THE RELATIVE MATURITY OF THE CHINOOK SALMON TAKEN IN THE OCEAN ALONG THE PACIFIC COAST.*

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This paper is in the nature of a preliminary report dealing with the maturity of the chinook salmon taken by troll and purse-seine in the ocean along the Pacific coast, and is presented for the purpose of making immediately available some of the results of the investigation. It is also believed that the method used for determining the relative maturity is new and may be of value to others engaged in similar investigations. A later report will give in detail the data upon which the conclusions presented in this paper are based, and will discuss several topics treated very briefly, or omitted entirely from this paper.

The amount of trolling and purse-seining for chinook salmon along the Pacific coast has increased enormously during the past few years, especially along the northern coast of California, the coast of Oregon, and off the mouth of the Columbia River. To anyone who has observed even casually the fish thus taken in the ocean it is perfectly apparent that a great proportion are immature and it is a point of considerable interest and practical importance to know just what percentage are immature and the relative degree of immaturity. 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 two to six years. If the percentages of individuals of different ages among the mature fish were constant, it would be possible, from a determination of the percentages 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 percentages of fish of the various age-groups vary greatly at different times among the mature fish and also among those taken in the ocean. Presumably these variations are due quite largely to racial differences but our present knowledge of the various races of chinook salmon is quite 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 the 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.

The method which has been developed for determining the relative maturity is based upon variations in the size of the eggs. Obviously this can be applied only to the females and no method has yet been devised for determining the relative maturity of the males. The percentages of males and females found among the mature fish of the various age groups will give some basis for estimating the percentages of mature and immature males from the determination of the relative maturity of the females, but a discussion of this topic must be reserved

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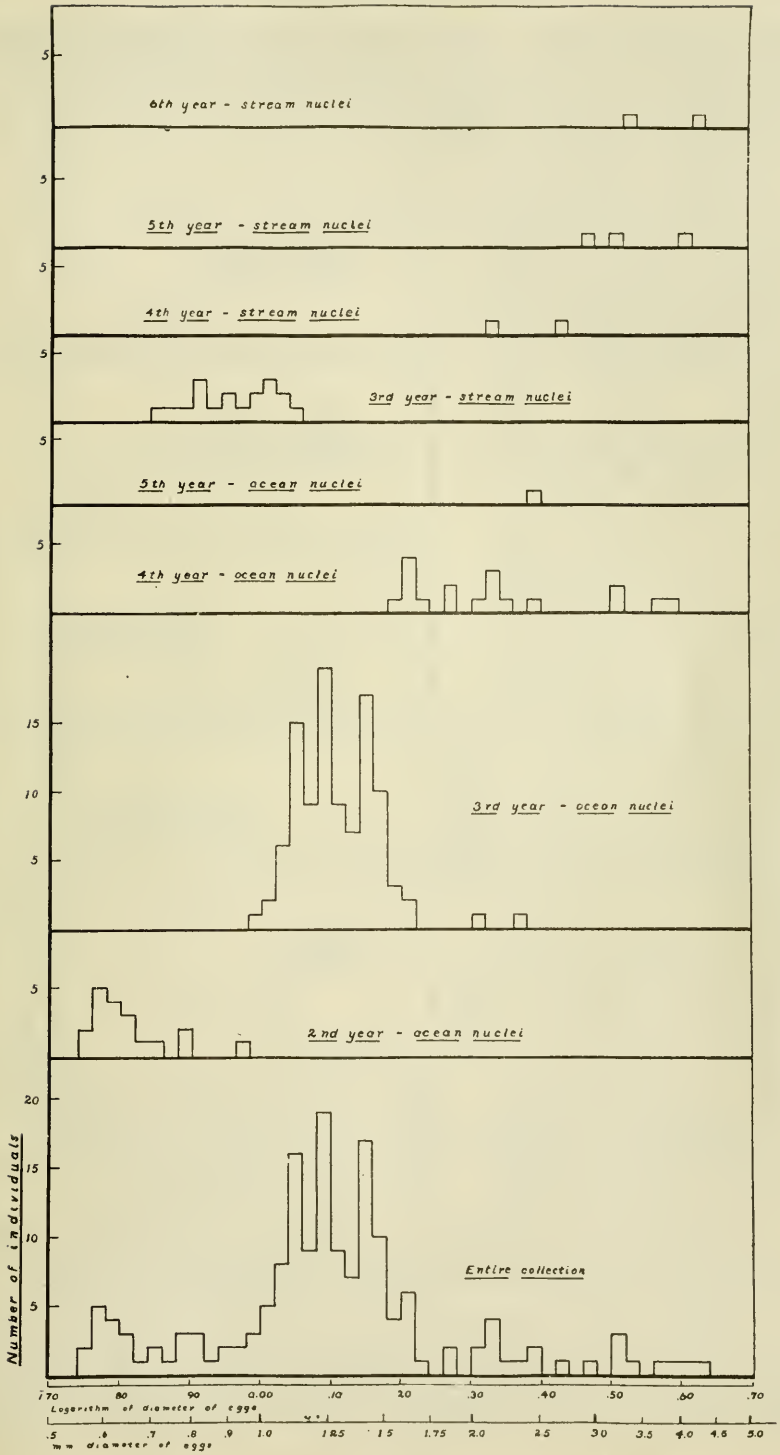

FIG. 8. Histogram showing frequency-distribution of 163 female salmon

for the complete report. It is sufficient to state here that, while there is a tendency for the males to mature somewhat younger than the females, the error which would result from assuming that the proportions of fish of similar degrees of maturity were equal in the males and females would not be serious.

Superficial examination of the eggs found in the females taken in the ocean shows that there is a wide diversity in the size and, further, that several more or less distinct size-groups are distinguishable even without careful measurement. It is a natural assumption that these various sizes of the eggs indicate different degrees of maturity. A careful study of several collections of fish taken within the Columbia River and by troll off the mouth of the Columbia, in Monterey Bay, California, and along the northern coast of California confirms this assumption and shows that, by means of a study of the variation in the size of the eggs and a determination of the age by means of the scales it is possible to distinguish, with certainty, in many cases, and with reasonable probability in most, between fish which would have spawned during the year in which they were taken and those which would not have spawned for at least one more year. The distinction between fish which would not have spawned for two years is not quite as definite but in some collections the interpretation is clear.

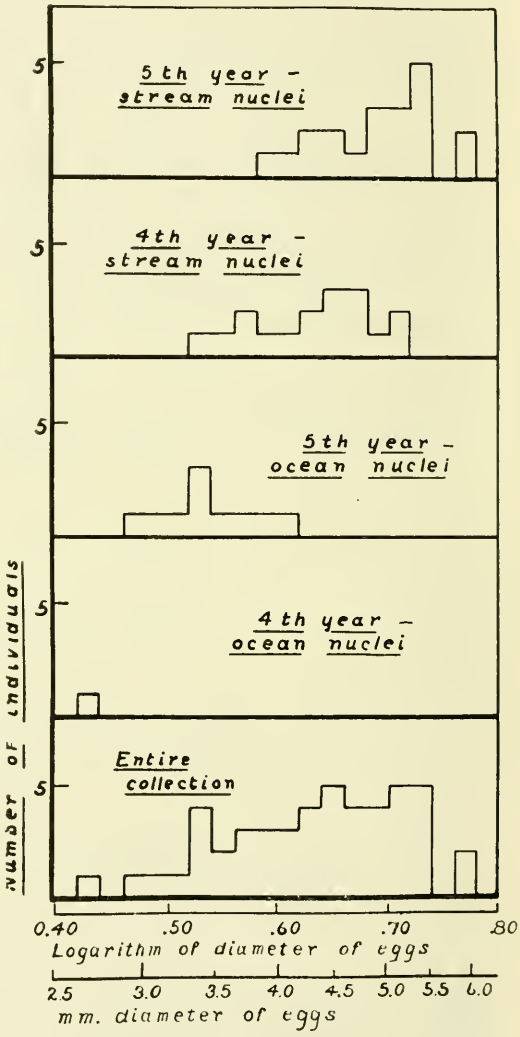

FIG. 9. Histogram showing frequency-distribution of 48 females taken by beach seines and wheels near Warrendale, Oregon, June 16, 1919, based on the logarithms of the diameters of the eggs.

In studying these collections the age has been determined by the usual method of scale study. The size of the eggs has been determined by measuring ten 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

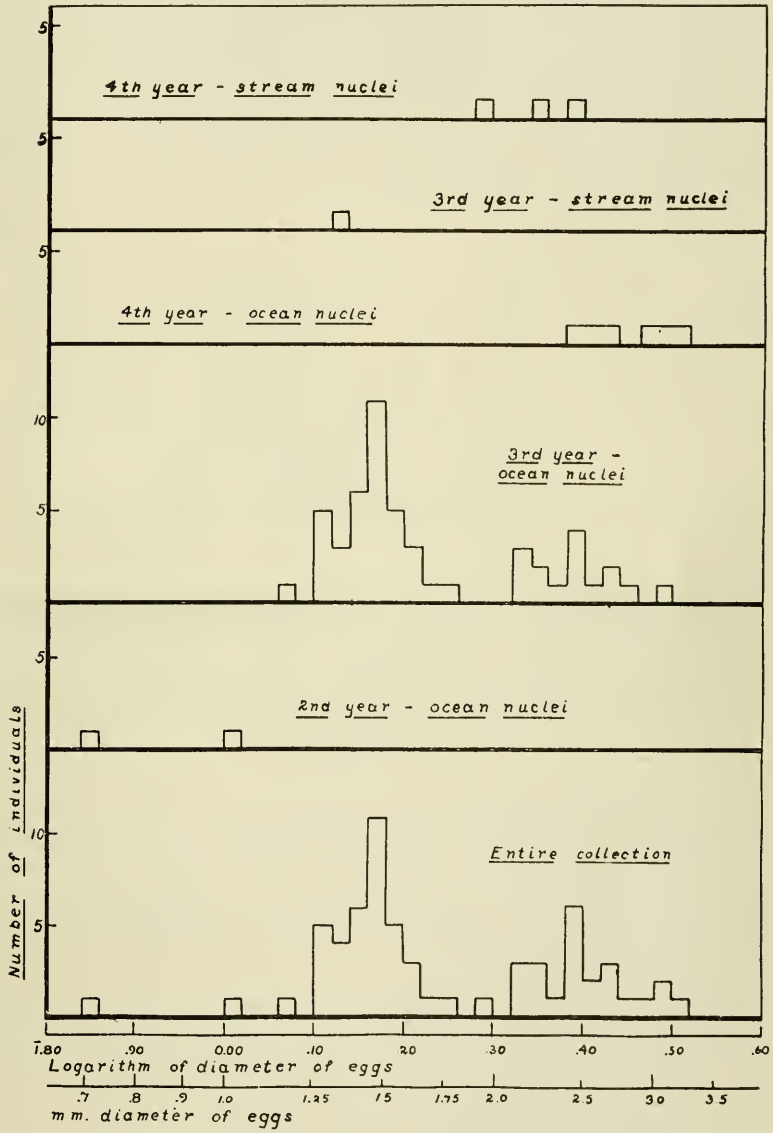

FIG. 10. Histogram showing frequency-distribution of 63 females taken by troll in Monterey Bay, California, June 19–21, 1918, based on the logarithms of the diameters of the eggs.

of the trough, and then are carefully pushed up to the zero end of the scale by means of a small piece which fits the bottom of the trough and on which is graduated a vernier enabling one to read accurately to tenths of a millimeter. The measurement of ten eggs by this scale

gives directly, by simply moving the decimal point one place to the left, the average size of the eggs to hundredths of a millimeter. As a matter of fact this measurement is finer than is necessary 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 shell 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 standardized. In using this method it was necessary, of course, to measure the ten eggs separately and then the average of these measurements was found.

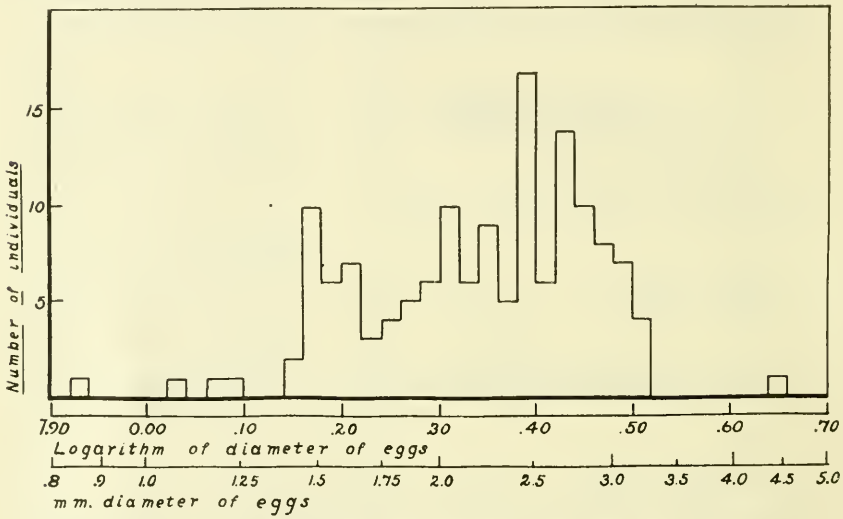

FIG. 11. Histogram showing frequency-distribution of 144 females taken by troll in Monterey Bay, June 29, 1915, based on the logarithms of the diameters of the eggs.

The tabulating and plotting of these egg measurements has been done on a logarithmic basis—that is, the logarithms of the actual measurements have been tabulated rather than the measurements themselves. The main advantage of this sort of tabulation lies in the fact that proportional variations in size are equally shown independent of the actual size, and it is the relative size of the eggs, rather than the actual diameter, which is significant.[1]

In preparing the tables and charts the classes have been arranged with intervals of .02 in the logarithm of the diameter of the eggs. This signifies that the mid-value of each class is 4.713 per cent greater than that of the class next preceding.

The following collections have been used in the preparation of this preliminary report:

1. 163 females taken by troll off the mouth of the Columbia River, May 8, 1919.
2. 68 females taken by troll off the mouth of the Columbia River, June 4, 1919.
3. 48 females taken by beach seines in the Columbia River near Warrendale, Oregon, June 16, 1919. (Warrendale is approximately 150 miles above the mouth of the river.)

[1] The writer is indebted to Prof. F. W. Weymouth of Stanford University for an acquaintance with this method of tabulating.

4. 48 females taken by traps in Baker Bay, Columbia River, July 3, 1919. (Baker Bay and Sand Island, where the next collection was taken, are both just within the mouth of the river.)

5. 41 females taken by beach seines on Sand Island, Columbia River, July 6, 1919.

6. 101 females taken by troll off the mouth of the Columbia River during August 13 to 17 and September 16 to 17, 1918. (But five of these were taken in September and these have been considered with the August collections.)

7. 95 females taken by troll off the mouth of the Columbia River, August 13, 1919.

8. 63 females taken by troll in Monterey Bay, California, June 19 to 21, 1918.

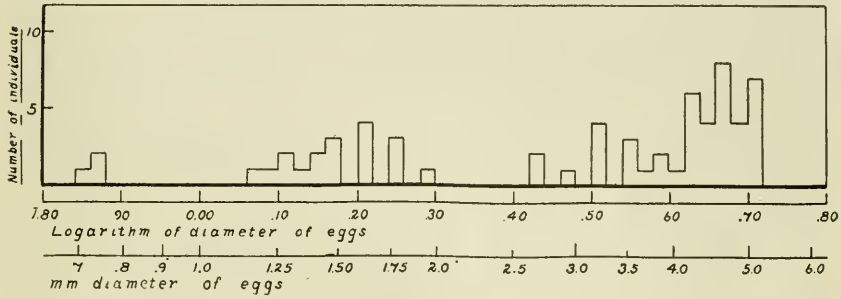

FIG. 12. Histogram showing frequency-distribution of 64 females taken by troll near Drake's Bay and Fort Bragg, California, July and August, 1918, based on the logarithms of the diameters of the eggs.

Full data including scales were taken with each of the above collections. In addition to these the following two collections consisting of eggs alone were studied:

9. Eggs from 144 females taken by troll in Monterey Bay, June 29, 1915.

10. Eggs from 64 females taken by troll near Drake's Bay, August 15 and 16, 1918, and Fort Bragg, July 17, 1918, on the coast of northern California. Scales and data were also collected from the females at the same time the collections of egg samples were made, but the records were not kept so that the egg samples could be referred to the corresponding data and scales. It has been necessary, therefore, to treat egg samples and other data independently.

It will be impossible, in this report, to give in detail the evidence necessary to prove the validity of this method for determining the relative maturity. The graphs will, however, give illustrations of typical results obtained from the measurement and tabulation of the eggs. An examination of the graphs shows that, in the collection of undoubtedly mature fish from Warrendale, the eggs were fairly uniform in size, ranging from about 2.5 to 6 mm. in diameter. The obvious graduation in size of the eggs in the different age-groups is probably significant of racial differences, but a discussion of this point cannot be given in this paper. In the case of the fish taken by troll in the ocean the frequency-distribution based on egg sizes shows a distinct grouping around several modes which are usually quite well separated.

Three modes are especially distinct and, in the case of the collections for which age determinations were also made, and which have, therefore, been separated into the component age-groups (Monterey, 1919, and Columbia River, May, 1919) it is apparent that the group characterized by the largest eggs (above 2 mm. in diameter) is composed chiefly of

fish in their third, fourth and fifth years, whose scales show the ocean type of nucleus, and of fish in their fourth and fifth years whose scales show the stream type of nucleus. [The nuclear growth here referred to is that located close to the center of the scales and represents the portion of the scales formed during the first year. The "stream" type indicates that the fish remained in the stream during the entire first year of its life. The "ocean" type of nuclei indicate that the fish have migrated seaward sometime during the first year, usually early.]

The group representing the next smaller size of eggs (1.25 to 1.5 mm.) in diameter is characterized especially by fish in their third year with either ocean or stream nuclei, while the group representing the smallest eggs (.6 to .8 mm.) is characterized chiefly by fish in their second year with ocean nuclei. The size of the eggs in the group having the largest eggs corresponds, in each instance, with the size of eggs in the Warrendale collection and are, therefore, without doubt fish which would have matured during the year in which they were taken.

It is apparent, then, that in general the group characterized by the largest eggs is composed of fish one year older than those composing the group with eggs of the next smaller size, and that these in turn are one year older than those composing the group with the smallest eggs. These differences in the size of the eggs are not dependent on corresponding differences in the size of the fish. There is, indeed, a distinct correlation between the size of the fish and the size of the eggs, but, as will be shown in the more detailed report, this correlation is by no means ample and is unquestionably modified by the approach of maturity. Of particular interest and significance is the presence of two groups of individuals within the same age-group which may be definitely separated on the basis of egg sizes. This is shown with unusual clearness in the third year fish with ocean nuclei taken at Monterey in 1918. The group with eggs greater than 2 mm. would undoubtedly have spawned during the fall of the same year in which they were taken, while the fish composing the other group would not have spawned for at least one more year. These facts which have been so briefly and incompletely discussed seem to fully justify the conclusion that the size of the eggs is a fairly reliable index of the relative degree of maturity of chinook salmon.

Without attempting to discuss further the method used for determining relative maturity, a tabular summary will be given of the results obtained by the study of the ten collections which have formed the basis for this report. It is hoped that further study will increase the accuracy of the results, and it seems probable that some of the percentages given in the table may be somewhat modified by additional investigations. It is believed, however, that the results as given here are fairly reliable. In preparing the table care has been taken to include doubtful cases always with the more mature of the two groups to which they might be assigned. This has been done in order not to exaggerate the degree of immaturity exhibited by any of the various collections.

TABLE I.

Composition as to age groups and relative maturity of a collection of 165 females taken by troll off the mouth of the Columbia River, May 8 to 10, 1919.

Age groups	Number of specimens and per cent which would mature during:						Total	
	Year taken		Following year		Second year following			
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 2d year					19	100	19	11.5
In 3d year	2	2	100	98			102	61.8
In 4th year	18	100					18	10.9
In 5th year	1	100					1	.6
Stream nuclei—								
In 3d year			18	100			18	10.9
In 4th year	2	100					2	1.2
In 5th year	3	100					3	1.8
In 6th year	2	100					2	1.2
Totals	28	17	118	71.5	19	11.5	165	

TABLE II.

Composition as to age groups and relative maturity of a collection of 68 females taken by troll off the mouth of the Columbia River, June 4, 1918.

Age groups	Number of specimens and per cent which would mature during:						Total	
	Year taken		Following year		Second year following			
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 2d year					18	100	18	26.5
In 3d year			32	97	1	3	33	48.5
In 4th year			1	100			1	1.5
In 5th year	1	100					1	1.5
Stream nuclei—								
In 3d year			10	100			10	14.7
In 4th year	2	50	2	50			4	5.8
In 5th year			1	100			1	1.5
Totals	3	4	46	68	19	28	68	

TABLE III.

Composition as to age groups and relative maturity of a collection of 48 females taken by seines and wheels near Warrendale, Oregon, June 16 and 17, 1919.

Age groups	Number of specimens and per cent which would mature during:						Total	
	Year taken		Following year		Second year following			
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 4th year	1	100					1	2
In 5th year	10	100					10	21
Stream nuclei—								
In 4th year	17	100					17	35
In 5th year	20	100					20	42
Totals	48	100					48	

TABLE IV.

Composition as to age groups and relative maturity of a collection of 51 females taken by traps in Baker Bay, Columbia River, July 3, 1919.

Age groups	Number of specimens and per cent which would mature during:						Total	
	Year taken		Following year		Second year following			
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 3d year	1	100					1	2
In 4th year	24	100					24	47
In 5th year	17	100					17	33
In 6th year	3	100					3	6
Stream nuclei—								
In 3d year			1	100			1	2
In 4th year	4	100					4	8
In 5th year	1	100					1	2
Totals	50	98	1	2			51	

TABLE V.

Composition as to age groups and relative maturity of a collection of 41 females taken by beach seines on Sand Island, Columbia River, July 7, 1919.

Age groups	Number of specimens and per cent which would mature during:						Total	
	Year taken		Following year		Second year following			
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 2d year					5	100	5	12.4
In 3d year	1	50	1	50			2	4.8
In 4th year	20	100					20	48.8
In 5th year	8	100					8	19.5
Stream nuclei—								
In 3d year					4	100	4	9.7
In 4th year	1	100					1	2.4
In 5th year	1	100					1	2.4
Totals	31	76	1	2	9	22	41	

TABLE VI.

Composition as to age groups and relative maturity of a collection of 102 females taken by troll off the mouth of the Columbia River, August and September, 1918.

Age groups	Number of specimens and per cent which would mature during:						Total	
	Year taken		Following year		Second year following			
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 2d year			1	20	4	80	5	5
In 3d year	21	84	4	16			25	24.5
In 4th year	19	95	1	5			20	19.5
In 5th year	19	100					19	18.5
Stream nuclei—								
In 3d year			2	100			2	2
In 4th year	3	100					3	3
In 5th year	27	100					27	26.5
In 6th year	1	100					1	1
Totals	90	88.3	8	7.8	4	3.9	102	

TABLE VII.

Composition as to age groups and relative maturity of a collection of 95 females taken by troll off the mouth of the Columbia River, August 13, 1919.

Age groups	Number of specimens and per cent which would mature during:						Total	
	Year taken		Following year		Second year following			
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 2d year			1	50	1	50	2	2.1
In 3d year	9	60	6	40			15	15.8
In 4th year	63	95.5	3	4.5			66	69.5
In 5th year	4	100					4	4.2
Stream nuclei—								
In 3d year			1	100			1	1.1
In 4th year	6	85.7	1	14.3			7	7.3
Totals	82	86	12	13	1	1	95	

TABLE VIII.

Composition as to age groups and relative maturity of a collection of 63 females taken by troll in Monterey Bay, June 19 to 21, 1918.

Age groups	Number of specimens and per cent which would mature during:						Total	
	Year taken		Following year		Second year following			
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 2d year			1	50	1	50	2	3.2
In 3d year	15	29	36	71			51	81
In 4th year	6	100					6	9.5
Stream nuclei—								
In 3d year			1	100			1	1.6
In 4th year	3	100					3	4.7
Totals	24	38	38	60	1	2	63	

TABLE IX.

Composition as to relative maturity of a collection of 144 females taken by troll in Monterey Bay, California, June 29, 1915. Determined from a study of the eggs alone.

Age groups	Number of specimens and per cent which would mature during:		
	Year taken	Following year	Second year following
Number	108	35	1
Per cent	75	24.3	.7

TABLE X.

Composition as to relative maturity of a collection of 64 females taken by troll near Drake's Bay and Fort Bragg, California, July and August, 1918. Determined from a study of the eggs only.

Age groups	Number of specimens and per cent which would mature during:		
	Year taken	Following year	Second year following
Number	43	18	3
Per cent	67	28	5

From the data contained in these tables the following generalizations may be made:

1. The fish taken in the ocean off the mouth of the Columbia River contain, in the spring and early summer, approximately 70 per cent of individuals which will not become sexually mature for one or two years.

2. By the middle of August this condition has changed so that nearly 90 per cent are fish which will soon enter the river for the purpose of spawning. The rate at which this change takes place and the time at which it occurs have not yet been determined, but will be taken up in the later report.

3. A comparatively small percentage of the fish found just within the mouth of the Columbia River are immature. It should be mentioned in this connection that it is only occasionally when unusual tidal conditions obtain that any immature fish are taken inside the mouth of the stream.

4. The fish taken by troll in Monterey Bay in June contain a considerable proportion of immature individuals. The data obtained in 1918 are most reliable, and indicate that only about 40 per cent of the fish taken would have spawned during the same year. The data for 1915 indicates that 75 per cent were mature, but selection may well have taken place in making this collection which, as noted above, consists of egg samples only.

5. The fish taken near Drake's Bay and Fort Bragg in July and August, 1918, contain approximately 30 per cent of immature fish. It is of interest to note that this is an approach to the conditions found off the mouth of the Columbia River in August and suggests that the composition of all the schools found near the coast changes materially during the summer season.

GEAR USED FOR SALMON TROLLING IN CALIFORNIA IN 1920.

By W. L. Scofield.

Object. These notes, by no means complete, are intended to be a rough record of the type of gear used in open sea salmon trolling in California at present (1920) as a partial supplement to the system of triplicate receipts for statistics of catch recently installed by the Fish and Game Commission. The fact that gear and methods have changed decidedly in the past few years and no doubt will continue to change makes this summary necessary.

The notes deal chiefly with *gear* used. Such subjects as history of trolling, points at which trolling is practiced and its extent, location for trolling in a given local area, prospecting for schools, and deep vs. shallow fishing, although most important, are omitted or merely touched upon here.

Variation in Methods. There is considerable variation in methods and equipment, with great divergence of opinion on most of the subjects taken up in these notes. While the industry was new this was an advantage, as established custom did not limit experimenting,