

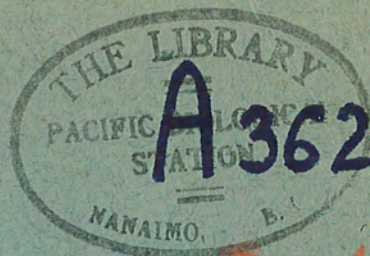
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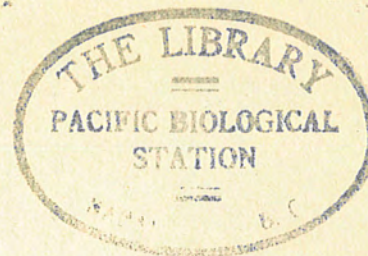
Some aspects of the growth and ecology
of the halibut (Hippoglossus hippoglossus L.)
in the Gulf of St. Lawrence

by

F. D. McCracken

1947

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SOME ASPECTS OF THE GROWTH AND ECOLOGY
OF THE HALIBUT (Hippoglossus hippoglossus L.)
IN THE GULF OF ST. LAWRENCE

By

F. D. McCracken

A thesis submitted as part of the requirements
for the degree of Master of Arts
in the University of Toronto .

1947

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Some aspects of the growth and ecology of the
halibut (*Hippoglossus hippoglossus* L.)
in the Gulf of St. Lawrence

INTRODUCTION

During 1946 a study of the life history and movements of the halibut *Hippoglossus hippoglossus* Linnaeus, in the Gulf of St. Lawrence and off the east coast of Nova Scotia, was instituted by the Fisheries Research Board of Canada. Previous to this, in 1944, the Department of Fisheries had introduced the long-lining fishing method, used in the Pacific coast halibut fishery, by means of the motor vessel "J. J. Cowie" designed after the west coast boats and equipped with a power-hauler or "gurdy". The same vessel was operated under instructions from the Fisheries Research Board during this investigation.

In contrast to the Pacific coast, where knowledge and conservation of halibut stocks has been the object of an international commission, very little literature is available dealing with the halibut along the Canadian Atlantic coast. Therefore the aims of the programme were to obtain information about the rate of growth, movements and migrations, maturity, availability, and some of the factors determining distribution.

A detailed study of all body proportions was not attempted,

although certain features such as dorsal and anal fin ray counts, pectoral fin measurements, and head measurements were made for the specimens examined. These were designed to give a basis of comparison between halibut caught in the Gulf of St. Lawrence and those caught from the Cape Sable region.

This paper presents an account and analysis of the data obtained during 1946. The programme of investigation is continuing, with special consideration being given to the determination of the origin of the halibut population, which forms the basis of the late summer and fall fishery of the Cape Sable region.

ACKNOWLEDGEMENTS

This investigation was carried out under the direction of Mr. W. R. Martin, Fisheries Research Board of Canada, St. Andrews, N. B. The author wishes to express his gratitude for the advice received throughout the problem.

The author is also greatly indebted to Dr. A. G. Huntsman and Professor J. R. Dymond for their supervision and advice in the analysis of the data obtained and preparation of this manuscript.

SOME NOTES ON THE EARLY HISTORY OF HALIBUT FISHING IN THE
GULF OF ST. LAWRENCE

In the late 1800's the halibut was not regarded very highly as a commercial fish by Canadian fishermen in the Gulf of St. Lawrence. Lavoie (1873) in his report, of the cruise of the government steamer "Lady Head" in protection of the fisheries of the Gulf and River St. Lawrence, states: "Halibut are not especially fished for around banks off Labrador and in the Gulf of St. Lawrence by our fishermen, but as it often frequents the same banks as the codfish the fishermen occasionally catch some. The Americans have been in the habit of catching halibut in large quantities on our coasts since they have begun carrying on this fishery. The fish are still found in as large quantities as ever in our waters". In the same year he reports that five schooners from Gloucester took loads of fifty to sixty thousand pounds. Three of the schooners made two trips.

Lavoie (1876) states: "Since our fishermen catch halibut only by accident while fishing for cod, it cannot be judged from the greater or lesser number of barrels which this fishing yielded in a particular year, whether halibut were more or less abundant in the waters of the Gulf". He comments on the fact that only one American vessel was in the Gulf during the season. This he attributes to the seizures of vessels, in consequence of Canadian violations, having deterred the American vessels from the Gulf of St. Lawrence.

The tenor of the foregoing statements continue throughout the balance of the 1800's. Wakeham (1887) states: "The cod fishermen report the halibut are becoming more plentiful and in view of this increase in halibut and the increase in facilities for marketing several fishermen propose to fit out next season exclusively for this fishery".

Lavoie (1902) reports that the grounds which halibut prefer seem to be those of Anticosti, Natashquan, Perroquet Islands, Moisie, and from Seven Islands to Godbout. He also reports that a few fishermen from Quebec devoted all their time to this fishery.

From this date onwards there seems to have been a more intensified halibut fishery conducted, judging from the records of total Quebec halibut landings presented in the following section.

Statistics of halibut landings for Nova Scotia and Quebec.

The total halibut landings for Nova Scotia and Quebec for the period from 1907 to 1944 are presented graphically in Figure 1. In the period from 1907 to 1926 marked fluctuations in total landings occur in an irregular manner. For the Nova Scotia landings these fluctuations seem to vary around a mean of approximately two and a half million pounds.

The Quebec landings vary around a mean of approximately 100,000 pounds. Since statistics, of the effort expended in fishing for halibut and the regions from which these fish were taken, were not available no possible explanation of these fluctuations is being offered.

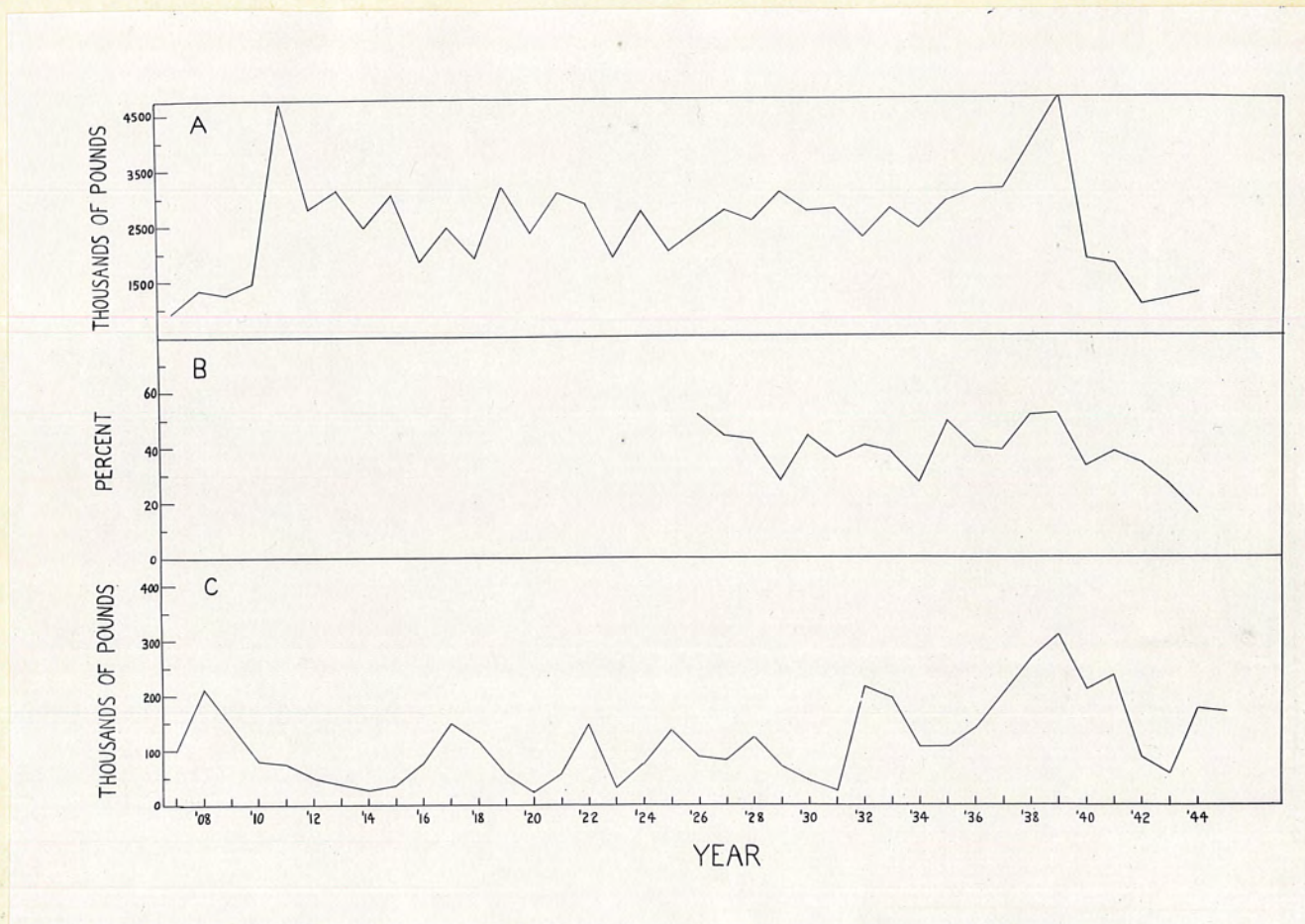


Figure 1 - A Total Nova Scotia halibut landings.

B Percentage of total Nova Scotia landings made by offshore fishing vessels.

C Total halibut landings for the province of Quebec.

During the period from 1926 to 1934 no large fluctuations in the Nova Scotia landings occurred, however, beginning in 1935 there was an increase in total landings culminating in a peak of over four and a half million pounds in 1939, followed by a very rapid decrease in 1940 and reaching a low of approximately one million pounds in 1943 and 1944.

The total Quebec landings showed more fluctuation during the period from 1926-1944 than the Nova Scotia catch, but they exhibited the same increase as the Nova Scotia landings from 1935-1939 with a peak of over three hundred thousand pounds in 1939. This was also followed by a decrease in total landings in 1940 and 1941. The greatest decrease in Quebec landings occurred during 1942 and 1943, while in 1944 and 1945 the total landings were increased to the level of the landings during the early 1930's.

From the size composition of the catch taken by the "J. J. Cowie" and that examined at Havre St. Pierre, the increase in total landings during 1944 and 1945 does not seem to be correlated with an influx of new year classes into the fishery.

One possible explanation of the changes in Nova Scotia total landings is economic rather than a change in number of fish available. The ratio of price per pound of halibut to the price per pound of cod shows a correlation with the change in total halibut landings. This ratio increases from five in 1925 to eleven in 1934. It would therefore seem logical that the effort directed into the halibut fishery

would increase and result in an increase in halibut landings throughout the subsequent period from 1935 to 1939. From 1939 to 1944, during the war years, while the price of halibut increased, the ratio of this price to the price paid for cod decreased very rapidly until in 1944 it was only four times as great. This might possibly account for the decrease in total halibut landings during this period.

The percentage of the total Nova Scotia halibut landings accounted for by the offshore vessels during the period 1926-1944 is shown in Figure 1. In 1938 and 1939, 72% of the total halibut landings in Nova Scotia was accounted for by the offshore fishery. Since 1939, this portion has decreased until in 1944 it represents only 34% of the total halibut landings.

This factor would seem to bear out the explanation that the increased total halibut landings for 1938 and 1939 were due to an increased effort, while the decrease since 1939 would seem to be due to lack of fishing effort, so that the amount of total halibut landings now depend mainly on the inshore fishery.

The larger fluctuations in total halibut landings for Quebec do not seem to follow any regular pattern. Since the fishing season is short and carried on mainly in shoal water such factors as weather or hydrographical changes would have a more marked affect. Any attempt to explain the cause of the fluctuation would be of a speculative nature, so it is being omitted.

MATERIALS AND METHODS

Material for this investigation was obtained during the period May to September, 1946, from the Gulf of St. Lawrence by the halibut fishing operations of the Department of Fisheries boat "J. J. Cowie", operated by the Fisheries Research Board. Table I gives a list of the localities from which specimens were taken, the nature of data obtained from each region and the month during which the locality was sampled. The commercial catch of two boats, which were fishing at Heath Point, Anticosti, was examined at Havre St. Pierre on August 3. Only lengths and weights were available from this sample. During September the writer examined forty-eight specimens from the commercial catch at Clarke's Harbour, Nova Scotia; the measurements made are given in Table I.

The records of the "J. J. Cowie" for operations in the Gulf of St. Lawrence during 1944 and 1945 were available and were used in the analysis of availability. Notes on the early history of the halibut fishery in the Gulf of St. Lawrence, as well as the statistics of the total catch for Nova Scotia and Quebec were obtained from the annual reports of the Department of Fisheries.

During May and June, 1946, emphasis was placed on the tagging of halibut. The methods of tagging and the fishing methods used throughout the season are given in a section devoted to tagging operations.

The major limitation on sampling using commercial gear is the lack of sampling for smaller sizes. Since the hooks are designed to catch commercial sizes they are too large to catch very small halibut, even if these sizes are present.

Table II outlines the measurements made and their definitions. The specimens from the Gulf of St. Lawrence were weighed using a beam balance suspended from the boom of the vessel, the specimens examined at Clarke's Harbour and Havre St. Pierre were weighed on a standard stationary scale. Since the commercial catch is completely eviscerated before being landed, all weights shown in this paper refer to the dressed weight.

During the first part of the investigation otoliths were preserved in 5% solution of tri-sodium phosphate, however, halibut otoliths preserved in this solution were found to be covered with a whitish material which obscured the growth rings. During the latter part of the investigation otoliths were preserved in 50% glycerin solution with a crystal of thymol added. This preservative was found to be more satisfactory.

Temperature recordings were made using a reversing thermometer, with a centigrade scale graduated in half degrees.

Table I

Sampling localities and data obtained

<u>Locality</u>	<u>Date</u>	<u>No. of Specimens</u>	<u>Data Obtained</u>
St. Pauls Island	May, 1946	2	Tagged and released.
Burgeo Bank	May, 1946	2	Tagged and released.
Point Riche	May, 1946	4	Tagged and released.
		5	Lengths, weights, sex, fin ray counts, body measurements.
Bay of Islands	May, 1946	2	Lengths, weights, sex, fin ray counts, body measurements.
South West Point, Anticosti	June, 1946	3	Lengths, weights, sex, fin ray counts, body measurements.
West Point, Anticosti		65	Tagged and released.
South West Point, Anticosti	July, 1946	11	Tagged and released.
		17	Lengths, weight, sex, fin ray counts, body measurements.
Havre St. Pierre	August, 1946	67	Lengths and weights.
Point Riche	August, 1946	1	Fin ray counts, lengths, weights, body measurements.
Clarke's Harbour	September, 1946	48	Fin ray counts, lengths, weights and body measurements, whenever possible.
South West Point	September, 1946	120	Lengths, weights, and sex.

Table II

Measurements made and definitions

<u>Measurement</u>	<u>Definition</u>
Total length	- the length in centimetres from the tip of the closed lower jaw to the end of the middle part of the tail, with the body extended back in a straight line.
Weight	- dressed weight - minus the gonads, viscera, and gills.
Pectoral fin length	- the length from the base of the pectoral fin to the extent of the longest ray.
Dorsal fin rays	- the total number of fin rays of the dorsal fin.
Anal fin rays	- the total number of fin rays of the anal fin.
Head length	- from the tip of the snout to the end of the operculum, not including the flap at the posterior end of the operculum.

RESULTS

Availability

Data obtained in the investigation of catch per unit of effort for the Gulf of St. Lawrence, also indicate that the decrease in total Quebec landings is not due to a decrease in the numbers of fish available.

Data presented in Table III were taken from the records of the motor vessel "J. J. Cowie", operating in the Gulf of St. Lawrence during the periods shown in the table.

Using a line of gear as a unit of effort, the greatest returns per line were obtained during June, 1944, June, 1946, and September, 1946, fishing in depths over 75 fathoms. In these years the catch per unit of effort was lower during July for fishing operations in both deep and shoal water. During 1945 the catch per unit of effort was greater in July than during the short period fished in May and June of that year. In all cases the catch per unit of effort was greater in depths over 75 fathoms, than in shoaler water during the same period of time.

Table IV illustrates the halibut landings for the province of Quebec using the year 1945 as an example. The peak catch for this year by the Quebec fishermen was obtained during July and August. This table illustrates the short season during which this fishery is carried on, mostly in very shoal water. No statistics of effort were available for the commercial fishery, to determine the catch per line

in order to make a direct comparison with the records of the "J. J. Cowie". It is interesting to note that operations of the "J. J. Cowie" for four weeks in the Anticosti region produced, by weight, one quarter of the total Quebec halibut landings for that year.

The average catch per line in the Anticosti region for 1944 and 1946 is comparable in weight to the catch per line of Pacific halibut during the period 1925-1933; however, the number of halibut comprising the weight per line in the Anticosti regions appears to differ greatly from the number of halibut comprising the weight per line in the Pacific fishery. The catch per skate for grounds west of Cape Spencer, shown in Table V, is taken from Thompson and Bell (1934). The catch per line is calculated on the basis of a six-line skate. Thompson and Herrington (1930) show that the modal length frequency of the catch, on grounds west of Cape Spencer, lies between 65 and 95 cms. with comparatively few specimens over 110 cms. in length being caught. In Figure 2 showing the length frequency of the halibut taken from the Anticosti region during 1946, the modal length class lies between 139.5 and 154.5 cms. The curve resulting from plotting frequency against length is skewed towards the larger sizes indicating a greater proportion of halibut larger than the modal class. Therefore a much smaller number of halibut make up the pound catch per line than is the case for the Pacific coast.

Stat. Statistics of catch shown for the west coast of

Newfoundland are meagre and show very low availability compared with the Anticosti region. Since the amount of gear fished is much less than in the Anticosti region and the sampling represents two very short periods widely distributed in time, no accurate comparison can be made.

For the Cape Sable region a catch per line of 8.7 pounds was obtained, from the records of total landings of sixteen boats, during a two week period in September. This is comparable to the catch per line in the Gulf of St. Lawrence.

However, the period for which information was obtained in the Cape Sable region, represents the time of peak catches in this area. From statements made by the fishermen, it would seem that during nine to ten months of the year the catch of halibut in this area is almost nil and as a result of this experience in previous years, halibut fishing operations are only carried on from August to October. During this period the grounds about 20 to 35 miles off Cape Sable are very intensively fished by numerous small boats.

Since no sample of a series of complete catches was possible, a quantitative comparison of size frequencies for the Cape Sable region and the Gulf of St. Lawrence can not be made. However, it appeared from general observation that the modal length frequency, of the halibut taken in this region, was lower than that from the Gulf of St. Lawrence.

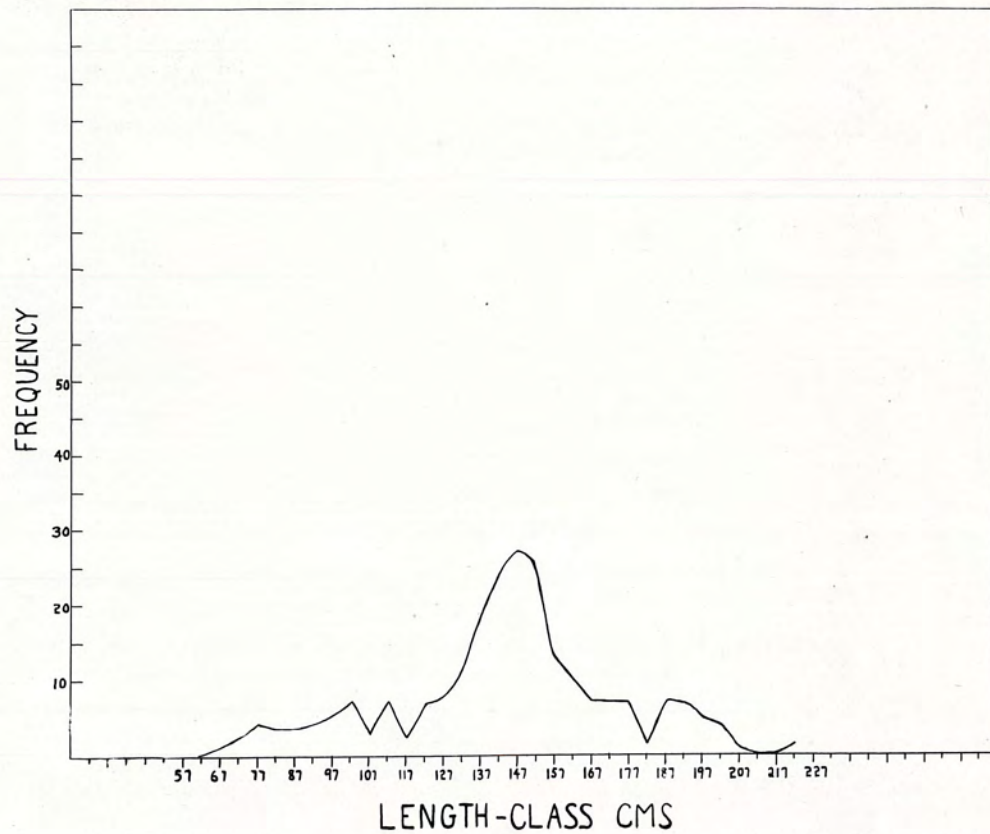


Figure 2 - Length-frequency of the total catch of halibut from the Gulf of St. Lawrence, taken by the motor vessel "J. J. Cowie" from May to September, 1946.

Thompson (1937) states that "when a fishery increases in intensity the proportion of large fish diminishes. This proportion is always large in a virgin, unexploited fishery. It is always less in an intensively fished species". Applying this criterion to the distribution of sizes caught in the Anticosti region it would appear that this fishery was relatively unexploited. The short fishing season indicated by the Quebec halibut landings for 1945 would also indicate that it is not being exploited to its fullest extent. However, no explanation for the relatively small proportion of halibut, less than 130 cms. in length is available. Any explanation attempted from the present data would be of a speculative nature.

TABLE III

Total catch and catch per line for Anticosti regions
from records of the motor vessel "J. J. Cowie"

<u>Year</u>	<u>Date</u>	<u>Depth in Fathoms</u>	<u>Lines Fished</u>	<u>Total Catch Lbs.</u>	<u>Pounds per Line</u>
1944	May 31-June 19	75-110	2046	32,900	16.1
	June 30-July 6	9-14	102	600	5.9
	June 30-July 6	80-105	840	7,300	8.7
			<u>2988</u>	<u>40,800</u>	Average 13.7
1945	May 26-June 3	85-130	540	2,400	4.4
	July 1-July 29	100-120	895	6,475	7.2
	July 1-July 29	8-20	880	5,500	6.2
			<u>2315</u>	<u>14,735</u>	Average 6.2
1946	June 8-July 1	95-130	545	7,815	14.3
	June 8-July 1	60-75	65	0	0
	July 25-July 30	100-150	205	1,328	6.5
	July 25-July 30	10-85	100	115	1.2
	Sept. 3-Sept. 25	20-30	75	200	2.7
	Sept. 3-Sept. 25	100-135	725	1,108	15.3
			<u>1715</u>	<u>20,566</u>	Average 12.0
West coast of Newfoundland					
1946	May 24-May 29	100-130	200	644	3.2
	May 24-May 29	47-80	25	0	0
	Aug. 13-Aug. 19	100-153	70	0	0
	Aug. 13-Aug. 19	9-75	110	10	.09
			<u>405</u>	<u>654</u>	Average 1.6

TABLE IV
Monthly halibut landings for the
Province of Quebec, 1945 - cwts.

<u>Month</u>	<u>Upper Saguenay</u>	<u>Anticosti Island</u>	<u>Others</u>	<u>Quebec Total</u>
January	0	0	0	0
February	0	0	0	0
March	0	0	0	0
April	0	0	0	0
May	0	0	5	5
June	128	0	37	165
July	753	4	10	767
August	568	7	31	606
September	79	2	14	95
October	28	0	8	36
November	0	0	7	7
December	0	0	0	0
TOTALS	1556	13	112	1681

TABLE V

Catch per unit of effort - Pacific coast - Thompson and Bell, 1934Grounds west of Cape Spencer

<u>Year</u>	<u>Catch per skate (lbs.)</u>	<u>* Catch per line (lbs.)</u>
1920	147.9	24.6
1921	141.4	23.6
1922	134.8	22.5
1923	150.3	25.1
1924	109.7	18.3
1925	95.2	15.9
1926	94.1	15.7
1927	86.9	14.5
1928	72.8	12.1
1929	72.6	12.1
1930	64.7	10.8
1931	71.7	11.9
1932	82.2	13.7
1933	84.0	14.0

* Catch per line calculated on the basis of a six line skate.

Seasonal Movements

A seasonal movement of halibut from deep to shoal water is commonly mentioned by experienced fishermen. Around Anticosti island a fishery in shoal water is conducted between mid-July and mid-September. The same type of fishery is found in the Cape Sable region of Nova Scotia between the middle of August and the middle of October. In this region halibut are found mainly in depths of 20 to 40 fathoms. According to experienced fishermen they are not found in these depths previous to mid-August. However, no exact data are available and the periods of these suggested movements are still a matter of conjecture.

Figure 3 compares the length-frequency distribution of all halibut taken in depths of 95 to 140 fathoms during June, July, and September by the "J. J. Cowie" in the Anticosti island region, with that of the catch of two vessels from a depth of 15 to 23 fathoms off Heath Point, Anticosti island, during the last week of July. Data used in preparing Figure 3 are given in Table VI.

Comparison of the curves shows that for June, July, and September in depths of 95 to 140 fathoms the modal length class of halibut taken was between 138 and 162 cms. For those caught in depths of 15 to 23 fathoms the modal length class was between 188 and 212 cms. From these samples it appears that the population of large halibut is relatively greater in shoal water during this period.

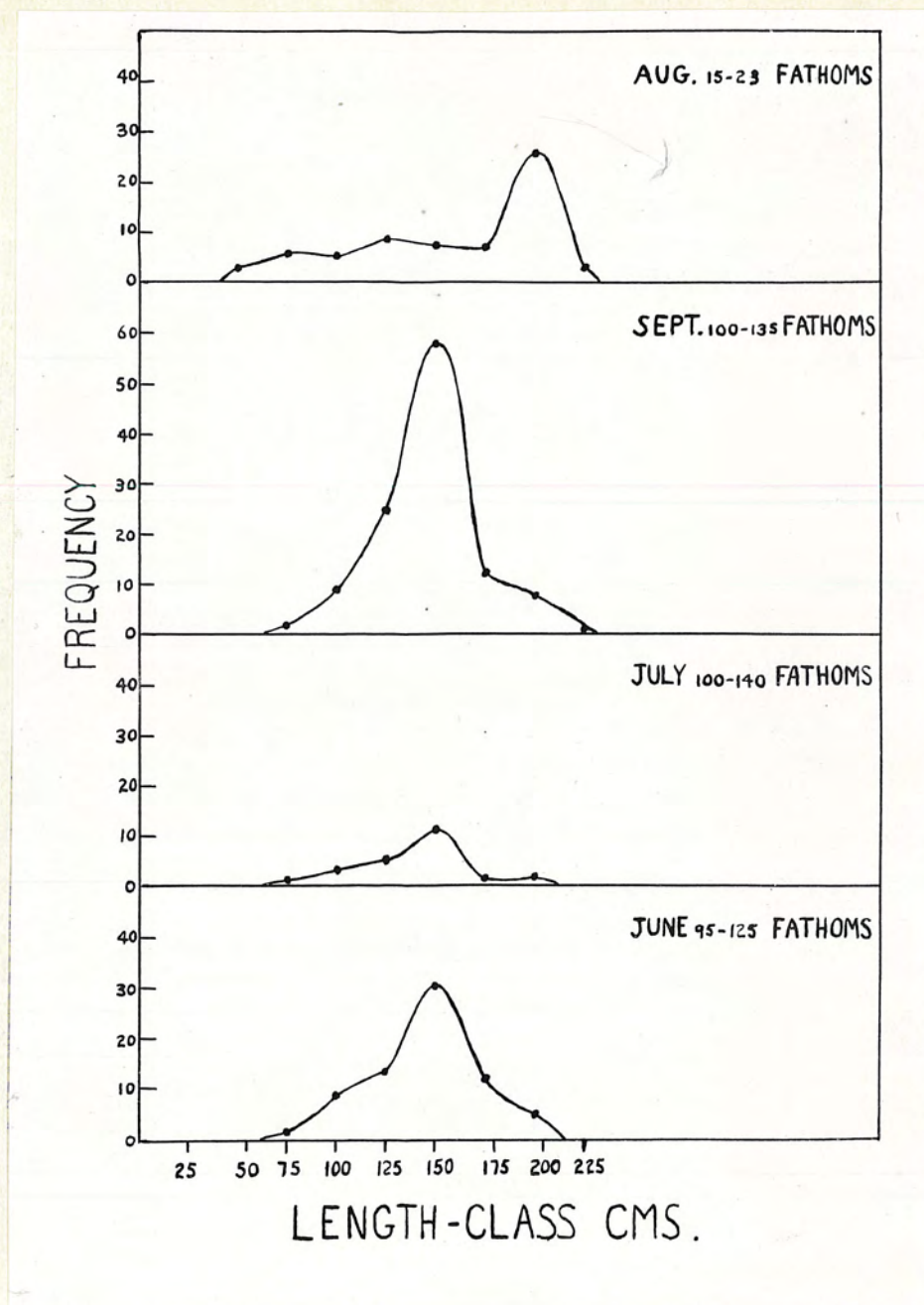


Figure 3 - Length-frequency distribution for halibut in the Gulf of St. Lawrence from the depths shown during June, July, August, and September, 1946.

Halibut of a smaller size also appear to be caught in shallow water. The possibility that the smaller size of halibut taken may be directly affected by the size of gear used tends to invalidate this result.

From Table VI a comparison of sex ratios relative to depths gives a much larger percentage of males taken in depths of 95 to 150 fathoms during July and September. Only four halibut, for which sexes were known, were taken in shoal water and these were all female. Data as to sex were not available for those halibut taken in 15 to 23 fathoms during July. However, using as a criterion the largest size for male halibut as determined from this investigation, it was found that of 67 specimens taken in shoal water 37 were larger than the largest male examined. On the preceding basis at least 55 percent of this sample population were females.

Jensen, Ad. S. (1925), referring to the halibut found in Greenland waters says, "This fish does not spend all its time in Greenland water. It appears first in early summer in the deep and constantly 'warm' water outside the Great Greenland Halibut Bank. As the summer advances, a rise in temperature takes place above this bank, the comparatively shallow waters of which are gradually warmed, not until then do the halibut move in over the Bank towards the coast. The average weight for halibut is greater in shoal water, as farther out there is a greater percentage of males and young specimens. In the fall the halibut are

forced back into deeper water due to the cooling of the shallow layers." Jensen correlates this movement with a search for food.

Evidence presented for the Anticosti area agrees with the foregoing statement of Jensen, with the exception that a larger percentage of young specimens was not taken in deeper waters. An explanation for the larger percentage of females in shoal water is outside the limits of available data.

TABLE VI

Length frequency of halibut caught in the Gulf of
St. Lawrence compared for depth and time

<u>Size class</u>	<u>Mean of</u> <u>Size Class</u>	<u>June 8-30</u>	<u>July 1-29</u>	<u>July 26-August 3</u>	<u>Sept. 4-25</u>
Depth		95 faths.	95 faths.	15-23 faths.	95 faths.
38- 62 cms.	50 cms.	-	-	3	-
63- 87 cms.	75 cms.	1	1	6	2
88-112 cms.	100 cms	9	2	5	8
113-137 cms.	125 cms.	13	5	9	24
138-162 cms.	150 cms.	31	12	8	58
163-187 cms.	175 cms.	12	1	7	13
188-212 cms.	200 cms.	6	2	26	8
213-237 cms.	225 cms.	-	-	3	1
	TOTALS	72	23	67	114

TABLE VII

Sex ratio relative to depth

<u>Period</u>	<u>Depth Fathoms</u>	<u>Number of Males</u>	<u>Percentage</u>	<u>Number of Females</u>	<u>Percentage</u>	<u>Total</u>
July 1-31	95-150	12	70.6	5	29.4	17
Sept. 3-25	100-135	75	64.7	41	35.3	116
Sept. 4-5	24-27	-	-	4	100	4

Distribution with temperature

From Table VIII it appears that halibut are taken in quantities only where the temperature of the water is above 2.5°C . In the Gulf of St. Lawrence very little fishing was carried on at a depth where the temperature was greater than 4.5°C ., so very little evidence pertaining to the maximum temperatures at which halibut are found is presented from this investigation.

Determination of the distribution of halibut, as related to temperature, through observation of the commercial catch indicates the range within which the halibut are found in sufficient numbers to warrant continued fishing operations. Therefore the amount of gear set in depths over 95 fathoms with temperatures over 2.5°C . is not directly comparable with the amount of gear set in colder water. The possible effect of factors, such as types of bottom and presence of food, is proportionately greater where less gear is used. Considering the combined results from all areas increases the amount of gear fished within each temperature range and so increases the validity of describing the distribution as correlated with temperature.

From the data shown, the distribution correlated with temperature can be described within broad limits. Below 1.6°C . catch per unit of effort was nil for both the Anticosti and Newfoundland areas, between temperatures of 2.4°C . and 4.5°C . the minimum catch per unit of effort was 3 pounds per line and a maximum of 20.5 pounds

per line. Therefore it appears that halibut are taken in commercial quantities only from water which is at least two or three degrees above zero centigrade.

Information obtained concerning temperatures greater than 4.5° C. is limited to observations made off Cape Sable on September 7. Temperatures taken at depths of 37 and 72 fathoms on this date were respectively 8.0° C. and 6.5° C. During the period August 31 to September 10, halibut fishing was being carried out in this region in a depth range of 35 to 80 fathoms. The catch per unit of effort was sampled by totalling the landings of 16 boats and obtaining information as to the number of lines used, from the fishermen. A catch of 8.7 pounds per line, thus derived, is comparable to the catch per line obtained in the Gulf of St. Lawrence throughout a temperature range of 2.4° C. to 4.5° C.

Jespersen (1925) correlates the movement of halibut in Greenland waters with increases in temperature. He states, "We found considerable depths with a temperature of 3° C. at the bottom.....it is evident that the halibut are to be sought for in the deep and constantly 'warm' water outside the banks. Experience in other waters (Norway, the Faroes and Iceland) has clearly shown that the halibut avoid ice-cold water".

Thompson, W. F., and Van Cleve, R., 1936, have shown that in both the Atlantic and Pacific the distribution of the commercial fishery for halibut conforms in general

to the distributions of temperatures between 3° C. and 8° C.

The results obtained from this investigation agree very closely with the general distribution, however, the maximum and minimum limits of temperature in which halibut are found can not be defined in this manner, since commercial operations are at the present time confined to depths and areas in which the return for fishing effort is at a maximum, inadequate sampling for determination of the extreme ranges is the result.

TABLE VIII
Catch per unit of effort as related
to temperature

Month	Depth range fathoms	Temperature range at depths shown	Number of lines set	Total weight (pounds)	Weight per line (pounds)
<u>South West Point, Anticosti Island.</u>					
June	95-125	4.5°...2.9° C.	290	5,957	20.5
July	95-125	4.2°...2.4° C.	125	947	7.6
July	130-200	4.2°...4.0° C.	100	653	6.5
July	10-20	1.4°...9.9° C.	60	115	1.9
July	20-45	1.4°...-0.7° C.	20	0	0.0
July	60-85	1.6°...0.0° C.	20	0	0.0
<u>Ellis Bay, Anticosti Island.</u>					
June	95-125	4.2°...3.0° C.	165	1,296	7.9
June	60-75	0.9°...0.2° C.	65	0	0.0
July	100-110	3.4°...3.1° C.	15	180	12.0
July	130-140	-	15	110	7.3
<u>Pointe Riche, Newfoundland.</u>					
May	100-130	4.0°...2.8° C.	160	476	3.0
May	47-80	1.3°...0.0° C.	25	0	0.0
August	100-123	-	40	0	0.0
August	125-153	4.5°...4.3° C.	30	0	0.0
August	9-75	-	110	10	0.09
<u>Bay of Islands, Newfoundland.</u>					
May	115-125	4.5°...3.1° C.	40	168	4.2
<u>Cape Sable, Nova Scotia.</u>					
August	-	-	1359	11,933	8.7

TAGGING OF HALIBUT

Methods

Tagging operations were carried out aboard the Department of Fisheries boat, "J. J. Cowie", operated by the Fisheries Research Board, in the Gulf of St. Lawrence during May and June, 1946.

The type of tag, region, and method of attachment were essentially as described by Thompson and Herrington (1930). Capture of halibut for marking purposes was accomplished by the commercial hook and line, using the long-lining method employed in the Pacific Coast halibut fishery. Five lines, fifty fathoms in length, were joined to form a skate of gear, then a number of skates, usually five, were set in a string. To each line approximately twenty hooks were attached, at intervals of two and a half fathoms, by means of a short line or "ganging". After the hooks were baited a string of gear was "set" while the vessel was moving forward at full speed. When making the "set" the line was passed out over a chute at the stern of the vessel. Each string of gear was anchored at both ends to hold it on the bottom and the ends were marked with buoys. Each string of gear was hauled back over a roller at the rail of the vessel, using a power hauler or "gurdy". Two men were required to handle the line being hauled back, one at the rail to "slat off" any unused bait and "gaff" the fish caught by the hooks, and the other to coil the line as it came off the "gurdy". In order to obtain the fish in a vigorous condition the

maximum "soak" (time on the bottom) of the gear was never greater than five hours.

When large halibut (approximately 50 pounds in weight and over) were taken, the "gaff" (short hook) used by commercial fishermen, was found to injure the head region and render these fish unsuitable for tagging. It was found possible to lower a noose around the body of the fish, pull it tight around the caudal region and using a block and tackle, lift the fish inboard. A very small percentage of the fish caught were injured in either the gill or visceral region when this method was used. All halibut released were active and apparently in good condition.

The total length (to middle of tail) of each halibut was taken before tagging. In order to aid in this measurement the fish was placed in a wooden box with a head-piece across one end, with the scale for length measurement offset one half centimeter from the head-piece and extended lengthwise along the measuring board. With the tip of the mandible against the head-piece and the mouth closed, the length was read to the nearest centimeter. Total length was used in all cases (i. e. the length from the tip of the mandible to the end of the middle caudal rays).

Date, tag number, length, place of release and depth were recorded for each halibut tagged.

To aid in the recovery of recaptured tags a reward of fifty cents was offered for the return of a tag, accompanied by information as to date captured, position, and sex.

Results

At the present time tag returns are too incomplete to give a picture of the movements of halibut. A total of 83 halibut were tagged, ranging in length from 79 cms. to 200 cms.

A summary of the number marked in the different regions is as follows:

<u>Number</u>	<u>Region</u>
65	South West Point, Anticosti Island
11	West Point, Anticosti Island
4	Point Riche, Newfoundland
2	Burgeo Bank, Newfoundland
2	St. Paul's Island

A detailed account of the length, tag number, depth released, where released and tag returns is given in the Appendix, Table I.

To date seven tagged halibut have been recaptured. Six of these were originally released in the region of South West Point, and one was released at West Point.

Five recoveries were made within the same region and the same depth as released, by the crew of the motor vessel "J. J. Cowie". The period between release and recapture ranged from 47 to 86 days.

Of these five recaptures, three were males (lengths 123, 140 and 152 cms.) and two were females, 114 and 142 cms. in length. One female, length 189 cms., was recaptured on July 29, at Seven Islands, more than 100 miles from the point of release, in a depth of 50 to 55 fathoms.

One male, released at West Point, was recaptured at South West Point about 50 miles from the point of release, but in the same depth of water.

Movement of the large female halibut into shoaler water adds further evidence to that obtained from the statistics of the commercial catch taken in shoal water during July and August, to indicate a movement of very large halibut from deep to shoaler water during these months.

Reports that several other tagged fish have been recaptured during the spring of 1947 in the same vicinity as their release have not been substantiated, as yet, by receipt of the tags.

Recovery of the greater proportion of the tags from the region in which the fish were released possibly indicates a relatively local population, and since the fishing intensity of this area is not great a tag return of nine percent seems to be high. This may indicate a small halibut population in the area in which the major portion of the tagging was performed.

Time of spawning

Evidence obtained during this investigation as to spawning time is slight, however, an analysis of such data as were obtained supports the conclusion that the spawning period lies between October and June. A comparison with the available literature suggests the probability that the main spawning period is between March and the end of May.

Table IX shows the condition of the gonads in fourteen male halibut examined during May and July, each of which had passed the age of maturity noted in the following section. It will be noted that in five specimens taken during the latter part of July, the testes were in a condition which suggests that these fish were spent. One specimen taken July 28 had milt running from the testes. Seven specimens had a residue of milt in the testes and only one specimen examined had no sign of residual milt.

During this period eight female halibut, ranging in length from 162 to 199 cms. were examined. While this examination was non-quantitative and did not follow the size development of the individual ova, the general observations provide an indication as to the condition of the ovaries during this period. In each of these cases small ova were present in the ovaries, but the ovaries were slack and not completely filled. This condition was not noticeably different in the specimens examined in either May or July.

Thompson (1914) has described the condition of the ovary from one spawning period to another for the halibut of the Pacific. He finds that immediately after spawning the gonad of the female is flaccid, the walls collapsed, but that the next generation of ova is visible to the naked eye. This contrasts sharply with the turgid condition of the ovary just before the spawning season commences. From this statement it is judged that the specimens taken during May and July had spawned before this time. Unfortunately no female specimens were examined by the writer during later

months, and so no direct comparison can be made as to changes in the ovaries.

Records taken from examinations by the crew of the "J. J. Cowie" indicate that in September the ovaries were firm and hard. Also during September seventy-four male halibut were examined by the same crew and in no case was any sign of milt found in the testes. If these observations are admissible, they indicate that the ovaries were reaching the condition preparatory to spawning as noted by Thompson (1914).

Since none of the halibut tagged during June, in the Anticosti area, were in a running condition when landed, it would appear that either the main spawning period was completed previous to this time or that spawning had not yet started. Only one male halibut examined during July was running, the remainder being spent or having what appeared to be residual milt in the gonads, it would seem more probable that the principal spawning period occurs previous to June in the Gulf of St. Lawrence rather than during the very short period between July 1 when tagging ceased and July 25 when halibut from the same region were taken and examined.

Very little material bearing on the spawning season off the Atlantic coast of North America was found in the literature. Bigelow (1925) gives the spawning time (taken from Goode, 1884) as from April to early September. Cox (1924) reports the finding of two post-larval stages 20 and 21.5 mm. long off the Nova Scotia coast between June 3

and June 6. Jensen (1925) reports finding two post-larval stages from Greenland waters during June and July. Prince (1915) quotes Dr. J. B. Gilpin, who stated that he observed spawn running from a ripe halibut in June off the Nova Scotia coast.

Taning (1936) lists the following references and remarks concerning the spawning period of halibut, under the appropriate headings.

- | | |
|---------------------|---|
| Eggs | - Damas (c. t. Rollefsen, 1934, p. 20)
gives March and November for Norway;
the latter month falls well outside all
other statements regarding the
spawning season for this region. |
| Post-larval stages | - Norway: March, April-June,
Rollefsen (1934). |
| Spawning in Aquaria | - March-April (Nordgard, Rollefsen). |
| Spent Females | - Latter half of March off S. W. Iceland,
Saemundsson, B. (1926)
April-June, Fulton (1893)
26 May-19 July ("Thor" 1903-1908). |

Taning (1936) concludes that spawning in the north-eastern area of the Atlantic takes place chiefly in the months of March, April, and May, with April as the principal period. Thompson (1935) states that for the Pacific halibut, Hippoglossus stenolepis, spawning takes place from the middle of December to near the last of March.

From this survey of the literature it appears that the spawning period may vary in different areas. From the evidence

obtained the spawning season in the Gulf of St. Lawrence would seem to agree with the conclusion of Taning (1936), for the north-eastern area of the Atlantic.

TABLE IX
Condition of male gonads for period
May 27 - July 30

Date	Age Class	Length	Depth	Condition of Testes
May 27, 1946	15	122 cms.	120-128 faths.	Milt present in testes - testes hard and yellow.
July 1, 1946	20	122 cms.	90-115 faths.	" " " "
July 1, 1946	22	157 cms.	100-115 faths.	" " " "
July 23, 1946	22	147 cms.	12-16 faths.	" " " "
July 25, 1946	20	143 cms.	95-115 faths.	" " " "
July 25, 1946	14	126 cms.	130-150 faths.	Testes soft-bloodshot.
July 25, 1946	24	150 cms.	130-150 faths.	" " " "
July 25, 1946	23	147 cms.	130-150 faths.	" " " "
July 25, 1946	23	153 cms.	95-115 faths.	Milt present in testes - testes hard and yellow.
July 25, 1946	20	147 cms.	130-150 faths.	" " " "
July 25, 1946	21	149 cms.	130-150 faths.	No sign of milt-testes hard and yellowish.
July 28, 1946	21	134 cms.	155-165 faths.	Running.
July 28, 1946	20	150 cms.	155-165 faths.	Testes soft-bloodshot.
July 30, 1946	24	154 cms.	125-115 faths.	" " " "

Spawning regions

Knowledge of the spawning regions of halibut in the north-eastern Atlantic has been obtained by the study of eggs, pelagic post-larval stages and 0 group bottom stages. Taning (1936) reviews the records of the finding of pelagic stages of halibut by Schmidt (1904), Jespersen (1917) and a number of specimens taken since these dates in the waters around the Faroes, Iceland, and in the Denmark Strait. He also records obtaining halibut eggs at two different places in May, 1934.

From the observations made by Taning (1936), given in Table X, it appears that most eggs occur at a depth of ca. 700 meters (one-third of wire Length out) and are bathypelagic. Table XI, Taning (1936), shows a very wide vertical range of distribution for pelagic stages of halibut. Taning accounts for the concentration in the shallower layers by the fact that 15 to 25 and 50 to 80 meters of wire were used many more times than the other lengths. Therefore a uniform distribution over the range of depths may be possible.

From Table XII it is seen that eggs were taken only over depths greater than 1000 meters and small post-larvae < 20 mm. only over depths greater than 700 meters. Both the seven stages in which metamorphosis was complete and the two largest pelagic stages were taken within a depth of 50 meters. From these data it appears that the post-larvae metamorphose and seek the bottom somewhere between the lengths of 34 to 47 mms.

From available data Taning (1936) concludes that spawning areas must lie about the 1000 meter line and beyond, with

hydrographical conditions indicating that the halibut seeks warm water in order to lay its eggs. At the depth of 1000 meters at 61°22' N. 9°53' W. N. W. of Faroe Bank, temperatures of ca. 4°..and ca. 7.5° C. and a salinity of about 35 ‰ are found. The possibility that at a later time the halibut may be able to spawn at a lower temperature is also suggested. He also points out that depth is not an absolute condition for the spawning, since specimens have spawned in a natural manner in aquaria.

TABLE X

Records of Eggs

May 6, 1934 61°22' N. 9°53' W. (Depth 1100 m)		May 7, 1934 62°45' N. 16°01' W. (Depth 1975 m)	
Meters of wire out	No. of eggs	Meters of wire out	No. of eggs
0	-	-	-
50	-	-	-
100	-	-	-
300	-	-	-
-	-	500	-
600	1	-	-
-	-	1000	2
-	-	1500	2
-	-	2000	6

TABLE XI

Vertical distribution of pelagic stages of halibut

Meters of wire out	Length of specimens		Total
	13-18 mms.	20-24 mms.	
15-25	4	5	9
50-80	12	17	29
100-150	1	7	8
200-250		2	2
300		1	1
1000-1500		1	1
Total	17	33	50

TABLE XII

Distribution according to depth of locality

Depth in meters	Eggs	Post-larvae 13-19 mm.	Post-larvae 20-34 mm.	Bottom stages 47-64 mm.
< 50	-	-	2: 30 - 34	7: 47 - 64
50-100	-	-	2: 26 - 28	-
100-200	-	-	1: 24	-
200-300	-	-	1: 22	-
400-600	-	-	2: 26 - 27	-
700-1000	-	10: 16 - 19	12: 21 - 28	-
1000-2550	11	7: 13 - 19	13: 21 - 29	-

Age of maturity

From evidence obtained during this investigation, only a general picture of the age of maturity can be given. All female halibut over the age of twelve seemed to be mature and while it is very difficult to determine maturity in males it would seem that males mature at approximately the same age as females.

During the period May to September, ten female halibut ranging from four to twelve years in age were examined and in none of these were signs of egg formation observed. For the same period forty-eight female halibut, ranging in age from thirteen to twenty-nine years, were found to have eggs present in the ovaries. Since only three females in the XIII age group and one female in each of the X, XI, and XII age groups were examined, no estimate can be made of the percentage of females maturing before thirteen years of age. If a greater number of specimens were available in each of the age groups, it is possible also that not all females of the XIII age group would be mature.

Male gonads are lobed in appearance and muscular in texture, therefore the presence of milt could be determined only by sectioning the gonad. The following table shows the condition of the gonad for six male halibut from the Anticosti region, examined during May.

Age	Length	Condition of Gonad	Date
7	70	No milt present	21/5/46
9	85	No milt present	27/5/46
11	118	No milt present	25/5/46
11	98	No milt present	29/5/46
14	96	Milt present	31/5/46
15	122	Milt present	27/5/46

It is apparent that for these specimens maturity had not been reached at eleven years, but at the age of fourteen and fifteen years maturity had been reached. No male specimens were examined during June while in later months the determination of the state of maturity in the males was not consistently possible. Since all specimens examined, during September, in the Cape Sable region were eviscerated no data was obtained as to state of maturity for either male or female halibut from this region.

Jespersen (1917) states "It would seem that halibut do not attain maturity until an age of nine to ten years". This conclusion is based on a very few specimens taken from Greenland waters. Thompson (1914) found that the earliest age of maturation for Hippoglossus stenolepis, the Pacific halibut, was eight years and only 50 percent had reached maturity at twelve years.

The material gathered during this investigation to the age of maturity agrees in general with the information found in the literature, but it is too fragmentary to allow detailed comparison.

A COMPARATIVE STUDY OF HALIBUT

IN THE ANTICOSTI ISLAND AND CAPE SABLE REGIONS

Colouration

A general description of the halibut, Hippoglossus hippoglossus is given by Bigelow and Welsh (1925); however, in comparing the halibut taken in the two regions a marked difference in colouration of the under surface, in large halibut, was apparent.

A great deal of variation in colour, on both upper and lower sides, occurred among the specimens examined. The colour of the upper surface varied from greenish brown to very dark brown, the colour being usually darker for larger fish. This colouration extended over both the dorsal and anal fins as well as the pectoral fin on the upper side. In numerous cases, particularly among the smaller fish, dark blotches of irregular shape were apparent on the upper surface. The smaller halibut in both the Gulf of St. Lawrence and Cape Sable samples had the under surface of the body as well as the dorsal, anal, and pectoral fins white in colour. The under surface of the caudal fin was also much lighter than the upper surface. In the Gulf of St. Lawrence sample the under surface, of the larger halibut, was mottled with grey in almost all cases. While no detailed comparison was made, it appears from general observations that the halibut taken in the Cape Sable region very seldom show a pronounced grey mottling of the under surface. In many cases, however, these fish have a pronounced reddish tinge to the under surface (known to the fishermen as "cherry-bellies").

Morphometry

From a comparison of body form and characters of halibut from the two regions only one difference in body form can be shown to have statistical significance.

Comparison of the length of halibut for similar age groups from the two regions indicates a difference in growth rate, which will be discussed in a later section.

In the following section the length-weight relationship,

number of anal and dorsal fin-rays, and the relative head lengths and pectoral fin lengths are presented on a comparative basis.

The length-weight relationship

When the weight in pounds is plotted against the total length in centimetres, on double logarithmic paper, a straight line results as is shown in Figure 4. The equation for this line has been determined by the method of least squares. The resulting equation can be expressed either as a logarithmic equation or as a power function of the form $y = ax^b$, where a and b are constants and x and y are the variables.

In the following equations:

y = eviscerated weight in pounds.

x = length in centimetres.

b = the slope of the line.

a = the intercept of the line.

The equations for the length-weight relationships represent the measurements and weights of 162 specimens from the Gulf of St. Lawrence ranging in length from 46 cms. to 221 cms. and 26 specimens from Cape Sable ranging in length from 67 cms. to 176 cms.

The resulting equations expressed logarithmically are:

Gulf of St. Lawrence sample - $\log y = 5.0091 + 3.196 \log x$

Cape Sable sample - $\log y = 4.7752 + 3.072 \log x$

or expressed as a power function

Gulf of St. Lawrence sample - $y = .00001021 x^{3.196}$

Cape Sable sample - $y = .0005959 x^{3.072}$

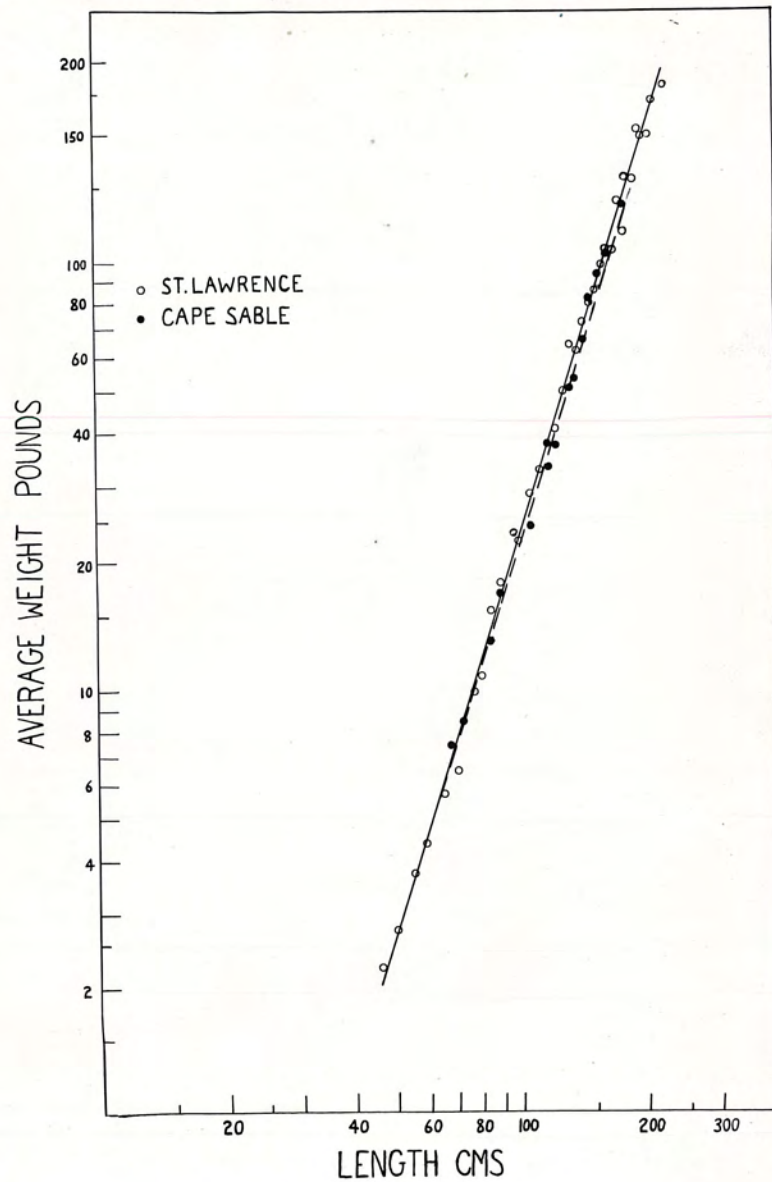


Figure 4 - Comparison of the length-weight relationship for halibut from the Gulf of St. Lawrence and those from the Cape Sable region.

Testing the difference in slopes using the formula:

$$t = \frac{b_1 - b_2}{\sqrt{s_{b_1}^2 + s_{b_2}^2}} \quad \text{Goulden (1939)}$$

a "t" value of .968 was obtained. The corresponding values given in Fisher's table of "t" are : 1.97 for the .05 level and 2.60 for the .01 level of significance. Using this basis of comparison there is no significant difference between these two samples in the rate of weight increase.

Testing the two samples for heterogeneity by means of an analysis of variance as shown in the appendix, Table II, an "F" value of 5.36 is obtained.

This "F" value lies within the 5% and 1% level of significance. The variation in mean weight for a given length in the two samples is significantly greater than the variation in weight between individuals of the same length in either sample. However, the individuals of the Gulf of St. Lawrence sample were weighed using a beam balance, while at sea, and the individuals of the Cape Sable sample were weighed using a stationary scale. The variation in mean weight between the two samples may be due to an error in the methods used.

Relative rate of growth of the pectoral fins

Over the range of sizes for the specimens examined the dextral pectoral fin (the pectoral fin of the eyed side) was always approximately 20 percent longer than the sinistral pectoral fin (the pectoral fin of the blind side).

However, the ratio of the rate of growth of both pectoral fins to the rate of growth of the body was not significantly

different.

In Figure 5 the length of the dextral and sinistral pectoral fins (the length of the longest ray of the pectoral fin) is plotted against the total body length on a double logarithmic scale. The resulting relation is in the form of a straight line.

Determining the equations for these relationships by the method of least squares, the straight line relationship can be expressed in the form $-\log y = \log a + b \log x$. Where x is the total body length, y is the pectoral fin length, b is the constant differential growth rate and a the intercept of the line.

The equation for the relative growth of the dextral pectoral fin is:

$$\log y = \bar{1.1099} + 1.1038 \log x$$

Similarly for the sinistral pectoral

$$\log y = \bar{1.2327} + 1.1023 \log x$$

Using the terminology applied to this form of relative growth, Huxley and Teisser (1936), the pectoral fins exhibit positive allometry in that they grow faster than the body as a whole.

Testing the difference in the slope of the two lines using the formula:

$$t = \frac{b_1 - b_2}{\sqrt{s_{b_1}^2 + s_{b_2}^2}} \quad \text{Goulden (1939)}$$

a "t" value of .016 is obtained. The corresponding values given in Fisher's table of "t" are 2.00 for the 0.05 level

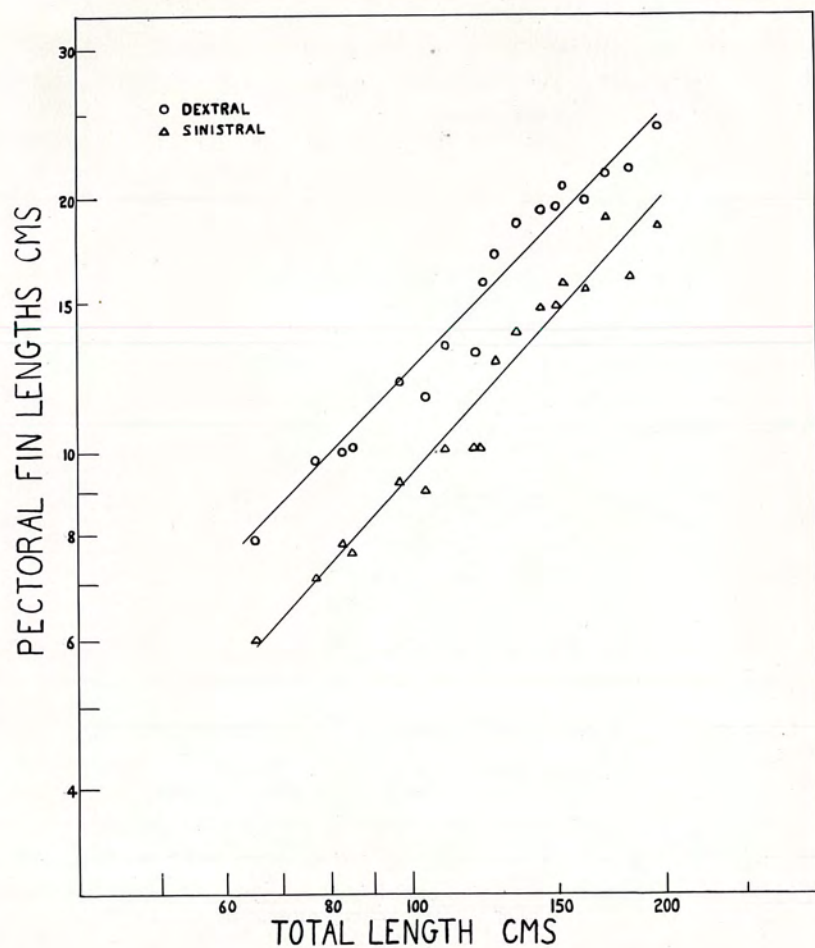


Figure 5 - A comparison of total length of dextral and sinistral pectoral fins for the same specimens, plotted on a double logarithmic scale.

and 2.66 for the 0.01 level. Therefore the constant differential growth rate, for both pectoral fins, is not recognized as being different by statistical criteria.

Using an analysis of variance as outlined in the appendix, Table III, the difference between the lengths of dextral and sinistral pectoral fins for each specimen is found to be significantly greater than the variation between dextral or sinistral pectoral fins of different specimens.

An "F" value of 153.0 lies well beyond the 1% point and from this criterion the differences between the lengths of the two pectoral fins is not due to error variation.

Thompson and VanCleve (1936) and Taning (1936) have shown from their studies of the early life history of the halibut that in the early stages preceding metamorphosis the pectoral fins are of equal length.

At some stage in the life history of the halibut, presumably during the time of metamorphosis, the relative growth rates of the dextral and sinistral pectoral fins must differ, resulting in the inequality shown throughout the size range examined in this investigation.

Relative rates of growth of the pectoral fins in male and female halibut

From the material obtained in this investigation there appears to be no significant difference between the relative rates of growth for the pectoral fins in male and female halibut.

In figure 6 the lengths of dextral and sinistral pectoral fins are plotted against the total length of the individual

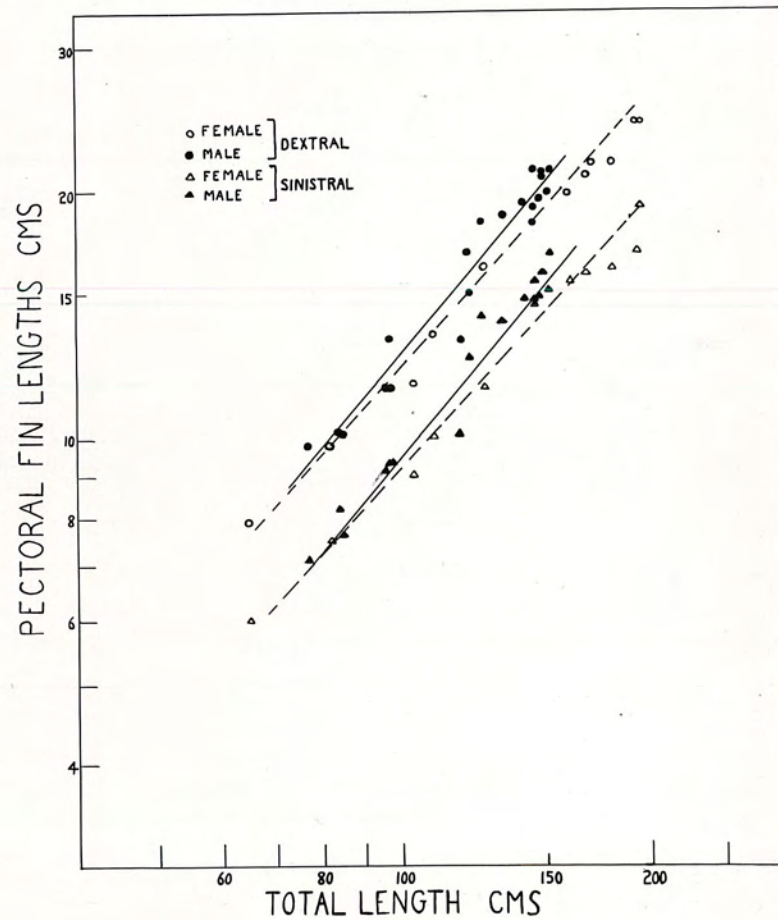


Figure 6 - Comparison of dextral and sinistral pectoral fin lengths of male and female halibut.

on a double logarithmic scale. Between 120 and 160 cms. total length the pectoral fin length in the male halibut appears to be greater than the relative growth line for the female halibut. However, the difference is not great enough to be recognized as significant by statistical criteria.

The equations for the relative growth lines of dextral and sinistral pectoral fins have been determined for twenty male halibut and eleven female halibut. These are:

Dextral Pectoral Fin

Male $\log y = \bar{1}.2411 + 1.1704 \log x$

Female $\log y = \bar{1}.0771 + 1.0816 \log x$

Sinistral Pectoral Fin

Male $\log y = \bar{1}.3978 + 1.1846 \log x$

Female $\log y = \bar{1}.0987 + 1.0644 \log x$

The slope of the relative growth line for both fins of the male halibut is greater than the corresponding slope for the female and from Figure 6 the male halibut tends to have larger pectorals, however, testing these for significant difference using the formula:

$$t = \frac{b_1 - b_2}{\sqrt{s_{b_1}^2 - s_{b_2}^2}} \quad \text{Goulden (1939)}$$

the resultant "t" value is not significant.

An analysis of variance applied to male and female pectoral measurements shows that the difference between these measurements is not significantly greater than the variation between individual male or female measurements.

Throughout the length range from 120 to 160 cms. in

Figure 6, that is the portion of the range which includes mature males, the greatest difference between male and female pectoral fin lengths is seen.

Since only two female specimens in this size range were available, a separate comparison of this portion of the range was not possible.

From the material available it is concluded that a significant change in relative growth rate of the pectoral fins at maturity could not be shown.

Comparison of pectoral fin lengths for the two samples

No significant differences were obtained for the lengths of dextral and sinistral pectoral fins when related to the total body length.

In Figure 7 the length of the dextral and sinistral pectoral fins is plotted against the total body length, using a double logarithmic scale. This graph illustrates that the relative lengths of pectoral fins, for the two samples, almost coincide.

The formulae for this relationship (the length of pectoral fins to the total body length) determined by the method of least squares are:

Gulf of St. Lawrence sample -

Dextral pectoral fin $\log y = \bar{1}.1099 + 1.1038 \log x$

Sinistral pectoral fin $\log y = \bar{1}.1237 + 1.1023 \log x$

Cape Sable sample -

Dextral pectoral fin $\log y = -.9952 + 1.0395 \log x$

Sinistral pectoral fin $\log y = \bar{1}.1561 + 1.0607 \log x$

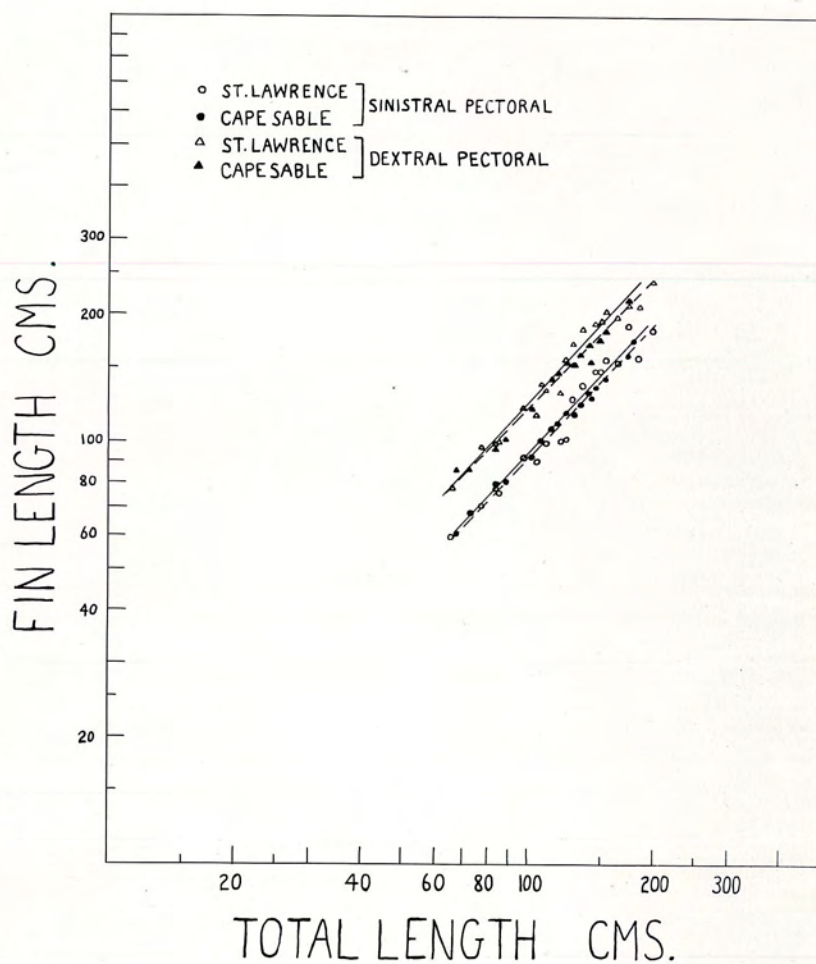


Figure 7 - A comparison of dextral and sinistral pectoral fin lengths for the two samples.

The differences in slope of the lines of proportional length tested using the formula:

$$t = \frac{b_1 - b_2}{\sqrt{s_{b1}^2 - s_{b2}^2}} \quad \text{Goulden (1939)}$$

do not give "t" values which can be considered significant using Fisher's table of "t".

Therefore it appears that the relative size of pectoral fins is the same for both samples.

Relative head lengths

A comparison of the head lengths plotted against total length of the halibut, for the two samples, shows that there is no significant difference in the relative head lengths of the two populations.

The head length (the length from the tip of the upper jaw to the end of the opercular bone, not including the flap at the end of the operculum) has been plotted against the total body length in Figure 8 on double logarithmic paper. The resulting relationship is a straight line. Determining the equations for these lines by the method of least squares gives the equation:

$$\log y = -.9223 + 1.1368 \log x$$

for the Gulf of St. Lawrence sample, where y is the head length and x is the total body length. Similarly the equation for the head length - body length relationship for the Cape Sable sample is:

$$\log y = -.7623 + 1.0629 \log x$$

Since the slope of this line is greater than one, the growth of the head exhibits tachyauexis increasing at a slightly faster rate than the total body length.

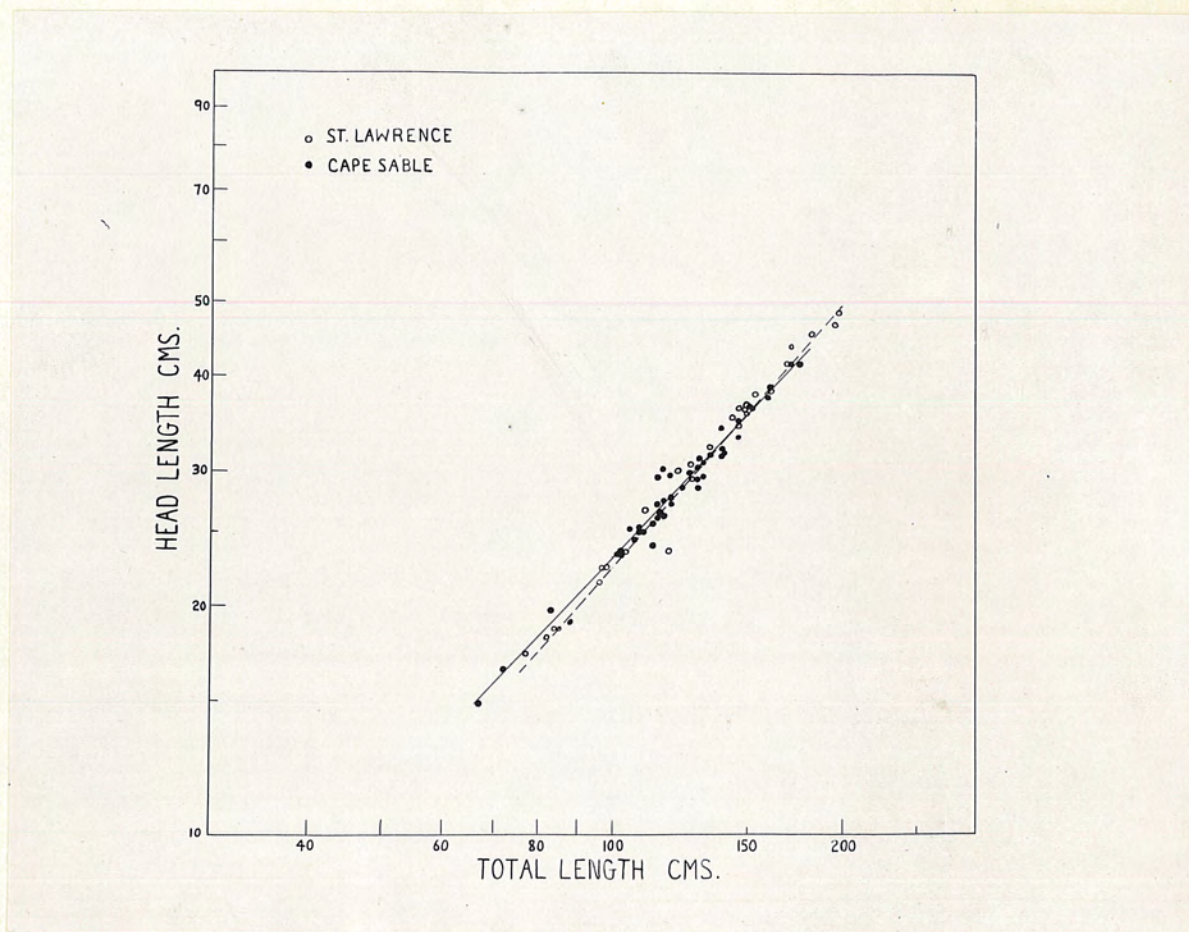


Figure 8 - Comparison of relative head lengths for specimens from the Gulf of St. Lawrence and Cape Sable regions.

Comparing the slopes of the two equations using the formula:

$$t = \frac{b_1 - b_2}{\sqrt{s_{b_1}^2 + s_{b_2}^2}} \quad \text{Goulden (1939)}$$

a "t" value of 1.1462 is obtained. From Fisher's table of "t" this is shown to be non-significant.

Dorsal and anal fin ray counts

No significant difference in mean values was obtained for either dorsal or anal fin ray counts. The numerical range of dorsal fin rays is 92-107 and 69-84 for the anal fin rays of 31 specimens from the Gulf of St. Lawrence. The corresponding numerical ranges for 47 specimens from Cape Sable is 92-105 dorsal fin rays and 69-84 anal fin rays.

The mean values for the number of dorsal rays are $100.48 \pm .63$ for the Gulf of St. Lawrence sample and $100.06 \pm .45$ for the Cape Sable sample. The difference between the two mean values is 0.42. Testing this difference using the formula:

$$t = \frac{\text{Diff.}}{S_{\bar{x}}} \quad \text{Goulden (1939)}$$

a "t" value of .753 is obtained. From the table of "t" values this is seen to be non-significant.

Similarly, the mean values for the number of anal rays are $75.26 \pm .63$ for the Gulf of St. Lawrence sample and $74.68 \pm .34$ for the Cape Sable sample. The "t" value obtained for this difference is 1.20, which is also non-significant.

It appears that there is no significant difference between the number of fin rays for the two samples.

AGE DETERMINATION AND RATE OF GROWTH

Methods of determination

The determination of age for the specimens examined was made by counting the number of opaque and transparent rings appearing on the otoliths. These were read by means of reflected light using a binocular microscope with a magnification of six. In accordance with the literature on age determination by means of otoliths, an opaque and a transparent ring together were considered to represent a year's growth.

A precise determination of the number of rings on the larger otoliths was not possible. Jensen (1938) has shown that a decrease in the growth rate of the otolith accompanies an increase in the length of the fish. Consequently in the larger specimens the outer rings were found to be small and indistinct.

Each otolith was read twice, an original reading and then a second reading several weeks later. Considerable variation occurred between the two readings, particularly in the larger specimens. The following table indicates the number and extent of the variations. In order to show this, arbitrary five year groupings are used based on the final determination of the number of annual rings.

TABLE XIII

Groups Number of rings	Number of Individuals	Variation of 0 rings	Variation of 1 ring	Variation of 2 rings	Variation of 3 rings	Variation of 4 rings
5-9 inclusive	21	71.4%	28.6%			
10-14 "	43	69.7%	23.2%	4.7%	2.4%	
15-19 "	39	61.5%	20.5%	12.8%	5.2%	
20-24 "	41	36.5%	31.8%	24.4%	4.8%	2.5%
25-29 "	17	29.4%	23.5%	35.3%	11.8%	
Total	161	89	41	23	7	1

From this table it is seen that the variation increases with the number of rings found on the otolith. In every case where variation between the two readings occurred a third reading was made to determine the most probable number of growth rings and this value was used in the presentation of the data on rate of growth in the following section. In several cases, not shown in the accompanying table no probable number of rings could be determined, due to irregularities in the structure of the otolith.

Since the variation in actual readings is frequent and in the older specimens the final number of annual rings decided upon would seem to be a matter of opinion, the use of the term year-class and age-group in the next section has many flaws.

RATE OF GROWTH

From the data obtained in this investigation it appears that females are usually larger than males of the same year-class. The maximum size reached by female halibut is larger than that reached by the males. A comparison of halibut from different localities shows a difference in growth rate for the two samples.

Figure 9 shows graphically the average total length of male and female halibut for the various year-classes examined in the Gulf of St. Lawrence. Figure 10 gives the average weights for the same specimens. Data used in preparing these curves are given in Table XIV.

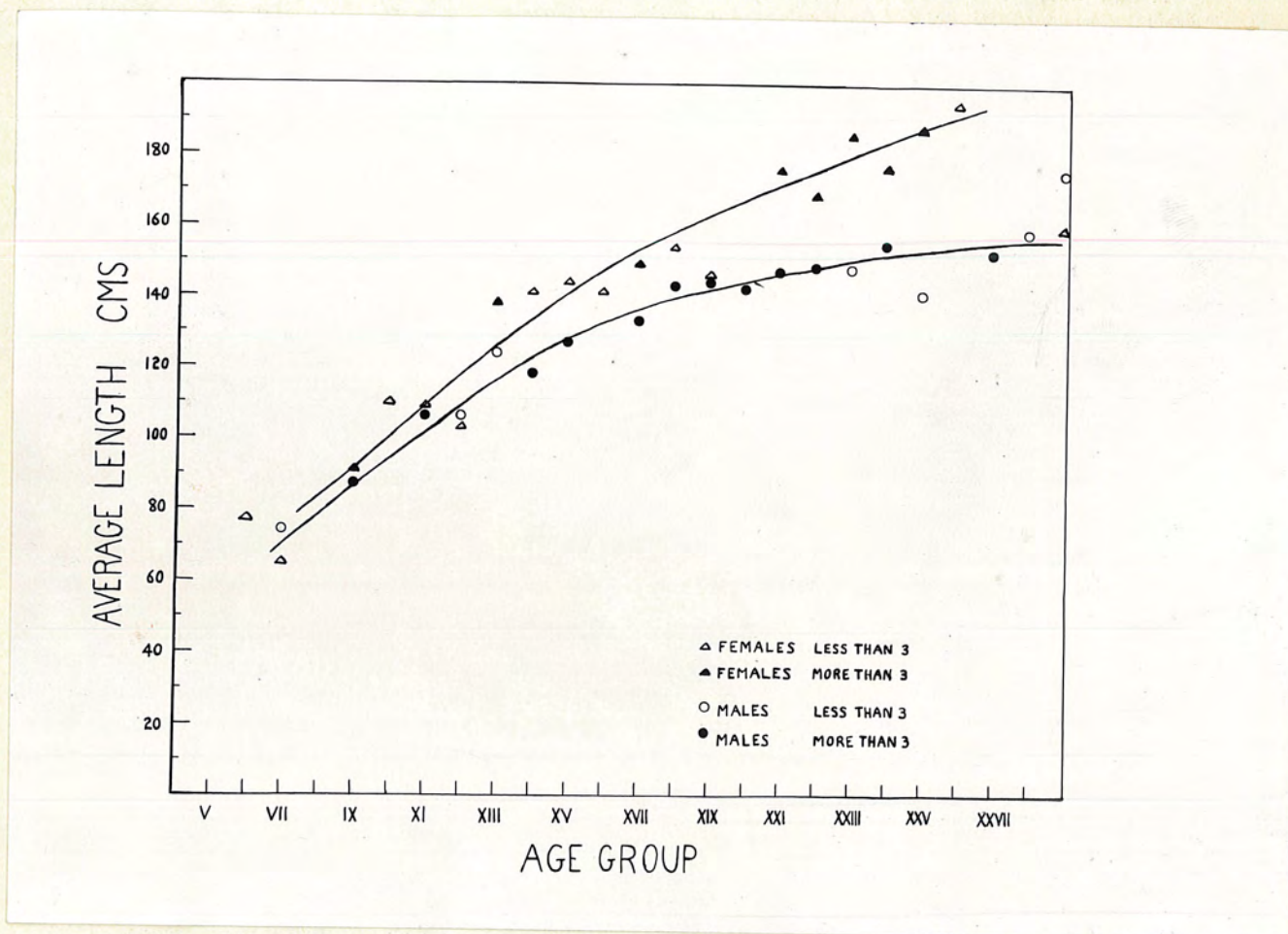


Figure 9 - Rate of growth for male and female halibut from the Gulf of St. Lawrence.

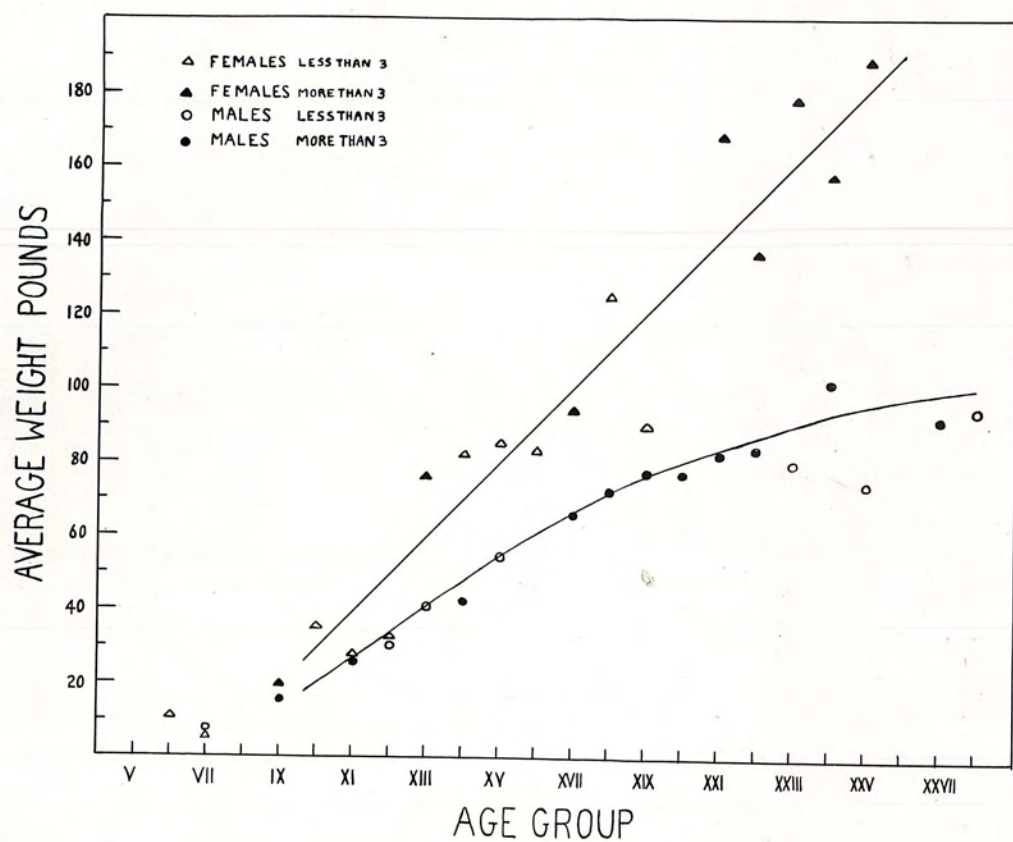


Figure 10 - Comparison of the weight increase for male and female halibut from the Gulf of St. Lawrence.

Sizes examined, for which the sex was determined, ranged from 65 to 195 cms. One of the factors affecting the lower limit was the type of commercial gear used. Since there are no more than a few specimens in any one of the year classes and also because of the previously discussed difficulty in making definite age determinations, this comparison is not presented as being conclusive but does give some basis for further investigation.

Throughout the size range examined, females had a faster growth rate than males. This is more noticeable in a comparison of growth in weight for male and female fish. The growth rate for male halibut slows down at approximately the XIII year-class and very little increase occurs throughout succeeding year-classes. This would appear to be corresponding with the age of maturation when the greater proportion of energy previously channeled towards increase in size would now be directed toward the sexual development. Female halibut show very little decrease in growth rate throughout the size range and age groups examined. Since there seems to be no apparent difference in the length of life for male and female halibut in the samples examined, the difference in maximum size reached by male and female halibut also bears out this conclusion. The largest male halibut examined was 176 cms. in length and weighed 105 pounds eviscerated, while the largest female examined was 203 cms. in length and weighed 248 pounds eviscerated.

Jespersen (1917) has shown this difference in growth

rate between males and females for populations of halibut from north-western and south-western Iceland. Thompson (1914) has found the same to be true for the species of Pacific halibut, Hippoglossus stenolepis.

Data in Table XV and Figure 11 compare growth rate for specimens from the region of Cape Sable, Nova Scotia, with those examined in the Gulf of St. Lawrence. Specimens from Cape Sable had been eviscerated before examination, therefore it was impossible to determine the sex. Comparison of growth rates for the halibut from these two regions is made by using the combined average lengths for both male and female.

Specimens from Cape Sable region seem to have a slightly faster growth rate than those found in the Gulf of St. Lawrence. This comparison would be invalidated if all the specimens from the Cape Sable region were females, however, this is improbable since both males and females were being taken in this region. Since the number of specimens in the different age classes is small, the extent of the difference in growth rate cannot be determined accurately. Jespersen (1917), (1935), has shown a difference in growth rate for different populations of halibut taken from south-western and north-western Iceland and also from Greenland.

The range of sizes examined from the Cape Sable region does not represent the complete size range of the population. Further investigations are to be conducted in this region and it would be of interest to determine whether this seemingly faster growing population reaches the same maximum size as the

halibut taken from the Anticosti region of the Gulf of St. Lawrence. Huntsman (1918) has shown that the Canadian plaice has a more rapid rate of growth in warmer waters, but that in very warm water the death rate is higher than in the colder areas, therefore very few fish reach the ultimate size obtained by plaice which are living in water of colder temperatures.

During the period that the halibut are found in quantities around the Cape Sable region they would appear to be subjected to a higher temperature of water than those of the Gulf of St. Lawrence. Since little is known about the movements of the halibut, which are taken from the Cape Sable region, it is unsafe to conclude that they are always subjected to or able to find warmer water than the halibut in the Gulf of St. Lawrence.

Although it would seem logical that their more rapid growth rate is a result of higher temperatures, until further knowledge of their origin is obtained such an explanation can be substantiated only by evidence obtained for other species of fish.

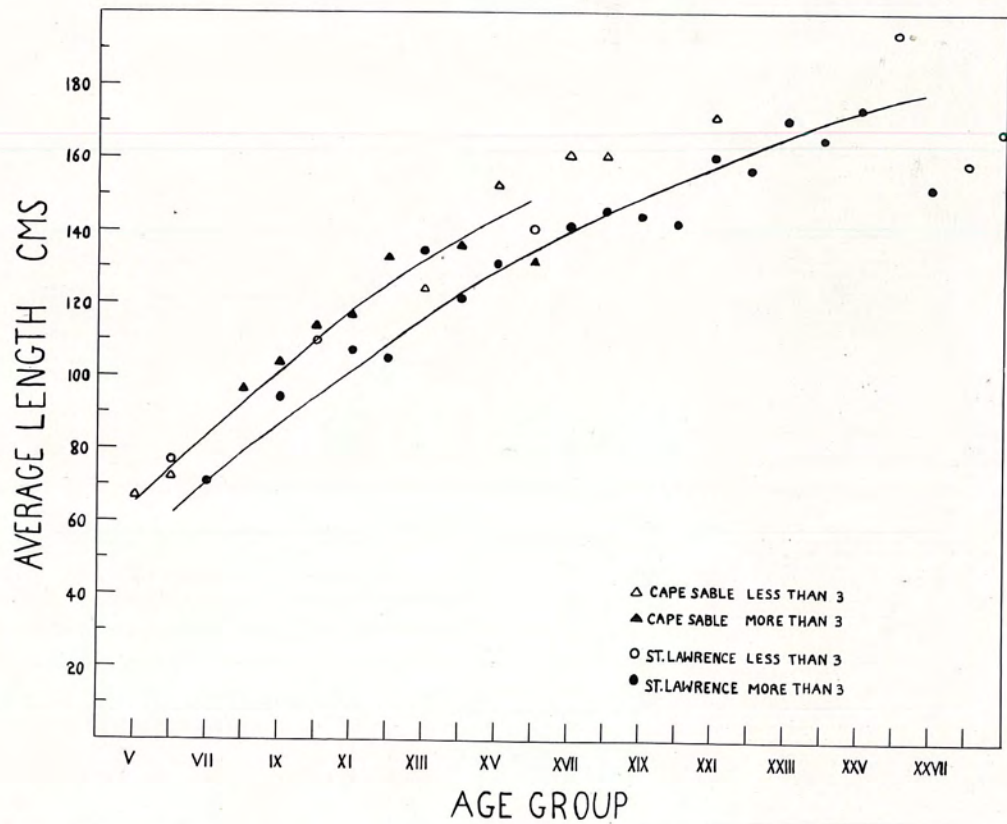


Figure 11 - A comparison of growth rates for halibut from the Gulf of St. Lawrence and the Cape Sable regions.

TABLE XIV

Comparison of average lengths and weights of male and female
halibut from the Gulf of St. Lawrence

Age Group	No. of Specimens	Average Length Male	Average Weight Male	No. of Specimens	Average Length Female	Average Weight Female
VI	-	-	-	1	(77.0)	(11.0)
VII	2	(74.0)	(7.75)	1	(65.0)	(5.8)
VIII	-	-	-	-	-	-
IX	4	87.0	15.5	3	91.0	19.7
X	-	-	-	1	(110.0)	(35.0)
XI	3	106.6	26.0	1	(109.0)	(28.0)
XII	2	(106.0)	(30.1)	1	(103.0)	(32.0)
XIII	1	(124.0)	(41.0)	3	138.6	76.1
XIV	5	118.0	42.5	1	(141.0)	(82.0)
XV	6	127.0	54.8	2	(144.0)	(85.5)
XVI	-	-	-	1	(141.0)	(83.0)
XVII	4	133.0	65.8	4	149.7	94.6
XVIII	4	143.7	72.3	2	(154.0)	(125.0)
XIX	6	144.3	77.7	2	(146.5)	(90.0)
XX	12	142.6	77.2	-	-	-
XXI	4	147.2	82.5	4	176.0	169.0
XXII	5	148.6	84.2	4	169.0	137.0
XXIII	2	(148.0)	(80.0)	3	186.0	179.0
XXIV	3	155.0	102.6	3	177.0	158.6
XXV	2	(141.0)	(74.5)	5	188.0	189.0
XXVI	-	-	-	2	(195.0)	(205.5)
XXVII	4	153.0	92.7	-	-	-
XXVIII	2	(159.0)	(95.5)	-	-	-
XXIX	1	(176.0)	(105.0)	1	(160.0)	(110.0)

() denotes less than 3 specimens

Length in centimetres, weight in pounds.

Comparison of total lengths for the year-classes of halibut
from the Gulf of St. Lawrence and Cape Sable regions

Age	No. of Specimens	Gulf of St. Lawrence Average Length Male and Female	No. of Specimens	Cape Sable Average Length Male and Female
IV	-	-	-	-
V	-	-	1	(67.0)
VI	1	(77.0)	1	(72.0)
VII	3	71.0	-	-
VIII	-	-	4	96.5
IX	7	94.4	4	104.2
X	1	(110.0)	4	114.5
XI	4	107.4	10	117.8
XII	3	105.0	5	133.8
XIII	4	135.0	2	(124.0)
XIV	6	121.8	4	136.0
XV	8	131.5	2	(153.0)
XVI	1	(141.0)	3	131.0
XVII	8	141.6	2	(161.5)
XVIII	6	146.6	1	(161.0)
XIX	8	144.8	-	-
XX	12	142.5	-	-
XXI	8	161.6	1	(172.0)
XXII	9	157.7	-	-
XXIII	5	171.0	-	-
XXIV	6	166.1	-	-
XXV	7	174.7	-	-
XXVI	2	(195.0)	-	-
XXVII	4	153.0	-	-
XXVIII	2	(159.0)	-	-
XXIX	2	(168.0)	-	-

() denotes less than 3 specimens.

Length in centimetres, weight in pounds.

SUMMARY

At the present time halibut landings on the Atlantic coast of Canada are approximately one-tenth as much, by weight, as the halibut landings on the Pacific coast of Canada. Quebec halibut landings, from the Gulf of St. Lawrence, are one-tenth of the total east coast halibut landings. The amount of halibut caught seems to be correlated with the ratio of halibut prices relative to cod prices.

During this investigation 84 halibut were tagged and 263 halibut were examined as a basis for comparisons made.

In certain areas of the Gulf of St. Lawrence the availability is comparable with the Pacific coast banks.

Distribution of halibut in the Gulf of St. Lawrence appears to be correlated with temperature, as halibut were only taken in commercial quantities, from water which was at least two or three degrees above zero centigrade.

The commercial halibut fishery in the Gulf of St. Lawrence and Cape Sable regions is a seasonal fishery conducted in shoal water. However, it appears from the operations of the M. V. "J. J. Cowie" in the Gulf of St. Lawrence, that for this area fishing was available in deeper water over a longer season.

Tag returns, while limited, suggest that there is no great movement of the halibut population of the Anticosti region.

A survey of the literature available leads to the conclusion that in the north-eastern Atlantic and in the

Pacific spawning takes place in deep water. This is probably also true in the Gulf of St. Lawrence. From an analysis of the literature the time of spawning appears to vary in different areas. From the data obtained during this study, spawning in the Gulf of St. Lawrence seems to occur between October and June and although no conclusive evidence is available the latter part of this period is the most probable spawning peak.

A comparison of the halibut from the Gulf of St. Lawrence and Cape Sable regions, shows differences in colouration, size and age composition, and in rate of growth, but they are similar in their length-weight relationship, dorsal and anal fin ray counts and relative rates of growth for the head and pectoral fins.

Female halibut have a faster rate of growth than males and also reach a larger maximum size; this is most apparent in the rate of weight increase.

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Appendix

TABLE I

Record of Tagged Halibut in the Gulf of St. LawrenceMay and June, 1946

Date Released	Length Cms.	Tag Number	Where Released		Depth Released Fathoms	Date Recaptured	Sex	Where Recaptured		Depth Recaptured Fathoms
			Lat.	N. Long. W.				Lat.	N. Long. W.	
May 18	123	3851	47°16'	62°22'	80-95					
May 18	94	3852	47°16'	62°22'	100-110					
May 21	103	3853	47°10'	57°51'	100-108					
May 21	102	3854	47°10'	57°51'	100-108					
May 25	99	3855	50°47'	57°27'	100-110					
May 25	140	3856	50°47'	57°27'	100-110					
May 25	96	3857	50°46'	57°28'	90-105					
May 25	130	3858	50°46'	57°28'	90-105					
June 8	157	59102	49°22'	63°46'	108-115					
June 8	110	59601	49°22'	63°46'	108-115					
June 8	186	59105	49°22'	63°46'	108-115					
June 8	147	59106	49°22'	63°46'	108-115					
June 8	176	59101	49°23'	63°48'	95-115					
June 8	197	59103	49°23'	63°48'	95-115					
June 8	198	59107	49°23'	63°48'	95-115					
June 8	138	59108	49°23'	63°48'	95-115					
June 8	114	59109	49°23'	63°48'	95-115	10/9/46	♀	49°24'	63°46'	100-120
June 8	189	59110	49°23'	63°48'	95-115	29/7/46	♀	50°04'	66°11'	50-55
June 8	200	59111	49°23'	63°48'	95-115					
June 8	137	59112	49°23'	63°48'	95-115					
June 8	152	59113	49°23'	63°48'	95-115	9/10/46	♂	49°20'	63°45'	95-115
June 8	144	59114	49°23'	63°48'	95-115					
June 8	160	59115	49°24'	63°47'	110-125					
June 8	191	59116	49°24'	63°47'	110-125					
June 8	142	59117	49°24'	63°47'	110-125	25/7/46	♂	49°22'	63°42'	95-110
June 11	112	59602	49°20'	63°45'	105-115					
June 11	138	59119	49°20'	63°45'	105-115					

TABLE I (cont'd)

Date Released	Length Cms.	Tag Number	Where Released		Depth Released Fathoms	Date Recaptured	Sex	Where Recaptured		Depth Recaptured Fathoms
			Lat. N.	Long. W.				Lat. N.	Long. W.	
June 11	147	59120	49°20'	63°45'	105-115					
June 11	153	59122	49°20'	63°45'	95-115					
June 11	148	59123	49°20'	63°45'	95-115					
June 11	165	59124	49°20'	63°45'	95-115					
June 11	145	59125	49°20'	63°45'	95-115					
June 15	172	59126	49°39'	64°22'	110					
June 15	150	59127	49°40'	64°25'	120	18/9/46	♂	49°23'	63°42'	110-120
June 15	143	59128	49°40'	64°25'	120					
June 15	150	59129	49°39'	64°23'	110					
June 15	158	59130	49°39'	64°23'	110					
June 24	103	59131	49°21'	63°42'	105-115					
June 24	158	59132	49°21'	63°42'	105-115					
June 24	128	59133	49°21'	63°42'	105-115					
June 24	186	59134	49°21'	63°42'	105-115					
June 24	158	59135	49°21'	63°42'	105-115					
June 24	149	59136	49°21'	63°42'	105-115					
June 24	150	59137	49°21'	63°42'	105-115					
June 24	147	59138	49°21'	63°42'	105-115					
June 24	137	59139	49°21'	63°42'	105-115					
June 24	125	59140	49°21'	63°42'	115-125					
June 24	168	59141	49°21'	63°42'	115-125					
June 24	140	59142	49°21'	63°42'	115-125					
June 24	143	59143	49°20'	63°42'	110-120	18/9/46	♀	49°23'	63°42'	110-120
June 24	134	59144	49°20'	63°42'	110-120					
June 24	120	59145	40°20'	63°42'	110-120					
June 24	142	59146	49°20'	63°42'	110-120					
June 24	136	59147	49°20'	63°41'	95-112					
June 25	125	59148	49°22'	63°45'	95-115					
June 25	192	59149	49°22'	63°45'	95-115					
June 25	99	59604	49°22'	63°45'	95-115					
June 25	88	59605	49°22'	63°45'	95-115					
June 25	167	59151	49°22'	63°45'	95-115					

TABLE I (cont'd)

Date Released	Length Cms.	Tag Number	Where Released		Depth Released Fathoms	Date Recaptured	Sex	Where Recaptured		Depth Recaptured Fathoms
			Lat. N.	Long. W.				Lat. N.	Long. W.	
June 25	176	59152	49°22'	63°45'	95-115					
June 25	104	59606	49°22'	63°45'	95-115					
June 25	174	59153	49°21'	63°45'	115-127					
June 25	145	59154	49°21'	63°45'	115-127					
June 25	146	59155	49°21'	63°45'	115-127					
June 25	107	59156	49°21'	63°45'	115-127					
June 25	123	59157	49°21'	63°45'	115-127	5/9/46	♂	49°20'	63°41'	100-120
June 25	143	59158	49°21'	63°45'	115-127					
June 25	120	59159	49°26'	63°44'	100-110					
June 25	163	59160	49°26'	63°44'	100-110					
June 28	79	59608	49°40'	64°34'	105-119					
June 28	141	59161	49°40'	64°34'	105-119					
June 29	137	59163	49°38'	64°30'	115-123					
June 29	161	59164	49°39'	64°29'	110-117					
June 29	148	59165	49°39'	64°29'	110-117					
June 29	137	59166	49°39'	64°29'	110-117					
June 29	186	59168	49°40'	64°29'	100-110					
June 29	156	59169	49°40'	64°29'	100-110					
July 1	97	59609	49°22'	63°45'	95-110					
July 1	136	59170	49°22'	63°45'	95-110					
July 1	122	59171	49°22'	63°45'	95-110					
July 1	176	59172	49°22'	63°45'	95-110					
July 1	162	59173	49°22'	63°45'	95-110					
July 1	156	59174	49°22'	63°45'	95-110					

TABLE II

Analysis of variance of mean weights for the
Cape Sable and Gulf of St. Lawrence samples

Source of Sums of Squares	D. F.	Adjusted Sums of Squares	D. F.	Variance	F.	5% Point	1% Point
Between samples	1	.0134	1	.0134	5.36	3.90	6.78
Within samples	<u>N_1+N_2-2</u>	<u>.4582</u>	185	.0025			
Total	N_1+N_2-1	.4716					

TABLE III

Analysis of variance for relative lengths of
dextral and sinistral pectoral fins

Source of Sums of Squares	D. F.	Adjusted Sums of Squares	D. F.	Variance	F.	5% Point	1% Point
Between samples	1	.3098	1	.3098	153.0	4.02	7.12
Within samples	N_1+N_2-2	.1214	185	.0020			
Total	N_1+N_2-1	.4312					

