

**FISHERIES RESEARCH BOARD
OF CANADA**

MANUSCRIPT REPORTS OF THE BIOLOGICAL STATIONS

No. 423

Title

Scallop Investigations and Explorations in the Southern
Gulf of St. Lawrence - 1950.

Author

L. P. Chiasson

1951

FISHERIES RESEARCH BOARD
OF CANADA

HOWARD SMITH
MANAGEMENT REPORT OF THE BIOLOGICAL STATION

BELLFAST BOND



Author

TABLE OF CONTENTS

	<u>Page</u>
Introduction	1
General Features of Survey.	
1. Fishing craft	1
2. Equipment	1
3. Dragging procedure	2
4. Records	2
5. Remarks on dragging operations	3
Results of Survey.	
1. Areas surveyed	3
2. Positions of hauls	3
3. Catches of scallops and features of stocks	3
4. Meat yield	9
Mortality Studies.	
1. Recent mortalities on different beds	9
2. Putative causes of mortalities	13
Review of Conditions in Promising Areas.	
1. Boughton Island bed	14
2. Pictou Island bed	15
3. Richibucto bed	15
Scallop Dragging with Lobster Boats	
1. Prospects	15
2. Small gear trials	16
Efficiencies of Toothed and Toothless (Digby) Drags	17
Future Work	19
References	20

SCALLOP INVESTIGATIONS AND EXPLORATIONS IN THE SOUTHERN GULF
OF ST. LAWRENCE - 1950.

INTRODUCTION

This report is based on findings made in the course of a scallop survey by the Fisheries Research Board of Canada, during the summer of 1950. This was a continuation of the previous year's work and covered areas on both sides of the western part of Northumberland Strait and some further to the north along the New Brunswick coast. Besides this some grounds off eastern Prince Edward Island were re-examined in connection with the mortality problem encountered in 1949. Some attention was given to the practicability of fishing with light dragging equipment from lobster boats, and to a comparison of the relative efficiencies of different types of scallop drags. A summary description is given of the potentially commercially valuable scallop beds examined during the two years' survey.

GENERAL FEATURES OF SURVEY

1. Fishing Craft

The major portion of the survey was made on board the M.B. "Singer", a 56-foot gasoline-powered scallop dragger registered at Tiverton, N.S., and owned by Small Brothers. Boyd Robinson of Parker's Cove, N.S., skippered the craft throughout the charter period, June 1 to September 4.

During the first few weeks in September, some work was done in the vicinity of Pictou Island and Boughton Island aboard the M.B. "My Boy's" under charter from the owner and skipper, Bertram Polley of Trenton, N.S. Lobster boats were also hired locally for special work with light gear at Richibucto, Pictou Island and Boughton Island.

2. Equipment

The "Singer" was equipped with drags of the Digby type, six of these being attached to a single drag bar. "My Boy's" was equipped with six toothed drags on a bar, but, in other respects, the fishing equipment aboard both crafts was essentially the same. Digby drags from the "Singer" were also used aboard the "My Boy's" for a short period to test the relative efficiency of the two types of gear.

A Bendix Sounder (Model DR-8A) was installed aboard the "Singer" in preference to the Bantam Model used in the 1949

explorations. While the performance of the DR-8A is in many respects superior to that of the Bantam, it still leaves much to be desired in satisfying the purpose for which it was intended in these explorations. There seems to be difficulty in obtaining a sounding apparatus that will produce a good uniform record at all boat speeds on boats of the size of the "Singer". While depths could be determined at all speeds with the DR-8A, the character of the record was quite variable. On that account it was hopeless to attempt to determine the bottom character from the records taken at normal cruising speeds. Depth records taken at reduced speeds, made it possible to distinguish rough hard rocky bottom from very soft mud and this provided some advantage in the work but it was still impossible to recognize the different types that make up the gamut between these extremes. The sounder was quite useful in determining water depths at each station, even if it failed in the detection of bottom types as had been hoped.

3. Dragging Procedure.

The skipper was responsible for the operation of the boat and dragging equipment. It was he who decided the length of cable used during each haul, the speed at which the boat travelled while dragging, and all other details which concerned the sailing of the craft, and the handling of its gear. The writer was responsible for navigation and for determining the positions of all the hauls that were made.

Normally, the position of a particular haul was established by taking bearings on prominent landmarks shown on the marine charts, by navigating from buoys whose positions were known, or by interpolating between known positions determined as above. In the Richibucto area considerable difficulty was experienced in getting accurate positions because the land on both sides of Northumberland Strait in this area is low and because most of the hauls were 8 to 10 miles from shore where useful landmarks were usually not visible. Summer haze partly accounted for this. The unpredictability of tides in this region made it difficult to use compass courses and log distances as sole criteria for the determination of positions of hauls. However, by repeated checks, by the study of bottom types, and by the use of marker buoys on areas worked extensively, it was possible to so describe the larger areas that they could be reached by compass courses mainly, when allowance was made for ordinary tide effects and boat speeds.

The period of each haul was 15 minutes except under special conditions such as when dragging over very rough bottom. In this interval approximately one half mile of ground was covered.

4. Records

A separate record was kept of the results of each haul and of the pertinent conditions surrounding it on multigraphed,

"Scallop Dragging Report Forms", a sample of which follows this page.

In several instances representative samples of the catch were collected for shell-height measurements. Shell heights are diameters measured from the middle of the hinge to the diametrically opposite free edge of the shell. In the plotting of histograms (figs. 9-32), these measurements were grouped in size classes with a 5 mm. range, 37.5-42.5, 42.5-47.5, 47.5-52.5, etc. In the calculation of constants (table 2) the measurements were grouped in 2 mm. size classes.

5. Remarks on Dragging Operations.

By all reports, the early summer of 1950 in the Gulf of St. Lawrence was one of the roughest experienced in the last quarter-century. Frequent winds impeded the progress of the explorations especially during June and July. Out of a possible total of 55 working days aboard the "Singer", only 32 (58%) were fit for putting the drags overboard. On some of these 32 days only part of a day's work could be successfully completed. The small number of good harbours, and the comparatively great distances of these harbours from the dragging grounds further limited the actual time spent in explorations. Last year's weather was considered bad with 36(69%) actual out of 52 potential working days but it was appreciably better than 1950.

RESULTS OF SURVEY

1. Areas Surveyed in 1950.

Figure 1 shows the areas surveyed for the first time during 1950. The letters G, H, J and K used to identify the different series of 1950 hauls are sequential with those described in 1949 so as to avoid confusion.

The hauls in series G were made while Summerside, Pointe du Chene and Buctouche were used as the "home ports"; series H and J were both completed while working from Richibucto and series K from Tracadie and Shippegan.

2. Positions of Hauls.

It has already been pointed out that difficulties were occasionally experienced in fixing the exact positions of hauls. Figures 2 - 4 show the positions of the hauls plotted to the closest 15" of latitude and longitude. These represent the estimated positions of the boat at the end of the hauls. This fact had to be taken into consideration when the limits and the extent of scallop beds were later drafted.

It will be noticed that the successive hauls lack the neat arrangement usually found in charts representing hydrographic

SCALLOP DRAGGING REPORT

Series _____ Haul _____

Date _____ Time _____ Weather & tide _____

Position (Compass bearings on land marks) _____

Distances off land marks _____

Latitude _____ Longitude _____

Depth _____

Bottom character _____

Length of haul (minutes) _____

Direction of haul _____

Gear _____ Cable length _____

Catch commercial drags _____ bushels

no. above 4" _____ no. below 4" _____

Catch small-mesh drag _____ bushels

no. above 4" _____ no. below 4" _____

Associate animals. _____

Remarks:

stations or plankton stations. Several factors are responsible for this seeming lack of plan. The chief were that in cursory sampling of an area promising results were occasionally obtained which were followed by a more intensive dragging, and that weather and tide conditions rather than the positions of former hauls determined the positions of the later hauls.

3. Catches of Scallops and Features of Stocks.

Figures 5 - 7 depict the quantities of scallops caught in separate 15-minute hauls. Other things being equal, a catch of two bushels of live scallops per haul is considered to be the lower limit of potential commercially valuable areas. The figures show that relatively few beds of worthwhile proportions were found in the areas surveyed during 1950. These were all close together west of Miminegash and northwest of Richibucto and were encountered in hauls in series H and J. These beds and their stocks were studied in some detail.

(1) Richibucto Bed.

Figure 8 shows the outlines of a bed (A) henceforth called the Richibucto bed which holds good promise as a future producer even though the size of the scallops was too small in 1950 (fig. 14) to be apt material for a commercial fishery. Figure 8 shows that the long axis of the bed runs roughly NE-SW, and that the south, and north ends of the bed are located at $46^{\circ} 49' 30''$ N latitude $64^{\circ} 37' 30''$ W longitude, and $46^{\circ} 52' 30''$ N latitude $62^{\circ} 35' 00''$ W longitude respectively. The mean catch per haul for 20 hauls taken within the boundaries of this bed was roughly 2.5 bushels with a range from 0.5 to 4.5 bushels (Table I). The bottom here is of fairly firm sandy mud which makes for easy dragging because the gear does not dig in. The mean depth is 13.5 fathoms.

Sailing Directions. From Richibucto Harbour, this bed is reached by steering ENE from the Richibucto Buoy for an approximate distance of 9 miles. A road called the Strang Road (or the O'Leary Road) then "opens" out among tall trees on the horizon on Prince Edward Island. The "open" road is in line with the southern tip of the Richibucto bed.

Figures 14, 20, 22 and 24 and tables 1 and 2 describe catches made on the Richibucto bed. These show that the stock was remarkably uniform for size. The average approximated 3" which was too small for profitable commercial exploitation in 1950. Far too much labour would have been required for shucking out meats. The individual meat yield of survivors will approximately double within two years and it may then be worth while to drag this bed.

Table I. Quantities of Live Scallops Caught in 15-minute Hauls on the Richibucto Bed.

<u>Haul No.</u>	<u>Catch in Bushels</u>	<u>Haul No.</u>	<u>Catch in Bushels</u>
H31	2.5	H106	2.5
H32	1.5	H108	2.5
H33	2.0	H109	2.0
H34	3.5	H110	4.0
H87	0.5	H111	3.0
H88	2.75	H112	3.75
H89	2.0	H114	2.5
H90	1.75	H121	2.25
H91	3.5	H128	4.5
H92	1.25	H130	3.0

Table 2. Statistical Constants of Frequency Distributions of Scallop Heights.

Haul No.	Plotted Fig. No.	Size Range (mm.)	No. in Haul	Mean & Standard Error (mm.)	Standard Deviation	Coefficient of Variation
G79(L)	9	80-140	126	106.0±1.1	12.5	11.8
G92(L)	10	46-119	189	88.1±1.2	16.6	18.8
H6-8(L)	11	75-130	36	94.9±2.2	13.4	14.1
H19&20(L)	12	60-143	143	76.4±1.0	12.0	15.7
& (D)	12	64- 83	52	72.2±0.5	3.6	5.0
H28(D)	13	58-123	210	72.0±0.7	9.9	13.8
H34(L)	14	58-129	451	73.2±0.3	7.2	9.8
H38(L)	15	70-141	63	107.7±1.1	9.0	8.2
H58(L)	16	62-139	164	90.9±1.3	17.1	18.8
H58(D)		74-120	30	93.8±2.3	12.5	13.3
H67(L)	17	66-127	141	78.5±0.6	7.8	9.9
H67(D)		64-125	59	74.6±1.0	7.9	10.6
H76&77(D)	18	70-127	67	102.7±1.4	11.4	11.0
H77(L)	19	42-127	102	96.2±1.7	16.7	17.4
H88(L)	20	60-111	193	74.5±0.4	5.6	7.6
H88(D)		58-129	194	71.7±0.5	7.2	10.0
H101(L)	21	68-139	85	93.5±1.8	17.0	18.2
H106(L)	22	56-101	202	73.6±0.4	5.1	6.9
H106(D)		60-105	210	71.8±0.4	5.8	8.1
H124(L)	23	42-145	317	96.4±0.9	16.4	17.0
H124(D)		60-127	94	95.4±1.6	15.2	15.9
H128(L)	24	60-105	259	72.5±0.3	4.9	6.8
H128(D)		56-121	224	69.5±0.4	6.6	9.4
H136(L)	25	46-133	123	92.9±1.7	18.5	20.0
J16(L)	26	66-129	204	93.0±1.1	15.5	16.8
P.I.3(L)	29	72-111	119	88.8±0.7	8.0	9.1
P.I.3(D)		52-115	249	84.3±0.6	8.7	10.4
B.I.1(L)	30	40-117	95	85.3±1.3	12.3	14.4
B.I.1(D)		50- 99	47	81.3±1.7	11.4	14.0
B.I.2(L)	31	40-115	164	82.7±1.0	12.5	15.1
B.I.2(D)		56-105	94	80.9±1.1	11.0	13.6
C.Bear*	32	75-125	192	98.2±0.9	12.9	13.1

(L) indicates live scallops, and (D) indicates shells of dead scallops.

* The Cape Bear sample measurements were grouped on a 5-mm. basis while all other measurements were grouped on a 2-mm. basis.

The limited size range and uniformity of age composition suggests irregularity of recruitment of the scallop stocks on this bed.

(ii) Neighbouring Beds.

Besides the Richibucto bed there are four small nearby areas with scallop concentrations that showed interesting features, although too limited in extent to ever be of great industrial importance.

Bed B. This is a small patch of scallops (fig. 8) off a rocky ledge at $46^{\circ} 51' 45''$ N latitude, $64^{\circ} 38' 30''$ W longitude. Its stock shows a bi-modal distribution for size (figs. 19 & 25). The smaller scallops are apparently of the same age as the stock on the Richibucto bed but the larger are not represented in the population of the latter area. The bi-modality of the stock suggests irregularity of recruitment.

Bed C. This is at $46^{\circ} 49' 30''$ N latitude, $64^{\circ} 31' 30''$ W longitude (fig. 8). It is a small patch of scallops which may provide some worthwhile dragging in a year or two. Its stock (fig. 12) resembles that of the Richibucto bed except that there are a few older scallops present.

Beds D and E. These small areas (fig. 8) are off Miminegash at $46^{\circ} 52' 30''$ N latitude, $64^{\circ} 18' 15''$ W longitude and $46^{\circ} 52' 15''$ N latitude, $64^{\circ} 21' 15''$ W longitude. Their stock consists of large scallops (fig. 26) as well as small. There seems to be three distinct size-classes suggesting, possibly, more regular recruitment or a lower natural mortality rate than on the Richibucto or other neighbouring beds.

(iii) Other Areas Surveyed.

The other areas examined for the first time were of such minor importance that no special remarks will be made about them. They are sufficiently described in the figures in this report.

(iv) New Area Discovered by the Industry.

Since the summer's work was completed the writer has been in communication with Mr. Bert Polley of Trenton, N.S., skipper of "My Boy's" who described a scallop area discovered last autumn by haddock draggers who took unusually large numbers of scallops in their fish drags. News of this was passed along to several persons interested in scallops and a vigorous fishery was pursued there by commercial craft including "My Boy's" and Mr. Horace Hewitt's boat, "Robert H."

"My Boy's" maximum day's catch was 483 pounds of meats which would be considered excellent fishing by Digby standards. Other catches that were smaller but still very good were made by both boats. Five to seven bushels of scallops per haul with a six-gang drag were the regular catches obtained over a considerable period. Fishing stopped there in the autumn because of foul weather not because the bed was exhausted. The new ground lies half-way between Cape Bear, P.E.I., and Arisaig, N.S., and is a few miles to the east of Pictou Island. Although this area was not visited in the course of this survey and no samples of the catch were examined by the writer it seems proper that it should be mentioned here.

4. Meat Yield.

Measurements of catches in terms of bushels of whole scallops per haul could be quite deceptive if no check were kept on the quantity of meats obtainable. The meat yield of scallops is known to vary considerably from one area to another. This fact was well illustrated by the results obtained in the Gulf during the past summer. In the West Point area hauls G 66 - 73 combined gave a meat yield of 4.2 pounds per bushel of whole scallops and G 79 gave 4.9 pounds. In two tests with three-inch Richibucto bed scallops yields of 6.5 and 6.7 pounds per bushel were obtained and at Miminegash haul J 16 gave a yield of 7.3 pounds.

Part of these differences in yield may be attributable to differences in the size composition of the scallop stocks involved but we have no information to show that this is or is not the case.

MORTALITY STUDIES

1. Recent Mortalities on Different Beds.

Table 3 shows the percentage mortalities observed in 1950 in the various hauls from different beds - some visited last year and some visited for the first time in 1950. The "percentage mortality" was calculated by dividing a hundred times the total number of "recently dead" shells by the number of live scallops plus the number of "recently dead" scallops. Since the term "recently dead" as used here includes only shells with both valves still hanging together it is obvious that the percentage mortalities recorded in Table 3, are always minimum figures since many recently dead shells may have broken apart in the process of entering or leaving the drags.

Experimental work carried on by J. C. Medcof in indoor tanks of flowing sea-water at 10-15°C. at St. Andrews, N.B., during

the latter part of 1950 indicated that dead scallop shells of sizes regularly encountered in the Gulf, do not hang together as "bivalves" longer than twenty or thirty days. It remains to be demonstrated how this result should be applied in considering summer observations on shells in their natural habitat in the warm waters of the Gulf of St. Lawrence. One might expect that the period of attachment would be less. However that may be, it seems highly probable that the % "recent mortalities" referred to here are much below the total natural mortality for the year.

In several instances the size composition of representative samples of recently dead scallops was examined. The results appear as histograms with similar data for live scallops from the same areas. These do not attempt to show the relative abundance of live and dead animals in catches from these areas.

Where not otherwise specified, histograms apply to living animals.

(1) Richibucto Bed.

The newly-discovered Richibucto bed has suffered a mortality which has reduced its scallop population by about 23%. The high incidence of "dead" shells on this bed was so characteristic that it was occasionally used on foggy days to identify the bed itself. Just as characteristic were the large numbers of starfish. They were as abundant as the scallops themselves. As many as fifteen hundred starfish have been counted in one haul and comparable numbers were frequently observed. Most averaged only five to six inches in diameter.

In the absence of contrary evidence, the Richibucto bed scallop mortalities are attributed to starfish, since their damaging effects on other molluscs, oysters for example, are so well known. A few scallops with partly-destroyed meats were found with starfish inside. This is taken as evidence that these small starfish do destroy scallops. It might be argued that this was possible only where the scallops were already sick or dying but the few specimens that were found dying did not have decomposed or otherwise abnormal-looking meats. This suggests that a predator was involved.

Table 3 shows an average recent mortality of 22% for the Richibucto bed and 8% for Bed C (fig. 8) whose scallop stocks are closely similar. The numbers of starfish taken per haul from Bed C were only about 10% of those on the Richibucto bed so this also may be taken as indirect evidence of the importance of starfish as scallop predators. One might expect that even such concentrations of starfish as were found in Bed C would cause more extensive damage to the scallop stocks than are indicated by the counts on empty

Table 3. Percentages of "recently dead" scallops in catches in the summer of 1950.

Haul No.	No. of scallops caught alive	No. of dead shells with attached valves	% Dead
<u>Richibucto Bed</u>			
H20*	700	80	10*
H22*	700	35	5*
H27	1750	420	19
H28	750	368	33
H29*	280	37	12*
H31	1500	315	12
H32	840	210	20
H33	1120	210	16
H34	1960	625	24
H67*	560	54	9*
H74*	560	37	7*
H75*	560	32	6*
H88	1540	427	22
H89	1120	209	16
H90	980	315	24
H91	1960	620	24
H92	700	132	16
H106	1400	458	Av. for Richibucto bed 22% 25
H108	1400	375	21
H109	1120	220	17
H110	2240	450	17
H111	1680	500	Av. for bed C 8% 20
H112	2100	830	29
H118	560	142	20
H121	1260	420	24
H128	2520	1050	29
H130	1680	735	30
<u>Pictou Island Bed</u>			
Five separate hauls	300	798	Av. for Pictou Island bed 74% 73
	241	531	69
	120	399	77
	241	532	69
	215	931	81

* The hauls marked with an asterisk were made on bed C (fig. 8). Others from the H series were taken from the Richibucto bed.

shells if the starfish were feeding on them continually and exclusively. One would also expect to discover numerous partly-eaten specimens in the catches yet of the many thousands of specimens that were handled and shucked, only five partly-eaten ones were found and four of these had starfish between their valves.

(ii) Pictou Island Bed.

In the latter part of August, 1950, the Pictou Island bed discovered in 1949 was re-examined to see what had happened since July 1949. It should be recalled (Chiasson 1949) that, in October 1949, it was estimated that from 35 to 50% of the July population had already succumbed to a mortality. Series of hauls in August 1950 (Table 3) have established the fact that over 70% of the 1949 summer population has now died. Commercial fishermen working on this bed claimed that things were not too bad in late July 1950 and that a dollar could be made but that even then about one third of the shells brought up were empty. They further reported that during the first few weeks of August the empties increased until they constituted over 70% of the catch.

In spite of the large number of empty shells there were never more than 15 to 20 starfish in any haul made on the Pictou Island bed. The writer is not inclined to attribute the scallop mortality there to starfish as he did in the case of the Richibucto bed.

(iii) Boughton Island Bed. This bed has been fished periodically for the last 20 years and mortalities have been observed fairly regularly - so much so that some claim that they follow a cyclic pattern. Little time was spent on this bed during the 1949 survey beyond plotting its position because it was already established as a productive area. About a dozen hauls were made with a yield of 2 - 4 bushels per haul. These catches were described in last year's report (graphs 2, 3 and 6 for hauls A 44, 46, 76 - 77 and 83, Chart I, part 1 and Chart II, part 2). They are comparable with those described in figures 30 and 31 and table 2 of this report. The latter, taken on September 4, 1950, show that there has been an increase in the average size of the scallops since 1949 but that there was an August 1950 mortality as reported by Mr. Horace Hewitt.

Some of the local fishermen are of the opinion that sea urchins are chiefly responsible and that the "explosive" character of these mortalities is due to the relative inactivity of the scallops during the spawning period and their consequent greater susceptibility to attack by the sea urchins.

(iv) New Area Discovered by the Industry.

There is a difference of opinion as to whether this bed was affected by the 1950 mortality. Mr. Polley remembers no un-

usual numbers of empty shells but Mr. Hewitt who has had a longer fishing experience in the area maintains that there was evidence of a small recent mortality.

(v) Unaffected Areas.

The picture of scallop mortalities would be out of perspective if no mention were made of potentially productive areas that show no evidence of serious mortalities. At Miminegash (fig. 8, Beds D and E), only nine dead scallops were recorded in the 26 hauls in series J. At Cape Bear (Table 2) only 3% of the shells brought up were empty. These observations may be valuable in determining the biological or environmental factors responsible for the large-scale mortalities that have occurred in adjacent regions.

2. Putative Causes of Mortalities.

As yet no definite cause or causes have been shown to be responsible for the scallop mortalities but several suspected conditions and agents have been investigated in this connection. Three seem more likely than others that have been suggested:

(i) Microscopic parasites;

(ii) Predators like starfish, sea urchins, etc.;

(iii) Hydrographic phenonema.

(1) Microscopic Parasites.

In 1933 Dr. H. B. Fantham of McGill University examined dead scallop material supplied by Dr. A. W. H. Needler for the possible presence of pathogenic microbes. Negative reports were received for all samples submitted. It is true that relatively little work has been done in this line of study and it seems desirable to have a thorough examination of comparative material from the tissues of live and of dead scallops in the different areas where mortalities take their toll.

(ii) Predators.

There is little doubt but that starfish do destroy scallops. This was fairly well established by observations on the Richibucto bed. The method of attack used by starfish on scallops seems to be quite different from that on oysters. In scallops, small starfish apparently work their way into the mantle cavity between the valves, thus gaining access to the edible portions contained therein. It would appear that small starfish are more efficient in feeding thus than the larger specimens.

(111) Hydrographic Phenomena.

Rapid changes in the vertical position of the thermocline have been considered possible conditions of sufficient effect to bring death to a good percentage of scallops. It is difficult to judge the importance of hydrographic changes since no continuous observations have yet been made on the beds involved in these mortalities. The hydrographic experiences of scallops can therefore only be inferred from observations made in other parts of the Gulf at the same or at different times.

In this connection, it is interesting to note that, in the Hydrography section of the Report of the Atlantic Herring Investigation Committee for 1948, Dr. L. Lauzier reports pronounced and rapid changes in the temperatures and salinities of the water at Cheticamp and North Rustico following local atmospheric disturbances. These rapid changes attributed to fluctuations in the level of the thermocline amounted to as much as 9.6° C. and 1.90‰ salinity at a depth of 30 metres. Normal conditions were restored in each case within two days. It seems probable that scallops on beds in the Gulf of St. Lawrence are occasionally subjected to such extremely rapid changes in environmental conditions because the beds for the most part lie at depths of 12 to 15 fathoms which, according to Lauzier, is not far from the normal level of the thermocline. However, it is impossible to affirm that such environmental changes are sufficiently disturbing to the scallops to bring about their death. Unfortunately there is no published information concerning tolerance of scallops to sudden changes in temperatures and salinities. Experimental work might determine the aptness of this theory in explaining scallop mortalities.

Dickie (1950) reports that in 1946 the mortality on the Boughton Island bed involved mostly the older scallops and he interprets this as evidence of hydrographic changes as causal. The 1950 observations (figs. 12, 13, 16-18, 20, 22-24, 27 and 29-31) show just the reverse condition. The scallops that died were mostly small ones. This may or may not be significant but it should be kept in mind in considering the problem.

It is conceivable that the three putative causes discussed above might all be responsible for mortalities at different times and places acting either separately or in conjunction.

REVIEW OF CONDITIONS IN PROMISING AREAS

1. Boughton Island Bed.

On the Boughton Island bed periods of successful scallop fishing have alternated with years of mortality and poor catches.

Mortalities plus commercial exploitation have frequently reduced the available stocks to the point where fishing was unprofitable. Yet, after several years, some beds have recovered to commercial production. There is every reason to believe that these periods of relative abundance and scarcity will keep recurring. Mortalities usually spell the end to a cycle of abundance and this bed is in an excellent spot for the detection of mortalities in sufficient time to subject them to scientific scrutiny. The catches are low now (Table 2) but will probably improve in the next few years.

2. Pictou Island Bed.

The Pictou Island bed was discovered in 1949. In the summer of that year it showed great prospects for a future commercial fishery. In the late summer of 1949 and in 1950, mortalities have accounted for about three-quarters of the population originally sampled. Yet, if this bed should follow a pattern of cyclical productivity like that of the Boughton Island bed, it might still be periodically a very important commercial scallop bed.

3. Richibucto Bed.

The Richibucto bed is not only newly discovered but, judging from the size distribution of its scallop population, is a new bed in the basic sense of the term. It is impossible to predict whether or not the mortality that claimed about 25% of the stock in the recent past is a continuous or discontinuous process. Growth is rapid enough to provide good commercial fishing in 1952 and 1953 if reasonable numbers of scallops survive.

SCALLOP DRAGGING WITH LOBSTER BOATS

1. Prospects

At Digby and in the Gulf of St. Lawrence areas, scallop dragging as a means of revenue now attracts only fishermen who are well situated financially or who depend on such persons for equipment. This is because the type of scallop dragger now used represents such a large investment that few fishermen can afford it.

This was not the case at Digby 20 years ago when only the shoal waters were fished and it has never been the case on the south shore of Nova Scotia. "Hand drags", so-called because they are hoisted by lobster-pot haulers, were or are the only equipment and proved quite efficient. They have disappeared from Digby because the shoal-water beds have disappeared. All fishing

is now at depths of 40 - 50 fathoms which demands other types of equipment. It is true also that their use on the south shore of Nova Scotia has decreased in the last few years but the local fishermen maintain that this is because the scallop stocks have dwindled, not because the gear was inefficient. No new type of gear has replaced the hand drag in this area. The fact that light, inexpensive fishing gear has been used and still is used from small boats profitably elsewhere suggests that it could be successfully introduced in the Gulf of St. Lawrence and there are good reasons to believe that small-gear scalloping could be fitted into the Gulf fisherman's program.

Many fishermen along the Northumberland Strait own their own boats and get most of their annual income during a brief, two-month lobster season. Their second most important effort is at farming but from time to time they interrupt this to engage in other types of seasonal fishing such as herring and smelt fishing, without seriously affecting their farming programs. Scallop fishing requires less preparatory work than either smelt or herring fishing and can be interrupted at any time without risk of loss because none of the gear is "set". Scalloping could be carried on in good years (i.e. when scallop stocks are abundant) and omitted in poor years. When fishing is worth while it should add appreciably to the income because scallop prices are reasonably stable and demand is steady in summer.

The Gulf lobster boats (25-45') are of about the same size as those successfully employed in south shore Nova Scotia scalloping and the depths of the water on the Gulf beds so far explored (10 - 15 fathoms) are about the same.

Altogether the prospects seemed so good that it was decided to make some small gear trials in 1950.

2. Small Gear Trials.

From August 28 to September 9, Mr. Frank Vaughan of Western Shore, Lunenburg County, was engaged to act as technical assistant in a brief investigation of the commercial possibilities of scallop dragging with lobster boats and light hand drags. It was planned to spend about a week each on the Pictou Island bed and on the Richibucto bed.

(1) Pictou Island Bed.

The several days that were spent on the Pictou Island bed were more or less in vain because, as has been mentioned previously, the numbers of surviving scallops were insufficient to provide material for a good test.

A lobster boat owned by Mr. Kenneth Langille was chartered for the work and operated by Mr. Langille himself. In one day's trials, six and a half hours were spent dragging with two of Mr. Vaughan's hand dredges and only 9 pounds of meats were obtained. Trials on other days gave similar results. The usual catch per 15-minute haul with the pair of drags even on what was considered the best spots was half a peck of whole scallops - far below what would be considered commercially worth while.

(ii) Richibucto Bed.

The catch per 15-^{minute} haul of a pair of drags on this bed gave better results. It averaged $\frac{1}{2}$ - $\frac{3}{4}$ bushels, and five hauls of the pair gave $3\frac{1}{2}$ bushels. The work done was not sufficient to permit certain clear statements as to the commercial possibilities of the area but had the average size of the scallops been larger, it would appear that this volume of catch would repay commercial exploitation with light gear.

The lobster boat used in this work was chartered from Mr. Amedee Robichaud of Richibucto.

(iii) Boughton Island Bed.

During one day's work on the Boughton Island bed, 20-minute hauls with 2 drags yielded from $\frac{1}{2}$ to 1 bushel of live scallops. It seems possible that, with four drags fishing, two men could bring in from 75 - 100 lbs. of scallop meats per eight-hour day. At present prices such catches should be worth while. Mr. Langille's lobster boat was used in this trial.

(iv) Summary

The results of the work in the three areas with light gear suggest that 2 men fishing four light drags from an ordinary lobster boat would not find dragging profitable unless the scallops are sufficiently abundant to make fishing with larger boats profitable. It has already been pointed out, however, that it is not feasible to maintain larger boats in this area because the stocks in the Gulf fluctuate so violently. The fact that the stocks must be high enough to support larger boats before small boats can fish them profitably does not, therefore, detract from the possible usefulness of light gear.

There is an obvious need for continuing these trials with hand drags and it is hoped that this can be done next year.

EFFICIENCIES OF TOOTHED AND TOOTHLESS (DIGBY) DRAGS

Fishermen in the Digby region have a conviction that teeth on drags (See Dickie 1950 fig. 4A) are a nuisance rather

than a help. Gulf and South Shore fishermen are equally convinced that drags without teeth do not fish well and gather much more trash than the toothed type. In early September a comparison was made of the two types on the Pictou Island bed with a Digby-type scallop boat, "My Boy's", chartered from Mr. Bert Polley. This same boat was used in exploring Cape Bear and Boughton Island.

1. Method.

Three drags of one type were placed together on one end of the six-drag drag-bar and three of the other type on the opposite end. The catches of the three drags of each type were kept separate at each haul and the numbers of scallops in each of the two lots were counted and the amounts of trash compared.

Possibly the arrangement of the different types of drags on the bar should have been better randomized to avoid effects that might be introduced by bias positions of the bar in dragging caused by one type of drag being "heavier" than the other. This defect in the design of the experiment should be kept in mind in considering the results of the 9 hauls that were made. These are reported in Table 4.

2. Results.

The results for scallop catches as they stand (Table 4) show that the toothless drags consistently brought up more live scallops than the toothed and averaged 40% more.

At the same time they brought up considerably more trash. The amounts of this were not measured except in the case of haul #11 which showed the greatest contrast of all. In it the toothless drags collected one bushel of trash (shell, weed, rock, etc.) and the toothed, six bushels. A partial measure of the amount of trash in the two types was obtained for haul #10. As table 4 shows the toothed and toothless took approximately equal numbers of live scallops at this haul but the former took 531 recently-dead shells (a type of trash) while the latter took only 399. This is the only observation suggesting that the toothless drags may not be heavier collectors of trash than the toothed.

The presence of large amounts of trash is a definite disadvantage because it increases the work of sorting the catch and delays fishing operations somewhat. Whether this disadvantage is great enough to offset the advantage of heavier catches which toothless drags apparently make, still remains to be seen.

Table 4. Numbers of scallops caught in each of 9 hauls of 3 toothed and 3 toothless drags on the same drag bar.

Haul No.	Catches of three toothed drags	Catches of three toothless drags
9	80	118
10	105	110
11	30	57
12	18	28
13	52	93
14	20	42
16	53	62
17	23	32
19	33	4
Average No.	46	65

FUTURE WORK

The need for further observations in the Gulf area is clearly indicated by this year's work. Periodically there are potentially valuable stocks of scallops there but no regular means of discovering their presence as there is in areas where there is an established scallop fishery that samples known beds every year. For this reason the Pictou Island and Richibucto beds should be watched closely for the next few years to determine the size of their stocks and their growth and mortality rates. Information along these lines gathered by the Fisheries Research Board should have immediate value in directing commercial fishermen who are beginners to worthwhile concentrations and as time goes on might improve our understanding the problems of the area to such an extent that we could eventually predict the times and places of good and poor fishing. This should certainly be helpful to the industry in getting established and in maintaining itself.

Once established Gulf scalloping probably would need little such assistance but for an introductory period it seems most desirable.

There is need for similar observations on the Boughton Island bed but it is not so great there because it is subject to periodic examination by interested fishermen who already know and work it.

Aside from the purely practical advantages of such a program but not altogether detached from them such observations might lead to a clearer understanding of the fascinating biological problem - what causes the periodic mass mortalities?

REFERENCES

- Chiasson, L. P. Report of scallop investigations and explorations in the southern Gulf of St. Lawrence - 1949. Fish. Res. Bd. Can. MS. Rep. Biol. Stns. 395, 1949.
- Dickie, L. M. Boughton Island, P.E.I., Scallop Investigations, 1946. Fish. Res. Bd. Can. MS. Rep. Biol. Stns. 415, 1951.
- Medcof, J. C. Lifetime of "clucker" shells and their value in estimating natural mortality rates of scallops. Fish. Res. Bd. Can. MS. Rep. Biol. Stns., 1950.

Fig. 1. Key map of southwestern Gulf of St. Lawrence showing areas explored in the 1950 series of hauls.

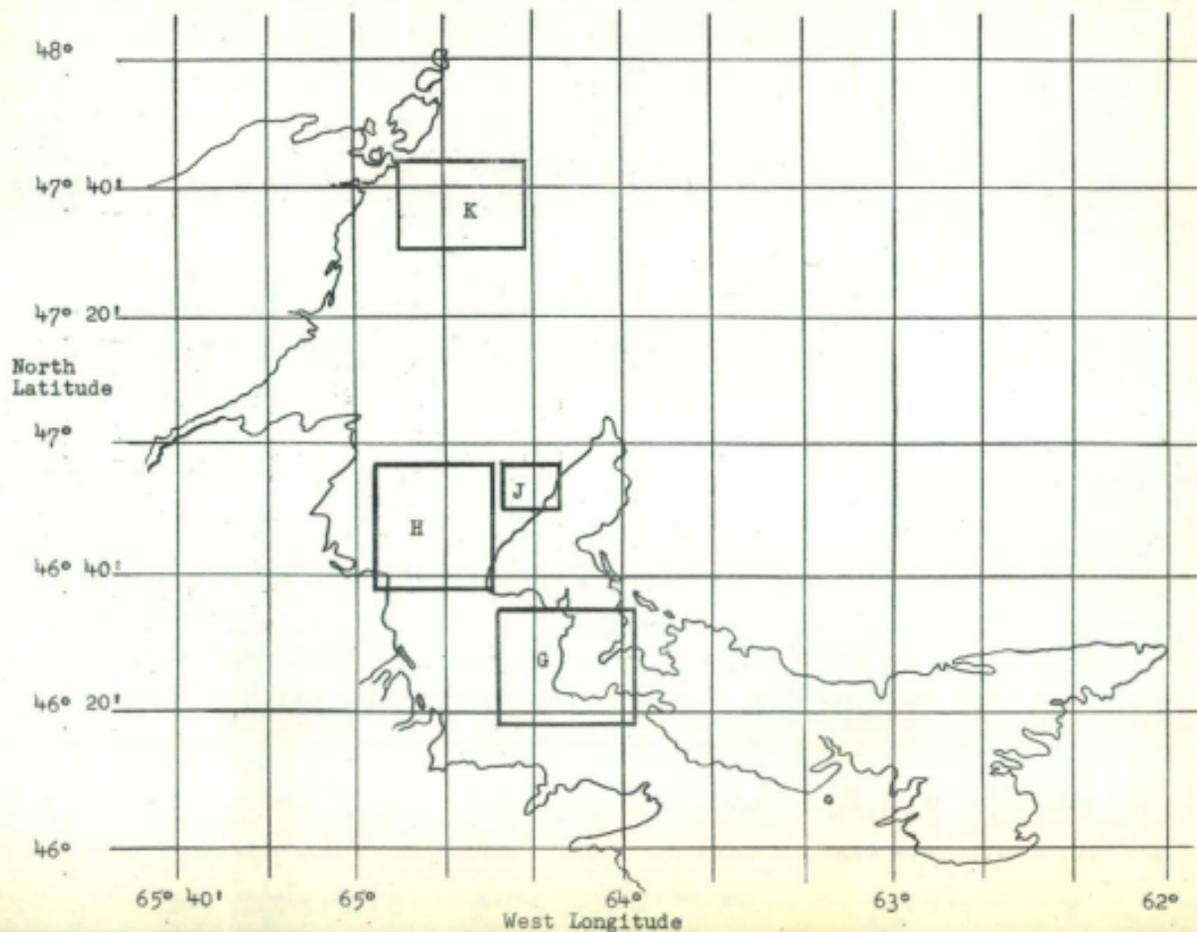


Figure 2. Locations of hauls in G series.

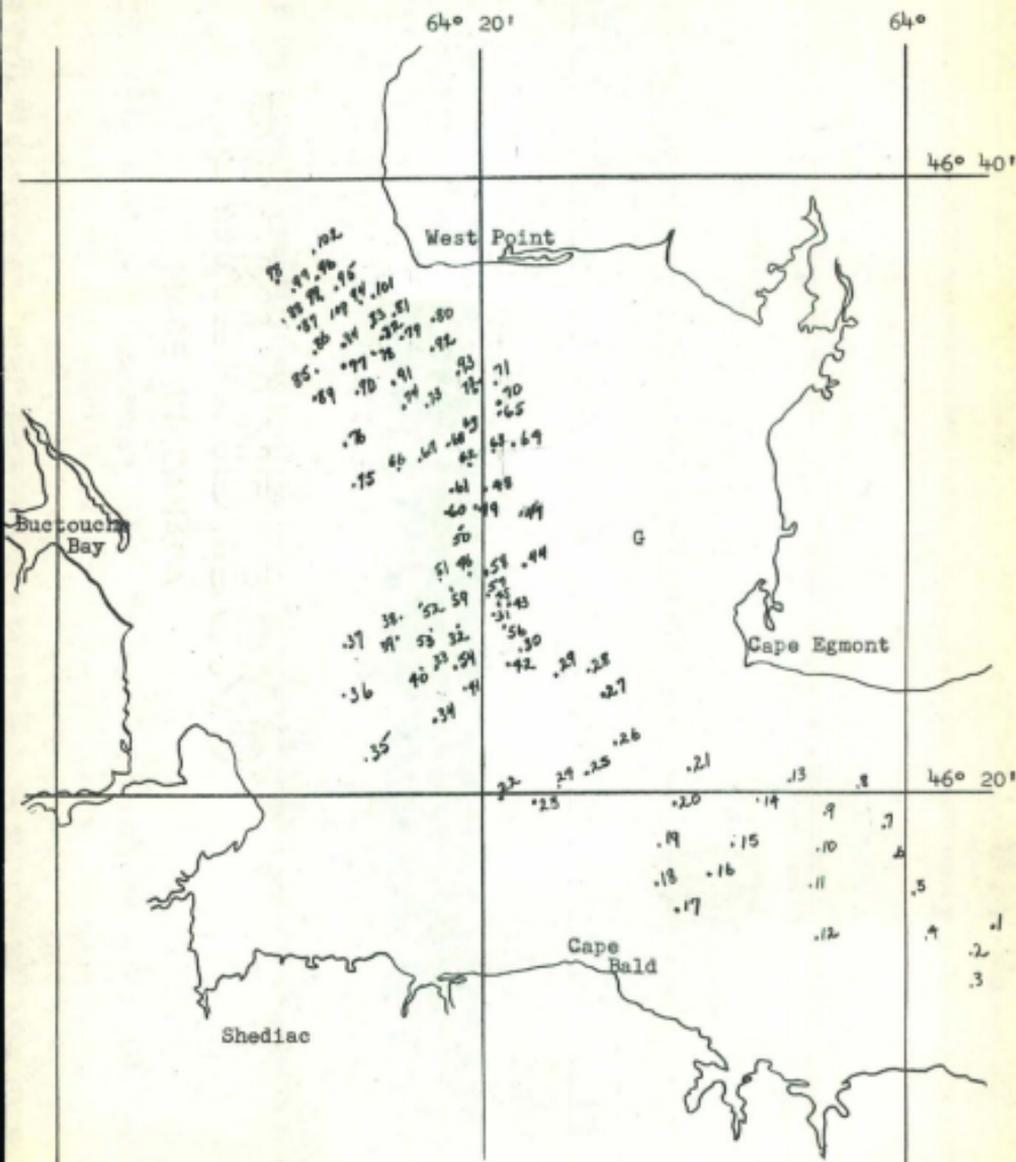
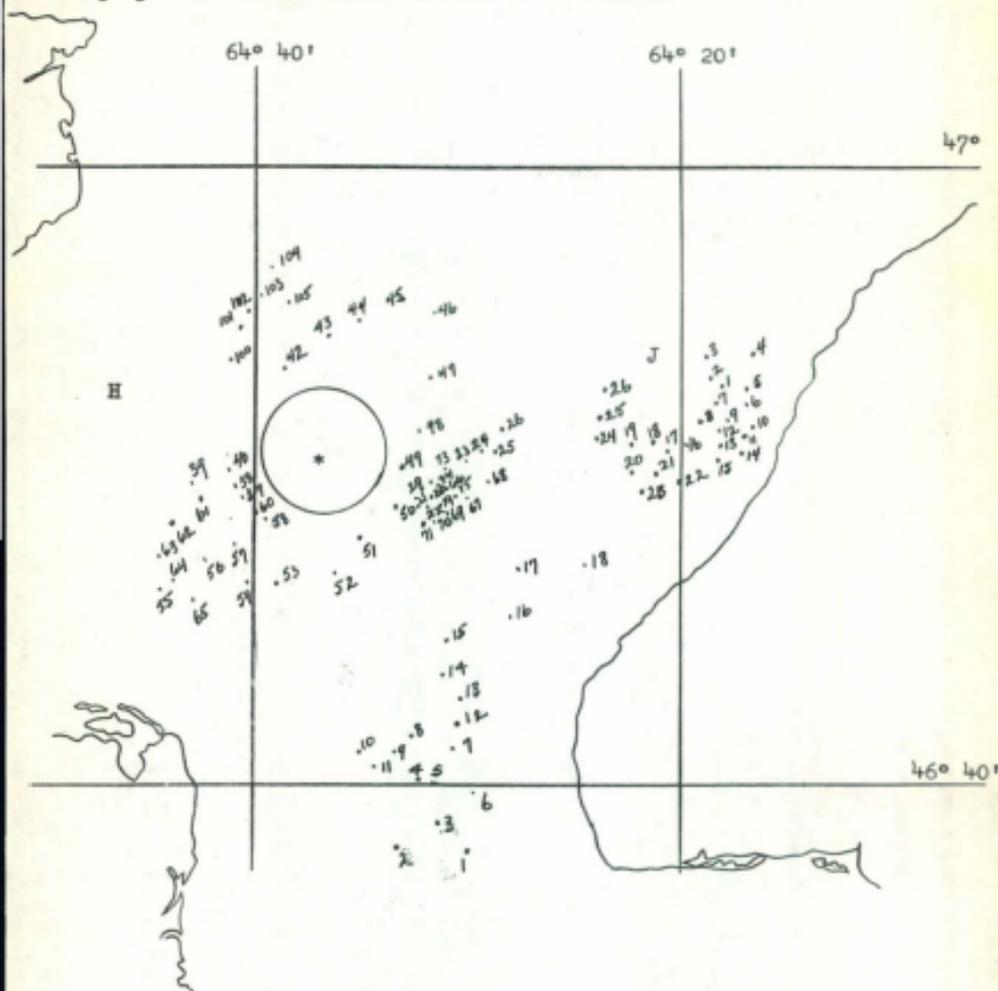


Fig. 3. Locations of hauls in H and J series.



* The following hauls in series H were concentrated within this circle: 27, 28, 30-36, 41, 59, 76-99, 106-109, 112, 113, 115-117, 119-136.

Fig. 4. Locations of hauls in K series.

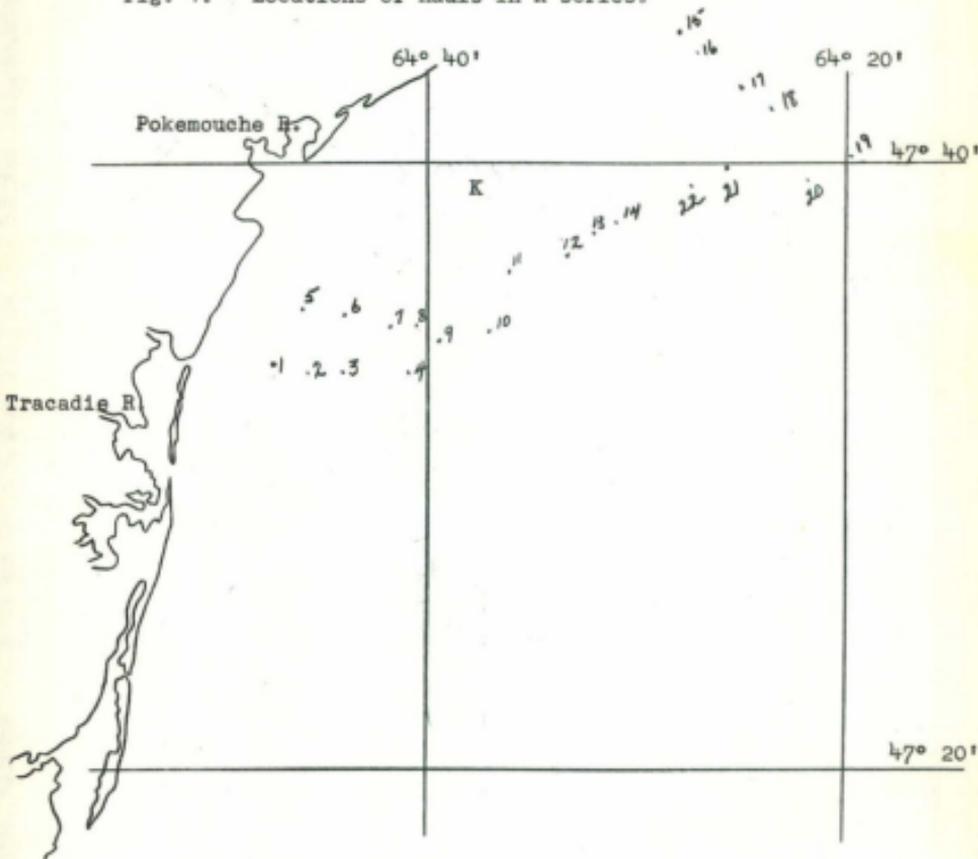


Fig. 5. Catches in G series.

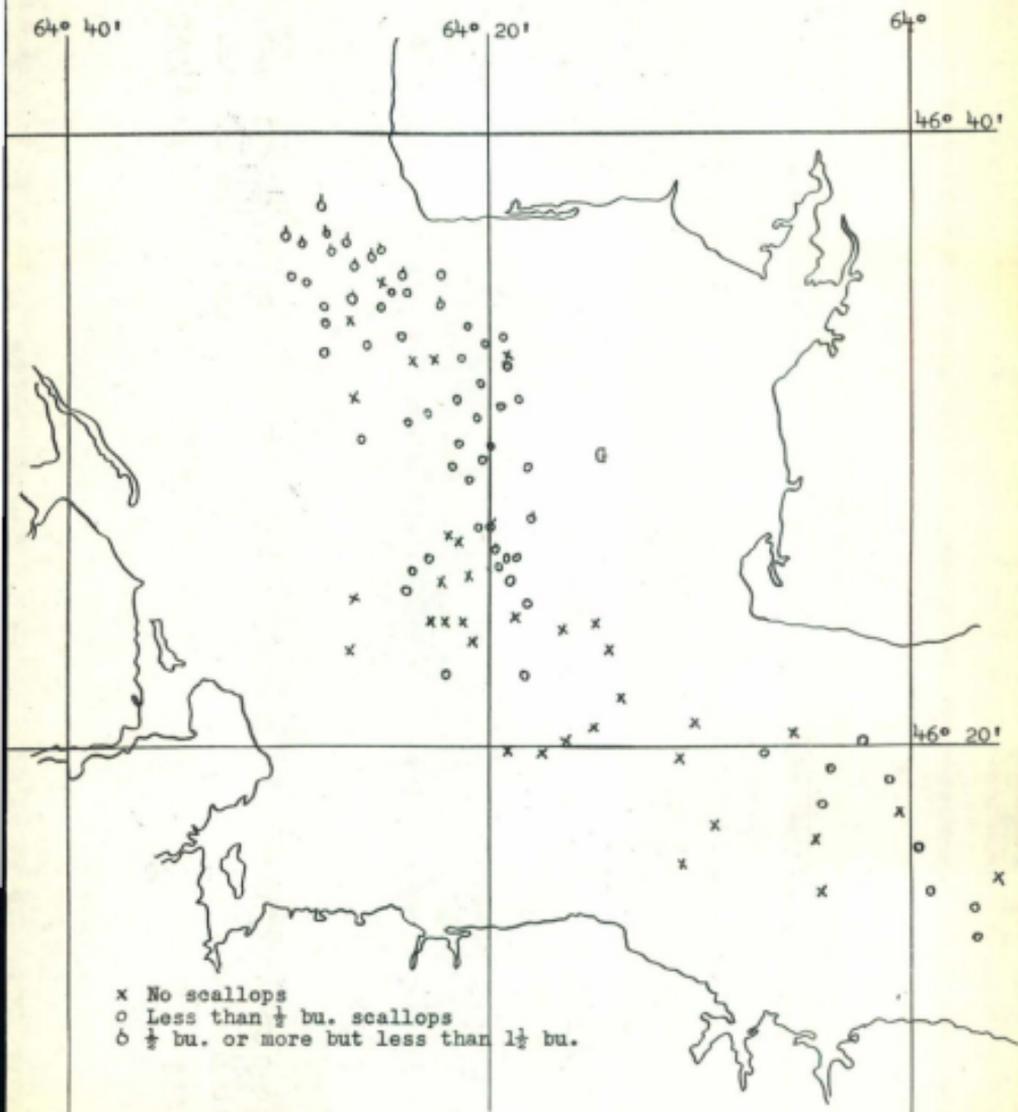


Fig. 6. Catches in H and J series.

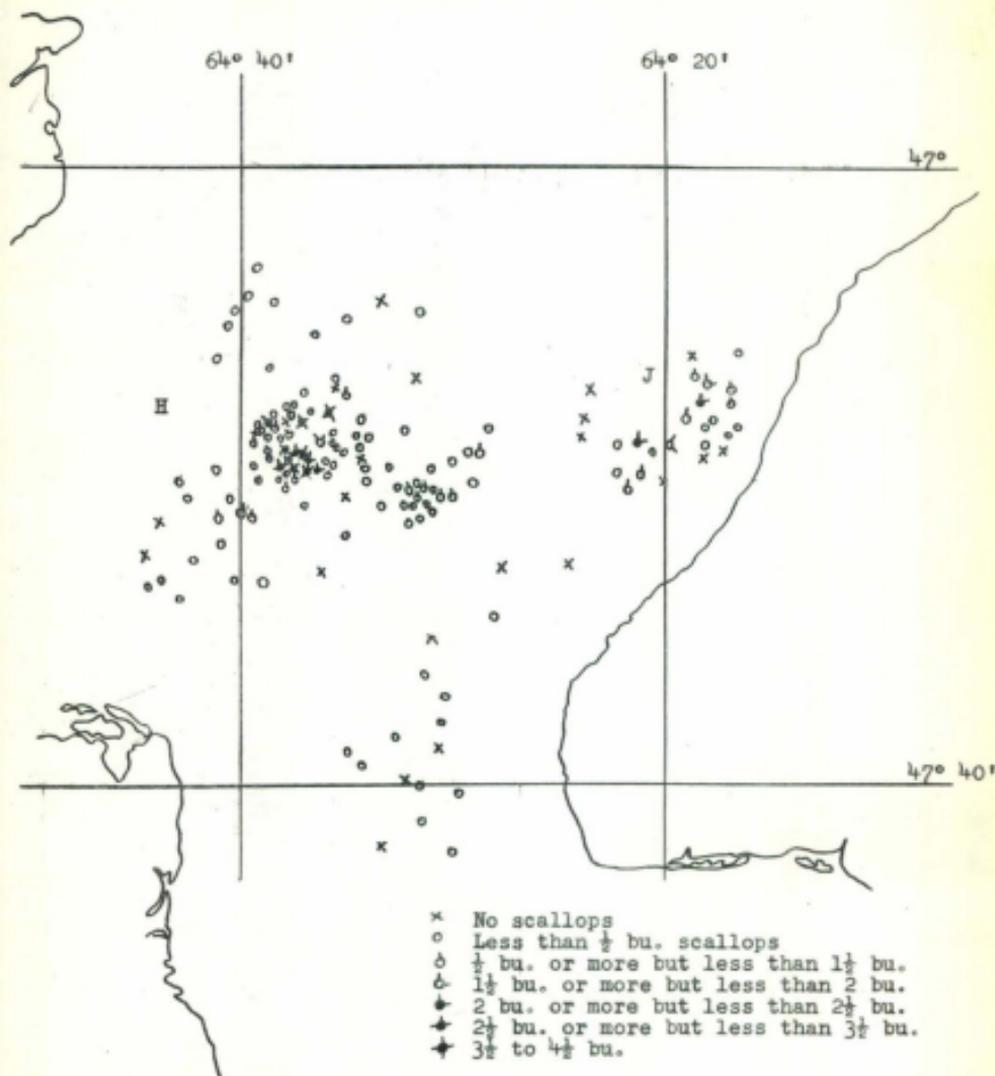


Fig. 7. Catches in K series.

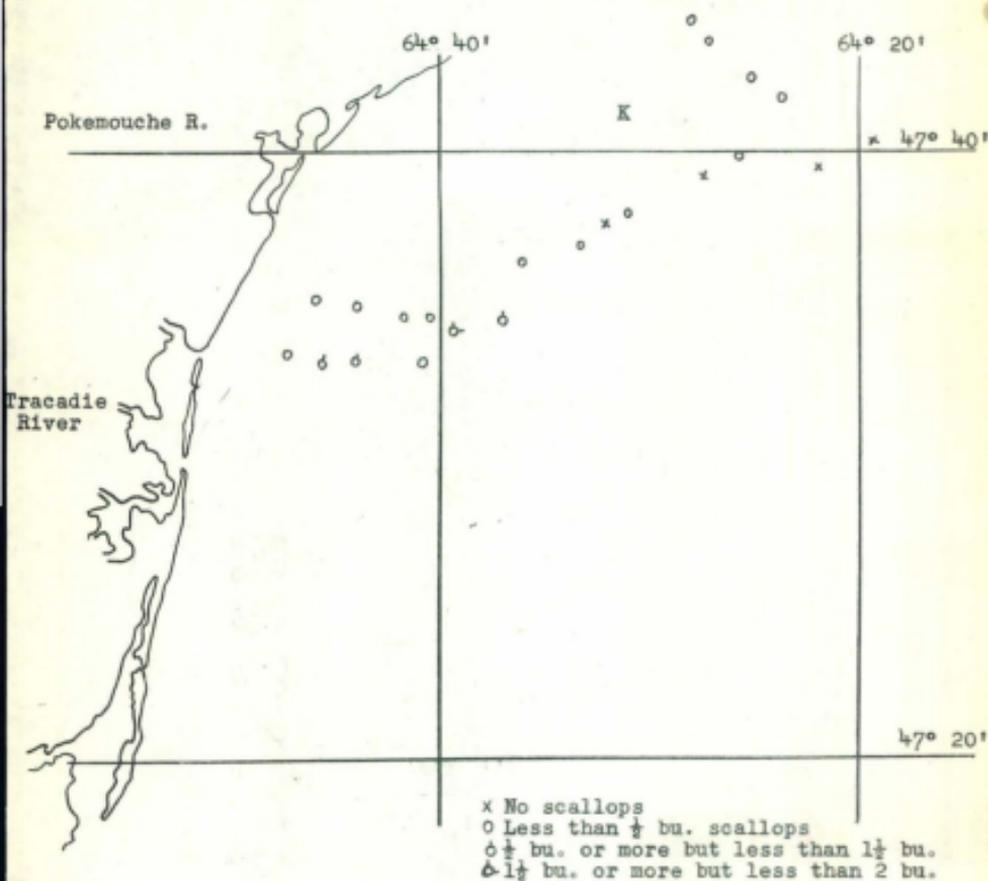
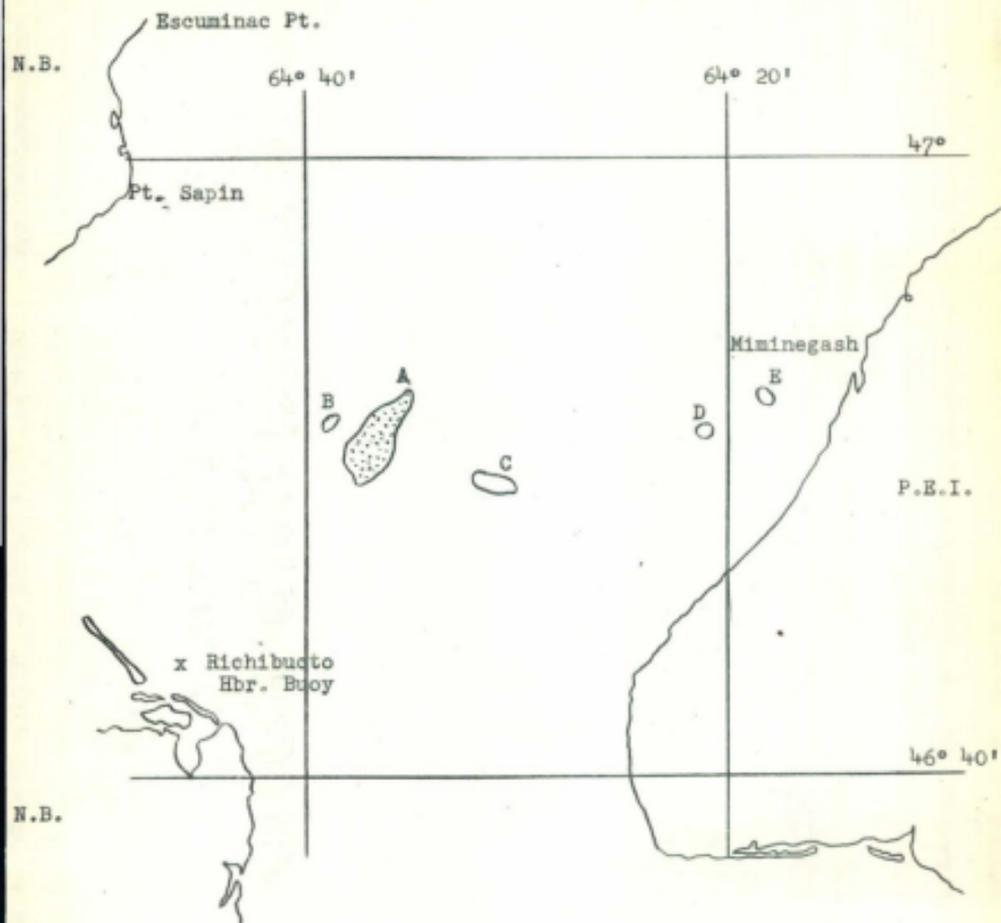


Fig. 8. Outlines of scallop concentrations between Richibucto and Miminegash encountered in hauls in series H and J.



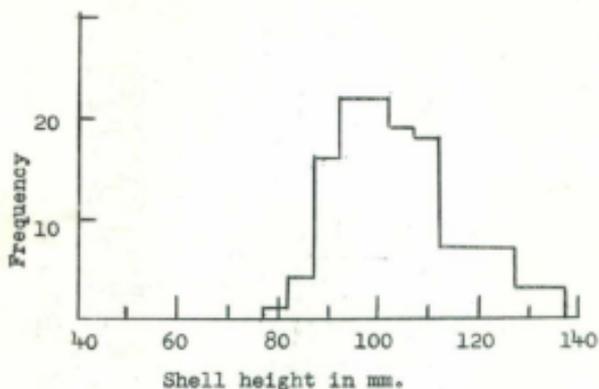


Fig. 9. Size-frequency distribution of scallops in haul G79.

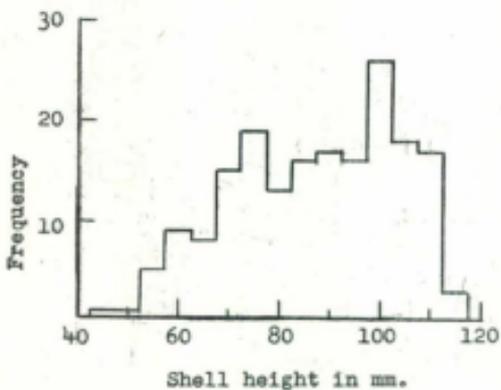


Fig. 10. Size-frequency distribution of scallops in haul G92.

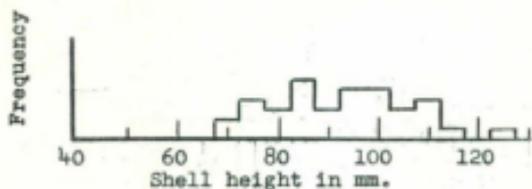


Fig. 11. Size-frequency distribution of scallops in hauls H6-8.

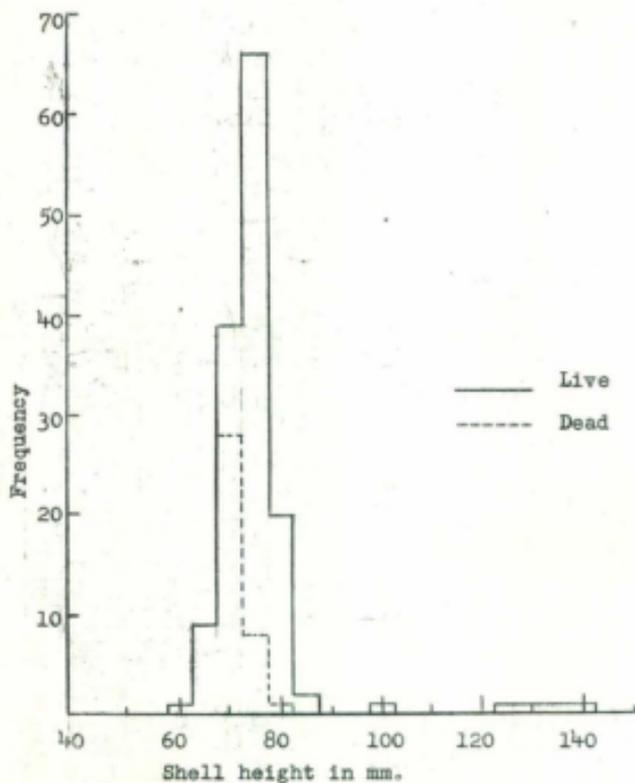


Fig. 12. Size-frequency distribution of scallops in hauls H19 and H20.

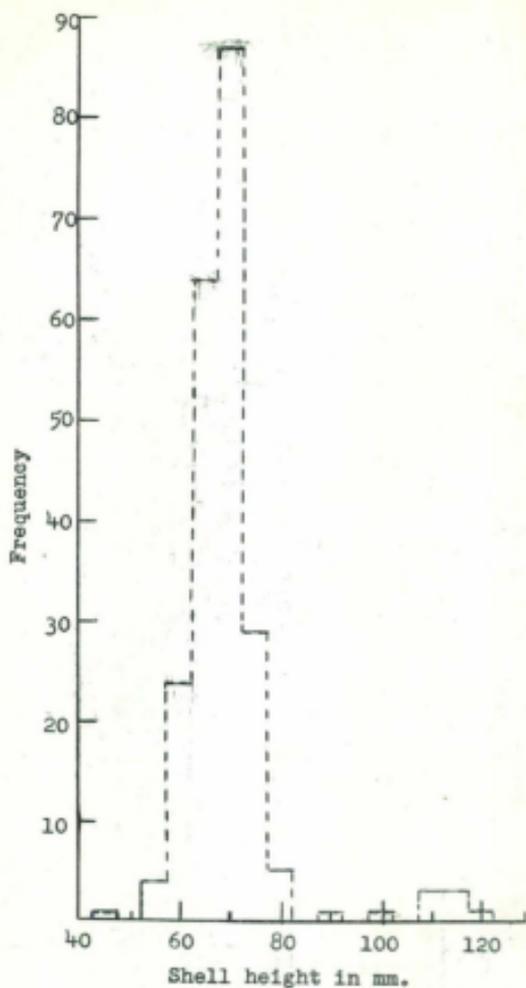


Fig. 13. Size-frequency distribution of recently-dead scallops in haul H28.

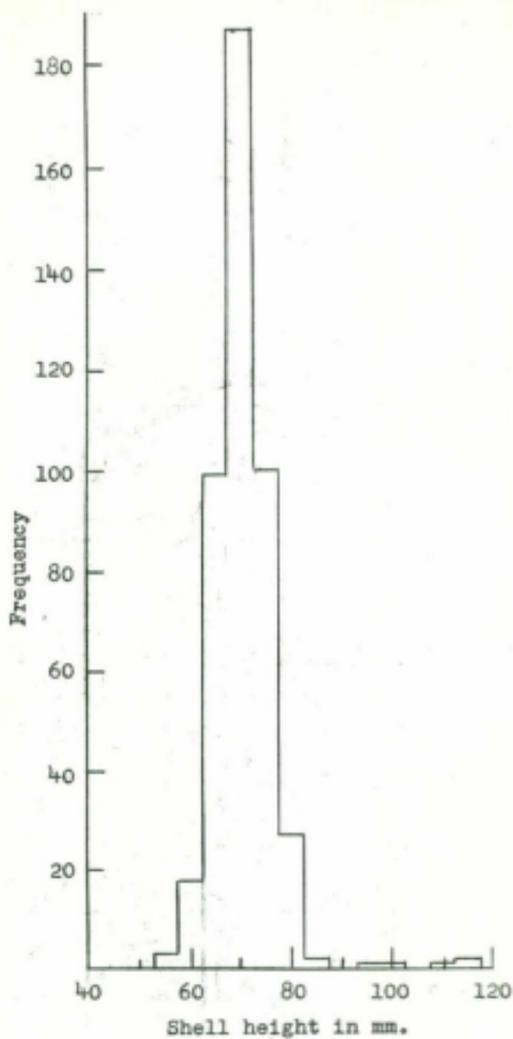


Fig. 14. Size-frequency distribution of scallops in haul H3+.

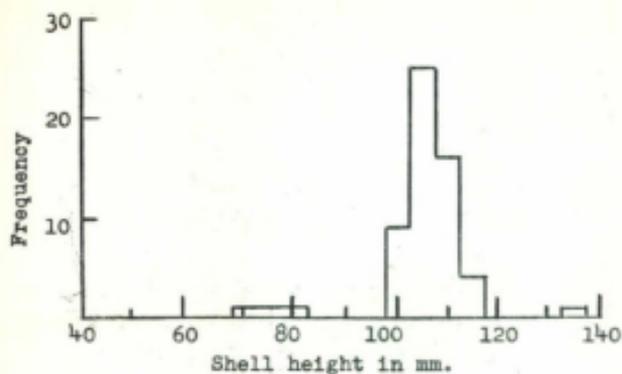


Fig. 15. Size-frequency distribution of scallops in haul H38

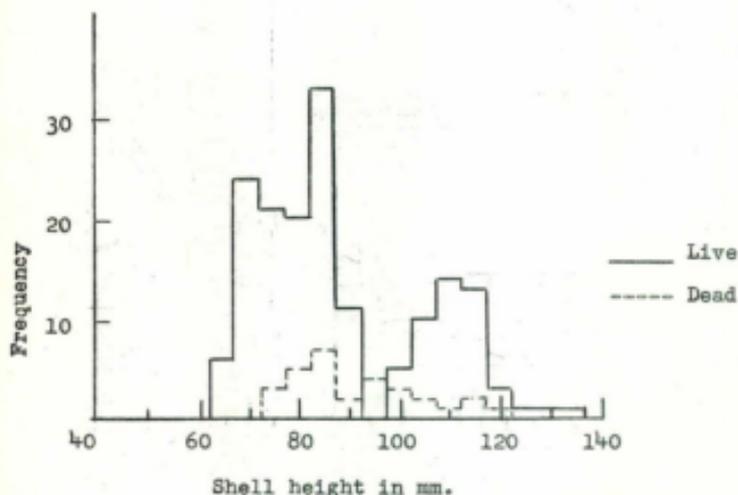


Fig. 16. Size-frequency distribution of live and dead scallops in haul H58.

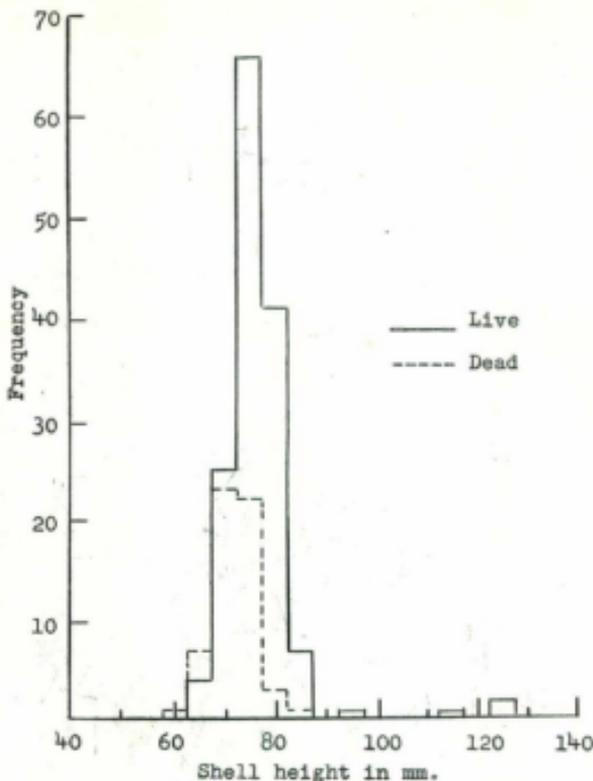


Fig. 17. Size-frequency distribution of live and dead scallops in haul H67.

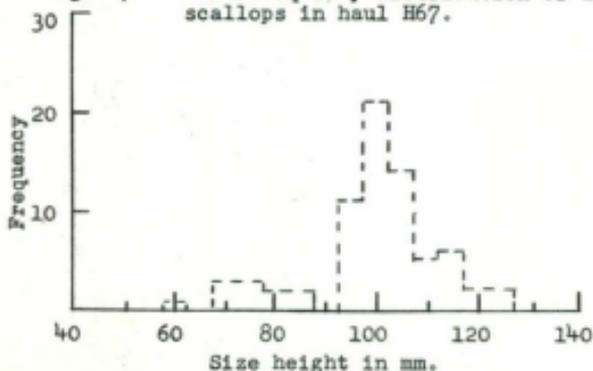


Fig. 18. Size-frequency distribution of recently dead scallops in hauls H76 and 77.

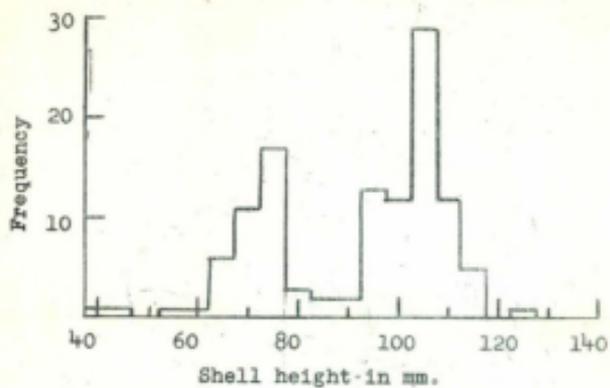


Fig. 19. Size-frequency distribution of live scallops in haul H77.

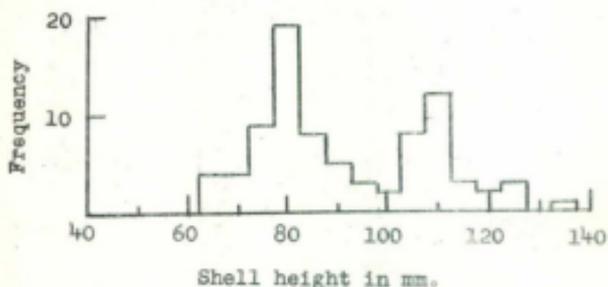


Fig. 21. Size-frequency distribution of scallops in haul H101.

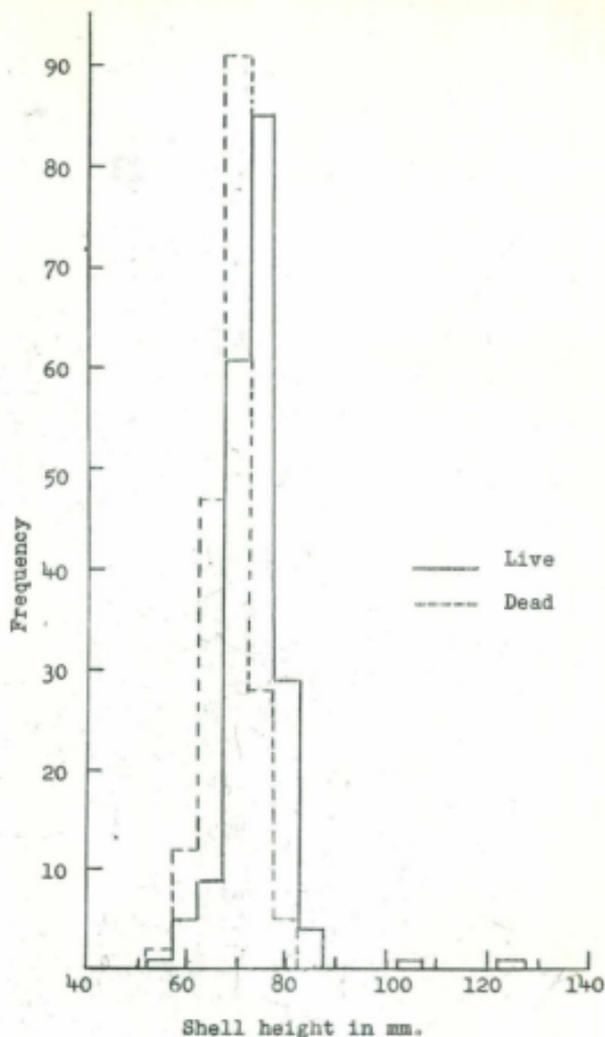


Fig. 20. Size-frequency distribution of live and dead scallops in haul H58.

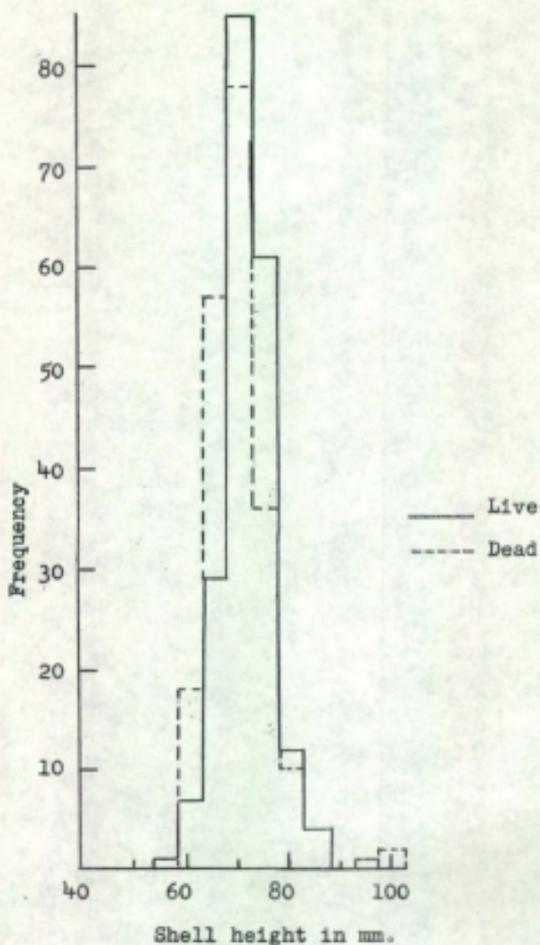


Fig. 22. Size-frequency distribution of live and dead scallops in haul H106.

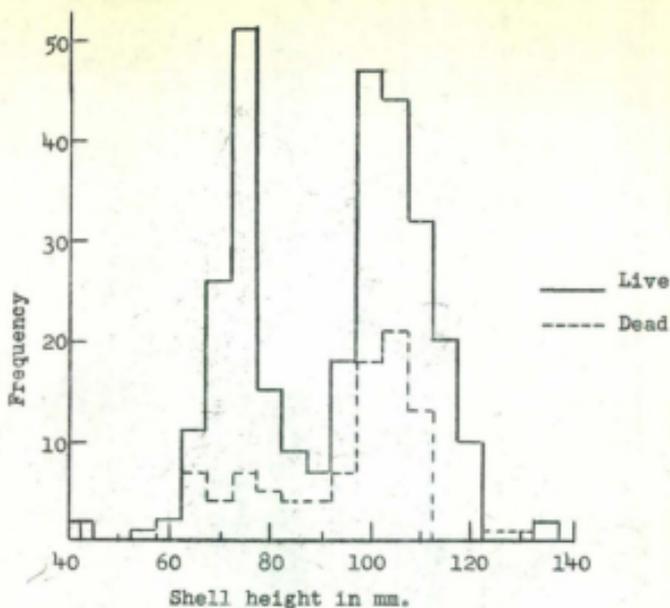


Fig. 23. Size-frequency distribution of live and dead scallops in haul H124.

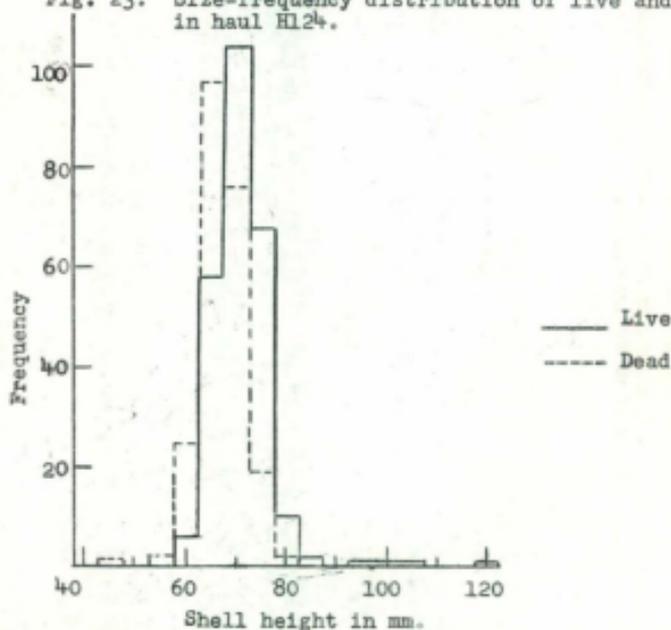


Fig. 24. Size-frequency distribution of live and dead scallops in haul H128.

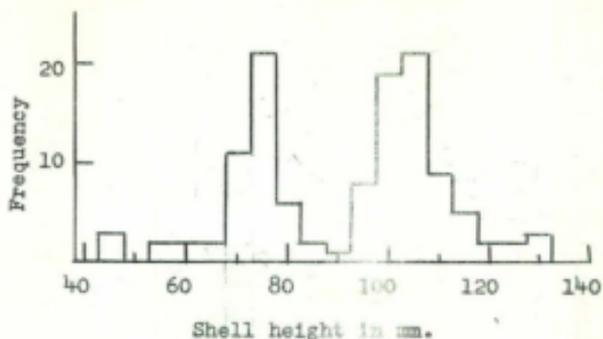


Fig. 25. Size-frequency distribution of scallops in haul H136.

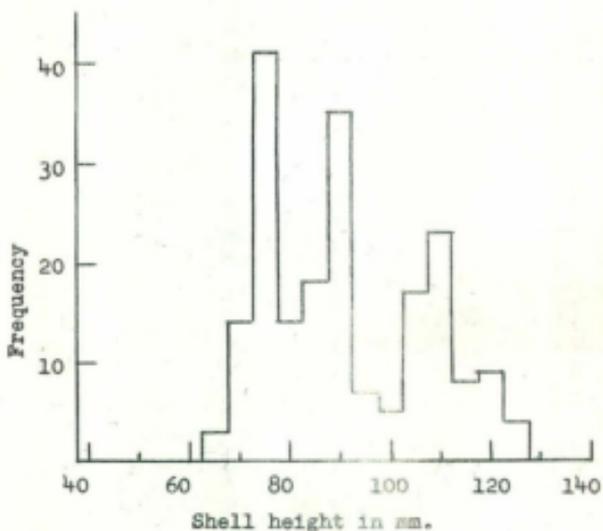


Fig. 26. Size-frequency distribution of scallops in haul J16.

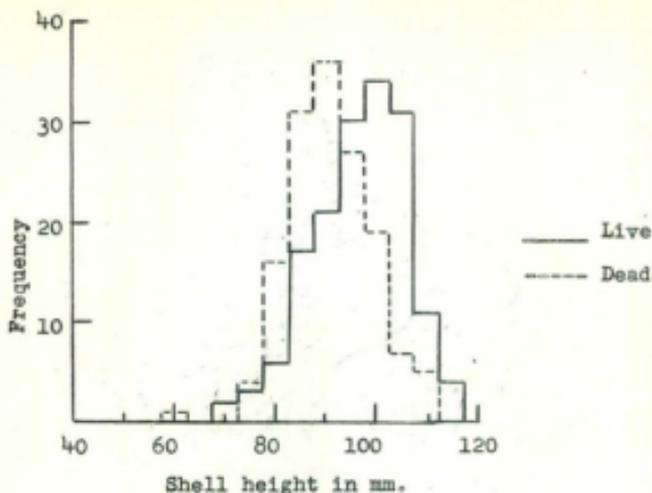


Fig. 27. Size-frequency distribution of scallops in haul #1 Pictou Island bed.

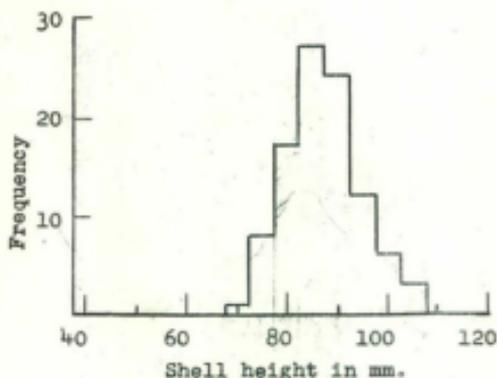


Fig. 28. Size-frequency distribution of scallops in sample #2 Pictou Island bed.

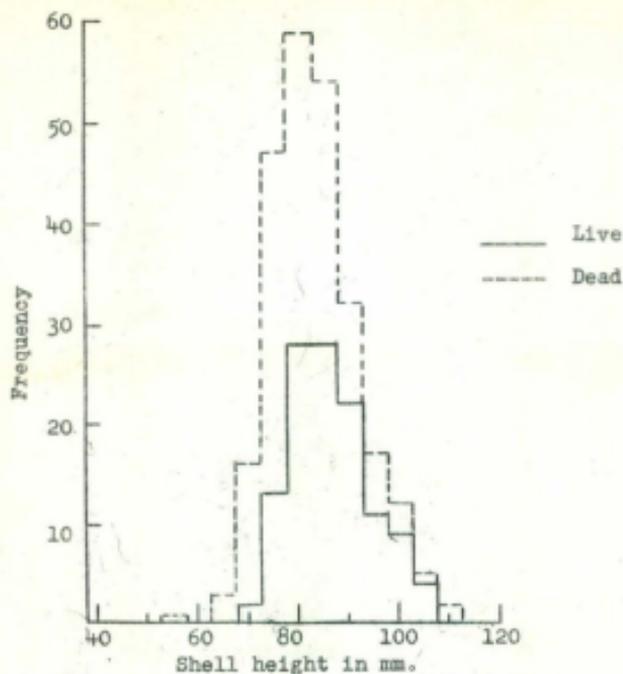


Fig. 29. Size-frequency distribution of live and dead scallops in sample #3 Pictou Island bed.

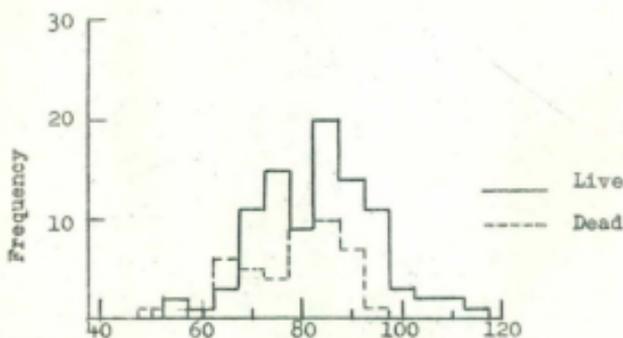


Fig. 30. Size-frequency distribution of live and dead scallops in sample #1 Boughton Island bed.

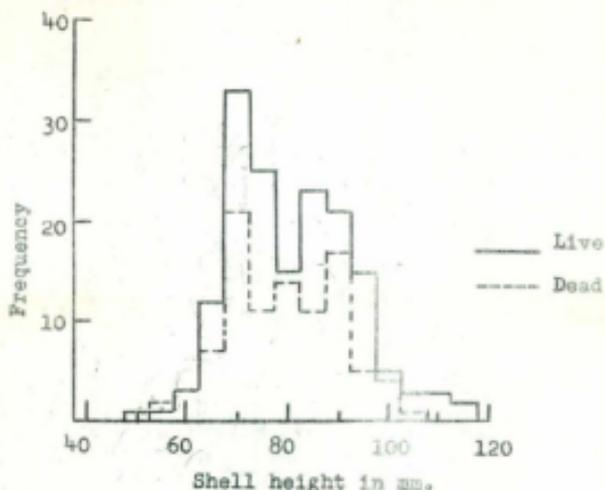


Fig. 31. Size-frequency distribution of live and dead scallops in sample #2 Boughton Island bed.

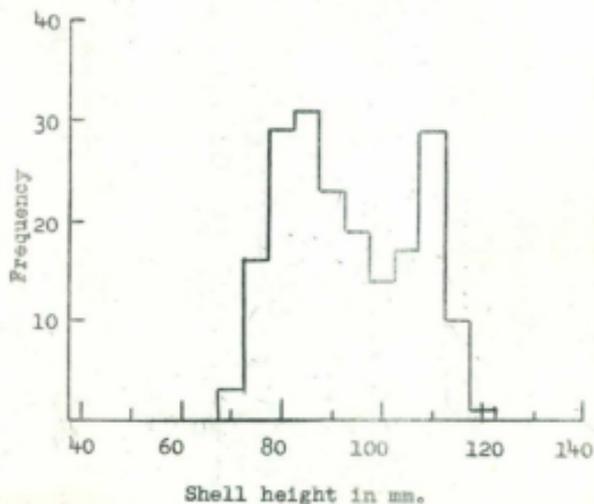


Fig. 32. Size-frequency distribution of scallops from haul off Cape Bear.

Committee on Biological Investigations

Fisheries Research Board of Canada

Symposium on the Migrations of Marine Fishes

Ottawa, January 2, 1951.

Some Migrations of Cod on the Atlantic Coast of Canada

by

W. Templeman*

*Newfoundland Fisheries Research Station, St. John's, Nfld.

Committee on Biological Investigations, Fisheries Research Board
of Canada.
Symposium on the Migrations of Marine Fishes
Ottawa Jan. 2, 1951

Some Migrations of Cod on the Atlantic Coast of Canada
by
W. Templeman*

INTRODUCTION

In the period 1925 to 1950 about thirty-nine thousand cod were tagged on the Atlantic Coast of Canada. In the Maritime Provinces tagging was carried out between 1925 and 1940, in the earlier part of this period, mostly 1925-27, by Calder directed by Huntsman, over eight thousand cod being tagged, and in the latter part, over ten thousand fish, by various people under McKenzie's direction largely between 1934 and 1938. Between 1930 and 1936 over 300 cod were tagged near Ellerslie P.E.I. by Needler. The Maritime results discussed in this paper are almost all from the later tagging under McKenzie. About three thousand cod were tagged in 1938-39 by Tremblay in Quebec and over eight thousand by Thompson in Newfoundland between 1933 and 1937. In so far as we are aware recent tagging in the area under consideration has been carried on only on the Newfoundland and Labrador fishing grounds by Templeman and staff, about eight thousand cod being tagged in 1947-50.

Most of these data apart from the results of the tagging under Huntsman, some of Tremblay's tagging and all of Thompson's tagging are as yet unpublished.

Earlier cod vertebral studies have been mostly carried out under McKenzie in the Maritime area and more recently by Templeman and staff in the Newfoundland and Labrador areas. This represents an immense mass of data - counts of forty thousand vertebral columns from the Maritime area and nearly ten thousand from the Newfoundland area, all at present unpublished. A small amount of published data is available on vertebral counts in the area by Schmidt and Thompson.

Studies on Parrocsecum, the cod nematode, which to some degree acts as a natural tag, are being carried out by Scott and the staff of the St. Andrews Station and also by the staff of the Newfoundland Station. In Newfoundland also we have kept an account of the occurrence of Lernaeocera branchialis, the large copepod parasite on the branchial arches of the cod. All this work is unpublished. Studies of growth and of variation in year class abundance are of some aid and we have found also that the weight of the

*Newfoundland Fisheries Research Station, St. John's, Nfld.

otolith offers a good character for distinguishing populations. Doubtless also measurements of body proportions, variations in size at maturity and other factors, such as the number of sclerites in the first year as used by Thompson, or in all years could be used but from lack of time none of these will be considered here.

Huntsman and McKenzie used a monel metal strap tag which was usually attached dorsally during Huntsman's tagging and ventrally by McKenzie at the base of the caudal fin as far onto the scales as possible. A trial was made of the dorsal opercular position for this tag as against the ventral tail position and there was a thirteen per cent advantage for the opercular tag.

In Newfoundland Thompson used a celluloid and aluminum bachelor button tag developed by Herrington for haddock and placed on the operculum by special pliers. In the present tagging in Newfoundland we are comparing the opercular tag inserted through the opercular bone with external celluloid tags attached by nickel wire anterior to the first dorsal fin, around the maxilla and around the pre-opercular and with two, three, four and five inch celluloid belly tags. McKenzie obtained good results from Canadian landings with the monel metal strap tag by wide advertising of the tagging and by frequent contacts with fishermen and fishing vessels. In McKenzie's offshore tagging however only 6 tags out of 285 were returned from the U.S. in spite of catches of U.S. vessels in the Maritime area being one third greater than those of Canadian vessels. This illustrates the failure of the monel metal strap tag unless the collection of the tags is undertaken as a special effort. In the Newfoundland area with most of the fishing on the banks being done by European vessels and with the isolation of the fishing villages, we have considered that not enough information can be placed on the monel metal tag and hence we are using celluloid tags all with an address and a request for information and of course promise of a reward. The reward is one dollar but we frequently have requests for a dollar for each man on the boat and even at times for a new engine as a reward. The Norwegian type hydrostatic tag has not yet been tried for cod in comparison with the other tags used in the north-west Atlantic area. In our tagging the belly tag has been proven to give six times as many recoveries as the opercular bachelor button tag in the third year after tagging while being approximately as good as the opercular tag in the year of tagging and over one and a half times as good in the second year.

The mass of unpublished and published data is so great and the time so short that no attempt will be made to deal with the material in detail and consideration will be given to a few of the main results which are interesting from the point of view of migration or theories of migration. Figures prepared by McKenzie and occasionally by Thompson have been used where necessary, usually without change. Most of the Newfoundland tagging accounts, however, are from our more recent results.

MIGRATION INTO AND OUT OF THE GULF OF ST. LAWRENCE

Southern Entrance around Cape Breton

March-April. Tagging, March 5-26, 1937, on Emerald Bank showed relatively little migration into the Gulf of St. Lawrence - one out of 14 recaptures, while tagging on the nearer Misaine Bank on March 1, in the same year gave considerable migration into the Gulf, 4 out of 6 recaptures.

Tagging near the north-eastern part of Sable Island Bank (south-east peak region) in 1937 during the last week in March and the first week in April showed some migration into the Gulf, 4 out of 46 recaptures, with 2 additional recaptures on the eastern Cape Breton Coast. Tagging of very large steak cod averaging 25 pounds on the western part of Sable Island Bank on April 24, 1938 gave no recaptures in the Gulf out of a total of 21 recaptures.

Cod tagged on eastern Banquereau, April 19 and 20, 1937 showed good penetration of the Gulf - 11 out of 59 recaptures, with 7 others being caught near Cape North at the eastern entrance to the Gulf and 5 additional recaptures being made near the eastern Cape Breton Coast.

It is noticeable that a very great part of the migration into the Gulf continued as far as Gaspé where there is a large summer cod fishery.

May. Cod tagged on Sable Island Bank, just north of the western tip of Sable Island on May 30, 1937, showed no movement into the Gulf - none out of 18 recaptures. Cod tagged on the southern edge of Banquereau in early May, 1937 did not penetrate deeply into the Gulf, one only out of 16 recaptures being in the Gulf in western Cape Breton.

Tagging on eastern Banquereau on May 28 and 29, 1937 in essentially the same area as the April 19 to 20 tagging gave no recaptures in the Gulf out of a total of 58 recaptures.

There was no migration into the Gulf from cod tagged at Chebucto Head, Halifax in May, 1935 and very little migration into the Gulf, 2 to Gaspé and one to Cheticamp out of 372 recaptures from cod tagged in late May, 1934 in the Jeddore Rock to Egg Island area just north of Halifax.

June-August. There was no migration into the Gulf from cod tagged at Chebucto Head, Halifax in June, 1934. Also none of 55 recaptures from tagging at Canso, July 31 and August 1, 1934 were taken in the Gulf. In all these inshore areas tagging was later and usually considerably later than the March-April dates showing good migration into the Gulf from the offshore banks. Earlier March and April tagging in the inshore areas may give some migration into the Gulf.

Tagging at Cheticamp, western Cape Breton, July, 1937, gave some recaptures across the Gulf to the Gaspé region but none in the year of tagging, the July date being apparently too late.

Migration out of the Southern Part of the Gulf

Tremblay's cod tagging in the Gaspé area July to September 1938 shows some movement out of the Gulf even as early as the winter of tagging. Of 231 mostly local recaptures 4 occurred on the Nova Scotian Banks and 4 near the northern part of Cape Breton at the exit to the Gulf. There were no captures in 1938 in eastern Cape Breton and the winter recaptures of that year were on the off-shore banks, possibly indicating an autumn migration at some distance from the eastern Cape Breton Coast.

Tremblay's tagging of cod in the Gaspé area between June and September, 1939, gave 354 recaptures mostly local. Four tagged fish were caught on the Nova Scotian Banks, all in January and March immediately following the tagging, 11 toward the eastern side of the Gulf and two on Rose Blanche Bank at the northern entrance to Cabot Strait. Of the 11 caught on the eastern part of the Gulf 3 were caught in eastern Cape Breton in the winter immediately following tagging and the 4 caught on the Nova Scotian Banks in the same winter were on the inner banks. This probably indicates a more inshore migration out of the Gulf in the winter of 1939 than 1938.

Tagging at Cheticamp in western Cape Breton, July 1937, showed a good migration out to the offshore Nova Scotian Banks with one to St. Pierre Bank and also to the inshore Nova Scotian fishing grounds in the autumn and winter of succeeding years. The migration outward was evidently mainly through the inshore fishing grounds of north-east Cape Breton.

Fifteen hundred and sixty-five cod were tagged between 1930 and 1940 mostly in July and August in the south-western part of the Gulf of St. Lawrence in three localities of Northern P.E.I. - Alberton, Ellerslie and Naufrage; also on Bradelle Bank and off North Point, P.E.I. From this tagging two fish were recaptured on Banquereau, one on St. Pierre Bank, one in Fortune Bay, Newfoundland and 7 in eastern Cape Breton. This compares with a capture of 8 on the offshore Nova Scotian Banks, 2 on the Rose Blanche Bank, Newfoundland and 9 in eastern Cape Breton from Tremblay's Gaspé tagging of approximately twice as many (2979) cod. Allowing for the different numbers tagged and the normal variation in results of tagging done in different years with differing intensities of search for tags, the numbers of cod moving out of the Gulf and to the exit from the Gulf are approximately the same in the north Prince Edward Island - Bradelle Bank area as in the Gaspé region.

Movement out of the Gulf on the Newfoundland Side

The tagging of 461 cod at Lark Harbour, Bay of Islands on the West Coast of Newfoundland, October 7 to 20, 1948 gave no less than 12 recaptures outside the Gulf in the following winter and spring, eleven in the Rose Blanche Bank and neighbouring areas of the south coast of Newfoundland and one on Burgeo Bank. An additional recapture was made in the Rose Blanche Bank area in July and four more in essentially the same area in the winter and spring of the following year. From April to June in these years there were seven recaptures half way between the wintering ground near Rose Blanche and the tagging ground at Bay of Islands. Six of these were in the April-June period following tagging: one on April 30, four between May 3 and May 15, and one on June 20. Moreover, there is a large winter and early spring fishery in the Rose Blanche area which declines greatly after April. There is good evidence therefore of an early winter migration southward out of the Newfoundland side of the Gulf of St. Lawrence to the Coastal Banks near Rose Blanche with little migration out of this wintering area until the return to the Gulf which appears to be mostly in the latter part of April and in early May. Tagging at Fortune, June-July, 1934 and 1935, at Burin June 1-July 10, 1948 and on St. Pierre Bank in July, 1935 gave no migration into the Gulf of St. Lawrence. These dates however were probably too late in any case to reveal any regular spring migration into the Gulf. It would, however, appear that on the Newfoundland side of the Cabot Strait entrance where deep water 130 to over 200 fathoms is to be found in the immediate neighbourhood of shore there is little migration to the Banks as far offshore as St. Pierre Bank, the cod spending the winter close to shore in deep but not necessarily very deep water since most of the deep water winter fishing on Rose Blanche Bank is in depths of eighty to ninety fathoms. The deep water below 130 fathoms is probably warm enough - over three degrees, to provide a partial warm water barrier. Usually few cod are caught in this deep water, both deep enough and warm enough for rosefish to exist in quantity.

FACTORS WHICH MAY INFLUENCE COD MOVEMENT
IN AND OUT OF THE GULF

In the Norwegian area great schools of cod spawn on the west coast near the Lofoten Islands - the eggs and larvae drift northward with the current, the spent fish also going in the same direction and a great many of the immature fish settle and grow up in the region of Bear Island, Spitsbergen and the Barents Sea, returning when mature against the prevailing current to the Lofoten Banks to spawn.

In the Iceland-Greenland area cod spawn on the banks to the south and west of Iceland. In certain years large quantities of cod larvae are carried by the current to east Greenland. Many cod from south and west Greenland migrate back against the current to the Iceland banks to spawn and some spent fish from the Iceland banks follow the current from Iceland to west Greenland.

In the Canadian Atlantic area the spawning grounds of the cod are poorly known and are probably very widespread. The paths of the drifting eggs and larvae from the spawning grounds are unknown except theoretically by considering prevailing currents, and the times of spawning are only approximately known in most of the very large area of well above a hundred and fifty thousand square miles over which cod are found.

What factors then may influence the cod movements which have been observed to occur in and out of Cabot Strait from the Gulf of St. Lawrence area? Currents, temperatures, migration to spawning areas and post-spawning or other dispersal in search of food are among the most likely influences.

Currents

It will be noted with regard to movements into and out of the Gulf of St. Lawrence that on the Cape Breton side the spring migration into the Gulf from the Nova Scotian Banks such as Banquereau is against the prevailing current, while the spring migration into the Gulf on the Newfoundland side from Rose Blanche Bank is with the prevailing current. In the late autumn and early winter, migration out of the Gulf toward the wintering grounds on the Cape Breton side is with the prevailing current while on the Newfoundland side it is against the prevailing current. We are inclined to believe that migration in the spring is migration in the upper water layers while migration in the early winter is almost certainly in deeper water. Much remains to be found out about the behaviour of the surface currents of the Newfoundland side and of the movements of the deeper water currents on both sides of Cabot Strait. There may be deep water currents moving in the opposite direction to the surface currents but the facts available at present do not lead to a logical interpretation of the movements of cod through Cabot Strait as resulting from current action.

Spawning

The fragmentary information on spawning periods handicaps us in our attempts to show the relation of spawning to migration into the Gulf. If spawning is a factor, the separate possibility on each side of the Cabot Strait is a movement inward to spawning grounds in the Gulf or as a post-spawning feeding dispersal from the offshore banks. If spawning occurred outside the Gulf the autumn migration outward could be considered as being for the purpose of pre-spawning gathering on the spawning grounds.

Apparently a large percentage of the cod migrating into the Gulf on the Cape Breton side do so from Banquereau with additions from Middle Ground, Sable Island and Misaine Banks and other neighbouring banks and inshore areas. We shall consider the Banquereau case in detail since it is closer to the Gulf than most other banks on which tagging has been carried out. Little information is available regarding cod spawning on Banquereau apart from the examination of several hundred cod obtained in 25 to 28 fathoms on Banquereau by the Investigator II on May 15, 1950. Only about 12 per cent of these were spent and 83 per cent were in the stage with large numbers of clear eggs which immediately precedes spawning.

Dr. Tremblay has informed us that at Gaspé spawning cod may be found all summer from June to August. In the area between the Magdalen Islands and Gaspé some information exists, meagre but all pointing in the same direction. In McKenzie's unpublished tagging manuscript it is recorded of the tagging off Alberton, P.E.I. in 1939 that 696 cod were tagged from July 8 to 17 by the M.V. Zoarces with Capt. Calder in charge. The cod were caught at a distance of 5 to 17 miles offshore in water about 20 to 40 metres deep and from bottom water about 2°C. In many cases the fish were so near their spawning season that the spawn ran out in handling them during tagging. Also during tagging 25-30 miles NE of North Point, P.E.I. on August 5 and 8, 1936 and on Bradelle Bank August 6 and 7, 1936 the cod were almost ready to spawn, quite a few males yielding milt under the handling necessary in tagging and several females yielding eggs.

Similarly Bigelow (Fishes of the Gulf of Maine, 1925) says that spawning cod were caught from the deck of the Grampus (Capt. Hahn in command) on Bradelle Bank in the Gulf of St. Lawrence late in August many years ago.

Samples of cod obtained by the Investigator II in November 1950 on Orphan and Bradelle Banks and from the area northeast of the Magdalen Islands were generally no further recovered from spawning than are the cod of the east coast of Newfoundland in July or August several months after spawning. It is fairly certain, therefore, that the spawning of the cod in this central area of the Gulf is in late summer rather than in the spring months as is common on the offshore Banks.

It is obvious from McKenzie's tagging results that most cod entering the Gulf from Banquereau leave this bank before the latter part of April. Consequently it is possible but not proven that the cod leaving Banquereau from the Gulf have not spawned on Banquereau but are cod of Gulf origin entering the Gulf to spawn there.

The peak of the cod spawning in the Sable Island Bank, Emerald Bank area is reported by Dr. Martin of the Atlantic Biological Station at St. Andrews to be late March to mid-April, spawning beginning in February and ending in May. Thus it appears that the spawning in the Sable Island Bank - Emerald Bank area is earlier than on Banquereau.

Cod tagged in the Sable Island Bank - Emerald Bank area showed some migration into the Gulf in March and the first week in April but not from tagging in the latter part of April and in May. Therefore these fish could have left for the Gulf before or after spawning on the offshore banks.

For the Newfoundland side we have no scientific observations on the time of spawning on Rose Blanche Bank where so many of the Gulf cod from the Newfoundland side spend the winter. Captain Baxter Blackwood, however, who was a field technician at the Newfoundland Station for ten years and then became manager of the fresh fish plant at Isle aux Morts which is engaged in the winter fishery says that the Isle aux Morts fish were full of roe to the end of the fishery near the end of April.

In St. George's Bay during the last week of May 1945 we noted that cod ovaries were fairly full and spawning had not occurred. The fishery in the Port aux Basques to Rose Blanche area declines greatly after April and our tagging also indicates migration into the Gulf in April-May in this area. It is thus possible that the cod passing into the Gulf on the Newfoundland side may also be moving in for spawning. Mature cod examined in Port aux Basques by our staff, June 2-9, 1949 were 98 per cent spent. Thus spawning occurred not later than May and could have possibly begun in April.

What evidence there is, therefore, is somewhat conflicting and it is possible that the local resident cod in the deep water wintering area spawn earlier than the cod migrating into the Gulf. Thus on both sides of Cabot Strait it is impossible to say whether the cod migrating inward have or have not spawned.

Food

On the east coast of Newfoundland it is an apparent fact that very large onshore movements of cod occur following the caplin when these fish come inshore to spawn in late June. In more limited parts of the coast there is a "herring run" consisting of schools of cod which follow the herring inshore in May. It is quite possible, therefore, that some of the inward migration into

the Gulf in the spring in late April and early May is due to schools of fish following the migration of herring. Portuguese otter trawler captains have told us of not infrequent catches of several thousand pounds of herring in a drag on Banquereau during the month of April. It is quite possible that these Banquereau herring move into the Gulf for spawning in May and that they are accompanied for some distance by schools of fish from Banquereau. A movement from Banquereau to Gaspé, however, following schools of herring would seem rather unlikely. An argument against the idea of migration into the Gulf being caused by pursuit of herring is the fact that no large schools of cod pursue the herring to Shediac and presumably not to the Magdalen Islands.

On the Newfoundland side, St. George's Bay is the Gulf area most nearly adjacent to the Rose Blanche Coastal Bank where many Gulf cod spend the winter. In St. George's Bay a large run of cod occurs in May following the herring into very shallow water. The fishery tapers off in June especially in the shallow water. It is also possible here, therefore, that many cod follow herring away from the wintering area and into the Gulf.

Temperatures

Spring. In the hydrographic section, Banquereau to Cape Breton, taken by the Canadian Fisheries Expedition on June 3 and 4, 1915, bottom temperatures on Banquereau ranged from 0°C to 0.15°C . Temperatures increased gradually to 4.6° at the surface. Between Banquereau and Cape Breton there was a cold water layer intermediate in position in the deep water but resting on the bottom in the shallow bank and coastal areas. The lowest temperatures were -0.55°C . From this colder layer, temperatures increased gradually to 4 to 4.75°C at the surface. In the Gulf the cold layer with temperatures only rarely below -1.0°C covered the bottom of all but the shallower areas. At this time of year there is a cold below zero centigrade intermediate or bottom layer over the Gulf generally.

On the Newfoundland side of Cabot Strait in a section taken by the same Expedition on June 13, 1915, there was a definite intermediate cold layer in the deep water with warmer water above and below. The lowest temperature in the cold layer was -0.9°C .

In these two areas from which spring migration into the Gulf occurs there is little or no change in the deep warm layer during the spring and little change in the deeper parts of the cold intermediate layer. The only considerable change has been the warming of the surface layer.

In the May "herring-run" of cod to St. George's Bay, the fish run into shallow water of 6 fathoms or less, a good indication that they are migrating to some degree in the surface layer. Also on the east coast of Newfoundland there is some evidence that the June migration towards shore in pursuit of the caplin

occurs in the upper layer of increasing temperature above the cold layer. Below-zero temperatures of -0.5 and up, however, occurring in the Banquereau to Cape Breton area are not always a barrier to cod on the east coast of Newfoundland, especially when they are pursuing food fishes such as caplin and launce.

Autumn. In the late autumn or early winter a condition will arise in a great part of the Gulf of St. Lawrence (where the bottom of the cold water layer is usually less than 100 fathoms by late summer) in which the water column below zero centigrade is almost or completely obliterated as an intermediate cold layer and is raised above zero centigrade largely by mixing and overturn from above and lesser mixing and encroachment from below. When the retreat of the cold layer is proceeding in the autumn, cod desert the shallow turbulent inshore areas long before they have chilled very much and are found most abundant deeper and deeper following the retreat of the cold water layer. Thus on the east coast of Newfoundland the cod are most abundant down to ten fathoms in June, ten to twenty in July and August and progressively deeper to 50 to 70 fathoms in October and November and 70 to 90 in December to January. That is, cod tend to move downward toward the very cold water layer and accumulate in the unused feeding grounds opened up as the cold layer retreats in the autumn. Thus, what little evidence there is, suggests that the autumn retreat from the shore occurs in the deeper water near the bottom and not in the surface layers. During the winter the surface layers chill down so that for a period in late winter and early March temperatures are approximately the same and below zero centigrade throughout the whole upper cold water column from the surface downward, while usually below approximately a hundred fathoms (still deeper on the east coast of Newfoundland) the deep water remains warm. Again there is some evidence for the east coast of Newfoundland that the winter movements are carried out in this deep warm layer. Deep channels with warm water exist in the Gulf throughout the winter and large numbers of cod certainly remain over winter in the Gulf.

We do not at present see any particular cause or mechanism by which cod are forced from the Gulf by lowering temperatures except that there may quite well be earlier chilling of the waters at the same depths to the north on the Newfoundland side and to the west on the Maritime side of the Gulf which may give an outward stimulus. Once cod are in the warm deep layer, however, judging from winter movements apparently in this layer on the east coast of Newfoundland, they may move considerable distances more or less parallel to the coast, the only barriers being the cold water near shore and the presence of too warm and too deep water offshore.

In general, evidence as yet is fragmentary regarding the cause of the movements in and out of the Gulf. The direction of the currents on the two sides of Cabot Strait is opposite while the time of movement in or out is approximately the same on both sides.

The knowledge of spawning times is inadequate. Inward pursuit of herring is possible on both sides but evidence is lacking.

There may be some initiation of deep water outward movements in autumn by temperatures decreasing earliest toward the north and west. The stimulus producing the spring inward movements which are possibly in the surface layer is unknown. It is however a common experience in eastern Newfoundland waters that after spawning the hungry cod come afloat after fishes such as caplin and launce rather than continuing to feed on the bottom and that at this time there is considerable dispersal from the spawning areas. The exact spawning condition of the cod migrating into the Gulf, however, is unknown. In so far as these migratory movements into and out of the Gulf would be almost certainly much less in extent if the waters were not warming in spring and cooling in autumn and winter, it may be said that temperature change is a major influence in the production of these movements.

FEEDING MIGRATION INSHORE WITH CAPLIN

Cod tagged on the western edge of the Grand Bank, June 4 and 5, 1948 were mostly spent or spawning and feeding heavily on caplin. Several weeks later when caplin came to the beaches to spawn in late June and early July some of these fish were caught inshore. A high percentage of fish from the western edge of the Grand Bank and from St. Pierre Bank appears to migrate inshore while from the south-eastern part of the Grand Bank there is very little inshore migration. In the latter half of June when the great inshore migrations of caplin and pursuing cod occur on the east coast of Newfoundland, the cold below-zero layer with temperatures as low as -1.5°C or lower is an intermediate layer over the water deeper than 120-180 fathoms and rests on the bottom at depths from about 10-20 to 120-180 fathoms. The channel separating the south-east Newfoundland coast from the Grand Bank is mostly 60 to 95 fathoms deep and is, except possibly in the shallower bottom parts in early winter, filled with water below -1°C , the greatest volume and the deepest and coldest water, down to -1.6°C in 1950, being near the coast. A similar large volume of cold water below -1°C swings to the east of the bank. At these temperatures below -1°C cod would be expected to die of cold. Cod caught on surface long lines which from the weight of cod sink into these cold waters are reported to freeze. Few or no cod are usually caught either by bait or otter trawl in these temperatures below -1°C and especially the -1.4 to -1.6°C temperatures. The earliest large catches of cod in the St. John's area in May are by surface long-lines set in ten to twenty fathoms, often over the deep cold water. On the occasions when we have detected caplin schools on the echo-sounder in June and July they have been at ten to twenty fathoms in the day time, coming to the surface at night. The cod when they come in after the caplin in June follow them to very shallow water near the beaches where they may sometimes be caught by dipnet during the night. The indications at present, therefore, are that the large June inshore migration of cod forming the basis of the great inshore fishery for cod on the east coast of Newfoundland is an upper layer rather than a bottom migration.

These fish with rare exceptions have all spawned in May and early June, and their migration to the coast in pursuit of caplin is a post-spawning feeding dispersal.

MIGRATION LABRADOR TO THE NORTHERN GRAND BANK

In the area from the southern side of Trinity Bay around the St. John's area to the Burin Peninsula the Channel between the coast and the banks is mostly between 60 and 95 fathoms and generally filled at the bottom with below -1°C water. On the other hand the east coast of Newfoundland from Trinity Bay north and to a lesser extent the coast of Labrador is close to water from 120 to 200 or even occasionally 300 fathoms - water deep enough for warm Atlantic water to exist below the cold layer. Thus cod can spend the winter in suitable temperatures close to shore.

In this area, tagging in Labrador, Englee and Fogo has shown considerable migrations. Judging from early June recaptures in water of 150 fathoms or more, many of these migrations apparently occur during the winter in the deep layer, over the area to the north of the Grand Bank but none of these fish tagged to the north of the Grand Bank have as yet been caught on the bank itself. In considering these migrations along the coastal fringe of the deep water north of the Grand Bank it is worth noting that the offshore area is covered by ice until late spring; there is no commercial fishing although cod are present over a very large area and there is no knowledge of particular spawning areas. Spawning is completed before the late June migration toward shore. The movements appear to be offshore in fall and winter to deep warm water, winter wandering in the deep water to join spawning schools, spawning almost certainly in May and early June and feeding dispersal in the deep warm layer toward the cold water barrier either on the coast or to the north of the Grand Bank with great numbers of the medium sized fish breaking through the cold water layer in pursuit of caplin, entering the warm upper layer and continuing into the shallow inshore water.

On the northern edge of the Grand Bank cod are concentrated in spring and summer in about 100 to 130 fathoms near the cold water barrier plentifully enough for the French and Portuguese trawlers to remain there often from April to November.

Vertebral Counts

The whole east coast of Labrador and Newfoundland area in which access to deep warmer water is relatively easy possesses cod of vertebral count 54.0 to 54.6 with no really significant differences. Some of these schools of cod with vertebral count of 54 or over penetrate as far as St. John's especially during the caplin season in June, July and August. The cod of the deep warm water fringe of the northern Grand Bank below the cold layer also possess fish of a high vertebral count, 53.8 to 54.3. There is no barrier between these fish and the north-east coast coastal fish. Both groups spend the winter in the same deep warm layer.

Explorations by the Investigator II in July, 1948, over the Northern Grand Bank revealed great bodies of cod in 100 to 120 fathoms in temperatures of 1.3 to 2.5° C. At this time the northern part of the Grand Bank from 40 to almost 100 fathoms was covered with water below zero centigrade. Since few cod can be caught in this northern portion between 40 and 100 fathoms (except possibly in late autumn and early winter on which there is no information) and the great quantities of cod are to be found at 100 to 120 fathoms or deeper in the warm layer it is apparent that over most of the year at least, a cold water barrier does exist on the northern portion of the Grand Bank. Agreeing with this is the fact that the body of the Grand Bank immediately south of the northern fishing area is populated during the summer time with cod possessing vertebral counts of 52.6 - 52.9 i.e. highly significantly different. With samples of approximately a hundred these cod vertebral counts are significantly different with about a 0.4 difference. These cod of very low vertebral count are related to schools on the south of the bank. These fish appear to retreat southwards to the warmer water to the south of the bank during the winter time. Some of them certainly spawn on the southern part of the Bank in late May and early June, the spent fish moving northward or north-east over the bank as warming proceeds from southwest to north-east in May and June. We consider it likely that many of these cod move northwards in the upper water layers before spawning actually occurs but there is no evidence as yet of this movement.

To the north of the bank where the high vertebral counts exist the slope of the bank is toward the north and therefore it is to be expected that most of these northern cod even if they penetrated the northern part of the bank in the late autumn would retreat to the deep water at the northern edge during winter. Thus the populations so distinct in vertebral count are kept separate and distinct.

About half way down the eastern edge of the Grand Bank approximately in the latitudes 45 to 46 there is, within a very small area of the bank slope, a mixture of cod of significantly distinct high and low vertebral counts. From south to north the vertebral counts are - 52.7, 54.3, 53.8, 52.8, 53.1, 53.9. It is indicated here that northern schools are penetrating southward along the eastern edge of the bank probably in the deeper water and fish from the southern part of the bank are penetrating northward partially at least in the shallow water. The great differences between the vertebral counts indicate the possibility that schools of widely different vertebral counts may exist in the same area without mixing.

On the southern half of the west coast of Newfoundland where tagging indicates that the migration out of the Gulf is in general southward through Cabot Strait rather than northward out of the Strait of Belle Isle, low Gulf vertebral counts (52.7 - 53.0) are also very similar to those at the western corner of the

south coast where so many of these southern west coast fish spend the winter (52.8 - 53.4). Proceeding northward along the west coast there are gradually increasing vertebral counts from 52.7 at Bay of Islands to 53.7 at Port au Choix, to 53.9 - 54.1 just north of Flowers Cove at the southern entrance to the Strait of Belle Isle and 54.2 northward in Domino, Labrador and southward at Englee on the East Coast of Newfoundland outside the mouth of this Strait. There is here, therefore, as in the tagging, an indication that little migration occurs northward out of the Strait of Belle Isle from the southern half of the west coast of Newfoundland but that there is, as is shown by the tagging recaptures, some penetration of east coast fish of high vertebral count inward through the Strait of Belle Isle to the northern third of the west coast.

The channel through the Strait of Belle Isle is at its shallowest cross section only about thirty-five fathoms deep as compared with over 200 fathoms for Cabot Strait. Consequently any movement outward in autumn would probably be early since most cod are to be found deeper than thirty-five fathoms by late autumn and during the winter the whole Strait of Belle Isle would be filled with water below -1° centigrade. There is thus a much shorter period for migration outward through the Strait of Belle Isle, only about 4 months with suitable temperatures along the bottom as compared with 12 months at Cabot Strait.

In the Nova Scotian and southern Gulf areas generally the differences between vertebral counts of neighbouring areas are so little and the overlapping so great that vertebral counts of particular small samples are not of so much assistance in studying the migratory characteristics of the population as in the Newfoundland Labrador area.

It is evident that tagging of cod thus far on the Atlantic Coast of Canada has been carried out solely with the idea of finding where and when the fish move, leaving the explanation of the cause of movement to chance. It is recommended that in future tagging lengths of the fish be taken, that when possible a full sample of 120 fish taken from the same school as the tagged fish be kept to be examined for spawning condition, for vertebral count and possibly for age and growth. Where feasible the necessary hydrographic work on temperatures and currents, egg-development and egg-distribution studies and investigations of egg and larval drifts should be integrated with the tagging work.

Studies on tag and tagging improvement including methods of obtaining returns especially from foreign ships and countries and the obtaining of better returns after the first year should continue.

The work of finding out where and when fish move is in itself in an unfinished state particularly in the very large Newfoundland area. Also much research is needed to reveal more precisely the times, not certain at present closer than a month, for

offshore and not known at all for inshore, when fish leave the Nova Scotian Bank and inshore areas for the Gulf. Actually by far the highest percentage migration into the Gulf from the offshore banks 4 out of 6 recaptures was from the tagging of only 115 fish on Misaine Bank on March 1, 1937. Two out of four of these Misaine Bank tagged fish were also captured in the central area of the Gulf from which relatively few returns were obtained from tagging on the other offshore banks. Additional tagging on this bank and earlier tagging in all the Nova Scotian Banks would probably give much further information on migration into the Gulf. The autumn spawning cod of the Halifax area could be tagged with profit. Spawning times can be studied with advantage more precisely and in more detail than at present over the whole area.

It is possible that with the development of tags which will give equally good returns in succeeding years as in the year of tagging some worthwhile figures on total cod mortality may be obtained. It is necessary to discount figures on mortality obtained in the year of tagging since cod are usually tagged and liberated in areas where heavy fishing is being carried out and many are caught before they can spread to areas of average fishing intensity.

REFERENCES

- Bjerkan, Paul. Results of the Hydrographical Observations made by Dr. Johan Hjort in the Canadian Atlantic Waters during the year 1915. Can. Fish. Exped. 1914-15. pp. 347-403, pl. 1-3, 1919.
- Gray, J. Migration of Vertebrate Animals. Endeavour Vol. V, No. 19, pp. 83-89, 1946.
- Hachey, H. B. The waters of the Scotian Shelf. Jour. Fish. Res. Bd. Can. Vol. V, No. 4, pp. 377-397, 1942.
- Hachey, H. B. Water Transports and Current Patterns for the Scotian Shelf. Jour. Fish. Res. Bd. Can. Vol. VII, No. 1, pp. 1-16, 1947.
- Hansen, Paul M, Ad. S. Jensen and Å Vedel Tåning. Cod Marking Experiments in the Waters of Greenland 1924-1933. Meddelelser fra Kommissionen for Danmarks Fiskeri- og Havundersøgelser. Serie Fiskeri, Bind X, pp. 1-119, 1935.
- Lauzier L. Reports of Atlantic Herring Investigation Committee, Section C. Hydrography 1947-1949. Manuscripts.
- Marion and General Green Expeditions to Davis Strait and Labrador Sea, 1928-1935. Scientific Results Part 2. U. S. Treasury Dept. Coast Guard, pp. 1-259, 1937.
- McKenzie, R. A. Cod Movements on the Canadian Atlantic Coast. Contrib. Can. Biol. and Fish. N.S. Vol. VIII, No. 31, pp. 433-458, 1934.
- McKenzie, R. A. Cod Migrations in the Halifax Region. Prog. Rept. Atlantic 26, pp. 8-11, 1940.
- McKenzie, R. A. Tagging of Canadian Atlantic Cod. Manuscript Reports of the Biological Stations (Canadian), No. 364, 1948.
- Rounsefell, George A and John Lawrence Kask. How to mark fish. Trans. Am. Fish. Soc. 73rd Ann. Vol. pp. 322-363, 1934.
- Schroeder, William C. Migrations and other Phases in the Life History of the Cod off Southern New England. U. S. Dept. Comm. Bur. Fish. Document No. 1081, pp. 1-136, 1930.

- Schmidt, J. The Atlantic Cod (*Gadus callarias* L.) and local races of the same. *Compte-Rendus des Travaux du Lab. Carlsberg*. Vol. 18, No. 6, pp. 1-72, pl. 1-10, 1930.
- Thompson, Harold. A Biological and Economic Study of Cod (*Gadus callarias*, L.) in the Newfoundland Area. *Res. Bull. No. 14*. Dept. Natural Resources, St. John's, pp. 1-160, 1943.
- Tremblay, J. L. *Station Biologique du Saint-Laurent. Rapport General pendant les Années 1936-1942*. pp. 1-100.