Centimeter length (mid-value of class)	Fourth year			Fifth year			Total
	Male	Female	Total	Male	Female	Total	
43							1
45							6
47							1
49							2
51							1
53							4
61*							3
63							2
65							2
67							3
69							2
71							3
73							2
75							2
79*		1	1				5
81	1		1				4
83							4
85							2
87		1	1				3
89		1	1				2
91		1	1				2
95*		6	6				6
97	1	5	6				6
99	3	5	8				8
101	4	7	11	1		1	12
103	2	1	3				3
105	4	2	6		1	1	7
107	1		1				1
109	1		1				1
111	3		3				3
113				1		1	1
115				1		1	1
Total	20	30	50	3	1	4	105
Mean	102.70±0.98	97.20±0.65	99.40±0.61	109.60	105.00	108.50	
Standard deviation	6.48± .69	5.30± .46	6.40± .43				

TABLE 27.—*Chinook salmon taken by troll near Drakes Bay and Fort Bragg, Calif., July and August, 1918*

Logarithm of diameter of eggs (mid-value of class)	Number of individuals		Logarithm of diameter of eggs (mid-value of class)	Number of individuals	
$\bar{1}$.85	1	Mean, $\bar{1}$.8667.	0.43	2	
.87	2		.47*	1	
0.07	1		.51*	4	
.09	1		.55*	3	
.11	2		.57	1	
.13	1	Mean, 0.1778±0.0095.	.59	2	Mean, 0.6244±0.0080.
.15	2	Standard deviation, 0.0600±0.0067.	.61	1	Standard deviation, 0.0780±0.0057.
.17	3		.63	6	
.21*	4		.65	4	
.25*	3		.67	8	
.29*	1		.69	4	
			.71	7	
			Total	64	

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