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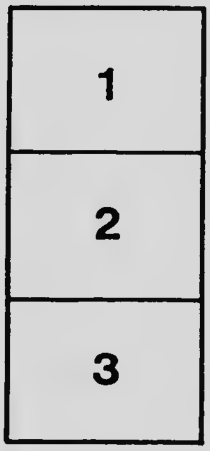
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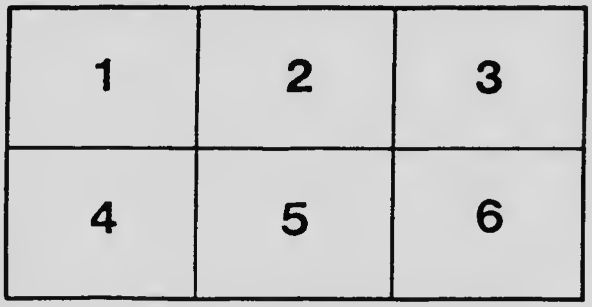
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BRITISH COLUMBIA FISHERIES DEPARTMENT, 1914.

A PRELIMINARY REPORT ON THE LIFE-HISTORY OF THE HALIBUT.

A NEW FISH OF THE GENUS SEBASTODES FROM BRITISH COLUMBIA, WITH NOTES ON OTHERS.

BY

WILLIAM F. THOMPSON,

Stanford University.

[REPRINTED WITHOUT CHANGE OF PAGING FROM THE REPORT OF THE BRITISH COLUMBIA COMMISSIONER OF FISHERIES, 1914.]

A PRELIMINARY REPORT ON THE LIFE-HISTORY OF THE HALIBUT.

BY WILLIAM F. THOMPSON, OF STANFORD UNIVERSITY.

INTRODUCTION.

The importance of the halibut as a food-fish, and the imminent danger that the supply may become depleted on both our coasts, if not completely exhausted, has aroused special interest in its present abundance and distribution, and in all the facts of its life-history. Fishermen and dealers are aware that the best banks are becoming exhausted by overfishing. Their catches are each year being brought from more distant banks, and it has become alarmingly evident that the supply is limited and is rapidly decreasing. It is beyond question that if this important source of food is not to be largely lost to the public some protection must be extended to the species in the near future. To effect this rationally and without undue disturbance to the industry complete knowledge of the life-history must be obtained.

In consideration of these facts the Fisheries Department of the Province of British Columbia decided to prosecute an inquiry into the growth-history, food, seasonal distribution, period of fertility, the development, and all other phases necessary to an understanding of the life of the halibut. To this field the writer has been assigned.

The work concerning which this preliminary report is issued was begun in May, 1914, when the first trip to the fishing-grounds was made. Since then numerous trips have been made to various banks, especially to those fished by vessels from Canadian ports. In each case the trip was made on a boat belonging to one of the fishing firms of the Province, and the writer wishes to express his appreciation of the permission given him to do this, and for other aid extended to him by these firms. For the summer of 1914 the Canadian Fish and Cold Storage Company of Prince Rupert allowed very cordially the use of its vessels, and the greater number of trips were made on them, for which sincere thanks are tendered, as well as for the courteous treatment received from the various individuals connected with the firm. The Canadian Fishing Company of Vancouver has likewise extended every aid in the use of its vessels and in the obtaining of fishing records for years past. Thanks are also due the Skeena River Fishing Company for information and the proffered permission to accompany its vessels. To Mr. Thomas Peterson, mate of the steam-trawler "James Carruthers," is due much credit for observations on the spawning season and his intelligent assistance at every opportunity. His contributions are mentioned in the text whenever they are made use of. For courteous treatment while on their vessels I thank Captains Freeman, Hill, Selig, Candow, and Knighthall, with whom the greater number of the trips were made.

The report has been compiled in the laboratories of Stanford University, with the kind permission of Dr. C. H. Gilbert, to whom I owe much in the way of advice and encouragement.

METHODS.

The work of collecting data was done on the fishing-vessels, it being necessary to accompany them to the banks on each trip, and the conditions met with on the boats modified the procedure greatly. Much time was thus lost, as the vessels usually fished only when the weather was suitable, and were compelled to prospect a great deal until banks were found which yielded well. The fish were examined on the deck as they were brought in. The decks were always so slippery and slimy that it was necessary to lash the fish down "fore and aft" to guard against the rolling movements of the vessels as they lay in the trough of the seas. Also, of course, the place chosen to work on could not be in the way of the fishermen at their work, and it was, therefore, necessarily distant from the "checkers" or pens of fish, despite the difficulty of handling heavy fish on a slippery deck. Care was likewise necessary that no cuts were made which could injure the market value of the fish. As a result of these conditions it was possible to examine less than a hundred fish in a day, save in exceptional cases where the fish were small. It need only be said that accurate work under such conditions was time-consuming.

It is perhaps a natural query to ask why it was not possible to examine the fish when they were brought ashore, and thus avoid the disagreeable working and living conditions. However, it cannot be too strongly emphasized that work of that sort would have been nearly worthless. The fish in a vessel may come from any bank, where conditions vary. The sexes cannot be told apart with any assurance whatever, because all the viscera are removed, and the cuts made in cleaning the fish, which is done on the banks, allow the head to assume an unnatural position and make the measurement of length inaccurate. The inability to distinguish the two sexes would alone be sufficient to invalidate any work after the vessels are docked.

Measurements of the length of the fish were made by laying a steel tape along the body from the tip of the snout to the base of the caudal fin. This has the advantage of being the only practical method with fish varying so widely in size and examined under such conditions, but is perhaps less satisfactory than a perfectly straight measurement made between vertical lines at the extremities would be. An attempt was made to utilize such a method, but a rigid measuring-stick was quickly broken by the fish or the passing fishermen, and proved decidedly awkward to handle where quickness was indispensable.

To allow of the translation of terms of length into terms of weight, such as are used by fishermen, a plotted curve giving the weight at various lengths is given. In estimating the accuracy of this there are several circumstances to take into account. The data for the curve have been obtained by means of a spring scale weighing up to 50 lb., and there is a slight error assignable to the use of this type of scale. No other kind was feasible aboard the halibut-boats, however. The possibility should also be considered that the results from other banks than the ones on which the measurements were made will prove to be somewhat different.*

Table I.—Weight of Halibut at any Length.

Length in Inches.	Weight "Round" (uncleaned). Lb. oz.	Length in Inches.	Weight "Round" (uncleaned). Lb. oz.
19	4 0	32	19 11
20	4 8	33	21 11
21	5 3	34	23 8
22	6 0	35	25 8
23	6 13	36	27 10
24	7 10	37	29 10
25	8 8	38	31 10
26	9 8	39	33 14
27	10 10	40	36 11
28	11 13	41	39 8
29	13 10	42	41 13
30	15 10	43	43 11
31	17 10		

PREVIOUS LITERATURE.

There is very little in the literature of the subject which requires any remark in a preliminary report. The fallacy of reasoning from the habits of other species of flatfish should be an evident one, and nothing has been accepted as true unless shown so by actual data obtained. The writer, however, freely acknowledges that the direction of his efforts has been very largely influenced by the splendid work of the English, Scotch, and German writers on the plaice (*Pleuronectes platessa*) of the North Sea.

* In giving the results they are sometimes presented with the aid of plotted curves. This graphic method is occasionally hard to grasp at once by one not accustomed to scientific methods, and in order to assist such a one, the use of the plotted curve showing the weight of the halibut at various lengths is explained. These are in each instance average weights and average lengths, so that in taking any one individual the correspondence would not be exact, but when many are considered this should be true. The results initially obtained were arranged in proper sequence, and "smoothed," by averaging each average weight with that for the length preceding and that succeeding it. This is, of course, an arithmetical process, not altering the truth of the curve, but eliminating small chance variations. To obtain the weight at any given length from the chart, the length desired should be sought along the base, then the vertical line above it should be followed up until it crosses the plotted curve at a certain point. Following the level of this point over to the right will lead to a certain given weight, which represents the average one for the length taken. Thus a fish 38 inches long would be 23 lb. in weight on the average, if the fish were cleaned and headed, but if still "round" it would weigh 32 lb., as shown by the plotted curve. The word "round" is applied by fishermen to the fish as it is taken from the water.

A single paper by J. Playfair McMurrich * has appeared dealing with the life-history of the halibut which it will be necessary to review. There are no others which are not mentioned in the text as their conclusions are touched upon. Dr. McMurrich reaches the main conclusion that the halibut becomes mature in its eighth year, gives certain lengths as attained at certain ages, and deducts from the scales various facts so contradictory of the results here presented that they must be treated in detail.

In so far as the age and rate of growth are concerned, it is sufficient to cite the material upon which his results were based. Three only of his specimens yielded perfect scales, and the sex or the locality from which it came was known for none of these. To any one acquainted with the nature and extent of the normal variation in fishes the futility of basing facts on but three specimens is obvious, and the failure to take into account the sexual differences and those due to locality, which are shown to be so great in this report, renders his results on the rate of growth of questionable value in so far as scientific work is concerned, and they were probably not meant as such.

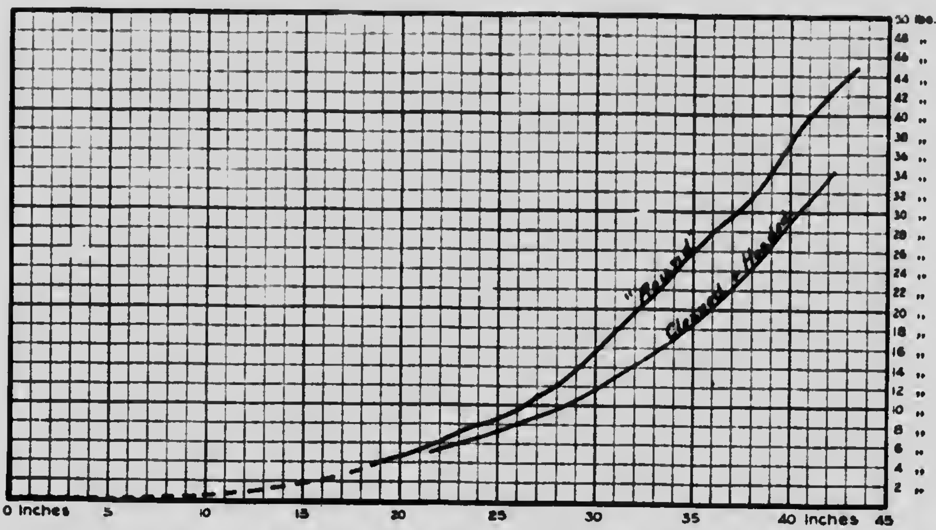


Fig. 1. Curves showing approximate average weights of "round" and cleaned fish of any length. (To use, see foot-note on page 77.) Round, from 141 specimens taken off Yakutat, Alaska; cleaned, from 56 specimens from off Frederick Island, B.C. (Broken line indicates theoretical weights.)

The remarkable hypothesis is made, however, that the age at maturity and the spawning "period" may be read from the scales, something which has assuredly never been seriously considered by any other investigator for a marine fish. It is not a case of a true spawning-mark, such as the Atlantic salmon shows, which is caused by a resorption of the margin of the scales, but rather a diminished breadth of the annual zones of growth. Dr. McMurrich states his deductions as follows (the italics are ours) :—

"The fish does not become sexually mature until about its eighth year," and "such fish are in their eighth year" (loc. cit., page 4). Taking his specimens in turn, he states that "throughout the entire scale no indication of any *marked interruption of growth such as might be produced by spawning* was to be seen . . . the fish required seven years to reach a length of 66.5 cm." (loc. cit., page 2). Again, of the second fish, "In the eighth year, 1908, a spawning period began, which lasted, apparently without any decided interruption, throughout the succeeding four or five years. During this period the growth of the fish proceeded at a much slower rate than formerly, but with the beginning of 1912 the *spawning ceased and a period of very*

* Notes on the Scale Markings of the Halibut and their Bearing on Questions Connected with the Conservation of the Fishery. Transactions of the Royal Society of Canada, III. Series, 1913, Vol. VII., Sec. IV.

rapid growth began." Considering the third fish, "It cannot be said that this entire zone represents a continuous period of reproductive activity, for the *intervals between the successive winter bands vary in width*, and the lines in some of the intervals are much less distinct than in others. More probably *periods of reproductive activity alternated with periods of normal, though diminished, growth* throughout the seven years represented by the zone; indeed, it would seem that the first three years were essentially reproductive periods," etc. (loc. cit., page 4). The further deduction is made that "It would seem that the ripening of the halibut ova is a gradual process and that the spawning is not a matter of a few days or even weeks, but is *prolonged*, it may be, *several years*." Again, "the nucleus was surrounded by a band of very narrow lines, which probably indicate a winter's growth, the conclusion being that the fish from which the scales were taken were spawned either in the late fall or early winter." Without quoting further, his hypothesis may be briefly summarized by saying that his only two mature fish had both first bred in their eighth year, that periods of reproductive activity were shown by diminished width of the annual zones, and that the fish did not spawn every year but alternated periods of reproductive activity with simple rapid growth, the reproductive stages being continued through a period of years.

The data given in this report will be found to controvert most of these deductions on the scales. Although both of the mature fish which he had were supposed to have bred at their eighth year, I find that there is only one female in twenty-five which may be said to be mature at that age, and the discovery of two at the same time, and no others save an immature example, is rather remarkable. There remains, of course, the possibility that both the examples were males, regarding which the age at maturity has not yet been worked out. But of a decreased rate of growth at the assumption of maturity there is no evidence of any sort, especially in the case of the males (*see* Figs. 2 and 3), and we know of no case in which the beginning of the breeding season has ever been correlated with a sudden decrease in rate of growth. This is contradicted by one of his own statements given above, that "the ripening of the halibut ova is a gradual process." Also, the spawning season is shown in this report to be of yearly occurrence, contrary to his opinion, and to lie between December and June. Hence the specimens cited could not have been spawned at the time assigned, and there is evidently something fundamentally wrong with the interpretation he has made of the nuclear rings. The spawning season of the halibut in the North Sea has been published, and reference to that should have given pause to such a statement. Furthermore, all the fish above a certain size examined in this work on the spawning season may be shown to have been breeding, none of them being in a resting state, and the examination of the ova of all the mature fish examined of any size showed normal growth and development in preparation for the following season. It seems conclusive, then, that no such remarkable life-history need be looked for, and Dr. McMurrich's hypotheses may be safely disregarded. Properly conservative deductions made from the scales are, however, of undoubted value, and these remarks are simply made in order to clear the field for further work.

THE AGE AND SIZE OF THE HALIBUT.

In determining the age of the halibut the writer has made use of the otoliths,* or ear-bones, as has been done with such signal success with the European plaice. The collection of these otoliths has been the main purpose of most of the field-work which has been done so far, and in order to do this most purposefully they have been worked over in a preliminary way, and several of the main conclusions may be here given. The interpretation of the otoliths has proven difficult in some cases, and certain of them require more study than has been given, but these difficulties are of minor importance, and do not affect in any way the truth of the comparisons made.

The accompanying tables are arranged in such a way as to compare the size of the sexes as well as those of different localities. It will be noted that: (1) The females are always larger than the males; (2) that the fish from Hecate Strait are very much larger than those

* The otoliths, it may be explained, are the "ear-bones," found inside the skull behind the eye-orbits, a pair in each fish, and situated in a part of the hidden, internal ear of the fish. They are concretions of limy material with a slight quantity of organic matter, and show on close inspection rings or zones which represent years of growth. When the head of the fish is cut off by the fishermen on landing, these small, oval, flat "stones" or "bones" may be found to have dropped out and may be picked up off the floor in numbers. The scales, as in the salmon, show the same zones, one for each year of the fish's life, but are harder to decipher than are the otoliths.

from the other two banks given, and that these, also, differ between themselves; (3) that the age of the oldest of the halibut is about twenty-two or twenty-three years, and that the youngest is in its third year. The facts as to the age attained are probably not entirely unexpected, as an estimate of twenty years is given by Captain Joyce. (*See* Alexander. Preliminary Examination of Halibut Fishing Grounds of the Pacific Coast. Bureau of Fisheries Document No. 763.)

The numbe of specimens utilized in making the table presented totalled 630, of which 290 were from Hecate Strait, 165 from Kodiak Island, and 84 from Frederick Island.

Table II.—Average Length in Inches of Halibut at Any Age.

Age.	Hecate Strait.		Frederick Island.		Kodiak Island.	
	Male.	Female.	Male.	Female.	Male.	Female.
III.	(17.0)	...	...	...	...	...
IV.	19.3	20.6	(21.0)	(22.5)	...	...
V.	(23.8)	24.2	(18.5)	(20.5)	...	...
VI.	24.3	28.1	(24.6)	(28.5)	...	...
VII.	27.6	30.7	(23.0)	(26.6)	(20.3)	(22.7)
VIII.	31.6	35.4	(27.8)	(25.5)	22.4	25.5
IX.	31.7	37.0	25.4	(25.1)	24.0	27.8
X.	33.6	(35.6)	27.4	30.7	25.2	26.8
XI.	34.[illegible]	39.3	29.4	32.8	26.3	28.6
XII.	36.6	41.8	(27.5)	(30.0)	27.7	29.0
XIII.	39.4	51.6	(30.2)	(36.8)	28.8	31.8
XIV.	(39.0)	48.2	(31.5)	...	29.0	34.5
XV.	(37.7)	49.9	...	...	29.7	(33.8)
XVI.	42.8	...	(37.5)	...	32.4	38.9
XVII.	(41.5)	61.2	(37.5)	...	(32.1)	(42.4)
XVIII.	(43.0)	69.0	(38.2)	...	(36.4)	38.4
XIX.	...	(65.0)	(36.7)	...	(30.7)	...
XX.	...	...	(37.5)	...	...	...
XXI.	...	(55.2)	...	...	...	...
XXII.	...	(57.7)	...	...	...	...

NOTE.—Those figures in parentheses are based on too few specimens, less than five, to be considered at all conclusive.

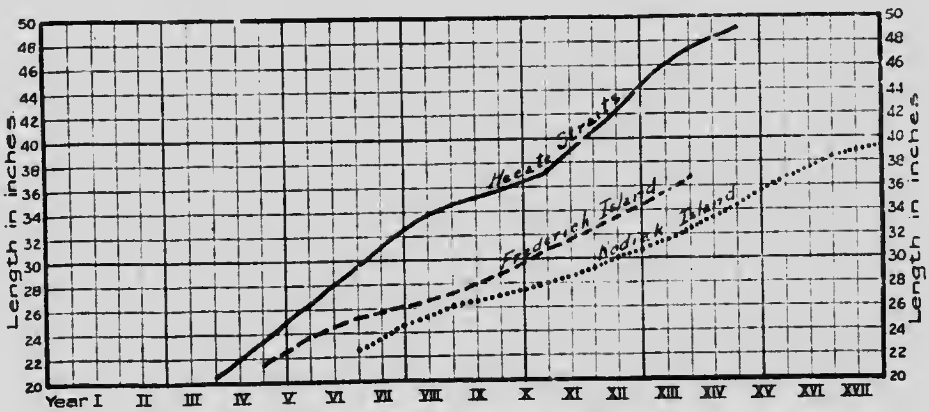


Fig. 2. Average length of female halibut at any age. Within limits caught by hook. ("Smoothed" curve; *see* page 77.) Kodiak Island, 125 specimens; Frederick Island, 32 specimens; Hecate Strait, 170 specimens.

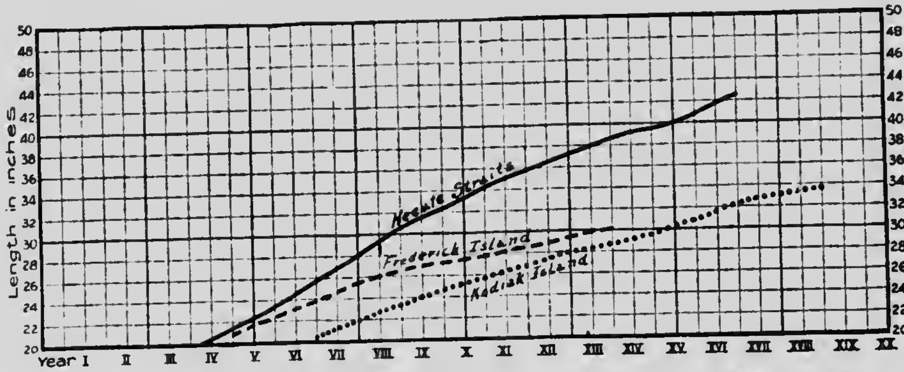


Fig. 3. Average length of male halibut at any age. Within the limits caught by hook. Kodiak Island, 140 specimens; Frederick Island, 52 specimens; Hecate Strait, 111 specimens.

By utilizing those figures based on enough specimens to be correct without averaging them with others, or by using the smoothed curves, it may be found that the males are but 88 per cent. (about ⅞) of the length of the females, practically the same proportion if any one of the three banks are considered. A male of 26 lb. (35 inches long) would be of the same age as a female of 35 lb. (40 inches in length), in terms of weight, the male being but 75 per cent. of the weight of the female. This discrepancy in size seems to be most marked in old specimens, but further data may throw a different light on it. The difference in ultimate size of the two sexes has been noted by G. Brown Goode.*

There is also a striking difference in the size attained by the fish from the different banks. A fish 26 lb. (35 inches long) from Frederick Island would be approximately the same age as one 45 lb. (43½ inches long) from Hecate Strait. In other words, the fish from Frederick Island are but 55 to 60 per cent. of the weight of those from Hecate Strait. The fish from Kodiak Island are, in turn, smaller than those from Frederick Island. They are approximately 73 per cent. of the length and 40 to 52 per cent. of the weight of those from Hecate Strait.

By making use of the curves given in Figs. 1 and 3, the difference in weight of male fish from various banks may be provisionally tabled in order to contrast the rates of growth on different banks. It must be remembered that these are average weights.

Table III.—Weight of Male Halibut from Different Banks.

Age.	Kodiak Island.	Frederick Island.	Hecate Strait.
	Lb.	Lb.	Lb.
IV.	...	...	4.9
V.	...	5.2	6.6
VI.	...	7.1	8.5
VII.	5.6	8.7	11.3
VIII.	6.8	9.7	14.9
IX.	7.9	10.4	18.7
X.	8.9	11.3	22.1
XI.	10.1	12.3	25.3
XII.	11.5	13.6	29.2
XIII.	12.7	16.1	32.1
XIV.	14.3	...	34.1
XV.	16.3	...	36.6
XVI.	18.7	30.5	40.5
XVII.	20.9	...	...
XVIII.	22.4	...	...

* Fisheries and Fishing Industries of the United States, Sec. 1, 1884, page 189.

These facts indicate that these small fish are not young, but have simply not grown at the rate that those on other banks have done. It also indicates that the superior quality of the fish from Hecate Strait has a very real scientific basis, as those taken from the banks in that region are almost always immature, young fish. As will be shown later, the white side frequently becomes grey with age in the larger fish, and this will explain the greater prevalence of "grey" fish in the catches from the Alaskan banks.

What peculiar characteristics of the banks cause this enormous variation in rate of growth is, of course, as yet totally unknown, there being no knowledge as to the rates of growth on other banks than those here treated. It will perhaps happen that the first discovery of a bank which ultimately gives small-sized fish will seem to show fish averaging well in size, although no very large ones are included. In such a case it is evident that the older fish are being caught first. Captain Freeman, of the New England Fishing Company, one of the oldest and best known of the fishermen on this coast, states that the fish on any bank are much larger when it is first fished. To confirm this there are no data at hand yet, although it may be possible to show that the percentage of mature fish will be smaller on the banks which have been fished the longest time. The statements of fishermen, therefore, which do not take into account this change in the size of the fish on a bank are of little value, the only conclusive test as to rate of growth being the determination of the age of a sufficient number.

Similar remarkable contrasts in the rate of growth of fish from different localities has been recorded for the plaice (*Pleuronectes platessa*) of the North Sea.* It is certainly a phenomenon of the greatest importance, as it may have a vital bearing on the questions of conservation and artificial propagation, as well as the natural history of the fish, and should be the object of a more thorough investigation than has been the case with the work on plaice.

These differences have been corroborated in several ways:—

(1.) The largest size reached on the various banks corresponded to the difference in the rate of growth of the fish. Thus the largest male taken off Kodiak was 37 inches in length, whereas in Hecate Strait the graphic curve constructed ended normally at a point between 40 and 44 inches. The longest female from off Kodiak was 45 inches long, comparing with 60 inches from Hecate Strait. The same comparison holds in so far as Frederick Island is concerned, although the smaller number dealt with leaves the limit of size inaccurate. The longest males were 39 inches, the longest females 42 inches.

(2.) The size at which the fish on each bank mature can be shown to be very closely related to the rate of growth; that is, the age at maturity is the same on all banks. In other words, the rate of growth could be foretold by comparison of the size at maturity with that of fish from another bank where the rate of growth is known. This is shown under the heading "Age at Maturity."

(3.) In connection with the striking difference in rate of growth might be cited differences in the proportionate length of the head. Fishermen have repeatedly made the statement to the writer that there were "big-headed" and "small-headed" fish, the former yielding less net weight after the removal of the head. As far as may be ascertained, their ideas in this regard do not conflict with the probability that the big-headed fish come from the banks on which the slow-growing fish are found, although such an hypothesis would not be maintained without further proof. It is interesting in this regard to repeat the statements published in a preceding article by the writer,† which were made before the rate of growth was investigated:—

* Garstang. Various papers in the Marine Biological Society Journal.
† *Pacific Fisherman*, December, 1914.

"Thus, as shown in the following table, the length of the head in Alaskan material is proportionately greater than in that from British Columbia. The head-lengths are given in terms of hundredths of the body-length:—

Sex.	No. of Specimens.	Head-length.
Kodiak Island.		
Male	80	29.33
Female	107	29.07
Middleton Island.		
Male	74	29.39
Female	148	29.16
Queen Charlottes.		
Male	85	26.8
Female	146	26.89

"Kodiak Island is in longitude 153° W., on the west side of the Gulf of Alaska, and Middleton farther east in longitude 146° 15′.

"Such differences may indicate the presence of local races, or they may be due to the modifying effect of climatal or other environmental factors. In this connection, averages from two intermediate localities are given below, although the number of specimens involved is much too small. They are Dry Bay, in longitude 138° 25′ W., and Cape Ommaney, in longitude 134° 45′ W.

Sex.	No. of Specimens.	Head-length.
Dry Bay.		
Male	7	28.92
Female	28	28.22
Cape Ommaney.		
Male	2	27.75
Female	12	27.89"

The measurements from Kodiak Island and Middleton were of fish of this characteristic slow growth, while those from the Queen Charlottes consisted in great part of Hecate Strait fish. Those from Dry Bay and Cape Ommaney are yet to be classified, and it may prove that they are intermediate in rate of growth.

It is suggestive in this connection to recall the characteristics of a poorly fed fish, which has a large head and lank body. Whether it would have a relatively longer head is, of course, open to speculation. It is, at all events, far from impossible that the difference in rate of growth results from differences in the food-supply.

THE SPAWNING SEASON.

For the European halibut the spawning season is said by H. C. Williamson * to be from January to May, a period of five months, for the northern part of the North Sea, as derived from the scattered records. As, of course, this could not well be applied to Pacific halibut without observations, it was attempted to ascertain the season on this coast as nearly as possible, but it was unfortunately not feasible to do this during the last season as definitely as was desirable. However, it may be stated with confidence that the halibut breeds on this coast between the middle of December and the last of April or the middle of May.

The fishing firms in Prince Rupert and Vancouver were asked to preserve a series of gonads throughout the season, but unfortunately were delayed until after the season was under way. However, Mr. Thos. Peterson, mate on the S.S. "James Carruthers" of the Canadian Fish and Cold Storage Company, kept samples and preserved them for me throughout the early part of

* Part III., Twenty-eighth Annual Report, Fishery Board for Scotland, page 46.

the season. Hence it is possible to state approximately its beginning. In March, from the 8th to the 24th, the writer was on the "spawning-beds," if that term is correct, off the Queen Charlotte islands, and during the previous year had examined fish during the months of May, June, July, August, September, and October.

The following are quotations from the notes of Mr. Thos. Peterson:—

(1.) "These samples were taken on the 14th of December off Middleton Island, Alaska. We got a few fish that were all through spawning. I spoke with fishermen on the S.S. 'G. E. Foster, in with 157,000 lb., and they told me that the fish were filled with spawn ready for spawning. These were caught off Icy Bay, Alaska."

(2.) "We just arrived to-day, and I am sending you more samples of spawn, ten only. They are very hard to get, as when the fish strike the deck the spawn runs out of them. Two marked samples were taken west-by-south, 110 miles off Ocean Cape, in 130 fathoms of water, on the 5th of February, all obtained in two days' fishing. The rest were taken from the 9th to 13th of February, west-south-west, off Cape Spencer. Some days I could not get a single sample, as the fish were spawned out. Some of the samples are not, perhaps, clean, as it was a hurry to get the spawn when the fish struck the deck in the night-time."

The samples sent in by Mr. Peterson corroborate his statements, and the results of their examination is given below.

On the voyage made by the author during March, 1915, the banks twenty-five miles south-west-by-south from Frederick Island (160-180 fathoms), those at Rose Spit (60-100 fathoms), and those off Goose Island (60-80 fathoms) were visited. In each of these places all the fish of large size, apparently all that were mature, were in either a spawning or spent condition. In about a hundred fish plainly mature but one fish was found which was mature but not quite ripe, evidently abnormally delayed. About 35 per cent. of those which were mature had left, in the lumen of the ovary or in the gonaduct, ripe ova in sparse or abundant quantity. No fish were found which had the gonad distended with ripe ova, although some of them were fairly well filled with them. The roe was in no case observed to run after the fish had been brought on deck, although occasionally the ripe ova left in the ovary could be milked out. If the fish lost its roe after being hooked, the loss took place while the fish was still in the water, but this was rendered doubtful by the retention of the ova by some of the fish. In the European halibut ovaries filled with ripe spawn have been obtained, and Mr. Peterson speaks of spawn running on the deck after the fish have been brought aboard. Hence it is probable that the fish observed in March were nearly spent, and had not lost their ova through being caught. It is evident that observations as to this must be made earlier in the season.

An occasional halibut was observed between June 7th and 12th, 1914, near Scudders Point, in Hecate Strait, which had apparently but recently spawned, the ovary being in all respects similar to the spent ovaries observed in March. It is evident, then, that the last of the spawning comes before the early part of June.

From June until October, however, no signs of spawning fish were noticed, but a gradual growth in the size of the ova could readily be followed, and in July, August, and September was found the best time for the distinction of mature and immature fish. The specimens collected by Mr. Peterson during the fall carried on this growth of the new ova until the spawning season commenced, as given above. It is possible that spawning fish could exceptionally be obtained before the first part of December.

It is evident, then, that the spawning period falls between the middle of December and the middle of May, or early part of June at the latest. The conflicting reports as to the time of spawning given by the fishermen are easily explained when it becomes evident that a great many of them do not know what a mature ovum looks like, and regard the time during which the ovary is enlarged and swollen as the spawning period.

There is no question but that the normal females obtained during March were in a spawning or spent condition, and that there were none which could be said to be mature yet not spawning. Furthermore, the uniform development of the ova during summer and autumn was observed in a great number of fish and no exceptions were seen. It is hence impossible to believe that the spawning of the halibut extends over several years and that there are alternating periods of plain growth and reproductive activity, a theory recently advanced by McMurrich.*

* Transactions of the Royal Society of Canada, III. Series, Vol. VII., Sec. IV., 1913.

HISTORY OF THE OVA.

The main points which it is desired to bring out in the history of the ova are: First, that it is possible to tell from an examination of the ovary whether a fish is mature or not, with all the information which that leads up to; and, second, that there is no indication, after fish are once mature, of a period of years during which no spawning takes place. It is also desired to place on record the size of the ova at various seasons, the range of variation in the size, as possibly throwing light on the variation in the time of beginning the season, and the history of the final stages in the ripening of the ova.

(A.) The history may be taken up at the time of spawning, as shown by samples collected in March, 1915, about twenty-five miles south-west-by-south from Frederick Island. It will be noticed that this falls in the latter half of the spawning season (*see* page 84). The condition of the ripe ova may be temporarily ignored in order to study the new generation of eggs.

The gonad of the female at this time is flaccid, its walls collapsed, and is no more than sufficient in bulk to fill the pockets extending back from the posterior portion of the body-cavity of the fish. This contrasts sharply with the turgid condition just before the spawning season commences. The ovarial tissue also shows typical characteristics, being often still very vascular. The ovarial walls are contractile, and when first removed very often contract until the gonad is tense, emphasizing the slight bulk. It is also apparent that there is considerable difference in the length of the gonad in fish of different ages or sizes, reflected by the depth of the blind pocket in which it lies, but the range of variation in this regard has prevented the presentation of any definite data as yet. It is obvious, however, that maturity and spawning bring about prominent and striking changes, admitting of few mistakes at the hands of an experienced worker.

The fact of most importance concerning the ovary at this time is that the next generation of small ova is visible to the naked eye. All the samples collected in March, from the 9th to the 15th, have been carefully examined and the size of these "new" ova determined, and in the following table these data are given. One to two hundred eggs from each sample were measured with an ocular micrometer, the average obtained, and a curve plotted to show the unity of the generation measured. It is impractical to present all these here, and a single typical case is presented in Fig. 4. However, the averages and the modes of the curves are here given.

If the size alone had been depended upon at this time there might have arisen mistakes, as in many immature fish there are a few, sometimes many, ova between the sizes of 0.4 and 0.5 mm. diameter. However, these individuals may be distinguished by other characteristics given on page 91.

Table IV.—Average Size of Small Ova during March in Mature Fish.

No. of Sample.	Average Size.	Mode of Curve.	No. of Sample.	Average Size.	Mode of Curve.
	Mm.	Mm.		Mm.	Mm.
1	0.68	0.69	22	0.62	0.65
2	0.67	0.68	23	0.67	...
3	0.517	0.54	24	0.502	0.51
4	0.604	0.607	25	0.71	[illegible]
5	0.55	0.572	26	0.58	[illegible]
6	0.61	0.64	27	0.64	[illegible]
7	0.585	0.58	28	0.57	0.58
8	0.61	0.61	29	0.63	0.65
9	0.78	0.755	30	0.75	0.78
10	0.57	0.58	31	0.455	0.494
11	0.63	0.65	32	0.68	0.71
12	0.64	0.635	33	0.50	0.547
13	0.497	0.51	34	0.52	0.547
14	0.62	0.625	35	0.46	0.468
15	0.53	0.53	36	0.69	0.73
16	0.565	0.60	37	0.445	0.44
17	0.54	0.63	38	0.55	0.547
18	0.71	0.75	39	0.52	0.53
19	0.51	0.52	40	0.585	0.61
20	0.705	0.73			
21	0.91	0.83	Average	0.595	0.617

It will be noted that the mode of the curve and the average are very close. In no single case is the mode more than 0.08 mm. from the average, and in the greater number of cases not more than 0.03 mm., illustrating the unity of the generation in its development and its independence from the succeeding and preceding generations. The minimum size encountered for any sample was a diameter of 0.445 mm., the maximum one of 0.83 mm., the majority falling between 0.52 and 0.70 mm., as compared with the average size of 0.595 mm. for the whole series of samples. The minimum-sized sample had ova visible without a lens in the fresh condition, and was classified as a mature female in the field-notes.

In Fig. 4 is given a typical plotted curve for all the ova in a sample which was taken from a gonad still containing large ripe ova fully ready for extrusion. The position of the next generation is indicated by (B).*

(B.) From the end of the spawning season, about June 1st, the ova grew steadily and in a uniform manner. The seasonal progression in size was easily noticeable, and, as far as the writer could ascertain from the examination of a great many mature examples, it was also universal. The fact that every example collected by Mr. Peterson, who made no attempt at selection on this score, had ova within the range of variation to be expected is conclusive on this point even without the experience of the writer. The first of these, a series of fourteen examples collected off Middleton Island, Alaska, on September 20th, 1914, were examined in the manner previously detailed, and are here given. The mode of the plotted curve is given for but five of the samples, as there was no question as to the distinctness of the generations of ova.

Table V.—Average Size of Ova in Samples collected on September 20th, 1914.

No. of Specimen.	Average of Size.	Mode of Curve.
	Mm.	Mm.
41	1.54	1.52
42	1.27	1.29
43	1.49	1.44
44	1.22	1.26
45	1.34	1.37
Average	1.37	1.38

No. of Specimen.	Average Size.
	Mm.
46	1.42
47	1.83
48	1.59
49	1.46
50	1.89
51	1.27
52	1.81
53	1.46
54	1.21
Average of all samples	1.48

It will be noted that, incidental to the marked isolation of this, the largest, generation from the genital cells destined to form later generations, the average modes of the plotted curves and the general average coincided in the first five samples. The range of variation in size was not greater than in the samples taken during March, and is included between diameters of 1.21 mm. and 1.89 mm. There was no evidence of any of the fish lagging behind in such a way as to indicate a deferred breeding season, nor was there any indication that the time of the next spawning would differ greatly among the individuals.

In Fig. 4 the positions of the generations just before the largest ova began their final rapid increase is indicated by the broken-line plotted curves, as compared with the unbroken-line curves (indicating the relative position of the generations at the end of the breeding season, when all the ova were ripe). It will be noticed that the second generation (b) is not to be distinguished from the mass of ovocytes (c), whereas the generation to be ripened the coming season is indicated by (a), as yet a long distance from the diameter it will have when it occupies the place of (A).

* For a comparison of these facts with the history of the ovary in the plaice (*Pleuronectes platessa*), the paper by Victor Franz on "Die Eiproduktion der Scholle," in "Wissenschaftliche Meeresuntersuchungen, N.F. 9 (1910), Abtheilung Helgoland," may be seen. The cytological changes in the ovum are there dealt with.

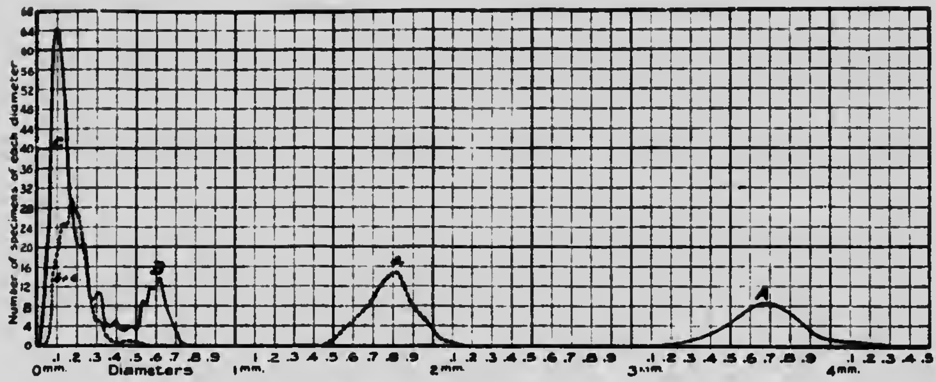


Fig. 4. Relation of the generations of ova in two sta~~s.
—— From a spawning fish: A—Ripe ova, full size. B—Second generation. C—Later generations.
---- From a fish before spawning: a—Ova just before rapid growth begins. b & c—Second and later generations not yet distinct.

Table VI.—Average Diameter of Ova in Samples collected on November 6th, 1914.

No. of Sample.	Average Diameter of Translucent Ova.	Average Diameter of Opaque Ova.	Average per Cent. of Translucent.
	Mm.	Mm.	Per Cent.
55	...	1.76	...
56	1.95	1.82	9.2
57	2.14	1.79	11.5
58	2.3	1.80	6.0
59	2.15	1.76	11.0
60	1.88	1.81	28.0
61	...	1.77	...
62	...	1.85	...
63	(Too few)	1.83	1.0
64	2.39	1.91	12.5
65	2.33	1.89	28.5
66	2.28	1.91	9.6
67	2.3	1.83	8.6
68	2.61	1.96	10.6
Average	2.23	1.84	...

(C.) With the approaching midwinter, however, there seemed to be a marked acceleration in the growth of certain of the ova, accompanied by an increasing translucency* easily detected by the naked eye even in preserved ova. There was no sharp distinction as yet between these and the other ova, but in order to obtain data on their size and growth the ova in each sample were sorted into two lots, termed loosely "translucent" and "opaque." The table gives the average sizes of these lots in the samples taken on November 6th, 1914, off Middleton Island, Alaska, together with the percentage of the total which were termed "translucent." No exact significance should be attributed to the percentages, as they are simply to show that there were not great numbers of translucent ova.

Regarding this stage the important facts are several. The increase in diameter since September 20th, a month and a half, was 0.36 mm.; and we have here what appears to be

* According to Franz (Wissenschaftliche Meeresuntersuchungen, N.F. 9, 1910, Abth. Helgoland), this translucent appearance has its origin at a much earlier stage, but here it is intended to imply simply a translucency easily visible without close examination and accompanying the rapid acceleration in growth.

the maximum diameter reached by the ova before they assume the more rapid growth of the final stages of ripening. This was apparently not began synchronously by all the ova, but at first a small percentage changed, indicating that certain of the ova would be ripe for discharge first. In Fig. 5 is given a plotted curve for one of these examples, typical of the others, in which the increased size is shown to be correlated with the increased translucency.

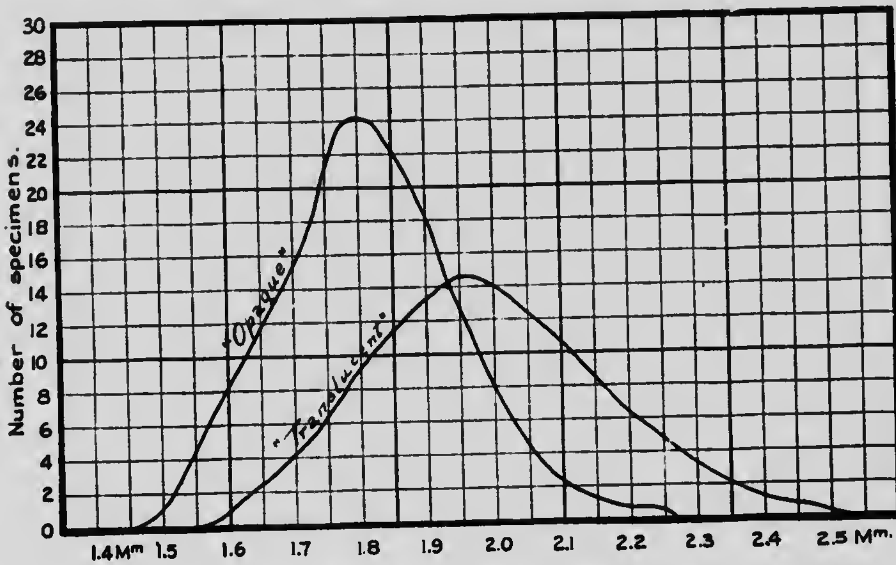


Fig. 5. Plotted curves of ova from a sample taken December 14th, 1914, showing differing size of opaque and translucent.

(D.) In the samples taken on December 14th, 1914, by Mr. Peterson there was admittedly an unconscious selection on his part, due to the rejection of ripe ova, perhaps because of his lack of familiarity with their appearance. Although he found fish "spawned out," he included none of the ripe spawn. However, it is interesting to note conditions in the samples given.

The ova were again sorted into two lots in each sample, "translucent" and "opaque," and a series of measurements made of each. The "opaque" ova were of nearly the same average diameter as those of the preceding set of samples taken five weeks previous, but the proportion of translucent was much greater in every case. Until a more perfect series of samples can be obtained, however, no further data will be given on these.

(E.) One more set of samples was taken by Mr. Peterson on February 9th to 13th, 1915, off Cape Spencer. These represented perhaps the height of the spawning season and should be very significant, as they were again chosen without selection. They should represent those stages where, if the ripening is a gradual process, there are still small opaque ova present in addition to the ripe ova. If the spawning of each fish were to cover but a short period of time, the probability of obtaining such samples would be very small at any one time. The occurrence of any number of them would indicate that each fish consumes a considerable period in spawning, as the chances of obtaining it in that condition would be proportionately greater.

The samples, ten in number, were in each case composed in large part of ripe ova, but in four of the cases small "opaque" ova were present. In making the following table the same methods were used of dividing each sample into groups of "translucent" and "opaque" ova. In some cases the two types of ova were seen to be attached by ovarial tissue, but it is evident that there may have been in some of the cases more of the ripe, loose ova taken than were representative of the whole ovary. In two of the cases in which opaque ova were present the averages of the two "groups" were widely separated, and the two were not connected by ova of intermediate size (*see* Nos. 70 and 72). It is therefore possible that successive groups of ova are ripened in each ovary and discharged in "batches." To prove this would require more evidence than is at hand at present. It is evident, however, that the taking of ovaries in a transitional state is frequent enough to lead to the assumption that the spawning extends over a considerable period of time in each female.

It may be noted that the large ova were nearly the size of the ripe ones collected in March, and in every case were equal to the diameter of those found loose in the lumen of the gonads. The "opaque" ova were, however, of very slightly larger diameter, if any, than those designated as "opaque" in the early part of November, and which were characteristic of the set of samples taken in December. Hence it may be inferred that a large part of the time intervening was occupied by the gradual increase in the percentage of ova ripened and discharged, a part of the "opaque" ova of the first examples being the ripe translucent ova of the last.

Table VII.—Average Diameter of Ova in Samples collected on February 9th to 13th.

No. of Sample.	Average Diameter of Translucent Ova.	Average Diameter of Opaque Ova.
	Mm.	Mm.
69	3.01	...
70	2.69	1.97
71	2.81	...
72	2.75	1.86
73	2.74	...
74	3.18	(Too few to average)
75	2.78	...
76	3.36	...
77	2.24	1.95

Brook (Fourth Annual Report, Fishery Board for Scotland, 1885, page 224) gives the following notes on a fish which was apparently in this transitional stage:—

"The eggs were in three stages of development: (1.) The bulk consisted of unripe ova about 2.55 mm. in diameter, which were yellowish in colour and very oily outside. (2.) Nearer the centre were patches of ova similar in size to the above, but white and opaque. In these a large number of yolk spherules could be made out. (3.) Among the patches of opaque eggs were little clusters of larger ova, which were quite transparent and showed no division of the yolk into small spherules. It is probable that these eggs were quite ripe. They floated at first on being placed in sea-water, but being dead they soon sank to the bottom. The largest measured about 4.25 mm. in diameter. I did not notice any oil-globule."

As the samples sent by Mr. Peterson were preserved in formaldehyde, it may be that this stage in which the yolk is collected in small spherules is the beginning of what I have termed the "translucent" stage, and that when observed alive this fact will become evident.

(F.) It remains to describe the ripe ova as found by the writer during March. The relative size of the different generations in the latter part of the spawning season is shown by Fig. 4, in which (A) represents the ripe ova of full size, (B) the next year's generation, and (C) the mass containing later generations. No importance should be given to the relative numbers of each generation counted. The eggs which were destined to be shed had in every case reached their full size among the specimens examined, save a single one which was full of eggs not yet ripe. No small opaque eggs were left of that season's generation. The uniformity with which this prevailed among the many mature fish examined indicates the uniformity of the spawning process.

When taken from the ovary, placed in sea-water for a time, and then preserved in formaldehyde, the ripe ova averaged 3.671 mm. (0.145 inches) in diameter, with a range from 3.3 mm. (0.134 inches) to 4.2 mm. (0.166 inches), roughly ⅛ to ⅙ inch. As viewed fresh in sea-water with the naked eye they appeared clear and transparent, with a white opaque fleck on one side. There was no oil-globule to be seen. The surface appeared faintly cross-hatched when viewed under the miscroscope, and was in all essentials as described by McIntosh.*

* Contributions to the Life Histories and Development of the Food and other Fishes. Report, Fisheries Board for Scotland, 10, 1891, page 273.

The eggs when first obtained from the fish were several times placed in sea-water. They at first floated, but in a few minutes seemed to become more turgid, slightly more opaque, and sank to the bottom. They remained there as long as kept, several days in one instance, and the sea-water could be easily decanted and renewed, though the ova showed no capacity of attaching themselves. It is probable that these eggs are not pelagic, as they have never been taken in the plankton by European workers, extensive as has been the work of that sort.

Whether the halibut discharges some of its ova after being caught on the hook and before being brought to the surface has not as yet been ascertained. This has been discussed in another part of the paper, but it may be here remarked that the observations on this were made during the latter part of the season, when, if the gradual ripening of the ova is to be taken into account, the gonad was not tense with ripe and unripe ova. The accounts by European writers of ovaries distended with ova may apply to the early part of the season, and Mr. Peterson refers in his notes to ova being spilled on the deck during the earlier part of the season.

It is probable that it is impossible for the fish to retain all the ova it sheds during the season in its ovary at the same time, but in order to estimate the bulk which would be discharged by a fish in each season it was necessary to know the number normally carried. Various European writers have given estimates of the number present in the Atlantic specimens, but for various reasons it was decided that these were not accurate enough for the purpose, and a count was made of the most mature ova in a pair of ovaries.

These gonads were obtained from a halibut 42½ inches long, at a time apparently just before the ova were to begin their last rapid increase in size. The ovaries were hardened in formaldehyde, after which it was comparatively easy to work the ova loose from the egg-follicles. The superfluous tissue was removed by many successive decantations and finally was carefully worked over for any ova which had escaped. When the ova were completely cleaned the bulk was measured and a certain known proportion of it counted. The total number of ova was then easily reckoned. The ovary of the eyed side contained 890 cubic centimeters, 25 of which contained 5,822 ova, and the whole ovary was found, therefore, to contain 207,263 ova. The ovary on the blind side contained 710 cubic centimeters, and there were 5,778 ova counted in 25 of them, the whole therefore containing 164,095 ova. The total number in the fish was hence 371,358 ova. By averaging the initial counts this result was obtained a little different, being 369,792 ova, on which the reckoning below is based.

Fulton* estimated the number of ova in three specimens as respectively 4,451,212, 2,803,975, and 1,489,510, on the basis of the weight of the individual ovum as compared to the bulk of the ovaries. This, of course, did not discount the weight of the gonad tissues and other generations of ova, as he was simply considering the relative fecundity of fishes. Brook† estimated the number in a 91-lb. halibut as 1,327,000. It is probable in both these cases that the weight of the gonad and minute ova was underestimated, but all the specimens were very much larger than that utilized in the present case, and this may well account in large part for the discrepancies. Franz‡ found that the egg production of the plaice increases with age and length, did Reibisch.‖ It would be expected that the same would hold true for the halibut, and with its attainment of a greater age this should be more susceptible of demonstration.

The average diameter of the ova taken in March was 3.67 mm., and figuring with this as a basis the volume occupied by the whole of the ripe eggs of the specimen whose eggs were counted may be determined. To do this there are three methods available. If the eggs were supposed perfect, turgid spheres, the formula§ used to obtain the total volume would be:—

$$\text{Volume} = \frac{\text{number of ova x (diameter)}^3}{\sqrt{2}}$$

Solving this gives 12.917 litres. This would equal 3.41 gallons, and at the density of sea-water would weigh 29.1 lb. The fish in which the eggs were carried weighed about 42 lb., being 42½ inches in length without the caudal fin, and hence the eggs would be approximately 70 per cent. of the bulk of the fish. If the eggs were turgid but elastic and under compression sufficient to eliminate the spaces between them, the volume of each would not change and the simple formula could be used of: Volume $= 369.792 \times 4/3\pi r^3$, giving a result of 9.45 litres, equalling

* Ninth Report, Fisheries Board for Scotland, 1890, page 261.
† Fourth Report, Fisheries Board for Scotland, 1885, page 224.
‡ Wissenschaftliche Meeresuntersuchungen, N.F. 9, Abth. Helgoland, 1910.
‖ Wissenschaftliche Meeresuntersuchungen, N.F. 4, Abth. Kiel., 1899, S. 233-248, Taf. I.
§ Nineteenth Annual Report, United States Geological Survey, Part II., 1899, page 208.

2.5 gallons, and weighing 21.3 lb., or approximately 51 per cent. of the weight of the fish. If, however, the eggs were not turgid, the formula utilized would be:—

$$\frac{\text{Number of ova x (diameter)}^3}{4} = \text{volume.}$$

Solving this gives 4.57 litres, or 1.2 gallons, weighing 10.3 lb., or 24.5 per cent. of the total weight of the fish. It is very easily seen, then, that it would be impossible for the fish to retain all the ova when they were of full size, and, in fact, the greatest volume of the ovary is reached just before the extrusion of the first ripe ova.

It is necessary, then, to postulate a gradual shedding of the ripe ova. The only conception of the relative length of time taken by this process is reached by the condition of the fish taken at any one time on the bank. If this were exactly the same in all fish obtained, then it would follow that each fish bred throughout the whole of the spawning season. The number of samples collected so far is not sufficient to give accurate results, but the uniformity has been shown to be sufficient to justify the statement that the spawning of each individual occupies a considerable period.

The bearing of this on any attempt at artificial propagation is obvious. To obtain the full quota or even any considerable part of the yield of any fish it would be necessary to keep it in captivity. In the case of such a large, valuable fish as the halibut reaching its mature state at such an advanced age and size, it would appear impracticable to do this. It still remains to be seen whether enough ripe ova may be obtained at any one time to make it profitable to gather the spawn from the fish on the banks when they are first caught. Furthermore, it is still unknown what proportion of the eggs are fertile of those which are retained by the fish.

As the number of eggs produced by a species is supposed to be somewhat proportional to the difficulties encountered in survival after being laid, the value of the eggs obtained from a prolific species would be correspondingly decreased, unless it could be shown that artificial propagation would carry the young over a period more than usually dangerous. The number of eggs of this prolific species which could be handled would be very small indeed compared to the number produced in the natural state to overcome the natural mortality, and the protection of the young would have to compensate for this great disadvantage in order that the commonly accepted value of artificial propagation be maintained. There are, of course, no data as yet on the relative mortality in different stages of the halibut life. It would seem that the fish which could be saved by a certain amount of regulation of the fisheries would produce enough eggs in a state of nature, even under the handicap of great destruction by natural enemies, to surpass anything which could be done artificially. There seems nothing which is more alarming to the careful observer of the halibut banks than the lack of mature fish in certain overfished localities, and it would appear that the protection of a single mature halibut, which would breed for a number of years, would far outweigh the value of the few eggs which might be obtained from it at any one time.

AGE AT MATURITY.

As is shown by the examination of the ovary at various seasons, it is possible to state with some degree of assurance whether or not a fish is to spawn the following season; in other words, to ascertain the maturity of the female at any time. The size of the largest generation of ova is mainly relied upon for this, especially after the early part of July, but there are many characteristics marking the fish which has just spawned which are of use to the observer.*

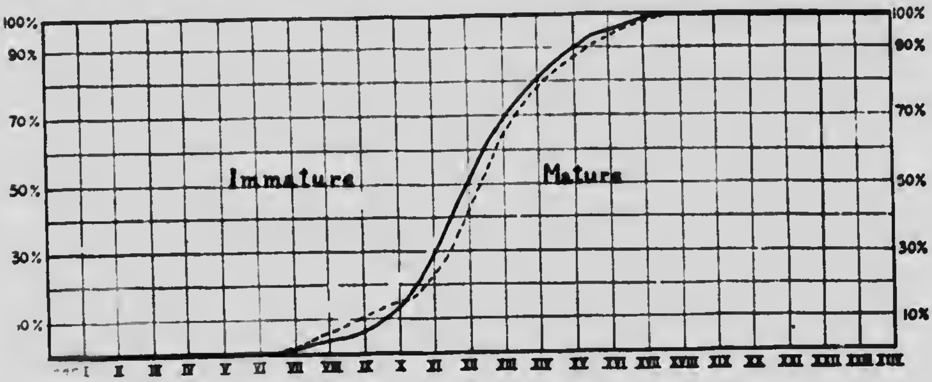
These are, of course, best learned by experience. It is possible to recognize the immature ovary by the translucent, homogeneous appearance, the narrow lumen, the degree of extension of the posterior point backward along the hæmal spines, and the absence of the flaccid condition which persists for some time, and of the vascularity, two characteristics of spent ovaries. There is rarely any question as to the category in which a fish should be placed. The validity of such methods has been sufficiently recognized by scientific workers, and in this preliminary report further details need not be given.

In a great many cases workers have contented themselves with deciding the minimum size at which a fish spawns. This is essentially misleading, as may be seen in the present case of a long-lived species, because it fails to take into account the amount of individual variation.

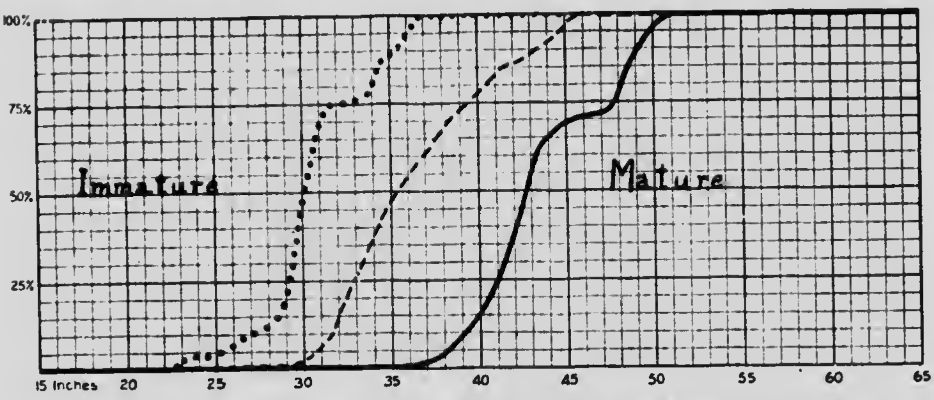
* Holt. Journal, Marine Biological Association, Volume II., 1891-92, page 363; also Maier. Beitrage zur Alterbestimmung der Fische, I., Wissenschaftliche Meeresuntersuchungen, N.F. 8, Abtb. Helgoland, No. 5, 1906, S. 95.

As far as is known at present, in so far as Pleuronectids are concerned, each individual female carries, in years preceding the one in which spawning begins, ova which are fit to become ripe, but fail and degenerate because the ovary as a whole is not yet ready. According to Franz,* this condition is found to be more pronounced in the oldest of the immature fish. There is thus great variation both in the time the individual ovum is ready to ripen and in the time the ovary is ready for spawning.

As each fish was measured and its scales and otoliths taken, the ovary, if the fish was a female, was examined and its state recorded. The percentage of immature and mature fish among those of each length was then reckoned, considering whole inches only. These from three different regions were thus treated—namely, Hecate Strait, Frederick Island (the off-shore banks), and Kodiak Island. Those from Kodiak Island were *recently spent* or with *ripe ova still in the ovary* or *oviduct*. This series thus makes an interesting comparison with the others, which were obtained during June, July, August, and September on alternate trips to the Alaskan and the Queen Charlotte Island banks. Of course, data is available for numerous other banks, but unfortunately none is yet ready to report on. The numbers of fish examined for the banks taken up here are as follows: Hecate Strait, 314; Frederick Island, 157; and



Hecate Strait ——. Kodiak Island ····.
Fig. 6. Percentage of fish mature at any age. (To use, see explanation of Fig. 1, page .



Frederick Island ----. Kodiak Island ..... Hecate Strait ——.
Fig. 7. Graphic curve showing percentage of fish mature, at any length, from Hecate Strait, Kodiak and Frederick Islands. (Smoothed as explained in text.) Method of use: *See* explanation of Fig. 1, page 77.

* Wissenschaftliche Meeresuntersuchungen, N.F. 9, Abth. Helgoland, 1910.

Kodiak Island, 125. In a way these numbers are hardly large enough to give absolutely accurate results, and the irregularity of the curves in places is probably due to that fact. The relative position of each is, however, sufficiently clear, which is the object sought.

The percentage of fish mature at any age was obtained in the same way. Those from Frederick Island were omitted, because the age of the fish examined had not been deciphered. The rate of growth of fish from this same general locality may be consulted, however (Figs. 2 and 3 and page 80). It will be observed (Fig. 6) that the maturity is entirely dependent on age, not on size, as the percentages mature at any one age are very close, sufficiently so to indicate merely the normal variation evident in small numbers. If this is true, then the length of the fish at maturity should be strictly dependent on the rate of growth. By comparing Figs. 2, 3, and 7 it will be seen that this is true, the fish from Frederick Island occupying a place between those from Hecate Strait and Kodiak Island in both cases. It will be seen that 50 per cent. of the fish from Kodiak Island are mature at 30 inches, 50 per cent. of those from Frederick Island at 35 inches, and 50 per cent. of those from Hecate Strait at 43 inches. These lengths in each case are those characteristic of fish in their twelfth year, reading from Fig. 2, page 80, which gives the rate of growth of female fish.

The difference in size at maturity has been previously noted by the writer (*Pacific Fisherman*, November, 1914, page 84), and the fact that this difference should be shown to depend so strictly on the rate of growth is a striking corroboration of the accuracy of the age determinations. In fact, one is tempted to make the statement that the length at maturity could be taken as an index of the rate of growth on different banks. It is believed by the writer that this is a more accurate and less laborious means of corroborating results as to age than the comparison of the maximum sizes attained would be, at least in the case of the halibut.

The most important point brought out by this method of determining the age at maturity is that this is much later than has been thought. There are but relatively few halibut which mature during the eighth year of their lives, the chances being one in twenty-five against obtaining such a one, and there are fish still immature in the fifteenth year of their age. The eighth is, however, the age of a large proportion of the fish in Hecate Strait at the time of capture. In Hecate Strait but 14 per cent. of the female fish caught had completed their twelfth year and but 5 per cent. their sixteenth year. Off Kodiak Island 31 per cent. were beyond the twelfth year and 12 per cent. beyond the sixteenth. This increased percentage of mature fish may, of course, be characteristic of the banks which have been less intensively fished. However this may be, it is evident that a large majority of fish caught do not reach maturity.

The fact that maturity is not reached until such a late age is [illegible] a way surprising, but in other fish of shorter life it is not possible to say that as a rule they have longer breeding life in proportion. The Pacific salmon breed but once, at the end of their second, third, fourth, fifth, sixth, or seventh years. The European plaice (*Pleuronectes platessa*) become mature during their third, fourth, or fifth years,* although the maximum age reached is twelve years, usually less, as compared with a maximum of about twenty-five years for the halibut. However, it is to be expected that the age at which maturity supervenes would vary, as does every other character, with the condition[illegible] to be met by the species. A late maturity would be counterbalanced in some degree by a[illegible]ased number of eggs, and vice versa.

It is believed that these [illegible]s as to the late maturity of the halibut are of the utmost importance in judging of the [illegible]ethods to be used in the conservation of the species, and in explaining the decrease on particular banks. Further investigation of the percentage of mature fish on the different banks is urgently needed, and is under way as fast as the opportunity offers. The relation of maturity to whatever migrations may occur may prove of importance.

THE FOOD OF THE HALIBUT.

It has long been known that the halibut has an appetite of extended range, and its food has been investigated by several writers in Europe and America, but this has not been done for the fish on the Pacific Coast. Scott† gives the food as observed in specimens examined in Aberdeen Fish Market. Thirty-four per cent. were found to lack food of any kind, or what was present could not be identified. The fish found were chiefly Gadoids, haddocks, and whitings, while codfish and brasses were rarely, and flounders sometimes, obtained. Crustacea were found

* Maier, loc. cit., page 98.
† Twenty-eighth Report, Fisheries Board for Scotland, Part III.

frequently, especially in the smaller halibut, as were Cephalopods, while Echinoderms and Annelids were found sparingly or very rarely. This represents very fairly the range of food found in the Pacific halibut, as may be seen.

On the statement by Scott that there is a seasonal variation in food no comment can be made, as the observations on the winter food of the Pacific forms are yet to be made, but a criticism at once suggests itself when it is considered that his observations were made in the market, and that, if fishing is carried on in the Atlantic as it is in the Pacific, the boats resort to different grounds during the two seasons.

It is believed that general purposes will be served by what is here presented, but more sharply defined programmes of the investigation of foods, especially as limited to certain banks, will have a very important bearing on numerous questions. These must lie in abeyance, however, until the more important features of the life-history are known, as age and rate of growth, to which the present work has been primarily directed. Such questions as the seasonal change of food on a bank, the effect of food-supply on distribution, and migration are among these.

As mentioned by Scott (loc. cit.), there were a large proportion of the stomachs empty. Actual data as to the exact percentage was obtained in several places. The fish taken September 3rd, 1914, on the bank off Middleton Island, Alaska, showed 77 out of 130 specimens, or 59 per cent., with empty stomachs; the remainder, or 41 per cent., had undigested food in the stomach; 26 per cent. only were recorded as having food among 241 specimens taken off Frederick Island, and 44 per cent. had food among 295 from Kodiak Island between August 12th and 15th, 1914. In all, over 700 specimens were examined to gather what data is here presented, and although the exact proportion was lost in one or two cases, it may be said that about 34 per cent. contained food.

The wide variety of the food which was found may be illustrated by tabulating the groups represented:—

- Cœlenterates: Sea-anemones, usually fastened to rocks.
- Echinoderms: Brittle-stars, starfish, sea-urchins, and sea-cucumbers.
- Annelida: Sea-hares and Echiuroidea.
- Brachiopoda: Unknown species of "lamp-shell."
- Crustacea: Crabs only.
- Mollusca: Clams and Cephalopods.
- Vertebrata: Fish (with many fishermen's stories of birds to indicate the capture of divers).

On some of the banks, particularly those in 100 fathoms or over, the predominating food was found to be the grey cod (*Gadus macrocephalus*), and it is not to be doubted that this is one of the species most used by the halibut. The following data were taken off Middleton Island, Alaska, in 80 to 100 fathoms, on the "long-liner" "James Carruthers." Of fifty-three fish with food still in the stomach, fifty-one of them had grey cod, one had the "ghost" (*Atheresthes stomias*), one had a red cod (*Sebastolobus alascanus*), and another had crabs.

The following table will give some indication of the relative frequency of the different foods in different catches. Usually but a single kind of food was found identifiable in a single stomach, although this was far from being a rule. A large quantity of the particular kind of food is usually found, indicating that the halibut has not moved so rapidly as to leave the type of bottom on which it was found before the food caught was digested. Hard parts, of course, survive much longer in the stomach than do soft, and frequently numbers of fish otoliths, eye-lenses, and cephalopod jaws are found, resulting in a larger representation than is correct of these forms. The same may be true of the crabs, although the chitin seemed to soften rapidly. Shells, gravel, stones, etc., are frequently picked up by the fish with other food, but at the same time it is probable that shell-fish are eaten whenever the opportunity offers, as may be witnessed by the presence of the tips of the siphons of burrowing clams that have been bitten off. Sea-anemones on stones are not seldom taken, and to them must probably be attributed the presence of the "ballast," which the fishermen regard as having been taken in preparation for storms. The presence of small worms serves to indicate the capacity the halibut has for picking up minute foods.

Table VIII.—Showing Numbers of Halibut Stomachs containing Various Foods.

Locality.	Fish.	Crabs.	Cephalopods.	Shell-fish.	Sea-anemones.	Worms.	Starfish.	Brachiopods.
Frederick Island	31	6	...	...	1	...	...	...
Pillar Bay	10	16	...	4	...	...	...	...
Kodiak Island	10	19	1	...	...	...	...	...
"	9	11	...	...	1	...	...	...
"	17	16	5	1	1	2	...	...
"	7	9	5	...	...	1	...	...
"	3	5	...	...	...	...	...	...
Yakutat	8	...	...	...	...	...	1	...
Banks Island	3	10	2	...	...	...	...	1
Burnaby Island	4	3	1	...	...	...	...	...
Middleton Island	55	1	...	...	...	...	...	...
Totals	157	96	14	5	3	3	1	1

The following is a list of the fish to be observed among the food of the halibut, placed somewhat in order of importance:—

(1.) *Gadus macrocephalus* (grey cod).
(2.) *Ammodytes personatus* (sand-lance).
(3.) *Atheresthes stomias* (ghost, or long-jaw).
(4.) *Squalus sucklii* (dogfish).
(5.) *Hydrolagus colliei* (ratfish).
(6.) *Sebastodes alutus* (red cod).
(7.) *Anoplopoma fimbria* (black cod).
(8.) *Clupea pallasi* (herring).
(9.) *Raja* { *rhina* / *binoculata* } (skate).
(10.) *Ophiodon elongatus* (ling-cod).
(11.) *Hippoglossus hippoglossus* (halibut, principally viscera).
(12.) *Cyclopterus ventricosus* (lump-fish).
(13.) *Prionistius macellus.*
(14.) *Sebastolobus alascanus* (red cod).
(15.) *Psychrolutes paradoxus.*
(16.) *Malacocottus zonurus.*
(17.) *Oncorhynchus kisutch* (cohoe salmon).

Professor Frank Walter Weymouth, of Stanford University, has kindly worked over the Crustacea collected from halibut stomachs, and his report is here included in its entirety.

LIST OF THE CAUSTACEA FOUND IN HALIBUT STOMACHS.

By Frank Walter Weymouth.

The following is a list of the Crustacea found in the examination of the contents of twenty-six halibut stomachs collected by W. F. Thompson in the summer of 1914. Only the Crustacea, which are stated to form a considerable portion of the food on certain banks, are here considered; the list may be taken as representative of the species eaten. The number of species is few, though the number of specimens is considerable. *Pagurus confragosus* and *Pagurus splendescens*, hermit-crabs very abundant in this region as noted by Miss Rathbun in her report on the Crustacea of the Harriman Alaska Expedition, occur in large numbers. *Hyas lyratus*, also recorded as abundant in dredging operations off the Alaskan coast, is very common. *Cancer gibbosulus*, though not reported as plentiful, seems to equal in numbers the others mentioned.

Aside from the question of the halibut food-supply in which the Crustacea apparently play an important part, there are here recorded considerable extensions of the range of two species.

Acantholithodes hispidus, whose northern limit is given as Vancouver Island, was taken off Banks Island, off Frederick Island, and off Kodiak Island. *Lopholithodes foraminatus* has its range extended from Victoria to Kodiak Island.

Macrura.

Crago sp. Two badly mutilated specimens of this genus taken at Halibut Rocks, off Banks Island.

Anomura.

Pagurus alaskensis (Benedict). One specimen, off Masset Harbour.

? Pagurus ochotensis, Brandt. Some fragments, apparently of this species, off Kodiak Island.

Pagurus confragosus (Benedict). Twelve specimens from six different stomachs, all from off Kodiak Island.

Pagurus splendescens, Owen. Thirty-one specimens from eight different stomachs, off Kodiak Island; one specimen from Albatross Bank.

Pagurus sp. Remains of at least twelve specimens, probably representing more than one species, from Kodiak Island and Pillar Bay.

Acantholithodes hispidus, Stimpson. One specimen well preserved from Halibut Rocks, off Banks Island, in 40 fathoms; one specimen from off Frederick Island in 45 to 50 fathoms; one specimen from off Kodiak Island in 50 to 70 fathoms. According to Miss Rathbun, the distribution of this species is as follows: "Vancouver Island, British Columbia, to Monterey, California. To a depth of at least 16 fathoms." These records extend its range northward to Kodiak Island and show that it may come from a depth of 40 fathoms.

Lopholithodes mandtii, Brandt. One large well-preserved specimen, quite a formidable meal even for a halibut, from La Perouse Rocks, north of Frederick Island.

Lopholithodes foraminatus, Stimpson. Seven specimens from three stomachs, off Kodiak Island in 70 to 100 fathoms. A considerable addition to the range of this species, which, according to Miss Rathbun, is "From Victoria, British Columbia, to near San Francisco."

Brachyura.

Oregonia gracilis, Dana. Four specimens, including one ovigerous female, from off Frederick Island, July 19th, 1914; one chela, apparently from this species, from Pillar Bay.

Chorilia longipes, Dana. Two specimens from off Kodiak Island; two specimens from Halibut Rocks, off Banks Island.

Chionœcetes tanneri, Rathbun. Three specimens from off Kodiak Island.

Hyas lyratus, Dana. Fourteen specimens from eight stomachs from off Kodiak Island; one from Albatross Bank; two from Pillar Bay. These include ovigerous females bearing the dates of July and August, 1914.

Cancer productus, Randall. Two young specimens from Halibut Rocks, off Banks Island.

Cancer gibbosulus (de Haan). Three specimens from La Perouse Rocks, north of Frederick Island; seventeen specimens from Pillar Bay; forty-three specimens from four stomachs from Halibut Rocks, off Banks Island, in 45 to 70 fathoms.

Pinnixa sp. Two unidentifiable specimens from off Kodiak Island.

Dr. S. S. Berry informs me that he is unable, in the present state of knowledge, to identify either the remains of Cephalopods taken from stomachs, or two very large specimens brought up on the trawl-lines, as the species types from this region are all very small immature examples. He says: "The halibut have been feeding on Polypus and some good-sized Œgopsid squid, most likely one of the Ommastrephidæ."

DESTRUCTION OF OTHER FISH BY THE FISHERMEN.

It has been repeatedly stated that as many fish are destroyed as are saved in fishing for halibut, but no accurate records have been offered as to this. Incidental to other work, a few counts were made of fish as they came aboard one of the "long-line" vessels during March 12th to 15th, 1915, on the banks off Frederick Island in 100 fathoms. As these were made during a period of poor fishing, the number of specimens counted were small.

Table IX.—Numbers of Fish of each Species brought up on the Halibut Trawl.

Species.	March.				Total.	
	12.	12.	13.	15.		
Hippoglossus hippoglossus	37	44	31	26		138
Anoplopoma fimbria	22	4	22	11	59	
Atheresthes stomias	8	16	7	12	43	
Squalus sucklii	3	...	24	3	30	
Raja { *rhina* / *binoculata* }	2	2	2	3	9	164
Sebastodes { *ruberrimus* / *babcocki* }	3	1	4	3	11	
Gadus macrocephalus	2	...	5	4	11	
Hydrolagus colliei	1	...	...	...	1	
Totals	78	67	95	62		302

As indicated in these counts, the number of halibut taken usually, but not always, exceeded the number of any one other kind of fish, forming, however, less than half the total. As the halibut was uniformly larger than the others, it composed more by weight in such a case than did the others. The fish differed greatly on different banks, however. Occasionally almost nothing but dogfish was obtained, while again the black cod (*Anoplopoma fimbria*) formed the bulk of the catch. On some of the Alaskan banks the grey cod (*Gadus macrocephalus*) was very abundant, while on others, along the whole coast, the red cods (*Sebastodes*) were most important.

The banks occupied by the dogfish (*Squalus sucklii*) are usually avoided by the fishermen as much as possible. They are very often in such great numbers that they literally clog the gear, and the fishermen are put to much labour in "slatting" them off. In such cases it does not matter much whether there are halibut present or not, as but few of them seem to get a chance to take the bait, and very often are taken through having swallowed the dogfish on the hooks. There is no demand for them, although they might be utilized for food or for fertilizer, and their livers produce oil.

The black cod (*Anoplopoma fimbria*) is undoubtedly one of the most valuable of the fish thrown away. As is the case with the dogfish, they at times form the bulk of the catch, although when that occurs the fishermen usually change their fishing-grounds. It is said to be harder to handle or cure than is the halibut, but its use is steadily growing as a fresh market fish. The name "black cod" is said by many of the dealers to handicap the sale of the fish, as the grey cod is usually a cheap fish. It is, of course, not a "cod" at all, being rather related to the "ling-cod" (*Ophiodon elongatus*), "greenlings," and to the "Atka mackerel" (Hexagrammidæ). Just as at first the sturgeon in the Columbia River, or as the halibut itself was in the Atlantic, so the black cod is regarded at present as a nuisance, on the whole.

Of the grey-cod (*Gadus macrocephalus*) little need be said, as its value and use is very well known. Owing to the difficulty in handling them on the halibut-boats they are rarely carried. It is said by the fishermen that since the great depletion of the halibut in the waters of Dixon Entrance and Hecate Strait the grey cod are being caught more abundantly. If so, it is the logical conclusion from the fact that the halibut are among the greatest enemies of the cod. This extension of their range is, however, of doubtful value, because they are not as yet taken in numbers to justify any systematic fishery.

The rock or red cods (*Sebastodes* and *Sebastolobus*) are found in great numbers on certain banks, the shoal waters along the shore-line containing great numbers of the smaller dark-coloured species, while the deep-sea banks are inhabited by the larger red forms. The latter are usually red with orange or scarlet markings. The fishermen say that they do not catch the trawl when it is on the bottom, but when it is half-way down, or up. It is probable, then, that a change in methods of fishing would bring better results. There is no question as to their value as market fish, as they are easily handled, will keep very well, and have an extensive market farther to the south in California. The market in British Columbia is steadily growing for them, and many are brought in to Vancouver by the halibut-boats and by the local fishermen of the "mosquito" fleet.

Of other species, the "ling-cod" (*Ophiodon elongatus*) is frequently obtained. This is one of the fish most used in the markets of Vancouver and Victoria, being brought in in great numbers by the local fishermen. The flounders are represented by the "long-jaw" (*Atheresthes stomias*) and by *Eopsetta jordani*, for which there is no local colloquial name. The former, although reaching a fair size, is of little value as food, owing to the flesh being watery and thin, and its destruction is probably a benefit in that it is a predaceous fish. The latter, *Eopsetta jordani*, is without doubt valuable as food (although caught in very small quantity), as it is one of the staple market fish in San Francisco.

The skates (*Raja rhina* and *Raja binoculata*) are obtained sometimes in small quantities, but are not saved as food, although there is a constant small demand for them in some localities on this coast. This is a result of the fact that many immigrants from Europe are accustomed to their use as food.

With regard to all these forms, which for the most part are thrown back into the water, the question naturally arises as to whether such fish survive. There can be no manner of doubt that the red or rock cods (*Sebastodes*) invariably die, by reason of the fact that they are unable to sink. They have air-bladders, filled with gas, which is greatly compressed by the pressure of the water at the depths at which they live, and which expands greatly when the fish is brought suddenly to the surface. The eyes and alimentary canal are forced out by the pressure, and the rupture of the tissues by this would seem alone to be sufficient to cause the death of the fish. It is a very common scene to see the water in the vicinity of the dories strewn with these splendid fish. Of the others, the grey cod seems to be unable to sink, and undoubtedly dies. The dogfish, black cod, skates, and flounders do not seem to have this trouble, and the mortality among them may be caused for the most part by the mutilation of the mouth-parts, the cuts by the gaff-hooks, and the failure to promptly return them to the water. So often are the jaws of all these fish badly mutilated that it would be not in the least surprising if 50 per cent. should subsequently die. This is especially true of the "long-jaw," which has very easily mangled mouth-parts. It would be difficult to make any statement regarding minor injuries. As a whole, it is safe to say that the destruction of fish is very great.

To eliminate this waste seems impossible with the present system of fishing, unless such fish could be utilized in the markets. With the present method of regulating fisheries by separate countries, there does not seem any prospect of adequate regulation.

PARASITES OF THE HALIBUT.

The halibut is extensively parasitized, by nothing, however, which is in the slightest degree detrimental to its wholesomeness as food, and not to a greater degree than are most of the other food-fishes. Examples of the important parasites were collected and forwarded to known experts, eliciting the general response that but little was known of them.

A round (or thread) worm is very abundant in the halibut from Alaskan waters, and seems to be one of the worst of the parasites. It becomes encysted in the tissues of the viscera, and occasionally in the body-walls, but it is for the most part to be found in the region of the liver, the gonads, and the wall of the stomach. Frequently cancer-like masses are formed in the walls of the stomach, forming in a few cases ulcer-like sores. They are not found to a very great extent in the younger halibut. Regarding them Dr. Edwin Linton writes me as follows:—

"The Nematodes are immature, but can be referred to the genus *Ascaris*. I think I should for the present record them as simply *Ascaris sp.* immature.

"Superficially they resemble *Ascaris (Agamonema) capsularia*, but the absence of cæca from the base of the œsophagus makes it impossible to refer them to that species. At any rate, there is an objection to the use of that term, which has been used only for larval, encapsulated forms. I thought before I examined them that they might turn out to be the young of *Ascaris clavata*, but they certainly do not belong to that species."

Dr. C. B. Wilson, to whom the species of parasitic Copepods taken from the gills were referred, says: "The specimens from the halibut prove to be a new species of the genus *Chondracanthus*." *Lepeophtheirus parviventris*, Wilson, was also taken from the halibut.

Dr. Harold Heath has kindly looked over the Trematodes, of the external parasites, finding them close to *Epibdella fratula*, Heath MSS., taken from the cod, which is a species very close to a form (*Epibdella squamula*, Heath) taken from the so-called "Californian halibut" (*Paralichthys californicus*). He has also examined a Cestode from the walls of the alimentary canal, and finds that it is a larval form of an unknown species of *Tetrarhynchus*.

NOTES ON ENEMIES OF THE HALIBUT.

Among the enemies of the halibut other than parasites may be mentioned the sea-lion (*Eumetopias stelleri*). At various times it has been observed by the writer on the halibut banks fifteen to twenty miles off-shore (Frederick Island), and in each case it was apparently feeding on the halibut. Coming to the surface with a fish, one would throw it repeatedly into the air, meanwhile being surrounded by a clamorous flock of sea-gulls, until it had apparently eaten it or had chosen to disregard it, when it would dive for more. This was observed in water over 100 fathoms in depth, but at some distance from the trawl-lines, and the fishermen seemed of the opinion that the sea-lion did not always take the fish from the trawl, but captured it. It is, of course, hard to believe that the sea-lion penetrates to a depth of 100 fathoms. They were repeatedly observed circling the vessel while the trawl-lines were being brought in, and in many of these cases there was no doubt that the halibut was taken from the trawl-lines. The fishermen frequently attribute mangled fish brought up on the lines to sea-lion attacks.

Another enemy of the halibut is the large "ground-shark" (probably *Somniosus microcephalus*). Although repeatedly brought nearly to the surface on the trawl-lines during the writer's work on the fishing-banks, he has as yet failed to secure a specimen for examination. The traces of its presence were very frequently met with, however, in mutilated fish on the trawl-lines, these showing great crescentric bites taken from the bodies, with the marks of the teeth plainly to be discerned. It is, of course, questionable whether the shark is able to catch the halibut unless it is caught on the hooks. It is very large, but so sluggish that it makes no attempt to escape when brought up on the trawl-lines until it is almost at the surface, when a very slight effort frees it. The fishermen say that during certain seasons there are great numbers of these fish on the banks, in shallow water especially.

Very often, particularly on certain banks, there are to be found numbers of round sores on the flanks of the halibut. This is said by some of the fishermen to be caused by "large, round worms," perhaps a lamprey (*Entosphenus tridentatus*). Other fishermen stoutly maintain that the "devil-fish" (*Polypus*) does it. There are great numbers of halibut to be observed with scars from these sores, but it is unknown whether they lead to death in any cases.

The list of the enemies of the halibut would certainly not be complete without adding the halibut itself. Not only do the halibut fishermen frequently utilize halibut flesh as bait, but frequently a large halibut is taken through swallowing a smaller one which had already taken the hook. There are, of course, great numbers of stories to be told by the fishermen regarding this, and it is a common expression in telling of good fishing to say that they caught "two fish on every hook." It is said that in the days when fish were so abundant that a great deal of hand-line fishing was done from the deck, that a halibut would be caught when the bait struck the bottom, but before that one could be brought to the surface it had been swallowed by a bigger halibut. To one who knows the voracious character of the halibut this does not seem so improbable, although it rarely occurs at the present time.

Stanford University, California, May, 1915.

A NEW FISH OF THE GENUS SEBASTODES FROM BRITISH COLUMBIA, WITH NOTES ON OTHERS.

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During the employment of the writer on an investigation of the life-history of the halibut (*Hippoglossus hippoglossus*) it was noticed that great quantities of edible fish were caught and destroyed by the fishermen incidental to the extensive fishery for the halibut. Some notes on these are included in the report for the present year (1914), and it may be seen that various species of rock-cods (*Sebastodes*) were found to be second only to the black cod (*Anoplopoma fimbria*) in potential value. Among these species of *Sebastodes* was one which appears to be new to science, although one of the most frequently caught. As the destruction among these fish is undoubtedly great, and unavoidable with the present methods of fishing in vogue, notes regarding the species found in the catches are here presented.

(1.) *Sebastodes babcocki*, new species. Type a mature female 18¼ inches in body-length and 21¾ in total, from latitude 59° 1′ N., off Middleton Island, Alaska, in 80 to 100 fathoms, taken on a trawl-line September 2nd, 1914, by the halibut-steamer "James Carruthers."

Dorsal rays XIII., 13; anal rays III., 7; pores in lateral line 48 on one side, 44 on other. Body not elongate but deep, its depth 2½ in body-length to base of caudal and 3 in total; its width 2½ in depth; caudal peduncle depth 3⅔ in head, or equal to snout; upper profile of head not flattened, arched slightly and evenly from occiput; head 2⅞ in length without caudal; snout 3⅔ in head to tip of opercular spine; interorbital space nearly flat, its width three-quarters diameter of eye, or one-fifth of length of head; orbit 4⅙ in head, nearly circular; maxillary 2 ¹/₁₀ in head, terminating under space between pupil and posterior margin of orbit; width of preorbital from between spines to eye two-fifths of orbital diameter; mandible 1⅞ in head, with low and blunt symphyseal knob; lower jaw projecting but very slightly, if at all; width of mandibular ramus contained 3¾ times in maxillary; space between rami two-thirds to three-quarters of width of one of them; posterior nostril distant its own diameter from eye.

Spines and ridges on skull weak, with entire edges; nasal, preocular, postocular, tympanic, and parietal spines present, a supernumerary spine present between the closely apposed postocular and tympanic on the sinistral side, but not on the dextral; parietal ridges plainly diverging, anterior ends but two-thirds as far apart as posterior ends; supraocular, coronal, and nuchal spines lacking; no spines below eye; preorbital with two strong spines, anterior usually single, occasionally bifid, posterior multifid, with 3 or 4 points; five preopercular spines, upper longest, its length one-third diameter of eye, the two uppermost pointing backward and upward in marked contrast to remaining three, which point downward and backward, the lower [illegible] due broadest and shortest, the three lowest all noticeably flatter than upper two; two sharp opercular spines, not divergent, but parallel, length of first contained 4 times in eye, longer than second, latter extending beyond edge of narrow opercular flap.

Teeth in bands on jaws, vomer, and palatines; about 6 equal indefinite series present laterally in mandible (3 in *S. introniger*), doubling in width at symphysis, where there are 11 or 12 series; no dentigerous knobs, a central naked space present; 9 or 10 series laterally in upper jaw, nearly twice width of bands in lower jaw, anteriorly increasing to one-fifth of orbital diameter; bands on palatines as wide as lateral bands in upper jaw; those on vomer in a V-shape.

Gill-rakers on first arches (anterior series) 10 + 21 and 9 + 22; 5 + 8 on second arch; 3 + 14 on third; longest on first arch equal to two-fifths of orbital diameter; most anterior on lower limb a prominent spinate knob, others broad, thin, spatulate, with a short free fork on posterior (inner) edge, this in each case extending under that raker next above (posterior); fine spinules on rakers, not grouped in separate knobs as in many long-rakered forms; none of rakers in second series on any arches forked, nor any in first series on arches other than first.

Dorsal spines high, fourth and fifth longest, contained 2⅕ in head, or 3 in body-depth; twelfth spine four-fifths length of thirteenth, which equals orbital diameter; membrane of spinous dorsal excised to two-fifths or one-half length of spines; longest dorsal ray 2⅘ in head. Anal spines strong, length of first contained 2¼ times in second, which is one-third length of head, longer and much stronger than third; longest anal ray 2⅔ in head.

Pectorals equal to head without snout, their base very broad, 3½ in head length. Ventral, not nearly reaching vent, length 1⅘ in head, width across both bases 4½ in head.

Scales not coarsely ctenoid to touch, smooth on head; fine scales on all fins, spinous or soft, on maxillary, mandible, suborbital, snout, subopercle, and branchiostegals; accessory scales numerous; pores in lateral line 47, plus 1 on caudal; 60 rows of scales below lateral line, counting rows running downward and backward.

Colour in spirits uniform, without dark markings anywhere; gill-cavity and buccal linings silvery. The following colour notes were taken from the fresh specimen: "A uniform faint red or pink, with four broad cross-bars extending as low as level of mid-pectoral base; first between third dorsal spine and occiput down to upper pectoral base; second a wedge-shaped saddle from sixth to eleventh spines down; third below third to ninth soft dorsal rays; fourth on posterior half of caudal peduncle; first three extended on fins. Anal, caudal, soft dorsal, and outer ventral rays deeper red than body; pectorals and other fins pink. A faint reddish streak running downward and backward from eye. Iris with a slight brown tinge. Gill-cavity lining in one specimen with black shades in places, in others a uniform pink. Peritoneum silvery, with dusky shades or nearly black. In one specimen a vividly black oblong spot above mid-length of pectoral rays. This latter, with another (the type), were females with unripe gonads."

Named for Mr. J. P. Babcock.

This species promises to become one of the most important of the red rock-cod in case of their utilization for commercial purposes, and the failure to obtain it for scientific description is very remarkable when its abundance is considered. It is found on some banks more often than is *Sebastodes ruberrimus*, which is without doubt the most important and which is the only species to be found consistently in the markets.

It is closely related to *S. crameri*, Jordan, with which it has not been compared. Dark markings, however, are everywhere absent save in cavity linings, while *S. crameri* has "a black spot on upper part of opercle; membrane of spinous dorsal black-edged; dorsals and pectorals a little dusky." The cross-bands mentioned in the description of this form are arranged in an essentially different manner in *S. babcocki*, and do not persist in spirits in the latter. *S. crameri* was but 6¼ inches long, and the following differences distinguishing the two forms should be accepted with caution, as the age changes are unknown: The gill-rakers are not "slender" in the new species; there is no supraocular spine present; the nuchal spines are not indicated in any way, while in *S. crameri* they are "marked off from parietal ridges only by depressions"; the preorbital has very distinct spines, not "triangular lobes, but no distinct spines"; the lowermost preopercular spine is not "obsolescent"; the second anal spine is longer, as well as much stronger than the third, not "equal to the third" as in *S. crameri*.

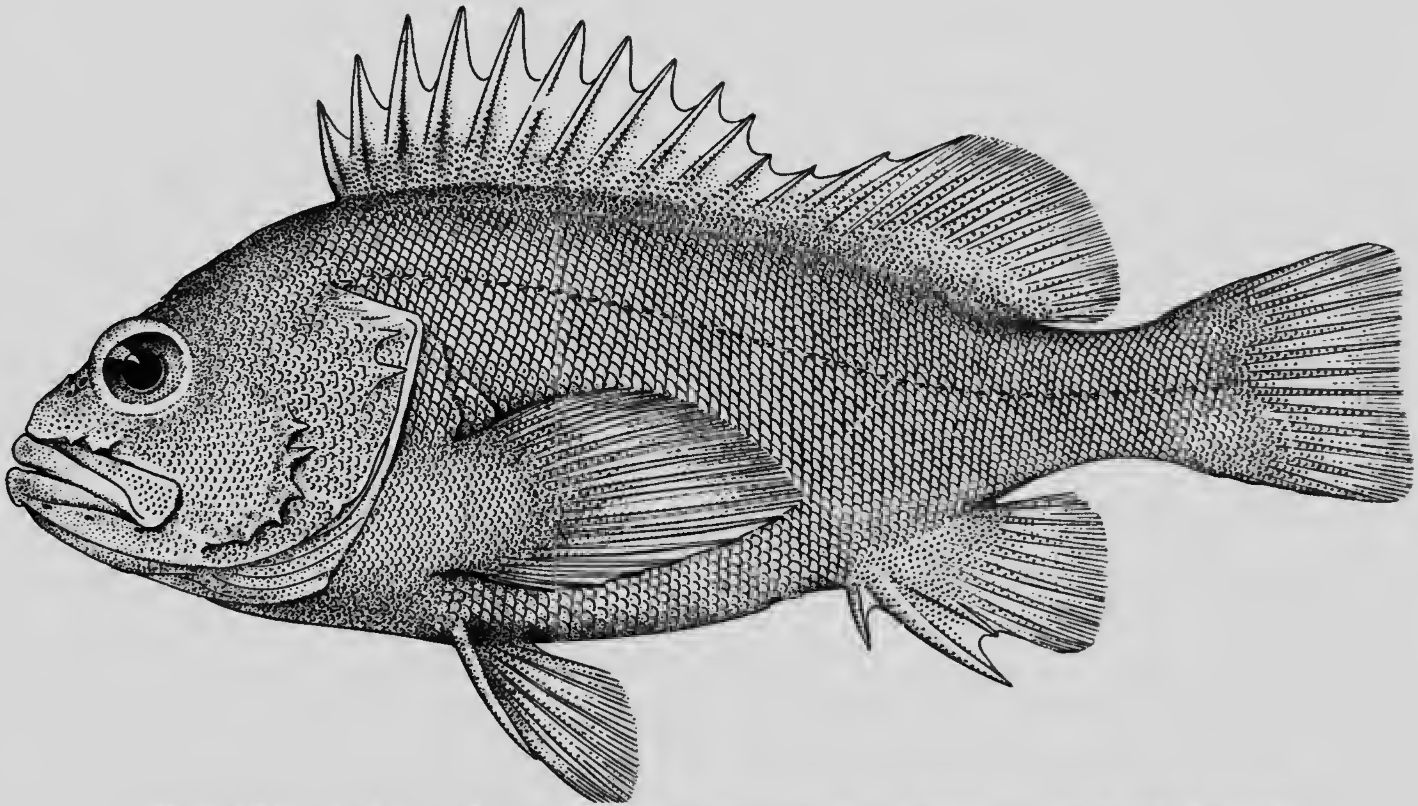
(2.) *Sebastodes ruberrimus*, Cramer. The most abundant of all the species of this genus on the halibut banks. It is brought in regularly to the markets of Vancouver, Victoria, and Seattle from the banks off Cape Scott and off Goose Island. It is also found in abundance off the Queen Charlotte Islands and as far north as Kodiak Island, Alaska. Specimens are at hand from off Frederick Island and from off Goose Island.

(3.) *Sebastodes alutus*, Gilbert. This is perhaps more frequently eaten by the halibut than is any other rock-cod, and it has been taken from their stomachs on practically every bank visited, save some of those in the shoaler water. It is therefore to be considered the most abundant of the smaller species, and is absent from the halibut-hooks more because of its small size than anything else.

(4.) *Sebastodes brevispinis*, Bean. This has been considered a very rare species, but on certain banks it is found in relative abundance, and two splendid examples are at hand from Rose Spit, at the junction of Hecate Strait and Dixon Entrance, from a depth of between 60 and 100 fathoms. It may here be mentioned that the depth given is that at which the halibut are caught, and the fishermen believe that the rock-cod are really caught at a considerable distance above the bottom. The longest specimen here recorded is 28 inches in total length.

(5.) *Sebastodes nebulosus*, Ayres. This is the most commonly caught of the smaller rock-cods in Hecate Strait, and numerous specimens are at hand from off Bonilla Island. It has been recorded from Alaska but once, all previous records being for Puget Sound.

(6.) *Sebastodes pinniger*. A single large specimen of this species, 21 inches in length, was taken at the junction of Hecate Strait and Dixon Entrance, at a depth of from 60 to 100 fathoms, on March 21st, 1915. It differed from two specimens taken in Monterey Bay in a lesser depth (2½ in length in the latter, 3 in the northern specimen), in colour, and in the forked condition of the second series of gill-rakers on the first arch. A skeleton of intermediate size from Monterey, however, showed the forked condition of the gill-rakers. This species is not very abundant on the halibut banks, and seems to be an inhabitant of the shallower waters.



***Sebastodes babcocki*, Thompson.** A new species caught in large quantities in British Columbian waters, but not hitherto described.