

HERRING POPULATIONS IN THE GULF OF ST. LAWRENCE

BIOLOGICAL CHARACTERISTICS OF SPRING AND AUTUMN HERRING
POPULATIONS IN THE GULF OF ST. LAWRENCE
AND THEIR INTERRELATIONS

by

SHOUKRY MESSIEH

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of the requirements
for the degree of Ph.D.
at McGill University

1973

ABSTRACT

Comparison of spring and autumn spawning populations of Atlantic herring in the Gulf of St. Lawrence showed that the two populations are significantly different. The differences were demonstrated in their length and age compositions, year-class strength, growth rates, maturation cycle, fecundity, spawning time, otolith structure, and meristic counts (pectoral and dorsal fin counts and gill raker counts). The hypothesis is that the two populations are biologically isolated and, for fisheries management purposes, should be considered as separate unit-stocks.

The two populations segregate on the spawning grounds during spawning, but mix on the feeding grounds and in wintering areas. Analysis of the meristic characters made it possible to follow the ratio of the components of the herring population on the American Bank (a major feeding ground) in the Gulf of St. Lawrence during the summer. It is suggested that the two populations retain their identity through separate life cycles.

RESUME

La comparaison de les parametres vitaux et les caractères méristiques des harengs frayant au printemps et qui fraient en automne a montré que les deux populations sont d'une difference marquée. Les differences ont été demontrees dans leur longueurs et leur âge, dominance de leur group d'âge, les taux de croissance, cycle de maturation, fecondité, temp de la fraie, structure de l'otolith, les nombres de rayons des nageoires et de branchictenies.

L'hypothese est que les deux populations sont biologiquement isolees et - pour ce qui est du reglement des pêcheries - devraient être considerees comme des unités separees.

Les deux populations se separent sur le terrain de la fraie, mais se melent sur le terrain d'alimentation et pendant l'hiver. L'analyse nous a permis de suivre la composition de la population du hareng sur le banc des Americains dans le golfe Saint-Laurant dans l'été. Il est suggéré que les deux populations retiennent leur identité, pendant leur cycles biologique separee.

ACKNOWLEDGEMENTS

I wish to thank Dr. M.J. Dunbar, my research director, for his advice and help during the conduct of this research.

My sincere thanks are due to Dr. R.O. Brinkhurst, Director of the Biological Research Station, St. Andrews, New Brunswick, for his support to this herring project, and for granting me an educational leave to complete my study.

I would like to extend my thanks to all members of the Marine Sciences Centre for much fruitful discussion.

The assistance and advice of my colleagues at St. Andrews Biological Station are gratefully acknowledged. Special thanks are due to Dr. L.M. Lauzier for giving me permission to use the data on drift-bottle and sea-bed drifter recoveries, and to Dr. A.C. Kohler who made the larval fish collections accessible to me.

This study was supported in part by a grant from the National Research Council through Dr. M.J. Dunbar.

Lastly, I wish to thank my wife for her continuous encouragement.

TABLE OF CONTENTS

	<u>Page</u>
Abstract	(ii)
Résumé	(iii)
Acknowledgement	(iv)
List of Figures	(viii)
List of Tables	(x)
 <u>Chapter No.</u>	
1 Introduction	1
2 Length Composition	8
Materials and Methods	8
Difference in Length of Spring and Autumn Herring	8
Difference in Lengths by Areas	10
Monthly Variations in Herring Lengths	16
Discussion	19
3 Aging and Age Composition	24
Otoliths for Aging Herring	24
Problems of Aging Herring	27
Age Composition	29
4 Growth	33
Materials and Methods	33
Back-Calculated Lengths	33
Growth Parameters	40
Discussion	42
5 Maturation, Fecundity and Spawning	48
Maturation	48
Monthly Variation in Maturation Stages	48
Discussion	59
Fecundity	62
Discussion	64
Spawning	67
Discussion	73

Table of Contents continued:

<u>Chapter No.</u>		<u>Page</u>
6	Use of Meristic Characters in Identifying Herring Stocks	81
	Use of Single Meristic Characters in Separating Spring and Autumn Herring Populations	81
	Use of Multiple Meristic Characters	88
7	Identifying Herring Stocks by Means of Their Otoliths	102
	Materials and Methods	102
	Results	104
	Discussion	114
8	Separation of Herring Stocks in Relation to Hydrographic Regime and Migration	119
	Circulation	120
	Drift of Herring Larvae	121
	Migration of Adult Herring	125
9	References	131
Appendix 1:	Report on Herring Spawning Time, Duration and Localities	140
Appendix 2:	Tables 1 to 20	150
Appendix 3:	Figures 1 to 17	173

LIST OF FIGURES

<u>Figure No.</u>		<u>Page</u>
1	Catch of herring and other major commercial species in the Gulf of St. Lawrence	2
2	Map of Gulf of the St. Lawrence showing fishing areas and ICNAF statistical areas	3
3	Length composition of spring and autumn herring in the Gulf of St. Lawrence in 1965 through 1970	9
4	Length frequency distribution of spring and autumn herring from the Gulf of St. Lawrence in 1949 through 1965	12
5	Deviations of spring and autumn herring from mean lengths of 20 years (1949-1968) sampling.....	14
6	Length frequency distribution of herring from spring and autumn fisheries in areas in the Gulf of St. Lawrence in four representative years	15
7	Length frequency distribution of spring and autumn herring sampled in 1970, separated by fishing areas	18
8	Length frequency distribution of herring in the Gulf of St. Lawrence in 1969 and 1970	20
9	Deviations of the means of individual samples from the mean length of all samples of herring collected at Grand Riviere during the fishing season of 1954	22
10	Otolith of Atlantic herring showing different parts from the proximal and distal sides	26
11	Age composition of spring and autumn herring in the Gulf of St. Lawrence, 1965-1970	30
12	Herring fish areas from which scales have been examined and deviations from mean calculated lengths based on scales of different areas	34
13	Growth curves of herring from the Gulf of St. Lawrence spring fisheries	43

List of Figures continued:

<u>Figure No.</u>		<u>Page</u>
14	Comparison of growth curves of herring from spring and autumn fisheries in the Gulf of St. Lawrence .	44
15	Seasonal growth of sardines in the Bay of Fundy in 1965 through 1968	47
16	Maturation stages of herring expressed as percentages of the total showing the maturation cycles of spring and autumn spawning populations	60
17	Herring spawning grounds in the Gulf of St. Lawrence	72
18	Monthly distribution of herring catches showing the shift in seasonal trend of the fishery in 1949 through 1968	75
19	Catch of herring by stationary fishing gear (gill nets and traps) in 1971	77
20	Catch of herring by stationary fishing gear (gill nets and traps) in 1971	78
21	Seasonal trend in the catch of herring in the Gulf of St. Lawrence in the Forties	79
22	Percentage ratios of spring and autumn herring in the Gulf of St. Lawrence	94
23	Monthly change in percentage ratios of spring and autumn herring on feeding grounds in the American Bank area	95
24	Surface and bottom temperatures on herring spawning grounds in Caraquet area, Gulf of St. Lawrence ..	98
25	Different types of herring otoliths from spring and autumn fisheries	106
26	Different types of herring otoliths	108
27	Frequency distributions of otolith nuclei sizes of herring from different fisheries	110
28	Regression of otolith lengths on fish lengths of herring from various areas and spawning groups ..	113

List of Figures continued:

<u>Figure No.</u>		<u>Page</u>
29	Surface currents in the Gulf of St. Lawrence as inferred from the drift-bottle recoveries and geostrophic currents	122
30	Dispersal patterns of spring- and autumn-spawned herring larvae in the Gulf of St. Lawrence, as inferred from their size distribution	124
31	A theoretical model of the life cycle of spring and autumn spawning herring	130

LIST OF TABLES

<u>Table No.</u>		<u>Page</u>
1	Nominal herring catch in the ICNAF Convention Area	4
2	Herring mean lengths (cm) by fishing areas in 1969	10
3	Mean lengths (mm) of herring from different areas	13
4	Herring mean lengths (cm) by fishing areas	17
5	Mean lengths of a spring herring sample back-calculated for various ages by direct proportional method ..	36
6	Mean lengths of a spring herring sample back-calculated for various ages by Lee's method	37
7	Mean lengths of an autumn herring sample back-calculated for various ages by direct proportional method	38
8	Mean lengths of an autumn herring sample back-calculated for various ages by Lee's method	39
9	Frequency distribution of lengths at first year's growth	41
10	Frequency distribution and means of marginal increment widths of scales among immature herring	46
11	Maturity stages and their description as recommended by ICES compared with maturity stages adopted in the present study	49
12	Frequency distribution of maturation stages in 1965	50
13	Frequency distribution of maturation stages in 1966	51
14	Frequency distribution of maturation stages in 1967	52
15	Frequency distribution of maturation stages in 1968	54
16	Frequency distribution of maturation stages in 1969	56
17	Frequency distribution of maturation stages in 1970	57
18	Mean fecundity by length for spring- and autumn-spawning herring in the southern Gulf of St. Lawrence during 1970	63

List of Tables continued:

<u>Table No.</u>		<u>Page</u>
19	Pecundity data by length of herring in the Gulf of St. Lawrence from various sources	65
20	Spawning times and locations in southern Gulf of St. Lawrence	69
21	Dates of arrival of herring on the spawning grounds (1946-63), and peaks of the spawning seasons (1965-69)	74
22	Frequency distributions, means, and Z test between the means of some meristic characters of herring from spring and autumn fisheries	82
23	Frequency distributions, means, standard deviations, and standard errors of mean vertebral counts of herring in the southern Gulf of St. Lawrence, in 1970	84
24	Frequency distributions, means, standard deviations, and standard errors of mean pectoral fin-ray counts of herring in the southern Gulf of St. Lawrence, in 1970	85
25	Frequency distributions, means, standard deviations, and standard errors of mean dorsal fin-ray counts of herring in the southern Gulf of St. Lawrence, in 1970	86
26	Frequency distributions, means, standard deviations, and standard errors of mean gill-raker counts of herring in the southern Gulf of St. Lawrence, in 1970	87
27	Maturation stages of herring samples used for discriminant function analysis	89
28	Numbers and percentages of spring and autumn herring as classified by the discriminant function analysis	92
29	Summary of herring samples examined for otolith measurements, maturation stages and meristic counts	103

List of Tables continued:

<u>Table No.</u>		<u>Page</u>
30	Mean values of herring otolith measurements from different fisheries with standard deviations included	105
31	Maturation stages of herring by otolith type and fishery	112
32	Mean pectoral fin ray counts by otolith type and fishery	115
33	Mean dorsal fin ray counts by otolith type and fishery	116
34	Feeding index of herring samples from the Gulf of St. Lawrence taken in May through September 1972 .	128

INTRODUCTION

Of the marine fishes exploited in the Canadian Northwest Atlantic the Atlantic herring (*Clupea harengus harengus* L.) has been for many years one of the most important species. This is obvious from the catch statistics of the Dominion Bureau of Statistics and the International Commission for the Northwest Atlantic Fisheries (Table 1 and Figures 1 and 2).

In the Gulf of St. Lawrence herring fisheries were traditionally based on concentrations of fish which come to this area during the spring and autumn for spawning. Until recently the herring were taken only in coastal regions during the spawning season. No fisheries were carried on on the feeding and wintering concentrations.

In 1967 a major change in the herring fisheries occurred after the introduction of purse seining. The seasons and areas of operation were expanded to cover offshore areas and banks where feeding and wintering occur. The fisheries administrators were then concerned about the sudden increase in effort and the problem of overfishing. Questions have been raised on whether the fish which have been exploited at different areas and seasons constitute separate stocks or whether they are only parts of one major stock whose members intermingle freely.

The question of the stocks of herring and their separation is not new. The first organized research in the Gulf of St. Lawrence

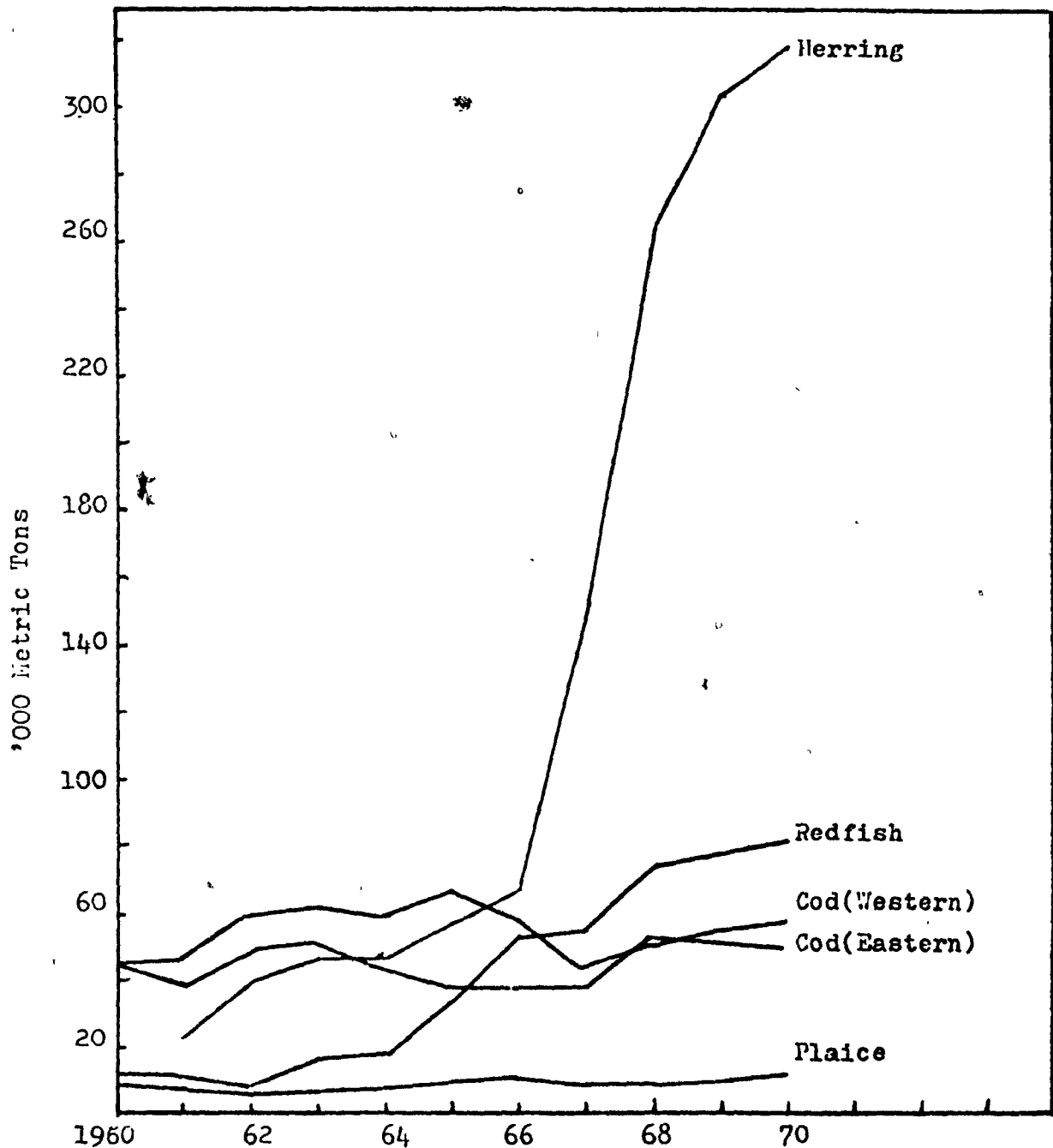


FIGURE 1: Catch of herring and other major commercial species in the Gulf of St. Lawrence (based on a figure produced by Fish Workshop, Gulf of St. Lawrence Project, MEL, Bedford Institute).

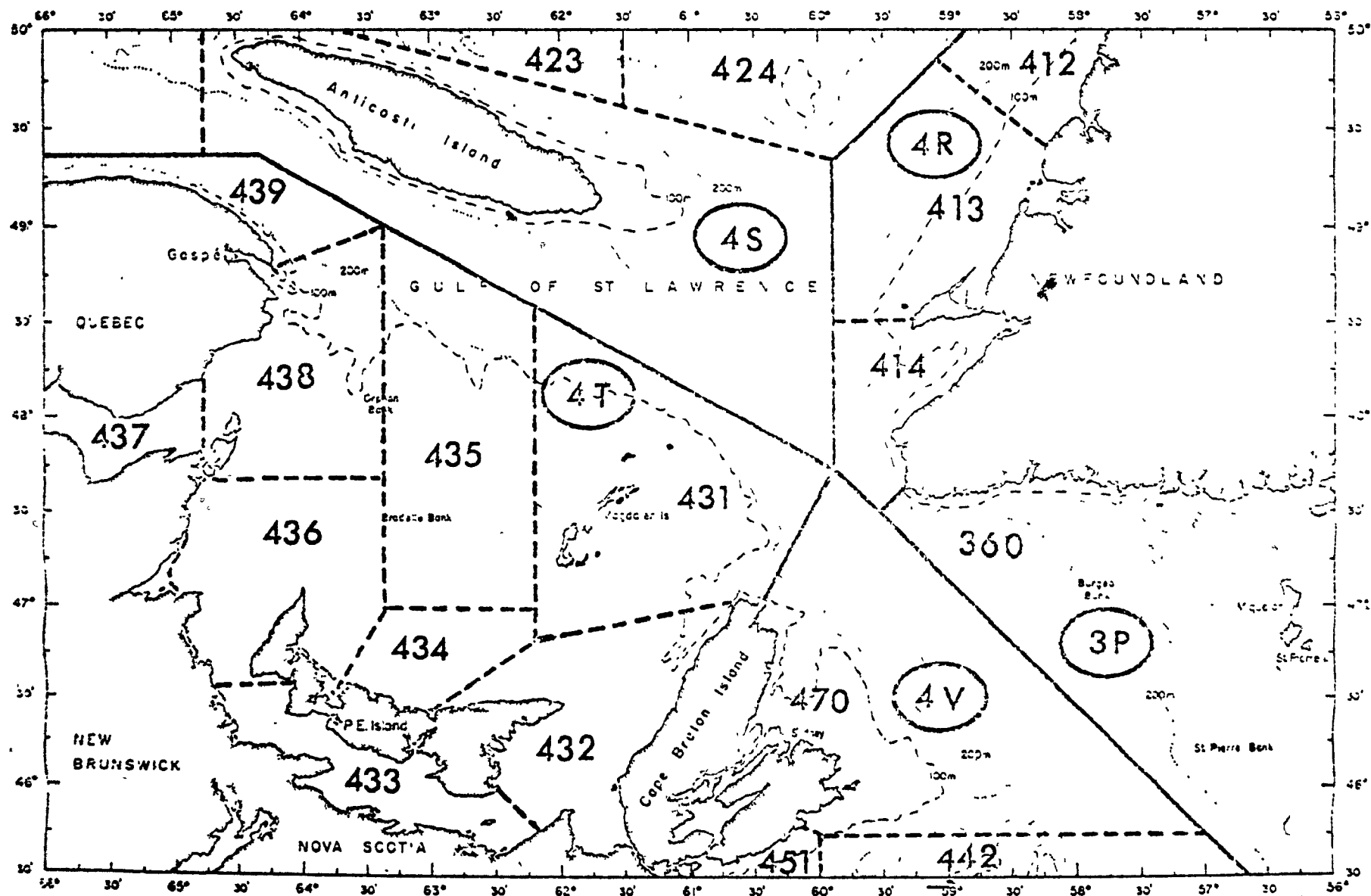


FIGURE 2: Map of Gulf of the St. Lawrence showing fishing areas and ICNAF statistical areas (circled).

TABLE 1

Nominal herring catch (metric tons round fresh) in the ICNAF Convention Area

(based on ICNAF Statistical Book 1972)

Month	Subarea 4							Total	Total Convention Area
	4R	4S	4T	4VN	4VS	4W	4X		
January	239	-	-	1604	-	14965	2339	19150	62085
February	-	-	-	1348	2482	13944	99	17873	47354
March	-	-	42	-	2626	15844	-	18512	46177
April	3213	7	10644	16	76	10694	218	33568	43255
May	2590	4	11895	56	397	3673	3051	21666	32855
June	188	10	4809	44	60	1880	11386	18379	36144
July	191	48	41521	5	15	1707	17676	61163	88641
August	365	273	23067	4	-	749	16803	41261	80956
September	278	349	36282	8	-	765	12495	50177	131680
October	197	4	5163	21	2	434	3606	9427*	66507
November	1439	-	1053	847	-	211	1262	4812	24072
December	1196	-	370	7450	-	3940	38	12994	30206
Not known	-	-	-	-	1371	125	57	1553	18985
Total	10596	695	134845	11406	7029	76931	69032	310535	705157

was done by the Canadian Fisheries Expedition in 1914-1915. Hjort (1915), in his report on the herring problem, raised a similar question: "Do herring that visit the Atlantic coast of Canada all belong to a single race, or is it possible to distinguish several races in these waters?"

Lea (1919) in his extensive work on herring in the Gulf of St. Lawrence hypothesized that several local tribes or races must exist, each having its own particular area of distribution. Without such a hypothesis, it would appear difficult to understand how the different waters could differ so remarkably with regard to age and growth of fish despite the short distance between these localities. He added that it would therefore be most useful if other methods of investigation could be brought to bear upon the problem of the existence of local races in these waters.

It was not until 1944 that the Atlantic Herring Investigation Committee was organized. Leim (1946) in his first report on the objective of the Committee reported: "This depends upon finding out how many of these fish could be taken from the sea annually in perpetuity. Such knowledge is not at present available but can be secured by proper investigation." Substantial progress was made by that Committee on herring investigation in the Gulf of St. Lawrence, but there remained several problems and questions waiting for convincing answers on the basic biology of herring.

Coincident with the activity of the Atlantic Herring

Investigation Committee, Jean (1956) was concerned with the relations between the spring and autumn spawning herring groups and whether they are distinct or interbreeding populations. On the basis of the similarity of the vertebral counts, Jean concluded that herring do not necessarily spawn at the same season as the one at which they have been hatched.

Some investigators seem to have accepted Jean's hypothesis, and classified each spawning group into two categories according to what they thought to be different hatching seasons (e.g. Tibbo and Graham, 1963; Graham, 1962). They used otolith nucleus appearance, a criterion used by some European investigators (Einarsson, 1951; Parrish and Sharman, 1959), as the criterion for separating the fish into their hatching seasons.

Other investigators, using the same criterion, concluded that herring could spawn at any time of the year (e.g. Humphreys, 1965). He based his conclusions on the observed gradation in the appearance of otolith nuclei from complete opacity to complete hyalinity.

On the other hand Messieh (1969a) examined the frequency distribution of hyaline and opaque otolith nuclei in relation to the back-calculated lengths at the first year of growth. He found that these differences are related to hydrographic variations, and concluded that the optical appearance of otolith nuclei should not be used as a criterion for separating herring populations. Messieh (1972) found

differences in otolith structure between spring and autumn herring. On the basis of these differences and other morphological characters he gave evidence for the discreteness of the two populations.

Due to the differences in opinion on the origin of herring stocks and their interrelations, it seemed necessary to re-examine this situation by studying the biological characteristics of the spring and autumn herring populations, and developing methods for delineating the stocks. The concept of herring stock adopted in the present study is the same as defined by the ICNAF/ICES/FAO Scientific Workshop in Lisbon in 1957 (Parrish, 1964) and reads as follows:

"A unit stock is a relatively homogeneous and self-contained population, whose losses by emigration and accessions by immigration, if any, are negligible in relation to the rates of growth and mortality."

It is shown in this study that spring and autumn herring populations retain their identity on the spawning grounds, though they intermingle on the feeding and wintering areas.

LENGTH COMPOSITION

Materials and Methods

Lengths of herring were taken from samples collected in the Gulf of St. Lawrence since 1965. For sampling areas and names of localities see Figure 2 and Appendix Figure 1. Herring were measured to the nearest millimetre using a special measuring board. The greatest total length of the fish was recorded. This is the length from the tip of the lower jaw, with the mouth closed, to the end of the longest lobe of the caudal fin when extended straight back in line with the body.

For the length frequency distribution, lengths were recorded in one-centimetre groups. A length of, say, 30.0 cm includes fishes ranging from 300 mm to 309 mm in length. For some younger fish the length groups were in 0.5 cm. In calculating the mean length of samples, the adjusted means, standard deviation and standard errors were computed. Herring lengths were compared with lengths of other herring samples collected in earlier years.

Difference in Length of Spring and Autumn Herring

Length frequency distributions of herring samples from spring and autumn fisheries in 1965 through 1970 are shown in Figure 3. Except for 1969 samples, herring from the autumn fishery were larger in size than those of the spring fishery. The discrepancy in the 1969 samples resulted from the inclusion of 679 fish (Table 2) caught from

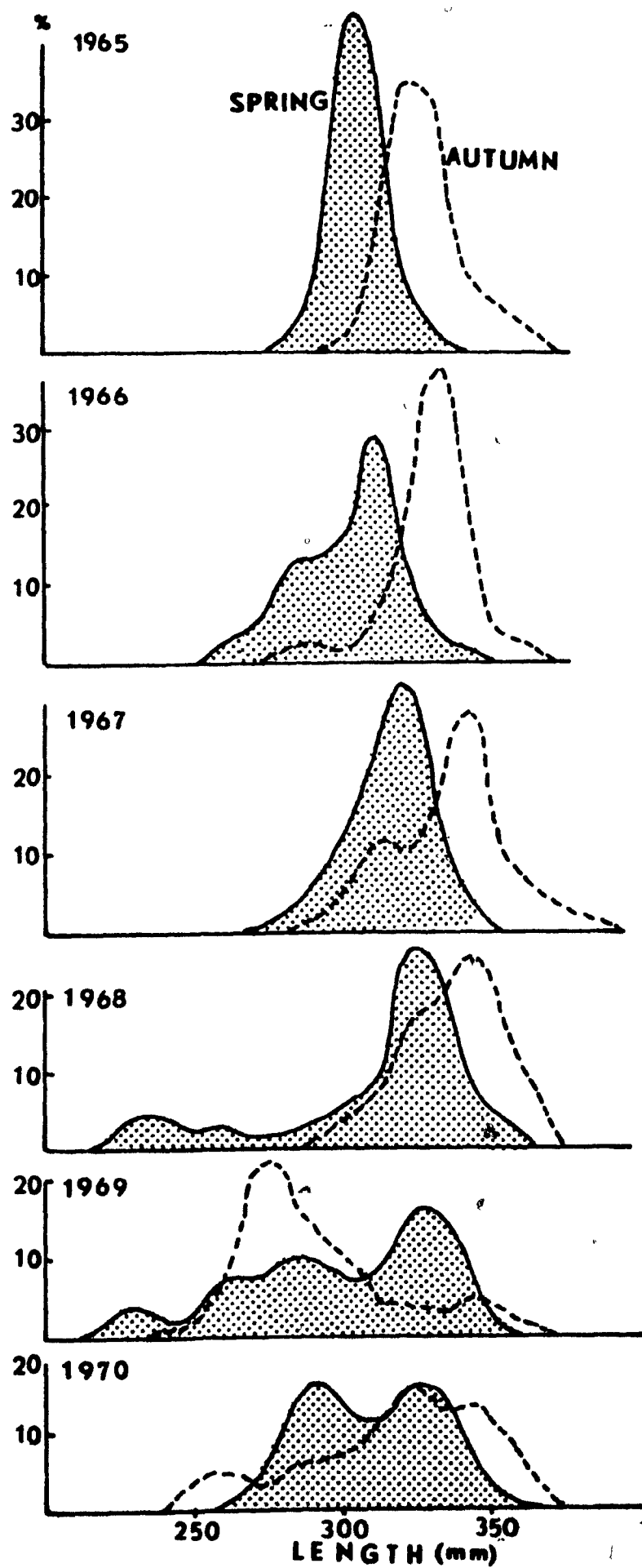


FIGURE 3: Length composition of spring and autumn herring in the Gulf of St. Lawrence in 1965 through 1970.

TABLE 2

Herring mean lengths (cm) by fishing areas* in the Gulf
of St. Lawrence in 1969 (number of fish in parentheses).

Month	431	432	433	434	Area 435	436	437	438	439	470
Jan.										
Feb.										
March										
April						43.0 (100)				
May		29.5 (150)	31.2 (197)	27.6 (100)		32.1 (100)	32.9 (299)			31.1 (50)
June							24.9 (100)	31.6 (807)		
July								31.6 (200)		
Aug.										
Sept.								29.1 (679)		
Oct.										
Nov.										
Dec.										
Total		29.5 (150)	31.2 (197)	27.6 (100)		32.0 (200)	30.9 (399)	30.6 (1686)		31.1 (50)

* For area codes see map on Figure 2.

the American Bank (Area 438) by otter-trawling during a research cruise. Maturity stages of these fish showed that they were a mixture of spent fish which were most likely recruiting to the fishery for their first time.

Comparison of length composition of spring and autumn herring from earlier years showed a similar trend as in Figure 3. Samples taken in 1949 through 1965 from the autumn fisheries were in all cases of fish of larger sizes on the average than in spring fisheries (Figure 4).

The differences in mean length of spring and autumn herring are clearly demonstrated when the deviations from the mean length of 20-year samples were plotted as in Figure 5. For all autumn herring samples the deviations were positive, while for spring herring the deviations in most of the sampling years were negative.

Difference in Lengths by Areas

Frequency distributions of herring lengths were separated by areas, and their mean lengths were calculated. Mean lengths of spring and autumn herring samples in five major fishing areas on the Magdalen Shallows collected in 1949 through 1968 are presented in Table 3. Herring length frequency distributions of the same samples for the period 1950 to 1954 are shown in Figure 6. This period was chosen for the plot because samples for these years were represented in most of the areas.

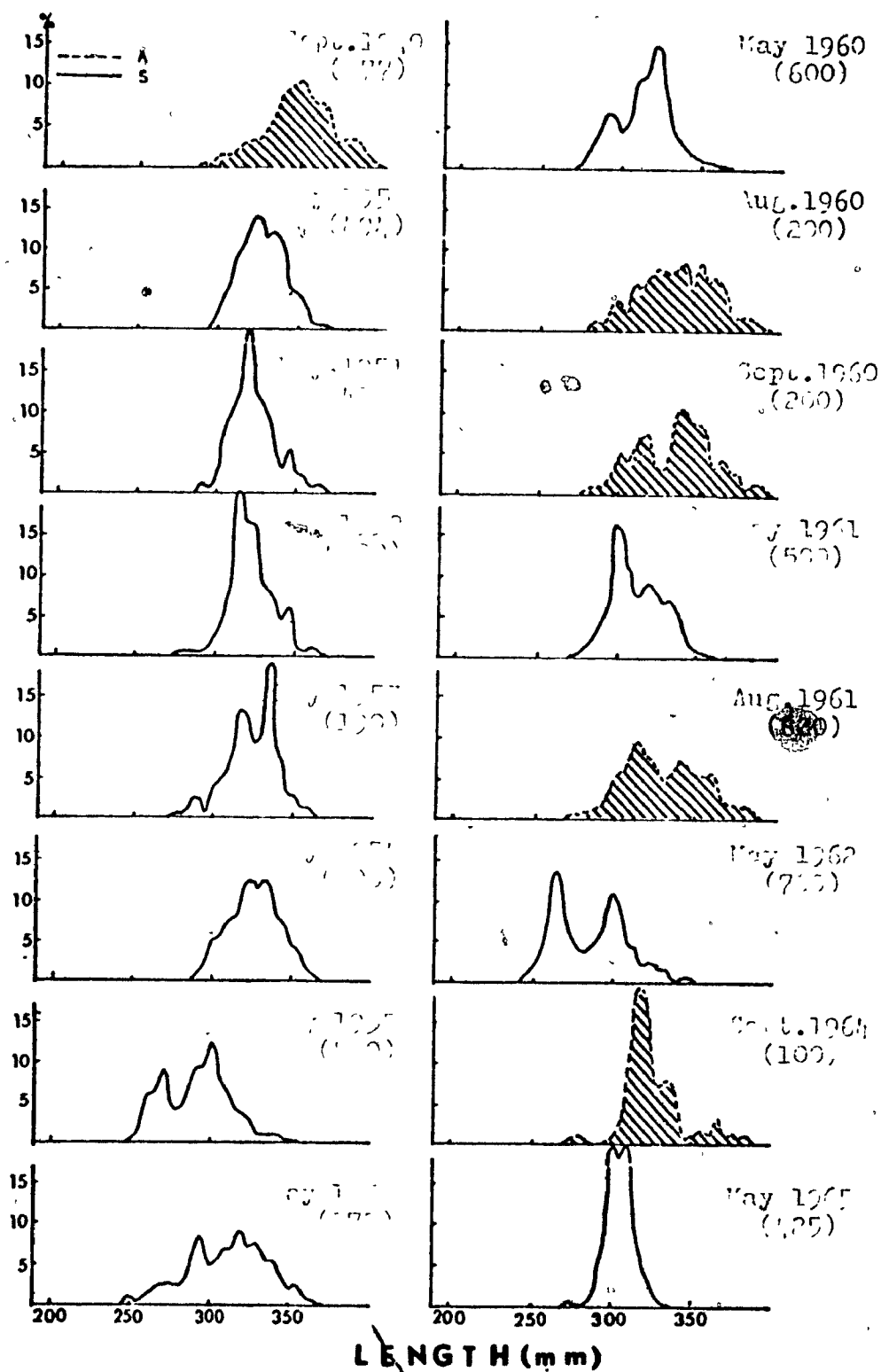


FIGURE 4: Length frequency distribution of spring (S) and autumn (A) herring from the Gulf of St. Lawrence in 1949 through 1965. Numbers of fish are shown in parentheses.

TABLE 3

Mean lengths (mm) of herring from different areas in the Gulf of St. Lawrence (1949-68). Standard deviations and number of fish (in parenthesis) are included.

Date	New Brunswick	Quebec	Prince Edward Island	Nova Scotia	Magdalen Islands
July 1949		(426)267.6±18.4			
Sept. 1949	(377)374.4±22.3				
May 1950	(494)352.5±14.6	(490)304.1±31.5	(550)332.1±19.2		
May 1951	(433)348.2±14.4	(220)330.2±20.8			
May 1952	(220)347.5±13.2	(110)305.6±18.6	(220)321.4±17.7		(139)339.8±23.7
June 1952			337.2±24.5		
May 1953	(190)348.0±16.4	(220)319.8±16.9	(220)301.0±20.5		
June 1953				(746)316.5±25.1	(1176)328.1±22.4
July 1953				(803)342.9±31.2	(490)344.8±28.7
Aug. 1953			(329)347.1±42.2	(503)351.1±31.8	(547)333.2±19.7
Sept. 1953		(396)320.5±22.1		(795)301.1±78.5	(281)323.9±14.2
May 1954	(300)341.1±15.9	(200)312.7±16.3			(100)320.7±13.1
May 1955	(500)316.9±20.2				
May 1956	(375)336.8±24.4				
May 1959					(488)332.6±21.6
May 1960	(600)339.2±17.4		(500)335.5±22.1		
Aug. 1960	(200)360.4±23.7				
Sept. 1960	(200)360.4±24.0				
May 1961	(500)337.5±16.9				
June 1961	(583)269.9±30.6				
Aug. 1961	(620)354.9±24.1				
Apr. 1962	(100)336.6±21.9				
May 1962	(700)311.4±22.6				336.6±23.6
Sept. 1964	(100)350.1±17.5				
May 1965	(425)331.0±8.7				
Aug. 1965	(450)353.9±12.5				
May 1966	(1000)334.4±15.8		(1198)327.7±15.9	(500)296.5±58.9	(700)316.4±21.1
July 1966	(500)358.1±9.6				
Aug. 1967	(200)358.7±13.1	(600)352.2±19.8			
May 1967	(727)333.2±30.7		340.1±10.6		
June 1967	(300)347.5±14.3				(200)332.4±18.5
Aug. 1967	(370)359.3±19.0	(900)359.4±22.0			
Sept. 1967	(200)358.6±18.7	(100)359.2±19.4			
May 1968	(800)352.3±10.6		(350)334.8±20.9	(172)293.8±37.9	(200)340.7±17.5
June 1968	(205)269.6±18.1		(200)363.6±13.6	(100)368.1±13.4	
Aug. 1968	(500)369.8±14.9	(100)347.9±12.4		(100)368.1±13.4	
Oct. 1963		(200)341.3±23.8			

DEVIATIONS FROM MEAN LENGTHS (mm)

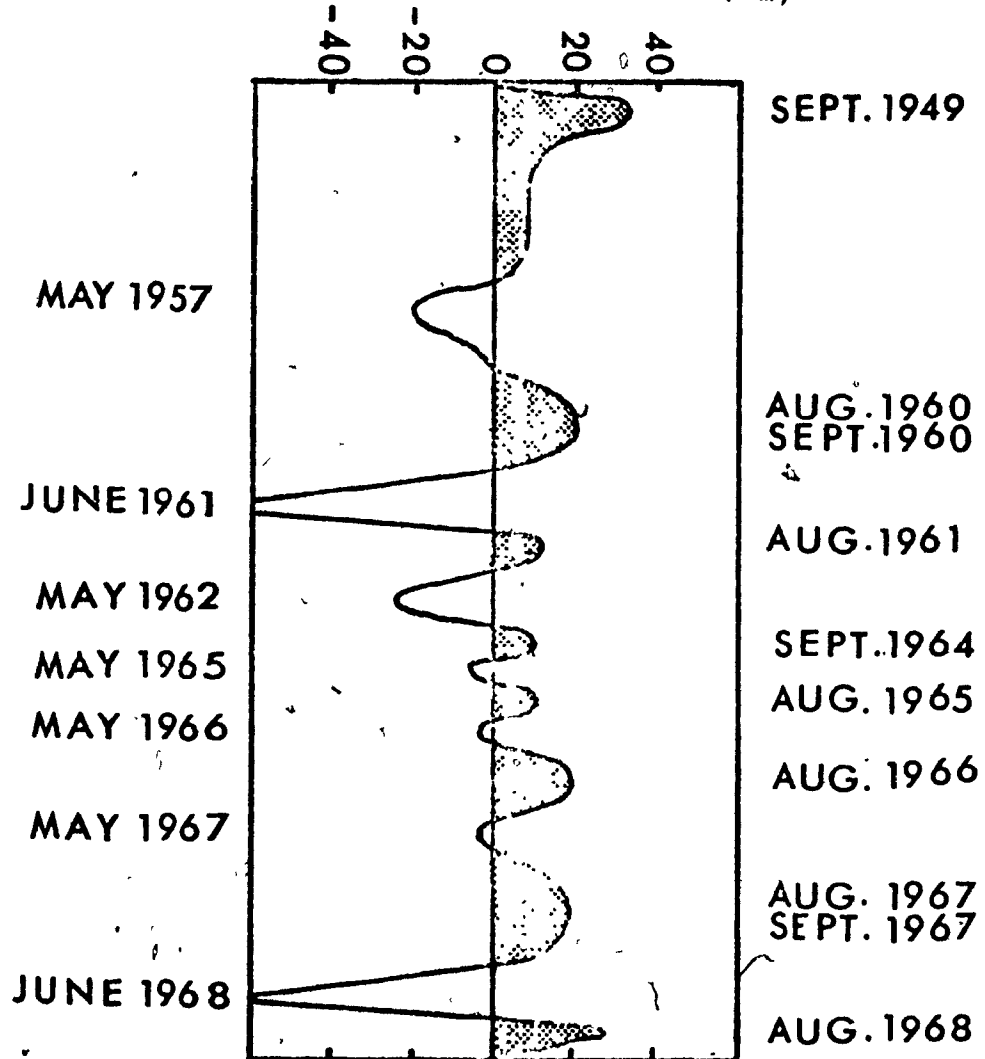


FIGURE 5: Deviations of spring and autumn herring from mean lengths of 20 years (1949-1968) sampling. Herring from autumn fisheries (shaded areas) show positive deviations.

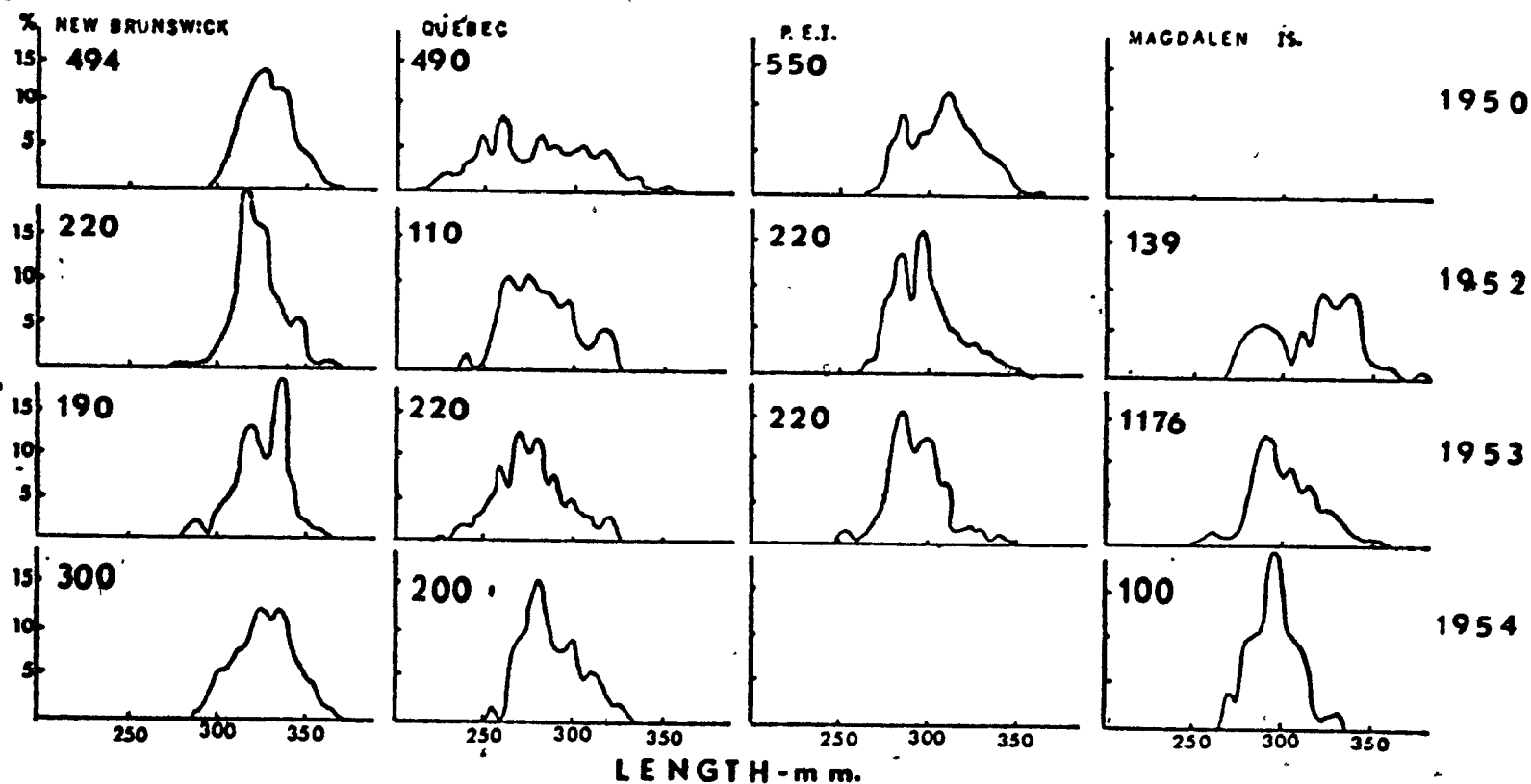


FIGURE 6: Length frequency distribution of herring from spring and autumn fisheries in areas in the Gulf of St. Lawrence in four representative years.

The differences in herring lengths by areas were striking. In most of the sampling years fish from the New Brunswick coast of the Gulf were larger than ⁱⁿ ~~any~~ other area. The smallest sizes were found along the Quebec coast.

Mean lengths of spring and autumn herring for 1969 and 1970 samples are shown in Tables 3 and 4 respectively. Length compositions of herring in these samples are included in the Appendix (Appendix Tables 1 to 17). The differences in mean lengths among areas are clear. In 1970 more samples were represented in most areas than in 1969. Thus they were used for plotting the length frequency distributions (Figure 7). Differences among areas are demonstrated for both spring and autumn fish, but the consistency in these differences were less conspicuous than in samples prior to 1969.

Monthly Variations in Lengths

Due to the seasonal character of the herring fishery in the Gulf of St. Lawrence, and the short fishing season in the spring and autumn, herring samples (mainly caught from the commercial fishery) were limited to two or three months each year. Since 1969 the development of a purse-seine fishery made it possible to collect samples during the summer. All available mean lengths by month for 1969 and 1970 samples are presented in Tables 2 and 4. Length frequency distributions of the same are shown in Figure 8. No monthly increase in length was observed in both years, and the change in mean lengths did not follow a trend.

TABLE 4

Herring mean lengths (cm) by fishing areas* in the Gulf
of St. Lawrence in 1970 (number of fish in parentheses).

Month	431	432	433	434	Area 435	436	437	438	439	470
Jan.										
Feb.										
March										
April	32.5 (100)		29.3 (200)	29.5 (200)						
May	30.6 (300)					30.9 (400)	31.7 (200)			28.9 (99)
June							33.1 (217)			35.2 (99)
July				31.7 (20)				32.0 (304)		33.9 (189)
Aug.							30.9 (909)	33.8 (1729)	31.9 (100)	
Sept.		32.0 (100)		31.9 (29)	33.7 (303)	33.6 (100)	33.7 (403)	33.5 (400)		
Oct.	31.7 (199)				29.4 (100)			27.5 (200)		
Nov.										
Dec.										31.8 (100)
Total	31.2 (599)	32.0 (100)	29.3 (200)	29.9 (249)	32.7 (403)	31.4 (500)	31.9 (1729)	33.1 (2633)	31.9 (100)	32.7 (485)

* For area codes see map on Figure 2.

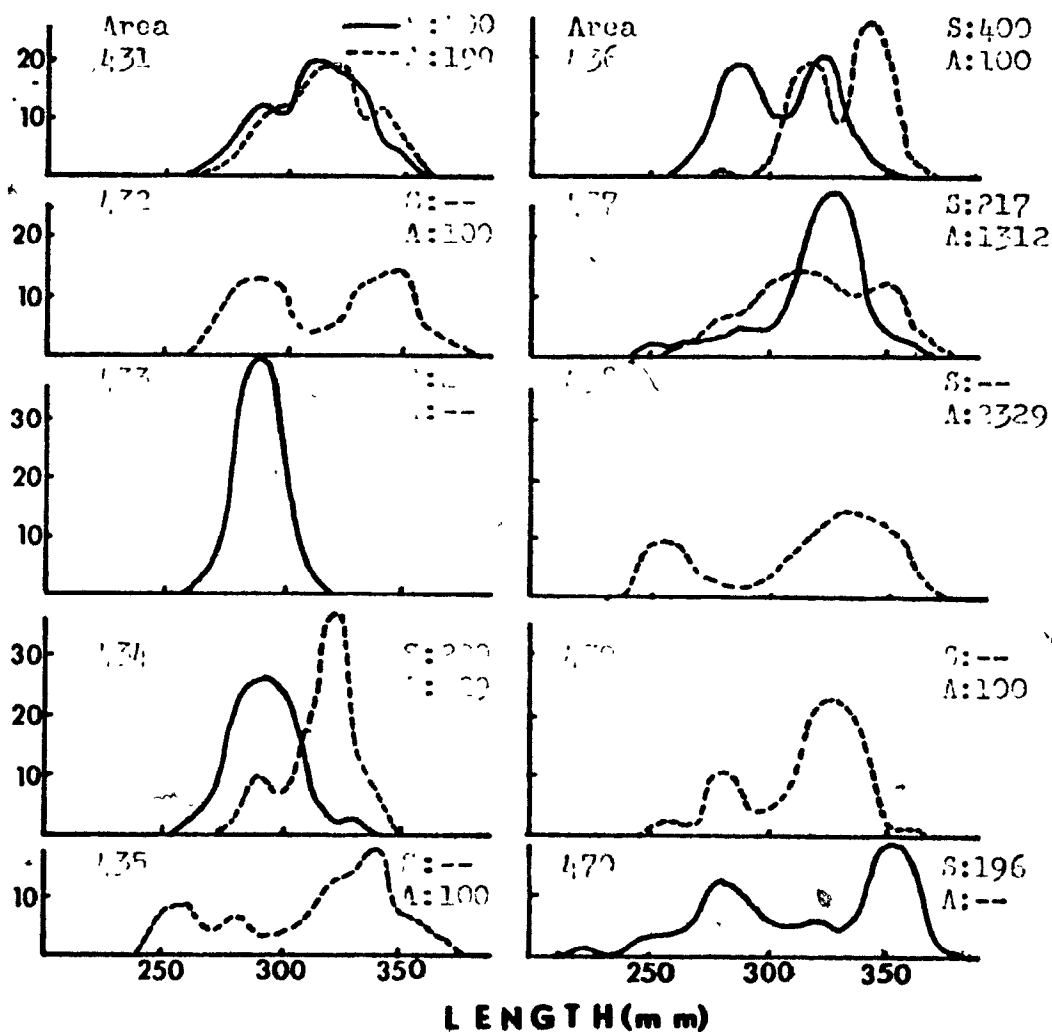


FIGURE 7: Length frequency distribution of spring (S) and autumn (A) herring sampled in 1970, separated by fishing areas. Numbers of fish are shown.

The length frequency distribution (Figure 8) showed poly-modality which reflects the contribution of different year classes to the samples. In a few cases a mode could be followed for two or three successive months. In June 1969 there were new recruits to the fishery from fish measuring about 230 mm in modal length. This size-group did not appear in the following months. Similar small fish appeared in the October 1970 sample, having a modal length of about 260 mm.

Discussion

A significant difference in length between the spring and autumn herring populations was demonstrated in this study. Fish from autumn fisheries were larger than those from spring fisheries. The larger sizes of autumn herring could not be attributed to a difference in growth rate only. The difference between lengths of autumn and spring herring is larger than the expected growth during the summer (see chapter 4).

Another factor contributing to the difference in lengths could be the accumulation of fish older by more than one summer in the autumn fishery than in ^{the} spring fishery. Traditionally, fish were caught by gill nets set near the spawning grounds, which are more inshore for spring spawners. Thus, spring herring were more vulnerable and subject to heavier exploitation than autumn herring. From analysis of age composition it will be shown that autumn herring samples comprise more fish of older year classes than spring herring.

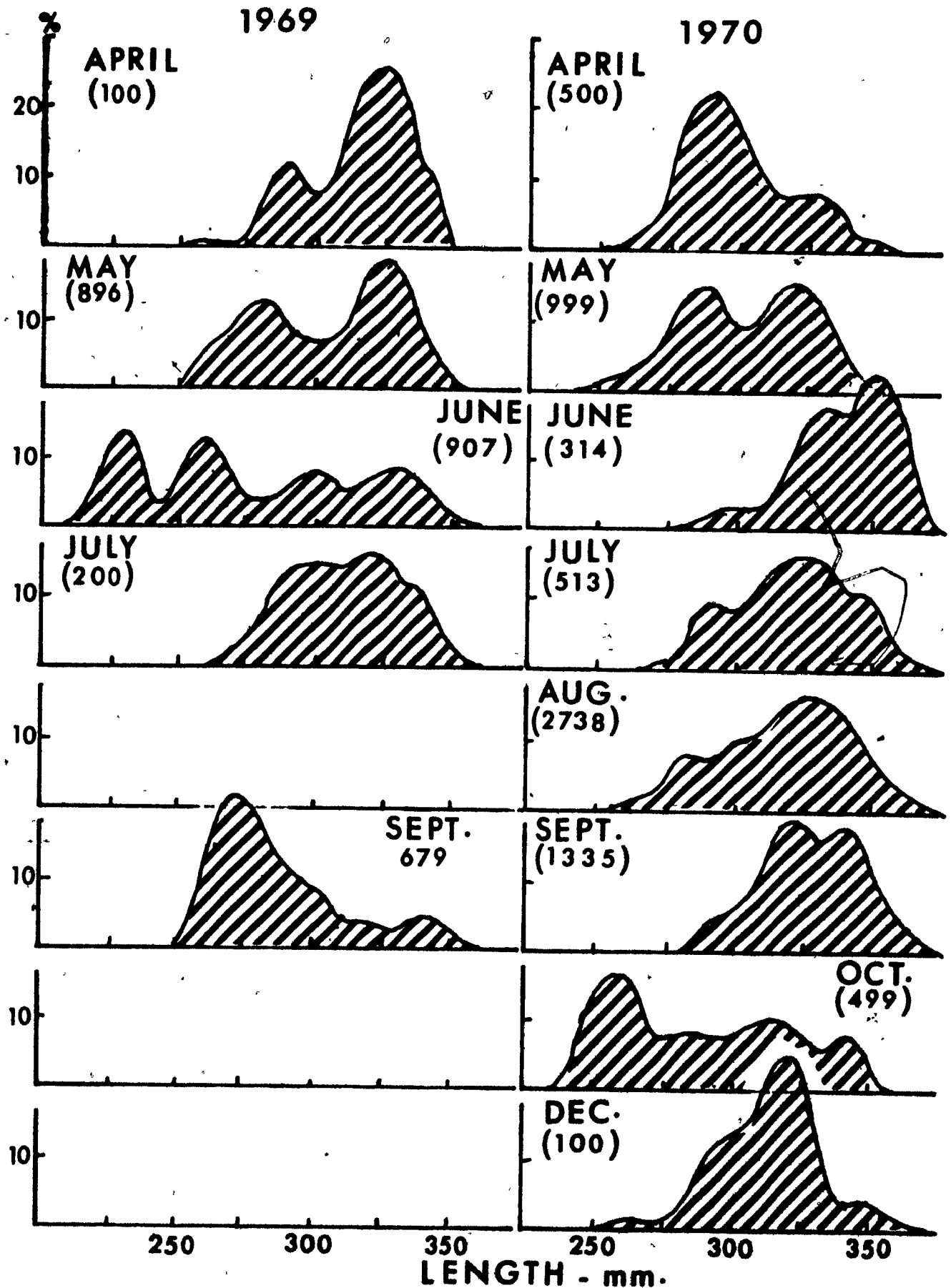


FIGURE 8: Length frequency distribution of herring in the Gulf of St. Lawrence in 1969 and 1970.

Jean (1956) recorded differences in fish lengths as the fishing season progressed from April to September. He found that larger fish came into the fishery at first, followed by smaller fish presumably slower in growth than the first ones (Figure 9).

~~An~~ Indirect evidence supporting Jean's observations was indicated from the growth study by back-calculation (see chapter 4). Back-calculated lengths (Tables 5 to 8) demonstrated positive Lee's phenomenon, i.e. fish lengths as back-calculated from older fish are smaller in size than those back-calculated from younger fish. This indicates that larger individuals (faster growing fish) likely come to the fishery earlier than smaller ones (Ricker, 1969).

Differences in herring length by area perhaps reflect differences in hydrographic conditions in these areas. They could also reflect different stages in the life history of the fish. Thus, fish from spawning areas gathering for spawning would presumably differ from fish caught on feeding grounds at the same time.

It is worth noting that in the large samples of herring measured for length frequency distribution, few if any of the fish were in the smaller size ranges (less than 20 cm long). This raises the question: Where do the small-size fishes go? During the 1915 Canadian Fisheries Expedition, Lea (1919) referred to a few specimens of smaller size caught in a trap-net. Day (1957) reported on the sardine-size herring (10 to 15 cm range) from the estuary of the St. Lawrence. In a trap-net



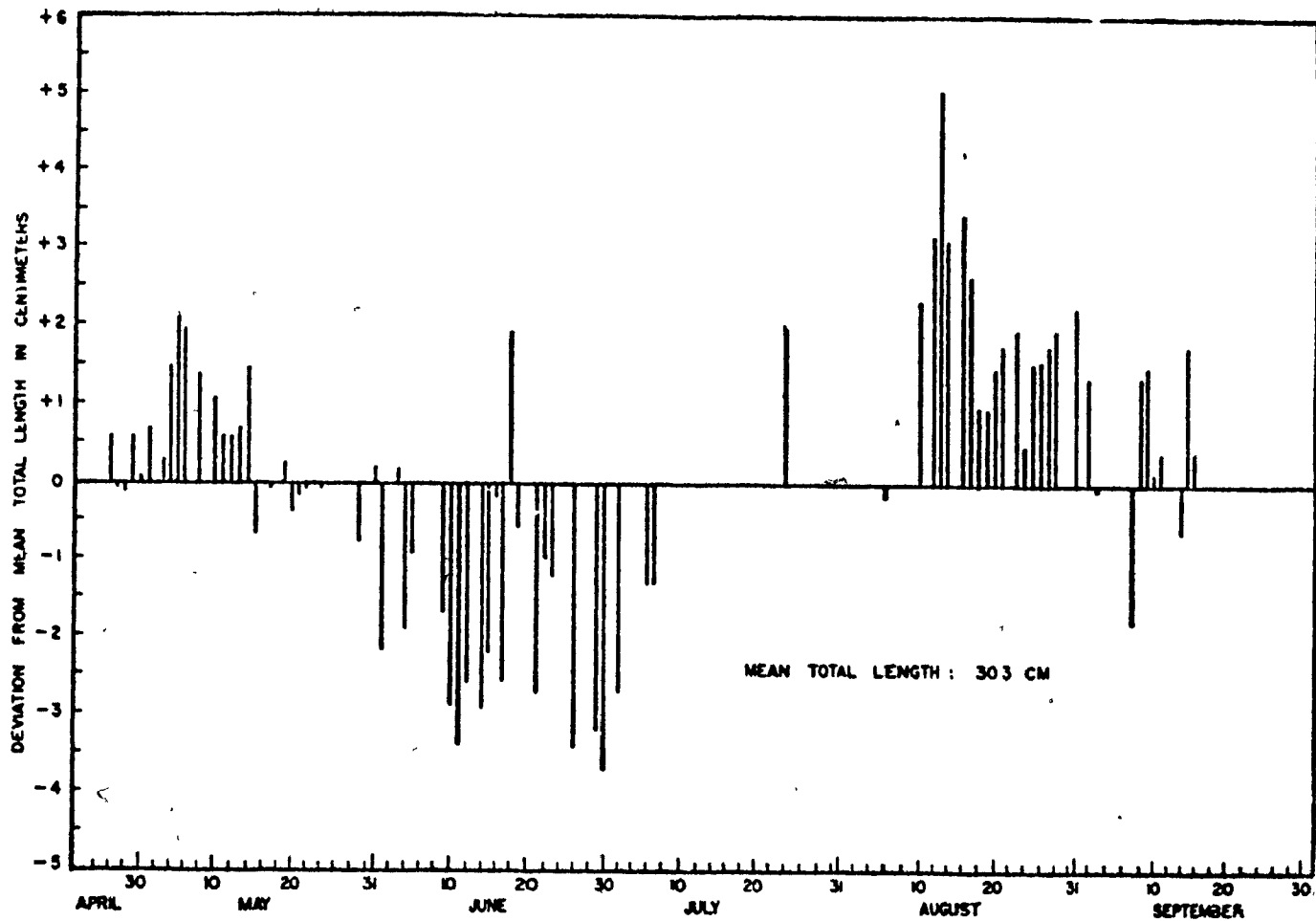


FIGURE 9: Deviations of the means of individual samples from the mean length of all samples of herring collected at Grand Riviere during the fishing season of 1954 (after Jean, 1956).

fishery centered off the mouth of the Saguenay River at Ile Verte, the fishery yielded 45,000 pounds of sardines in 1946.

Leim (unpublished data) from an interview with the fishermen and fishery officers in 1943/44 reported on some small herring (15 cm) caught in the smelt nets in October from the Richibucto area. Some other specimens (10 to 13 cm long) were taken in February around Point Sapin and Bay du Vin.

Messieh (unpublished data) reported on the results of a cruise (KEP-46) made in the Bay of Chaleur during May/June 1969. A few specimens of sardines were caught near the head of the Bay of Chaleur in a lined #41 otter-trawl. Whether these small fish were in any great concentration is not known.

In the French Report to ICNAF (Morice, 1971), small herring (11 to 14 cm) were reported to be caught near Miquelon in October and November. Recently, Russian investigators (Anon., 1972) found sardine sizes offshore near the edge of the continental shelf and on the Banks south to Nova Scotia, and on Georges Bank during January-March 1972. Whether these fish have any relation to the herring inside the Gulf of St. Lawrence is not known.

AGING AND AGE COMPOSITION

Otoliths for Aging Herring

Routine age estimates of herring were based on otolith readings. Otoliths were extracted from each fish. There are three otoliths lying on each side of the labyrinth. These are the *astericus*, *sagitta* and *lapillus*; only the *sagitta* is used for age determination.

After pertinent data on a fish have been recorded, a cut is made in the skull just in front of the occipital, opening the skull cavity. This cut exposes the otoliths which can be removed by fine forceps. Care must be exercised in making the cut, because if the cut is too deep the brittle otoliths could be broken.

On removal from the fish, the otoliths are wiped clean, rinsed in water, wiped again and placed on special trays with the distal side upward. These trays are made of plexiglas sheets approximately 14.0 cm long and 8.5 cm wide. Each tray contains 50 depressions, each of which will hold a pair of otoliths and is given a serial number.

The otoliths are fixed in these depressions by adding a few drops of 1,2-Dichloroethane which fasten the otoliths to the plexiglas. If for any reason the otoliths have to be removed, the same solvent is added in the depression, and after a few minutes the otoliths become loose and can be removed from the tray.

Otoliths are examined with a binocular microscope using a magnification of about 20 times. Ages are recorded as the numbers of hyaline (winter) zones shown on the otoliths regardless of the sampling time. An arbitrary birth day (January first) was taken in assigning the ages and year-classes. Examination of otoliths was done while they were immersed in alcohol to enhance the appearance of hyaline zones, in which case they appear dark on the black background while the opaque zones appear white.

In order to understand the use of otolith in aging, a short description of the otolith follows.

A herring otolith is generally oval in shape, laterally compressed. In the anterior part there is a long rostrum and an antirostrum separated by the excisura (Figure 10). Posteriorly the sulcus runs out in a slight cut of the posterior border 'excisura minor' which divides the posterior edge of the otolith into two parts, the postrostrum and the pararostrum. On the concave distal surface the centre of the otolith is occupied by an elevated ringwall which encloses a cavity called the nucleus. This cavity varies in size and in some otoliths is absent.

The otolith is formed of calcium carbonate in the form of aragonite crystals, and an organic network. These materials are deposited in a concentric manner, and increase during the growth of the otolith. The ratio of calcium carbonate to the organic network varies seasonally.

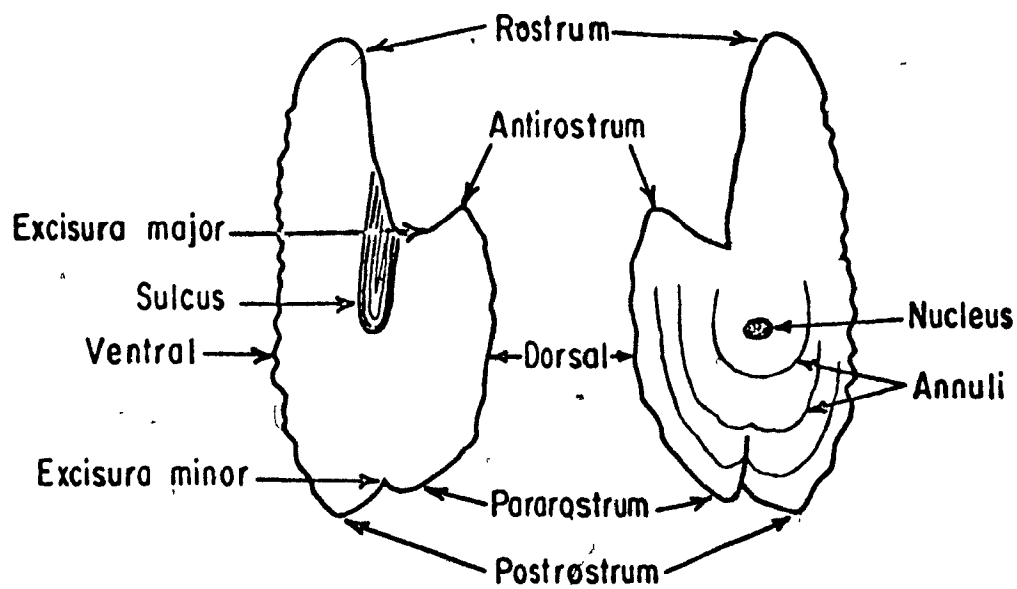


FIGURE 10: Otolith of Atlantic herring showing different parts from the proximal and distal sides. Drawing to scale (enlargement 12x).

Thus, in the fall and winter, due to the colder water, scarcity of food and less activity, the deposition would be deficient in calcium carbonate and appears hyaline (translucent in transmitted light). During the summer the deposited layers contain more calcium carbonate and appear opaque in transmitted light (white under reflected light). The hyaline (winter zone) and the opaque (summer zone) constitute one year's growth. The number of these rings (annual rings) should correspond with the age of the fish.

Problems of Aging Herring

Problems involved in aging herring are of two kinds: problems related to the nucleus of the otolith, and problems related to the recognition of the annual rings especially when they are crowded as in older fish.

For the first problem, namely the optical appearance of the nucleus, Messieh (1969) established the fact that the nucleus appearance should not be taken as a criterion for assigning the ages to spring and autumn herring. He found a gradation in the optical appearance of herring otolith nuclei from distinctly hyaline to completely opaque. He related the similar frequencies of the various types of nuclei in the spring and autumn herring populations to the variable hydrographic conditions in the Gulf of St. Lawrence area.

Prior to 1969 herring ages were estimated on the assumption

that an otolith with a hyaline nucleus was of an autumn spawned fish, and the one with an opaque nucleus was of a spring spawned fish (Tibbo and Graham, 1963; Humphreys, 1965). Hence, it was necessary to re-examine all samples for aging prior to 1969 and to assign to them ages regardless of the appearance of otolith nuclei. Various authors followed the same technique (e.g. Hourston and Parsons, 1969), and the nucleus optical appearance is no longer taken any more into consideration in age estimates in any of the laboratories engaged in herring research.

So far as the second problem (difficulty in recognizing the annuli) is concerned, much work has been done in this direction. The problem is in trying to identify the number of annual rings for old fish. Otoliths of these fish show crowding of the annuli near the margin with little contrast between hyaline and opaque zones, thus facing the investigator with subjective estimates and probable errors.

This problem has been recognized by member countries in ICNAF, and several programs for exchange materials were set up for checking age estimates among these countries. At the 1971 Annual Meeting of ICNAF, a program for exchanging otoliths between countries engaged in routine herring age determinations was set up.

Otolith samples have been examined by investigators at laboratories in Canada, USA, Germany and the USSR. Both age and year-class designations were recorded by all participants. Over-all results of this exchange revealed considerable discrepancies in year-class estimates

between participating laboratories. Valid comparisons could not be made for the southern Gulf of St. Lawrence and southwest Newfoundland samples because of the high proportion of relatively old fish (Parsons and Winters, 1972).

Despite these problems involved in herring age estimation, age compositions would furnish a key for comparative studies between different stocks. There would be a bias towards underestimating the older ages which could lead to erroneous results if used for growth studies. These results would not invalidate a comparison between age compositions, nor the following of a predominant year-class. The dominance of a year-class of an old age group would be correctly shown in the distribution, although the degree of dominance would be probably less than it should be.

Age Composition

Age composition of herring from spring and autumn fisheries in 1965 through 1970 are shown in Figure 11. In all years of sampling age compositions of the two populations were different. Except for 1969, samples of herring averaged older in autumn than in spring fisheries.

The discrepancy in 1969 samples, which also has been shown in their length frequency distributions, was due to the inclusion of a sample of younger fish caught on American Bank during a research cruise.

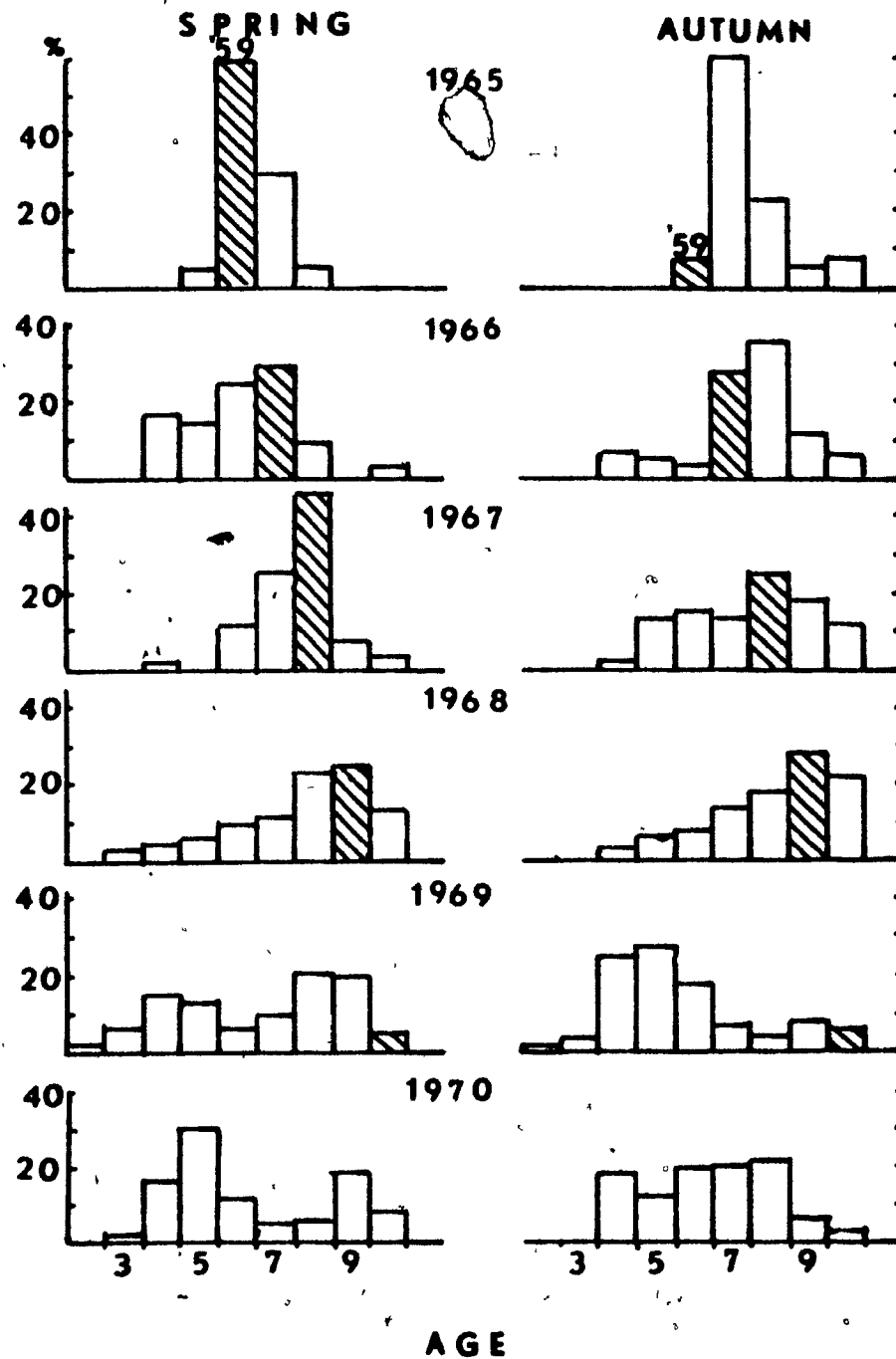


FIGURE 11: Age composition of spring and autumn herring in the Gulf of St. Lawrence, 1965-1970.

The 1959 year-class was dominant in the spring fishery of 1965, while the 1958 year-class was dominant in the autumn fishery of the same year. The 1959 year-class stayed dominant in the spring fishery until 1968. The year-class of 1960 which started to appear in the spring fishery of 1965 followed the 1959 year-class in its strength, and stayed strong in the fishery until 1969. In the last year of sampling (1970), a new year-class (1965) was dominant.

In autumn fisheries, however, the dominant 1958 year-class dominated again in 1966, and stayed strong in 1967 and 1968 samples. Another year-class (1959) which started to appear in 1965 samples gained strength in 1966 and dominated in 1967 and 1968.

The 1969 samples for both fisheries deviate from the age structure for the preceding years and younger fish (presumably first recruit spawners) were relatively abundant. The 1964 year-class dominated the autumn fishery in 1969, and the 1964 and 1965 year-classes together made up nearly 55% of the landings. In the spring fishery these two year-classes contributed about 30%.

In 1970 the year-class of 1965 was dominant in the spring fishery, followed by the 1961 year-class. In the autumn fishery of the same year most of the year-classes were equally distributed, and no dominance of a particular year-class was clear.

The age frequency distributions for each year were subjected to a chi-square test of the hypothesis that samples from the two

fisheries were drawn from the same population. The chi-square values obtained were very large ($p < 0.01$), thus rejecting the hypothesis. The evidence is therefore conclusive that the two groups of fish were not drawn from a single population.

GROWTH

Materials and Methods

Scales were used for the study of herring growth in the Gulf of St. Lawrence. Herring scales were available from 371 fish taken from the spring fishery and 155 fish from the autumn fishery. Herring scales are difficult to collect, since most of the scales are removed from the fish during capturing and handling.

Scales were taken from the pectoral area of the fish body (area E-F in Figure 12). This area was selected because it showed the least deviation from the mean back-calculated lengths. This has been demonstrated by taking five scales from different areas of the fish body and back-calculating the lengths at first year's growth (L_1) from these scales. The deviations from the mean back-calculated length were calculated and plotted as in Figure 12.

Back-Calculated Lengths

Fish scales were projected with known magnification (20 times) and the position of the annuli were plotted and measured as the distances from the line separating the covered and exposed parts of the scale (centre of the scale) to the respective annuli. The growth increments on the scale were used for back-calculating the fish length at previous ages by two methods: direct proportional method (Lea, 1919) and Lee's method (Lee, 1920).

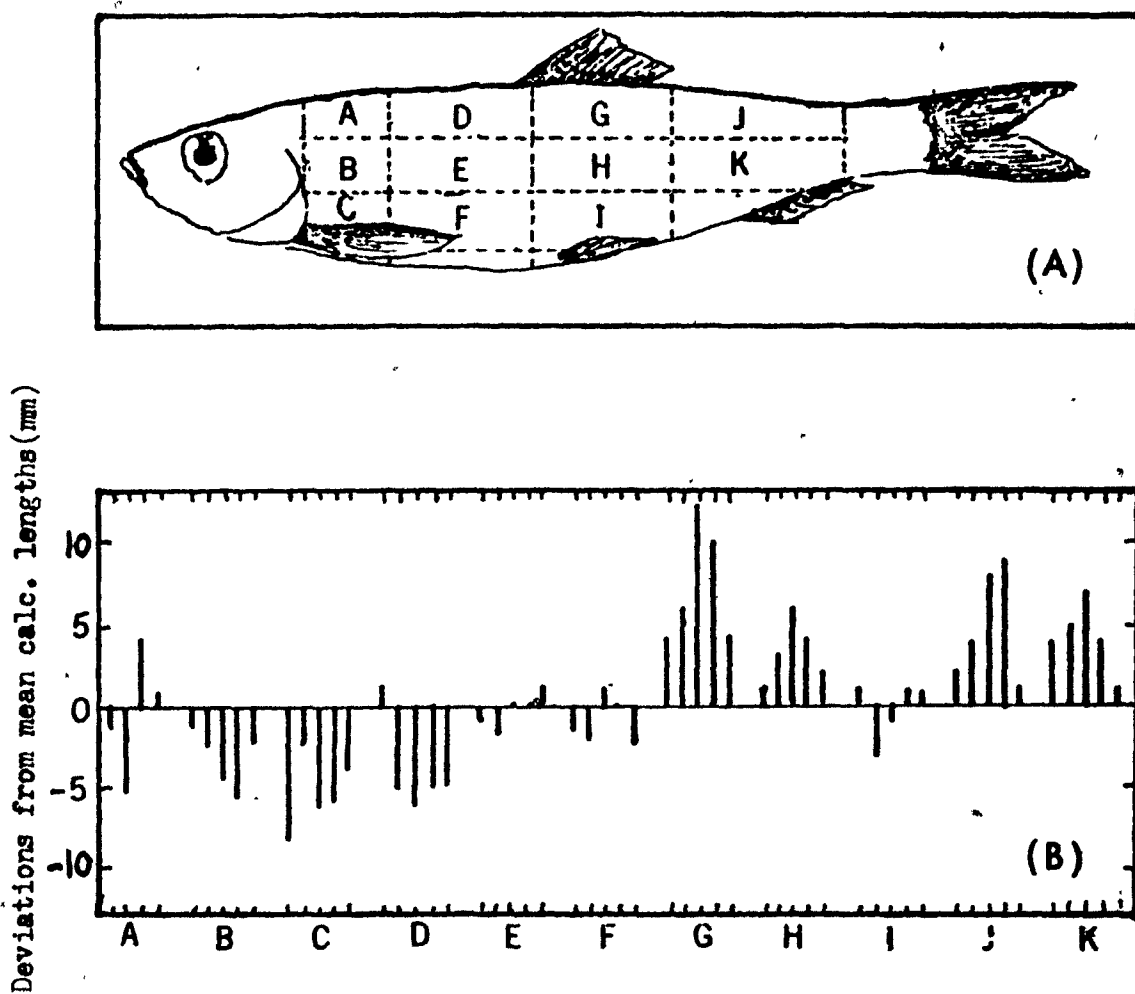


FIGURE 12: Herring fish areas from which scales have been examined (A) and deviations from mean calculated lengths based on scales of different areas (B).

The two methods are expressed by the following equations respectively.

$$\frac{L_{(n)}}{L} = \frac{V_{(n)}}{V}$$

and

$$L_{(n)} = (L - a) \frac{V_{(n)}}{V} + a$$

where

$L_{(n)}$ = estimated fish length at the time of formation of
'n' annulus,

L = fish length at time of capture,

a = fish length at time of scale formation,

V = scale radius to the anterior margin.

An example of the back-calculations by the two methods is presented in the appendix (Appendix Tables 18 and 19).

Comparison of the back-calculated lengths according to the two methods showed that the means of the calculated lengths by the direct proportional method are smaller than those by Lee's method (Tables 5 to 8). Empirical data indicate that the growth of scales on fish length are best fitted with a straight line intersecting the Y-axis at 40 mm. This value is similar to the length of herring at metamorphosis (Messieh, 1969), and is taken for the constant 'a' in Lee's equation shown above.

Mean back-calculated lengths of herring taken from the spring fishery were smaller than those from the autumn fishery (Tables 5 to 8). This is also clear from a comparison of the frequency distributions of

TABLE 5

Mean lengths of a spring herring sample back-calculated for various ages

DIRECT PROPORTIONAL METHOD

CODE 1652 DATE 68/5/6

AGE	SEX	L(1)	L(2)	L(3)	L(4)	L(5)	L(6)	L(7)	L(8)	L(9)	L(10)	L(11)	L(12)
6	1	112.29	220.55	272.95	297.45	311.16	320.33	0.00	0.00	0.00	0.00	0.00	0.00
		NUMBER	3.00	3.00	3.00	3.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00
		STD DEV.	31.42	10.55	20.67	17.02	18.83	19.50	0.00	0.00	0.00	0.00	0.00
		STD ERR.	18.14	6.11	11.93	9.82	10.87	11.25	0.00	0.00	0.00	0.00	0.00
6	2	140.33	247.32	304.83	324.96	342.22	352.00	0.00	0.00	0.00	0.00	0.00	0.00
		NUMBER	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
		STD DEV.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		STD ERR.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	COMBINED	119.30	227.24	280.92	304.33	318.93	328.25	0.00	0.00	0.00	0.00	0.00	0.00
		NUMBER	4.00	4.00	4.00	4.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00
		STD DEV.	29.23	15.93	23.21	19.55	21.85	22.45	0.00	0.00	0.00	0.00	0.00
		STD ERR.	14.61	7.96	11.60	9.77	10.92	11.22	0.00	0.00	0.00	0.00	0.00
7	1	121.09	207.79	253.06	282.97	300.97	316.72	327.42	0.00	0.00	0.00	0.00	0.00
		NUMBER	7.00	7.00	7.00	7.00	7.00	7.00	0.00	0.00	0.00	0.00	0.00
		STD DEV.	26.15	23.03	17.29	7.74	3.97	3.63	7.09	0.00	0.00	0.00	0.00
		STD ERR.	9.88	8.70	6.53	2.92	1.50	1.37	2.68	0.00	0.00	0.00	0.00
7	2	108.24	201.51	254.21	287.84	307.42	322.03	329.20	0.00	0.00	0.00	0.00	0.00
		NUMBER	10.00	10.00	10.00	10.00	10.00	10.00	0.00	0.00	0.00	0.00	0.00
		STD DEV.	21.45	30.13	33.51	23.57	16.96	16.44	15.81	0.00	0.00	0.00	0.00
		STD ERR.	6.78	9.52	10.59	7.45	5.36	5.20	5.00	0.00	0.00	0.00	0.00
	COMBINED	113.53	204.09	253.73	285.83	304.76	319.84	328.47	0.00	0.00	0.00	0.00	0.00
		NUMBER	17.00	17.00	17.00	17.00	17.00	17.00	0.00	0.00	0.00	0.00	0.00
		STD DEV.	23.61	26.83	27.27	16.47	13.36	12.82	12.66	0.00	0.00	0.00	0.00
		STD ERR.	5.72	6.50	6.61	4.48	3.24	3.10	3.07	0.00	0.00	0.00	0.00
8	1	93.93	190.21	247.85	276.75	294.61	308.63	321.55	330.23	0.00	0.00	0.00	0.00
		NUMBER	17.00	17.00	17.00	17.00	17.00	17.00	17.00	0.00	0.00	0.00	0.00
		STD DEV.	17.56	18.95	16.68	13.32	10.76	9.49	8.42	8.60	0.00	0.00	0.00
		STD ERR.	4.26	4.59	4.04	3.23	2.61	2.30	2.04	2.08	0.00	0.00	0.00
8	2	100.96	192.67	247.04	273.22	293.33	308.62	320.48	331.33	0.00	0.00	0.00	0.00
		NUMBER	12.00	12.00	12.00	12.00	12.00	12.00	12.00	0.00	0.00	0.00	0.00
		STD DEV.	42.51	33.35	18.49	13.86	11.30	10.76	9.67	10.00	0.00	0.00	0.00
		STD ERR.	12.56	9.62	5.33	4.00	3.26	3.10	2.79	2.88	0.00	0.00	0.00
	COMBINED	96.84	191.23	247.51	275.29	294.08	308.63	321.11	330.68	0.00	0.00	0.00	0.00
		NUMBER	29.00	29.00	29.00	29.00	29.00	29.00	29.00	0.00	0.00	0.00	0.00
		STD DEV.	30.54	25.37	17.13	13.42	10.80	9.84	8.81	9.05	0.00	0.00	0.00
		STD ERR.	5.67	4.71	3.18	2.49	2.00	1.82	1.63	1.68	0.00	0.00	0.00
9	1	86.90	171.03	223.47	258.70	283.01	300.02	314.26	323.83	332.12	0.00	0.00	0.00
		NUMBER	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	0.00	0.00	0.00
		STD DEV.	28.18	30.71	25.11	18.63	10.26	10.60	11.26	12.71	12.50	0.00	0.00
		STD ERR.	7.81	8.51	6.96	5.16	2.84	2.94	3.12	3.38	3.46	0.00	0.00
9	2	86.14	187.25	239.76	269.33	289.49	304.42	315.82	325.76	335.30	0.00	0.00	0.00
		NUMBER	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	0.00	0.00	0.00
		STD DEV.	23.31	10.35	24.28	16.89	11.82	9.27	9.14	8.91	14.64	0.00	0.00
		STD ERR.	4.54	6.77	5.42	3.77	2.64	2.07	2.04	1.99	3.27	0.00	0.00

TABLE 6
Mean lengths of a spring herring sample back-calculated for various ages

LEES METHOD
(A = 40.)

AGE	SEX	L(1)	L(2)	L(3)	L(4)	L(5)	L(6)	L(7)	L(8)	L(9)	L(10)	L(11)	L(12)
6	1	138.21	232.96	278.86	300.30	312.30	320.33	0.00	0.00	0.00	0.00	0.00	0.00
	NUMBER	3.00	3.00	3.00	3.00	3.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00
	STD DEV.	27.52	10.06	19.85	17.14	18.85	19.50	0.00	0.00	0.00	0.00	0.00	0.00
	STD ERR.	15.89	5.83	11.46	9.89	10.88	11.25	0.00	0.00	0.00	0.00	0.00	0.00
6	2	164.39	259.21	310.19	328.03	343.33	352.00	0.00	0.00	0.00	0.00	0.00	0.00
	NUMBER	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
	STD DEV.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	STD ERR.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	COMBINED	144.76	239.52	286.70	307.24	320.06	328.25	0.00	0.00	0.00	0.00	0.00	0.00
	NUMBER	4.00	4.00	4.00	4.00	4.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00
	STD DEV.	26.30	15.48	22.54	19.70	21.85	22.45	0.00	0.00	0.00	0.00	0.00	0.00
	STD ERR.	13.00	7.74	11.27	9.85	10.92	11.22	0.00	0.00	0.00	0.00	0.00	0.00
7	1	146.29	222.37	262.11	288.38	304.19	313.02	327.42	0.00	0.00	0.00	0.00	0.00
	NUMBER	7.00	7.00	7.00	7.00	7.00	7.00	7.00	0.00	0.00	0.00	0.00	0.00
	STD DEV.	22.99	20.02	14.95	6.65	3.61	3.93	7.09	0.00	0.00	0.00	0.00	0.00
	STD ERR.	8.69	7.56	5.65	2.51	1.36	1.48	2.68	0.00	0.00	0.00	0.00	0.00
7	2	135.11	217.08	263.40	292.90	310.06	322.89	329.20	0.00	0.00	0.00	0.00	0.00
	NUMBER	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.00	0.00	0.00	0.00	0.00
	STD DEV.	19.10	27.12	30.38	22.03	16.44	16.09	15.91	0.00	0.00	0.00	0.00	0.00
	STD ERR.	6.04	8.57	9.60	6.96	5.19	5.08	5.00	0.00	0.00	0.00	0.00	0.00
	COMBINED	139.71	219.26	262.87	291.04	307.64	323.88	328.47	0.00	0.00	0.00	0.00	0.00
	NUMBER	17.00	17.00	17.00	17.00	17.00	17.00	17.00	0.00	0.00	0.00	0.00	0.00
	STD DEV.	20.87	23.90	24.57	17.17	12.87	12.55	12.66	0.00	0.00	0.00	0.00	0.00
	STD ERR.	5.06	5.79	5.95	4.16	3.12	3.04	3.07	0.00	0.00	0.00	0.00	0.00
8	1	122.56	207.18	257.83	283.23	298.93	311.25	322.40	330.23	0.00	0.00	0.00	0.00
	NUMBER	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	0.00	0.00	0.00	0.00
	STD DEV.	15.53	16.97	15.08	12.20	10.16	9.20	8.39	8.60	0.00	0.00	0.00	0.00
	STD ERR.	3.76	4.11	3.65	2.96	2.46	2.23	2.03	2.08	0.00	0.00	0.00	0.00
8	2	129.80	209.41	257.21	280.23	297.92	311.36	321.79	331.33	0.00	0.00	0.00	0.00
	NUMBER	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	0.00	0.00	0.00	0.00
	STD DEV.	38.39	29.47	16.80	12.76	10.76	10.44	9.54	10.00	0.00	0.00	0.00	0.00
	STD ERR.	11.08	8.50	4.79	3.68	3.10	3.01	2.75	2.88	0.00	0.00	0.00	0.00
	COMBINED	125.14	208.18	257.57	281.99	298.51	311.29	322.26	330.68	0.00	0.00	0.00	0.00
	NUMBER	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	0.00	0.00	0.00	0.00
	STD DEV.	26.95	22.21	15.44	12.30	10.23	9.55	8.73	9.05	0.00	0.00	0.00	0.00
	STD ERR.	5.00	4.18	2.86	2.28	1.90	1.77	1.62	1.68	0.00	0.00	0.00	0.00
9	1	116.43	190.34	236.30	267.48	288.88	303.85	316.37	324.80	332.09	0.00	0.00	0.00
	NUMBER	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	0.00	0.00	0.00
	STD DEV.	24.84	26.75	22.04	16.78	9.87	10.30	11.14	12.10	12.42	0.00	0.00	0.00
	STD ERR.	6.38	7.42	6.11	4.65	2.73	2.85	3.09	3.35	3.44	0.00	0.00	0.00
9	2	115.79	204.76	250.94	276.94	294.67	307.80	317.83	326.57	334.96	0.00	0.00	0.00
	NUMBER	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	0.00	0.00	0.00
	STD DEV.	17.97	26.99	21.78	15.43	11.17	8.99	8.95	8.76	13.42	0.00	0.00	0.00
	STD ERR.	4.01	6.03	4.87	3.45	2.49	2.01	2.00	1.95	3.00	0.00	0.00	0.00

TABLE 7

Mean lengths of an autumn herring sample back-calculated for various ages

DIRECT PROPORTIONAL METHOD

CODE 1731 DATE 68/ 8/21

AGE	SEX	L(1)	L(2)	L(3)	L(4)	L(5)	L(6)	L(7)	L(8)	L(9)	L(10)	L(11)	L(12)
7	1	141.84	217.04	276.13	298.66	311.27	324.06	333.08	0.00	0.00	0.00	0.00	0.00
	NUMBER	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.00	0.00	0.00	0.00	0.00
	STD DEV.	39.36	35.57	28.19	16.39	15.28	14.46	12.04	0.00	0.00	0.00	0.00	0.00
	STD ERR.	12.44	11.25	8.27	5.18	4.83	4.27	3.80	0.00	0.00	0.00	0.00	0.00
7	2	142.72	223.01	274.09	301.25	318.14	329.08	337.55	0.00	0.00	0.00	0.00	0.00
	NUMBER	8.00	8.00	8.00	8.00	8.00	8.00	8.00	0.00	0.00	0.00	0.00	0.00
	STD DEV.	42.87	30.30	25.82	17.24	12.77	13.05	12.59	0.00	0.00	0.00	0.00	0.00
	STD ERR.	15.15	10.78	9.13	6.09	4.51	4.61	4.45	0.00	0.00	0.00	0.00	0.00
	COMBINED	142.23	219.70	273.22	299.81	315.32	326.29	333.06	0.00	0.00	0.00	0.00	0.00
	NUMBER	18.00	18.00	18.00	18.00	18.00	18.00	18.00	0.00	0.00	0.00	0.00	0.00
	STD DEV.	39.71	32.59	25.25	16.32	14.25	13.69	12.14	0.00	0.00	0.00	0.00	0.00
	STD ERR.	9.36	7.68	5.95	3.84	3.36	3.22	2.86	0.00	0.00	0.00	0.00	0.00
8	1	136.96	223.08	278.38	300.91	312.97	324.26	334.73	341.68	0.00	0.00	0.00	0.00
	NUMBER	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.00	0.00	0.00	0.00
	STD DEV.	44.21	21.14	13.69	16.82	16.84	15.10	13.15	12.25	0.00	0.00	0.00	0.00
	STD ERR.	13.98	6.68	4.32	5.32	5.32	4.77	4.15	3.67	0.00	0.00	0.00	0.00
8	2	152.57	234.61	278.01	297.85	313.14	325.46	335.28	343.40	0.00	0.00	0.00	0.00
	NUMBER	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	0.00	0.00	0.00	0.00
	STD DEV.	32.88	19.24	14.35	10.52	10.64	10.78	10.32	10.82	0.00	0.00	0.00	0.00
	STD ERR.	8.49	4.96	3.70	2.71	2.74	2.78	2.66	2.79	0.00	0.00	0.00	0.00
	COMBINED	146.33	230.00	278.16	299.07	313.07	325.98	335.06	342.71	0.00	0.00	0.00	0.00
	NUMBER	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	0.00	0.00	0.00	0.00
	STD DEV.	37.74	20.41	13.80	13.16	13.13	12.40	11.27	11.19	0.00	0.00	0.00	0.00
	STD ERR.	7.54	4.08	2.76	2.63	2.62	2.48	2.25	2.23	0.00	0.00	0.00	0.00
9	1	131.39	204.62	254.02	282.26	296.58	307.78	319.98	329.24	338.32	0.00	0.00	0.00
	NUMBER	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	0.00	0.00	0.00
	STD DEV.	34.69	30.64	41.52	19.50	19.74	14.26	11.05	9.34	8.22	0.00	0.00	0.00
	STD ERR.	11.56	10.88	13.84	6.50	5.24	4.75	3.68	3.11	2.74	0.00	0.00	0.00
9	2	119.87	209.65	270.35	293.12	307.96	319.19	330.17	339.49	345.63	0.00	0.00	0.00
	NUMBER	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.00	0.00	0.00
	STD DEV.	32.36	38.21	24.12	16.24	13.63	12.63	10.87	10.97	10.40	0.00	0.00	0.00
	STD ERR.	16.55	12.40	7.62	5.13	3.99	3.99	3.43	3.46	3.28	0.00	0.00	0.00
	COMBINED	125.32	207.27	282.61	287.98	302.57	313.79	325.34	334.64	342.17	0.00	0.00	0.00
	NUMBER	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	0.00	0.00	0.00
	STD DEV.	44.05	43.76	33.57	18.22	14.97	14.30	11.86	11.25	9.91	0.00	0.00	0.00
	STD ERR.	10.10	10.04	7.70	4.18	3.43	3.28	2.72	2.58	2.27	0.00	0.00	0.00
10	1	112.76	199.79	259.70	291.38	307.52	317.39	324.50	333.40	340.88	346.74	0.00	0.00
	NUMBER	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.00	0.00
	STD DEV.	59.77	55.10	35.96	10.06	7.81	12.65	12.58	13.73	12.70	12.62	0.00	0.00
	STD ERR.	29.88	27.55	14.98	5.03	3.90	6.32	6.29	6.86	6.10	6.31	0.00	0.00
10	2	123.72	204.79	257.26	281.38	298.96	313.26	324.14	332.68	340.20	346.85	0.00	0.00
	NUMBER	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	0.00	0.00
	STD DEV.	36.88	28.50	23.48	18.01	15.67	13.81	13.34	12.57	11.73	11.59	0.00	0.00
	STD ERR.	12.97	10.07	8.30	6.36	5.54	4.88	4.71	4.44	4.14	4.09	0.00	0.00

TABLE 8
Mean lengths of an autumn herring sample back-calculated for various ages

CODE 1731 DATE 08/ 9/21		LEES METHOD (A = 40.)											
AGE	SEX	L(1)	L(2)	L(3)	L(4)	L(5)	L(6)	L(7)	L(8)	L(9)	L(10)	L(11)	L(12)
7	1	165.25	231.42	283.76	303.63	314.75	326.04	334.00	0.00	0.00	0.00	0.00	0.00
	NUMBER	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.00	0.00	0.00	0.00	0.00
	STD DEV.	34.99	31.85	23.76	15.43	13.88	11.91	0.00	0.00	0.00	0.00	0.00	0.00
	STD ERR.	11.06	10.07	7.51	4.08	4.58	4.39	3.76	0.00	0.00	0.00	0.00	0.00
7	2	166.18	237.13	282.27	306.26	321.17	330.84	338.33	0.00	0.00	0.00	0.00	0.00
	NUMBER	8.00	8.00	8.00	8.00	8.00	8.00	8.00	0.00	0.00	0.00	0.00	0.00
	STD DEV.	38.15	27.47	23.69	16.09	12.37	12.75	12.44	0.00	0.00	0.00	0.00	0.00
	STD ERR.	13.48	9.71	8.37	5.69	4.37	4.51	4.39	0.00	0.00	0.00	0.00	0.00
8	1	165.66	234.06	283.10	304.80	317.60	328.17	335.92	0.00	0.00	0.00	0.00	0.00
	NUMBER	18.00	18.00	18.00	18.00	18.00	18.00	18.00	0.00	0.00	0.00	0.00	0.00
	STD DEV.	33.32	29.25	23.03	15.31	13.60	13.23	11.99	0.00	0.00	0.00	0.00	0.00
	STD ERR.	9.32	6.89	5.42	3.61	3.20	3.11	2.82	0.00	0.00	0.00	0.00	0.00
8	2	161.14	237.38	286.33	306.29	316.96	326.95	336.20	342.35	0.00	0.00	0.00	0.00
	NUMBER	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.00	0.00	0.00	0.00
	STD DEV.	39.01	18.90	12.93	16.08	16.18	14.70	13.01	12.25	0.00	0.00	0.00	0.00
	STD ERR.	12.35	5.97	4.09	5.08	5.11	4.64	4.11	3.87	0.00	0.00	0.00	0.00
9	1	175.14	247.85	286.29	303.86	317.41	328.32	337.03	344.22	0.00	0.00	0.00	0.00
	NUMBER	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	0.00	0.00	0.00	0.00
	STD DEV.	28.12	17.35	13.27	10.11	10.37	10.66	10.32	10.80	0.00	0.00	0.00	0.00
	STD ERR.	7.51	4.53	3.42	2.67	2.67	2.75	2.66	2.78	0.00	0.00	0.00	0.00
9	2	169.94	243.67	286.31	304.83	317.23	327.77	336.70	343.47	0.00	0.00	0.00	0.00
	NUMBER	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	0.00	0.00	0.00	0.00
	STD DEV.	33.38	18.47	12.84	12.57	12.68	12.15	11.21	11.19	0.00	0.00	0.00	0.00
	STD ERR.	6.67	3.69	2.57	2.51	2.53	2.43	2.24	2.23	0.00	0.00	0.00	0.00
9	1	156.15	220.93	266.62	289.57	302.22	312.13	322.90	331.09	339.12	0.00	0.00	0.00
	NUMBER	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	0.00	0.00	0.00
	STD DEV.	20.69	44.81	34.92	17.68	14.54	13.22	10.48	9.05	8.18	0.00	0.00	0.00
	STD ERR.	10.23	14.93	12.30	5.89	4.84	4.40	3.49	3.01	2.72	0.00	0.00	0.00
9	2	160.20	225.75	279.54	299.73	312.90	322.85	332.58	340.85	346.28	0.00	0.00	0.00
	NUMBER	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.00	0.00	0.00
	STD DEV.	46.39	34.77	21.44	14.72	11.94	12.06	10.76	10.94	10.44	0.00	0.00	0.00
	STD ERR.	14.67	10.99	6.78	4.65	3.78	3.81	3.40	3.46	3.30	0.00	0.00	0.00
10	1	150.91	223.47	272.47	294.92	307.84	317.77	328.00	336.23	342.89	0.00	0.00	0.00
	NUMBER	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	0.00	0.00	0.00
	STD DEV.	39.00	38.77	29.90	16.56	13.98	13.44	11.46	11.01	9.90	0.00	0.00	0.00
	STD ERR.	8.94	8.89	6.86	3.80	3.20	3.08	2.62	2.52	2.27	0.00	0.00	0.00
10	2	159.77	216.87	266.48	298.15	312.49	321.24	327.54	335.44	342.06	347.30	0.00	0.00
	NUMBER	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.00	0.00
	STD DEV.	92.61	48.17	25.67	8.37	7.95	12.35	12.32	12.32	12.19	12.58	0.00	0.00
	STD ERR.	26.30	24.08	12.83	4.18	3.97	6.17	6.16	4.76	6.09	6.29	0.00	0.00
10	1	149.65	221.49	268.02	289.42	305.01	317.69	327.33	334.90	341.55	347.45	0.00	0.00
	NUMBER	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	0.00	0.00
	STD DEV.	32.49	23.19	20.99	16.53	14.79	13.35	13.03	12.36	11.63	11.52	0.00	0.00
	STD ERR.	11.48	8.90	7.42	5.84	5.23	4.72	4.60	4.37	4.11	4.07	0.00	0.00

back-calculated lengths of spring and autumn herring at their first year of growth (L_1). These lengths were smaller for the spring spawners than for the autumn spawners (Table 9).

Growth Parameters

Estimates of growth parameters were obtained from the mean back-calculated lengths (according to Lee's method) by fitting the data to Von Bertalanffy's asymptotic growth curve using Allen's method (Allen, 1966).

The equation is as follows:

$$L_t = L_{\infty} (1 - e^{-k(t-t_0)})$$

where

L_t = body length estimated for time t ,

L_{∞} = theoretical maximum length,

k = coefficient of growth,

t_0 = theoretical time when body length = 0.

To find the value of 'k', mean back-calculated lengths at various ages were plotted according to Walford's method (Walford, 1946). All points fell almost on straight lines. These plots were used to find trial values of the growth constant 'k'. Knowing the lengths at time t , the growth parameters k , L_{∞} and t_0 were computed and the growth equations were derived as follows:

TABLE 9

Frequency distribution of lengths at first year's growth (L_1 's)
of spring and fall spawning herring populations

L_1 (mm)	90	100	110	120	130	140	150	160	170	180	190	200	Total
Spring fishery	1	36	52	101	84	52	36	9					371
Fall fishery			1	7	9	8	26	18	31	30	18	7	155

Spring 1966

$$L_t = 322.84 (1 - e^{-0.525(t + 0.015)})$$

Spring 1967

$$L_t = 321.75 (1 - e^{-0.514(t + 0.015)})$$

Spring 1968

$$L_t = 331.69 (1 - e^{-0.474(t - 0.084)})$$

Autumn 1967

$$L_t = 338.95 (1 - e^{-0.524(t - 0.277)})$$

Autumn 1968

$$L_t = 339.50 (1 - e^{-0.533(t + 0.189)})$$

These equations were used to construct the growth curves shown in Figures 13 and 14.

The similarity in growth curves for spring spawners in 1966, 1967, and 1968 was obvious (Figure 13). It was equally clear that growth curves for spring and autumn spawners in 1967 and 1968 samples were quite different. Maximum lengths (L_{∞}) were greater for autumn spawners as were the lengths at the end of their first year's growth. The latter are also clearly shown from their frequency distributions (Table 9).

Discussion

The results of growth analysis support two hypotheses:

- a. that spring and autumn fisheries exploit different populations,
- b. that the same group of spawners most likely come to the same fishery at successive years.

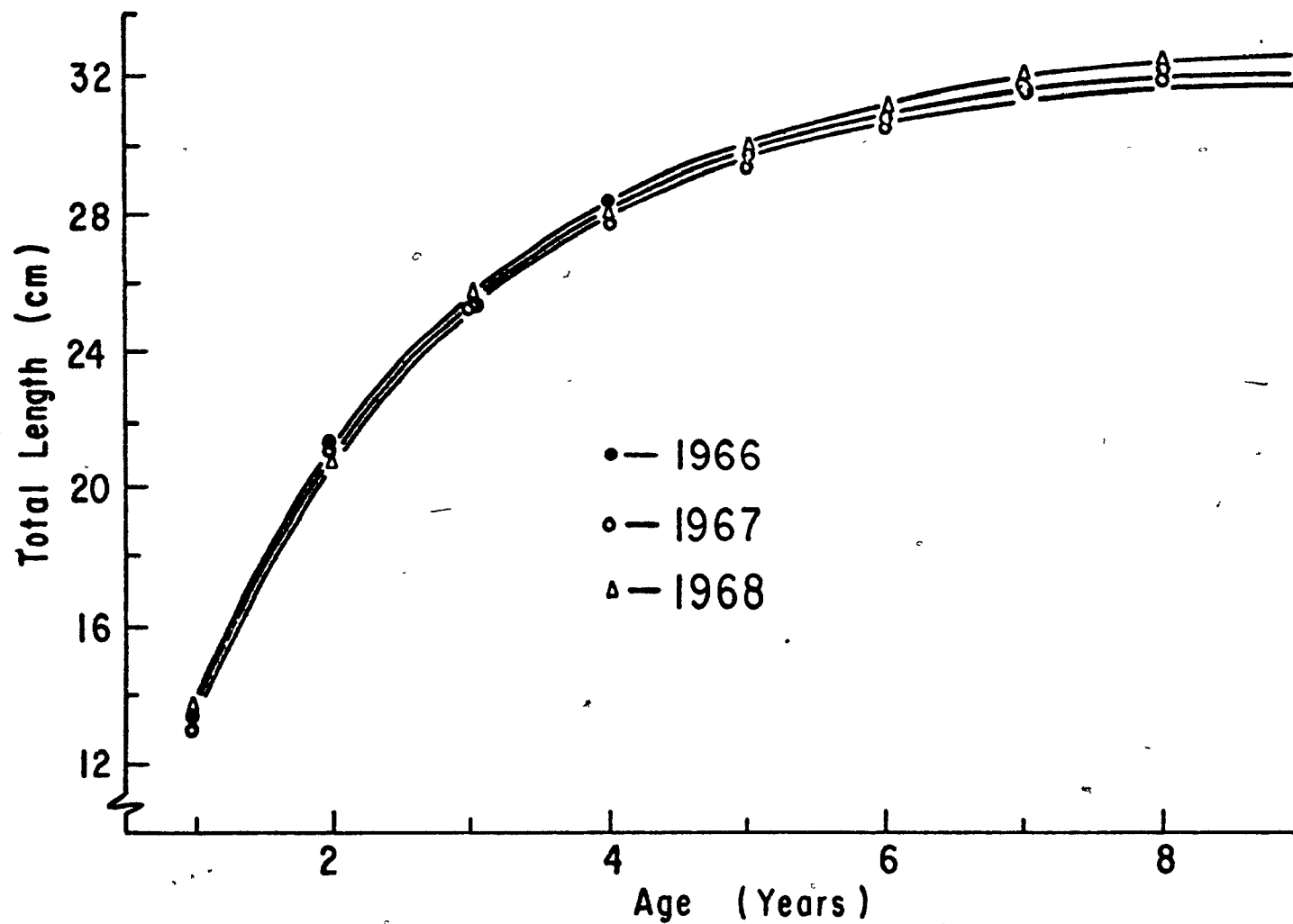


FIGURE 13: Growth curves of herring from the Gulf of St. Lawrence spring fisheries. Curves fitted to Von Bertalanffy growth equations.

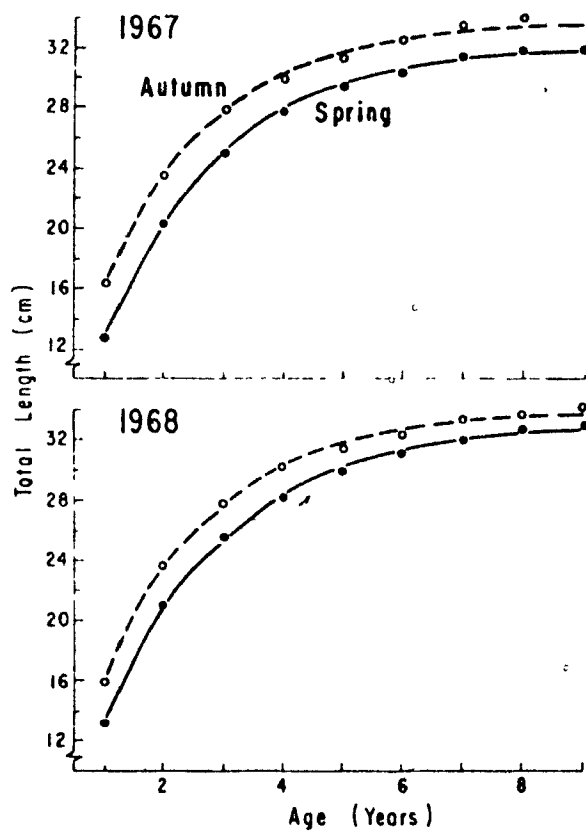


FIGURE 14: Comparison of growth curves of herring from spring and autumn fisheries in the Gulf of St. Lawrence. Curves fitted to Von Bertalanffy growth equations.

Lengths at first year's growth (L_1) were smaller for spring spawners than autumn spawners. The differences were most likely due to the difference in time of hatching between the two groups. Autumn spawned fish come late in the season where they fail to form a winter ring until the winter following their year of hatching, thus recording a larger size at their first year of growth.

Not enough data were available to study the seasonal variation in growth of adult herring. However, few samples of scales from immature herring (age-group 1) were available. Growth increments on these scales (Table 10) show that most of the growth is attained during the period from June to November. The growth was negligible (0.04 mm) during the winter (from December to April). This result agrees with results obtained from growth studies (Messieh, 1969b) on sardines in the Bay of Fundy (Figure 15).

TABLE 10

Frequency distribution and means of marginal increment
widths* of scales among immature herring

Width in mm	Apr.	June	July	Sept.	Nov.	Dec.
<0.10		10				
0.10-0.30		32				
0.30-0.50			3			
0.50-0.70			14			
0.70-0.90			25		1	
0.90-1.10	1		6	4	4	2
1.10-1.30	2		1	10	8	1
1.30-1.50	1			20	7	1
1.50-1.70	14			13	8	4
1.70-1.90	10			3	8	4
1.90-2.10	9				7	2
2.10-2.30	5				5	2
2.30-2.50	2				2	4
2.50-2.70	3					

* Distance between the outer ring and the anterior edge of the scale.

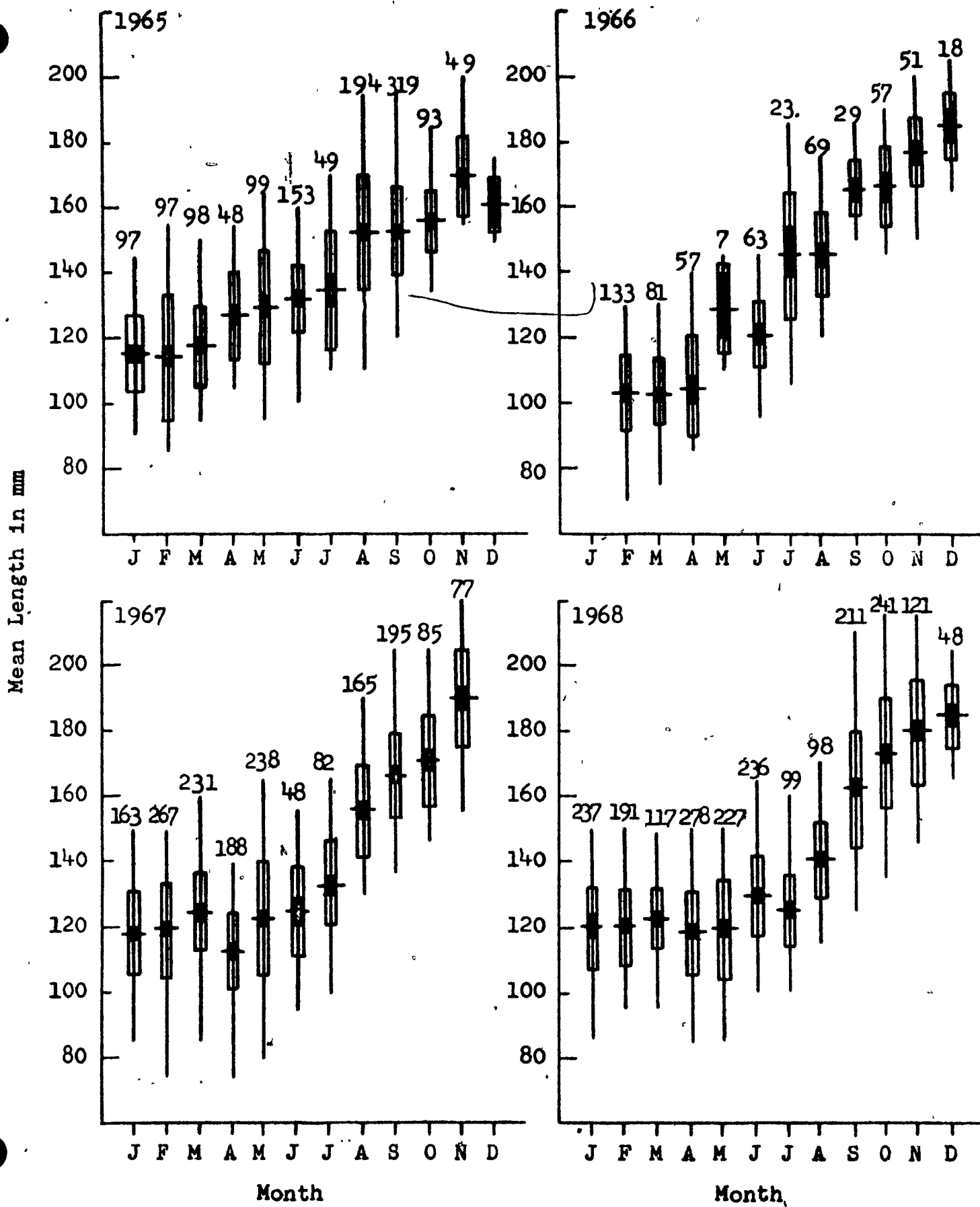


FIGURE 15: Seasonal growth of sardines in the Bay of Fundy in 1965 through 1968 (after Messieh, 1970).

MATURATION, FECUNDITY AND SPAWNING

Maturation

Maturation stages were recorded according to the maturity scale recommended by the Herring Group of the International Council of Exploration of the Sea (Anon., 1962). Maturity is divided into eight stages according to the size and the appearance of the gonads (Table 11).

For comparing the maturity stages of herring collected in the present investigation with those collected in earlier years, it was found necessary to establish criteria for converting the stages in the ICES maturity scale to the corresponding stages in the old system. This comparison is shown in Table 11.

The frequency distribution of maturation stages for 1965 through 1970 samples are presented in Tables 12 to 17. It is obvious that the majority of fish in both the spring and autumn fishery was in a spawning condition, i.e. either late stages of maturation or in ripe and running stage. This was less clear for 1970 samples in which there was more spread in the different maturation stages.

Monthly Variations in Maturation Stages

The seasonal nature of the herring fishery in the southern Gulf of St. Lawrence, and the deficiency of samples in non-spawning seasons, made it difficult to follow the variations in the maturation stages on a monthly basis. In 1970, however, sampling was expanded to

TABLE 11

Maturity stages and their description as recommended by ICES compared with maturity stages adopted in the present study.

Stages ICES Recom.	Description	Corresponding Stages in Previous Years	Definitions	Size of Gonads to Body Cavity
I	Virgin herring - gonads very small, thread-like.	A	Immature	Thread-like
II	Virgin herring with small gonads. Eggs can be seen by magnifying glass.			Very small
III	Gonads occupying about half of the ventral cavity. Eggs small but can be distinguished by naked eyes.			$\frac{1}{4} - \frac{1}{2}$
IV	Gonads almost as long as body cavity. Eggs larger varying in size, opaque.	B ₁	Maturing	$\frac{1}{2} - \frac{3}{4}$
V	Gonads fill body cavity. Eggs large, round, some transparent. Ovaries yellowish, testes mild white.	B ₂	Full	$\frac{3}{4} - \text{Full}$
VI	Ripe gonads, eggs transparent, testes white, eggs and sperms flow freely.	C	Ripe and Running	Products flowing
VII	Spent herring. Gonads baggy and bloodshot.	D	Spent	Baggy - small
VIII	Recovering spents. Ovaries and testes firm and larger than virgin herring in stage II. Wall of gonads striates.		Recovering	$\frac{1}{4} - \frac{1}{2}$

TABLE 12

Frequency distribution of maturation stages
of herring in the Gulf of St. Lawrence in 1965

Locality	Date	Sex	A	B ₁	B ₂	C	D	Total
Escuminac Pt.	May 7	M				45	9	54
		F				40	6	46
		T				85	15	100
Caraquet Is.	Aug. 12	M			2	23	1	26
		F				24		24
		T			2	47	1	50
Caraquet	Aug. 12	M			1	34	6	41
		F		1	3	55		59
		T		1	4	89	6	100

TABLE 13

Frequency distribution of maturation stages
of herring in the Gulf of St. Lawrence in 1966

M=male, F=female, T=total

Locality	Date	Sex	Maturation Stage					Total
			A	B ₁	B ₂	C	D	
Caraquet Is.	May 16	M	2		2	157	2	163
		F			9	78		87
		T	2		11	235	2	250
Pt. Sapin	May 19	M	3	1	5	129		138
		F	1	4	6	149	2	162
		T	4	5	11	278	2	300
	May 20	M	1		1	81		83
		F	1	1	2	113		117
		T	2	1	3	194		200
N. Rustico	May 23	M	1	12	37	41	2	93
		F		6	39	59	2	106
		T	1	18	76	100	4	199
Rustico	May 21	M		5	26	115	4	150
		F		4	32	110	4	150
		T		9	58	225	8	300
Egmont Bay	May 14	M			2	80	3	85
		F			2	60	3	65
		T			4	140	6	150
	May 16	M		1	3	93	4	101
		F		5	11	77	6	99
		T		6	14	170	10	200
	May 17	M		2	1	56	5	64
		F		5	17	92	12	86
		T		7	18	108	17	150
Souris	May 24	M	1	7	50	27	26	111
		F			50	15	22	87
		T	1	7	100	42	48	198
Magdalen Is.	May 18	M	3	20	20	126	27	196
		F	1	16	47	115	25	204
		T	4	36	67	241	52	400
	May 19	M	1	4	2	39	3	49
		F		1	7	39	4	51
		T	1	5	9	78	7	100
St. Ann's Bay	May 25	M	56	11	18	125		210
		F	54	15	19	166		254
		T	110	26	37	291	36	500
Grand Anse	May 17	M				148	2	150
		F			2	94	4	100
		T			2	242	6	250
Caraquet Is.	Aug. 2	M			5	49		54
		F	1	1	1	42	1	46
		T	1	1	6	91	1	100
Paspebiac	Aug. 1	M		1	45	1		47
		F	1	3	44	5		53
		T	1	4	89	6		100
Port Daniel	Aug. 3	M			62	1		63
		F	1	1	35			37
		T	1	1	97	1		100
Bonaventure Is.	Aug. 3	M	4		39	7		50
		F	2	2	43	3		50
		T	6	2	82	10		100

TABLE 14

Frequency distribution of maturation stages
of herring in the Gulf of St. Lawrence in 1967
M=male, F=female, T=total

Locality	Date	Sex	Maturation Stage					Total
			A	B ₁	B ₂	C	D	
Blue Cove	May 16	M	1	7	18	28	4	58
		F	3		12	23	4	42
		T	4	7	30	51	8	100
Blue Cove	May 17	M	2	1	7	44	2	56
		F	1		8	34	1	44
		T	3	1	15	78	3	100
Escuminac	May 18	M	1		9	141	6	157
		F	1			41	1	43
		T	2		9	182	7	200
Egmont Bay	May 25	M	1		9	95	2	107
		F			14	77		91
		T	1		23	172	2	198
N. Maisonette	May 30	M		1	19	20	6	46
		F		1	10	29	1	41
		T		2	29	49	7	87
	June 2	M			31	14	2	47
		F			19	31	3	53
		T			50	45	5	100
Orphan Bank	June 2	M		39	2		5	46
		F		43	2		3	48
		T		82	4		8	94
N. Maisonette	June 5	M			30	17	11	58
		F		1	19	16	6	42
		T		1	49	33	17	100
Magdalens	June 6	M	3			94		97
		F	5			98		103
		T	8			192		200
Grand River	Aug. 23	M			52		9	61
		F		1	30		5	36
		T		1	82		14	97
Paspebiac	Aug. 25	M	7		34		18	59
		F	8		19		14	41
		T	15		53		32	100
Miscou	Aug. 24	M			83	5		88
		F			67	13	2	82
		T			150	18	2	170
	Aug. 28	M			26	19	1	46
		F			4	50		54
		T			30	69	1	100

Table 14 continued:

Locality	Date	Sex	Maturation stage					Total
			A	B ₁	B ₂	C	D	
Paspebiac	Aug. 29	M			20		2	22
		F			28			28
		T			48		2	50
	Aug. 30	M			19	3	1	23
		F			23	4		27
		T			42	7	1	50
Miscou	Aug. 31	M			15	33	5	53
		F			6	37	4	47
		T			21	70	9	100
Paspebiac	Sept. 1	M			40	10	2	52
		F			28	16	4	48
		T			68	26	6	100
Miscou	Sept. 2	M			23	9	8	40
		F			21	25	14	60
		T			44	34	22	100
Miscou	Sept. 2	M			43	13	1	57
		F			37	6		43
		T			80	19	1	100

TABLE 15

Frequency distribution of maturation stages
of herring in the Gulf of St. Lawrence in 1968
M=male, F=female, T=total

Locality	Date	Sex	Maturation Stage								Total
			1	2	3	4	5	6	7	8	
Escuminac	May 3	M			2	16	13	89			120
		F			1	11	21	47			80
		T			3	27	34	136			200
Caraquet	May 4	M				9	9	103			121
		F				8	46	25			79
		T				17	55	128			200
Caraquet	May 8	M						71			71
		F					1	28			29
		T					1	99			100
Magdalen	May 5	M				14	29	63			106
		F				13	61	20			94
		T				27	90	83			200
Shippegan	May 7	M				18	15	26			59
		F				17	19	4		1	41
		T				35	34	30		1	100
Blue Cove	May 6	M			1	17	31	58		2	109
		F				11	36	40		4	91
		T			1	28	67	98		6	200
Egmont Bay	May 14	M						97		4	101
		F					2	96		1	99
		T					2	193		5	200
Egmont Bay	May 15	M				1	7	37		2	47
		F				1	5	45	1	1	53
		T				2	12	82	1	3	100
N. Rustico	May 30	M			6	5				11	22
		F			6	12				1	28
		T			12	17				1	50
St. Ann's Bay	June 1	M			15	26	11	11	1	27	90
		F			17	25	40	5		23	110
		T			32	51	51	15	1	50	200
Chaleur Bay	June 6	M	2	19		2		2	2	15	42
		F	1	17				2	9	29	58
		T	3	36		2		4	11	44	100
N. Rustico	June 20	M	1		53	36	2	1	1	3	97
		F			86	14				3	103
		T	1		139	50	2	1	1	6	200
Caraquet Is.	Aug. 17	M			5	7	27	57	21	2	119
		F			3		10	37	28	3	81
		T			8	7	37	94	49	5	200

Table 15 continued:

Locality	Date	Sex	Maturation Stage								Total
			1	2	3	4	5	6	7	8	
American Bank	Aug. 18	M			28	2			4	21	55
		F	1		25				2	17	45
		T	1		53	2			6	38	100
Escuminac	Aug. 21	M					36	51			87
		F					4	109			113
		T					40	160			200
Kouchibouguac	Aug. 22	M				17	19	5			41
		F				8	34	17			59
		T				25	53	22			100
Pictou, N.S.	Aug. 27	M				5	18	13			36
		F				6	25	33			64
		T				11	43	46			100
American Bank	Oct. 1	M	2	9	7	40				41	99
		F	1	3	46	1				50	101
		T	3	12	53	41				91	200

TABLE 16
Frequency distribution of maturation stages
of herring in the Gulf of St. Lawrence in 1969
M=male, F=female, T=total

Area Code	Month	Sex	Maturation Stage								Total
			1	2	3	4	5	6	7	8	
432	May	M			2	9	33	7		23	74
		F			12	3	37	12		12	76
		T			14	12	70	19		35	150
433	May	M			1		50	50	1	1	103
		F				1	34	59			94
		T			1	1	84	109	1	1	197
434	May	M		2	4	18	1			22	47
		F			14	12	8			19	53
		T		2	18	30	9			41	100
436	April	M			1		24	25			50
		F					36	14			50
		T			1		60	39			100
	May	M			1		39	8			48
		F					39	12		1	52
		T			1		78	20		1	100
437	May	M					109	18			127
		F					170	2			172
		T					279	20			299
	June	M	10	11	1	2	3		19	3	49
		F	3	8	4	7	18		5	2	47
		T	13	19	5	9	21		24	5	96
438	June	M	1	19	12	254	85		9	5	385
		F	8	32	95	208	31	1	26	14	415
		T	9	51	107	462	116	1	35	19	800
	July	M		2	1	5	83				91
		F		5	3	8	91				107
		T		7	4	13	174				198
	Sept.	M	21	103	35	13	12	4	112	26	326
		F	8	140	14	4	28		99	30	323
		T	29	243	49	17	40	4	211	56	649
470	May	M				1	10	11		2	24
		F			1	3	12	8		2	26
		T			1	4	22	19		4	50

TABLE 17

Frequency distribution of maturation stages
of herring in the Gulf of St. Lawrence in 1970
M=male, F=female, T=total

Area Code	Month	Sex	Maturation Stage								Total
			1	2	3	4	5	6	7	8	
431	April	M				2	41	2	1		46
		F			1	1	50	1	1		54
		T			1	3	91	3	2		100
	May	M				14	19	105	17		155
		F				21	55	59	10		145
		T				35	74	164	27		300
	Oct.	M		1	2	30	19		23	16	91
		F	3	13	20	31	1		16	23	107
		T	3	14	22	61	20		39	39	198
432	Sept.	M		1			9		30	4	45*
		F		4		2	8		25	10	55*
		T		5		2	17		55	14	100*
433	April	M				41	60	4			105
		F				83	10	2			95
		T			124	70	6			200	
434	April	M			1	43	36			4	84
		F			1	65	48			2	116
		T			2	108	84			6	200
	Sept.	M				1	12				13
		F				7	9				16
		T				8	21				29
	Sept.	M			19	12			9	9	49
		F		1	19		2		4	25	51
		T		1	38	12	2		13	34	100
435	Oct.	M		11	10	1			5	9	36
		F		15	4				33	12	64
		T		26	14	1			38	21	100
436	May	M				33	46	10			89
		F			5	53	26	18	7	2	111
		T			5	86	72	28	7	2	200
	Sept.	M					37	25			62
		F					18	20			38
		T					55	45			100
437	May	M			3	15	25	28	30	1	102
		F			3	14	31	24	26		98
		T			6	29	56	52	56	1	200

Table 17 continued:

Area Code	Month	Sex	Maturation Stage								Total
			1	2	3	4	5	6	7	8	
437	August	M	1	20	8	2	44	10		1	86
		F		20	13	9	52	9		10	113
		T	1	40	21	11	96	19		11	199
	Sept.	M				2	46	65	7		120
		F				14	31	32	1	2	80
		T				16	77	97	8	2	200
	July	M			14	23	30	8	8	2	85
		F		1	27	55	3	1	14	2	103
		T		1	41	78	33	9	22	4	188
438	August	M			66	12	112	29	60	2	281
		F		1	57	9	60	30	56	5	218
		T		1	123	21	172	59	116	7	499
	Sept.	M			11	13	4	37	18	2	85
		F			19	18	31	14	17	16	115
		T			30	31	35	51	35	18	200
	Oct.	M		52	22	2			12	11	99
		F		77	10		1		8	5	101
		T		129	32	2	1		20	16	200
439	August	M		5	31	5	2		4	1	49*
		F		8	33	5	1		2	1	51*
		T		13	64	10	3		6	2	100*

* Includes unknown stage

nine months of the year. Maturation stages of this year were plotted in percentages for each month to follow the monthly variations in these stages.

Results are shown in Figure 16. At each month the frequency distributions of maturation stages were plotted as percentages of other stages in the same month. This figure is useful not only to show the percentage distribution of maturation stages, but also to examine the dynamics of the maturation cycle and the duration of the maturation stages.

Discussion

The frequency distribution of maturation stages provides convincing evidence that each fishery is concerned mostly with a particular spawning group. This is not surprising, however, since prior to 1969 the fisheries were, for the most part, conducted on spawning concentrations. With the expansion of the fishery offshore it is to be expected that some fish of mixed origin would be caught and there is evidence of this in the 1969 and 1970 samples.

From the study of maturation stages as shown in Figure 16, the following conclusions could be reached. There are two spawning peaks, one in May and the other in September, separated by a short interval. The spring spawning is more restricted in its duration than the autumn spawning. The latter is extended from early July to late September. It is proposed that the fish belonging to this group should be described

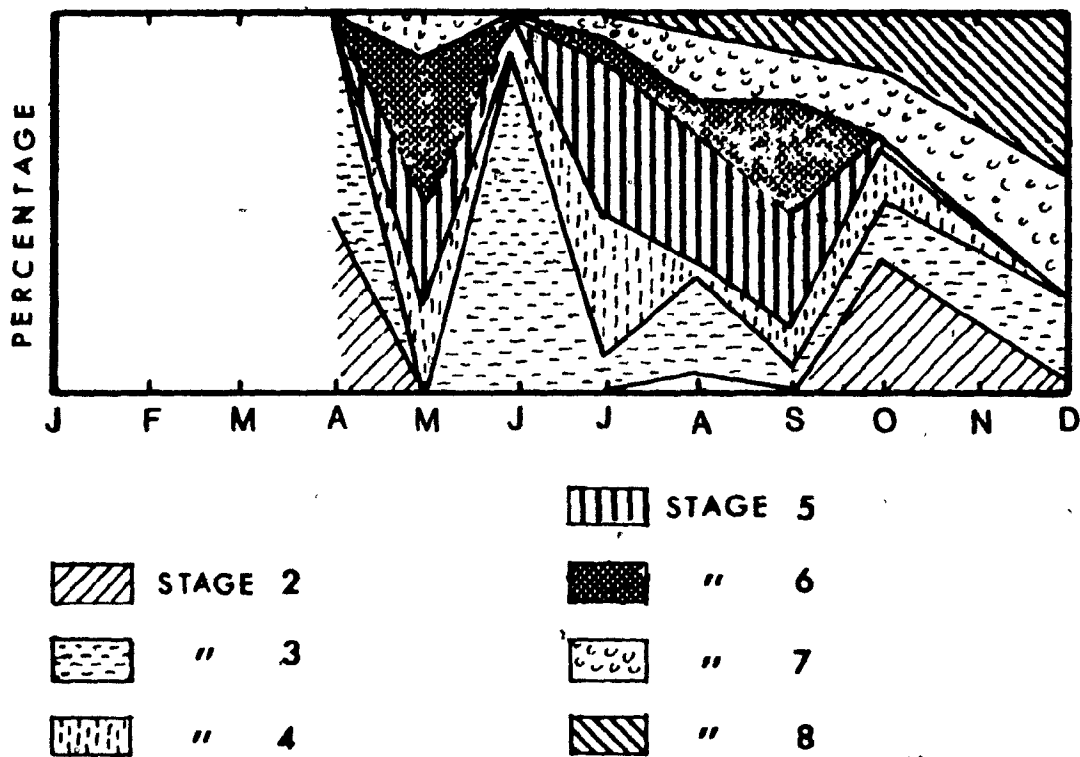


FIGURE 16: Maturation stages of herring expressed as percentages of the total showing the maturation cycles of spring and autumn spawning populations.

as 'summer-autumn spawners' as opposed to 'spring spawners'. The summer spawning part of the 'summer-autumn' spawners contributes a minor part compared to the autumn spawners.

It is also clear that maturation stage 3 was the dominant stage in June. None of the fish were in the recovering stage (stage 8) during this month, as would be expected. According to the maturity scale (Table 11) maturation stage 3 should follow stage 8 directly. It is difficult even to the experienced person to differentiate between these two stages especially when the fish are not in a fresh condition. This raises the question of the validity of separating these two stages (stages 3 and 8).

Another question logically follows: To which spawning group would the fish in stage 3 sampled in June belong? The same question could be asked about stage 3 fish caught in August. The answer to these questions would involve the problems of the use of maturation stages as criteria for discrimination between the spawning populations in seasons outside their spawning seasons, i.e. during the summer and possibly during the winter.

These problems will be discussed in Chapter 6 in conjunction with the use of other characteristics as criteria for separating the two spawning populations when the time of capturing does not permit the use of maturation stages in distinguishing the spawning populations.

Fecundity

A few samples, comprising 95 pairs of gonads, from spring and autumn herring spawners in the southern Gulf of St. Lawrence, were available, and used for fecundity estimates. After extraction, the ovaries were kept in Gilson's fluid until the connective tissue had been disintegrated and ova separated. The ova were subsequently washed and dried.

Two methods were used for estimating the numbers of ova. In 1968 samples, the estimates were made by the use of an electronic 'Decca Master Count' similar to the one used by Boyar and Clifford (1967) and Hodder (1972). Estimates of 1970 samples were taken from direct counts of subsamples in a counting tray. A subsample including from 200 to 300 ova was weighed and the ova counted. From the average number of the ova in the subsample, the weight of both the subsample and the whole sample being known, the number of ova for individual fish was estimated.

Fecundity estimates by fish length are presented in Table 18. Samples of spring spawning herring were few compared with autumn-spawning fish, but the difference between the two populations was clear; the autumn spawners were more fecund than the spring spawners. An exception was the sample from Maisonetfe in August 1970. Fecundity estimates for that sample were low, even lower than the spring spawners of the same length group. There was strong indication that the fish of this sample were partially spent. Hence it was decided

TABLE 18

Mean fecundity by length for spring- and autumn-spawning
herring in the southern Gulf of St. Lawrence during 1970.
Number of fish in parenthesis.

Length (cm)	Spring Spawners		Autumn Spawners				
	Egmont Bay April (thousands)	Summerside May (thousands)	Miscou July	Maisonette August	Escuminac September (thousands)	N. Rustico September	East Pt. September
26	19.6(10)						
27							
28	33.0(4)						
29			92.3(1)	81.5(1)		155.6(1)	
30	51.9(1)	78.0(2)	77.6(3)	54.2(3)			
31		97.6(2)	108.6(6)	61.8(4)	89.1(2)	100.7(2)	
32		89.4(1)	126.3(5)	61.7(6)	96.6(2)	112.6(6)	105.5(1)
33			216.((2)	85.4(4)		156.7(1)	
			130.4(4)	78.5(4)	122.1(4)	134.8(2)	96.2(1)
35			128.4(2)	72.8(10)	120.0(1)		113.3(3)
				72.4(3)			133.8(1)
37				85.9(1)			

to eliminate this sample from further analysis.

The estimates (Table 18) ranged from 92,300 to 133,792 eggs for fish of 29.0 cm to 36.0 cm respectively in the case of autumn spawners. Estimates of the eggs of the spring-spawners ranged from 19,600 to 89,400 for 26.0 cm to 32.0 cm length groups respectively.

A sample of ova from fish taken at Caraquet in August 1968 comprising 23 fish was available (Barrett, unpublished). Fecundity estimates for this sample were comparable to those of the autumn spawners found in this study (Table 18).

Discussion

Fecundity estimates showed clearly that autumn spawning herring are more fecund than spring spawning herring. This is in agreement with the general conclusion on herring from other areas, and reported by various authors (Baxter, 1959; Parrish and Saville, 1965; Hodder, 1972).

The estimates from spring spawners, however, were much higher than those reported by Barrett (1968) for a sample from the same general area. This author gave fecundity estimates of 49,600-61,400 eggs for herring ranging 30 to 34 cm in length (Table 19), compared to 69,300-89,400 eggs for herring ranging from 30 to 32 cm, shown in this study. Hodder (1972), commenting on the low values of Barrett (*op. cit.*) suggested that the samples could have included partially spent fish.

TABLE 19
Fecundity data by length of herring in the
Gulf of St. Lawrence from various sources
(in thousands)

Length (cm)	Spring Spawners			Autumn Spawners	
	A	B	C	D	E
26	19.6				
27			38.5		
28	33.0		45.2		
29			52.8	82.6	
30	69.3	49.6	61.3	77.6	
31	97.6	52.3	70.9	103.1	95.0
32	89.4	55.2	81.6	114.7	113.0
33		58.5	93.5	137.2	107.3
34		61.4	106.7	144.2	146.7
35			121.3	119.5	125.8
36			137.1	133.8	137.2
37			155.2		

- A: Southern Gulf (present study)
B: Southern Gulf (Barrett, 1968)
C: SW Newfoundland (Hodder, 1972)
D: Southern Gulf (present study)
E: Southern Gulf (Barrett, unpublished)

It appears from this study ~~that~~ this is most likely the explanation for this discrepancy.

A similar discrepancy was observed in the present data for the sample taken from Maisonette in August 1970. Values of fecundity estimates of this sample were obviously lower than the other samples in the same length group. The only explanation is that the fish in this sample were in a late stage of maturation and they were partially spent. Discussions with field technicians who were involved in field collections revealed that this possibility should not be excluded. It appears also that the larger fish within a sample manifests this discrepancy more than smaller fish. This would be expected since larger fish start spawning a few days earlier than younger fish of the same population.

Estimates of fecundity of autumn spawners taken in August 1968 (Barrett, unpublished) were comparable with the results shown in this study despite the fact that the estimates were made by two different methods.

In attempting to find an interpretation for the differences in fecundity between spring spawners and autumn spawners, various authors put forward different hypotheses (Blaxter and Saville, 1965; Baxter, 1959). These authors related the differences in fecundity to both genetic and environmental factors.

Vladykov (1956) emphasized the importance of food; an abundant food supply prior to spawning results in higher fecundity. Hodder

(1972), assuming the importance of food abundance to herring and its possible effect on their fecundity, suggested that the significant difference in fecundity between spring and autumn spawners could be attributed to the very different environmental conditions existing in the months preceding the spawning periods.

Food and stomach conditions of herring presented in this study - and shown in another section of this text - indicate that spring spawners were fasting prior to spawning. They pass directly from the wintering stage to the spawning stage. Autumn spawners feed vigorously during the summer on the growth of the secondary production on the Magdalen Shallows prior to their spawning. This might explain the higher fecundity of autumn spawners.

Other authors (e.g. Dunbar, 1960) were concerned with the various physiological differences involving, among other things, fecundity, spawning seasons, etc. Dunbar (*op. cit.*) referred to the fact that in higher latitudes many species produce their young not simply at any time of year, but specifically in the dead of the winter, when sources of food other than phytoplankton must be used. The relatively high fecundity is interpreted as a mechanism safeguarding the stock from recruitment failure.

Spawning

Records on herring spawning localities and times of their arrival were collected from Fisheries Service Officers. A questionnaire was sent in December 1970 to the Officers who have herring in

in their districts. The questionnaire included among other things questions on spawning localities, times and duration of spawning in their districts.

Eleven persons reacted to the questionnaire and sent their replies in January 1971. A summary of the information collected appears in Table 20, from which it appears that most of the localities support both spring and autumn herring. Their relative strengths, however, vary by the locality. Spawning times also appeared to vary from one locality to the other. The trend was towards an earlier autumn spawning off the mouth of Chaleur Bay, and a progression to a later autumn spawning in a southeastern direction. During the summer another spawning group appeared, although to a much less extent. These fish were probably intermingling with the two other spawning groups on the feeding grounds. In their remarks, the Fisheries Officers pointed out possible shifts, either in spawning times or localities, which appear to have taken place in recent years.

More information on herring spawning and fishing were available from an unpublished report by Leim (1943-1944). The report concerned a trip which he had made in 1943-1944 during which he interviewed the herring fishermen and the Fisheries Officers in Nova Scotia, New Brunswick, P.E.I., and Quebec. This report contains much information on various aspects of herring fisheries, and I found it useful to present a concise summary on the results of these interviews which are more pertinent to the subject. The summary is presented in the Appendix.

TABLE 20

Spawning times and locations in southern Gulf of St. Lawrence
based on information received from Fisheries Officers

District	Spring Spawning	Autumn Spawning	Other Spawning	Remarks
Cheticamp N.S.	May 15 1½ month	September 1 month	July	
Arichat N.S.	April 20 20 days	None		No changes observed in Bras d'Or Lake and St. Peter's Bay.
Caraquet N.B.	1st week May 2 weeks	1st week August 1½ month		
North Sydney N.S.	May 1 week	August 1 week	None	
Ingonish N.S.	April 15 (or as soon as ice moves) stay until late fall.	September, lasts to November occasionally.	June, several weeks until July 1st.	Mixture of herring, not sure which herring are spawning and which are not.
North Rustico N.B.	April 20, then several more 2-3 weeks.	August 25 3 weeks	Summer in some years.	Much scarcer than it used to be 70 years ago. At that time the waters in spring used to be white as milk for acres and acres; lobster traps coated with spawn ½ inch thick.
Escuminac N.B.	May 1st 2 weeks	September 3 weeks		In the last two years there has been a large decrease in the catch.
Pictou N.S.	May 4-6 weeks		Last of July 6 weeks	

Table 20 continued

District	Spring Spawning	Autumn Spawning	Other Spawning	Remarks
Port Hood N.S.	April 20 in late years May 15-20 10-15 days.	October 10-15 2-3 weeks	June 20-25 1 month	Three runs of spawning, early spring, summer and fall.
Alberton PEI	April 20 4 weeks	Late August and early September.	June 25- July 15, 3-4 weeks.	Spring herring are not coming any more; the first run seems to be getting stronger. The June run might be the same but a bit larger. Full run herring are quite large.
Egmont Bay PEI	April 15 until May 20.	August 30 until September 4-6.	June 30 1-2 days	

Hourston (1968, 1969) reported on herring spawning along the Newfoundland coast. From the records of spawning which had been collected from the Department of Fisheries officers he concluded that herring spawn relatively close to the shore in spring (April, May and June) at locations spread over most of the coasts of Newfoundland.

The fish appeared to spawn as large groups or schools in relatively shallow water. None of the fish were reported to spawn in the autumn.

Hourston also reported that in 1967 the fish failed to spawn in traditional spawning areas, and shifted from the major inshore spawning locations. He related these marked changes in the distribution and timing of spawning to deviations from the 'normal' environmental conditions on the traditional spawning grounds.

On the basis of the information that has been collected on herring spawning grounds (Table 20) and the probable spawning times and locations inferred from sampling the catch for maturation stages, spawning grounds were plotted (Figure 17). It is shown that the spawning localities are numerous and scattered. Records of smaller spawning patches or minor spawning beds of local nature were not included in the figure. However, practically in every bay and off the mouths of big rivers there are spring spawnings of variable sizes.

Spring spawning grounds are more inshore than the autumn grounds. A major spring spawning ground is concentrated around the Magdalen Islands. Another major ground is located in Caraquet-Miscou area near

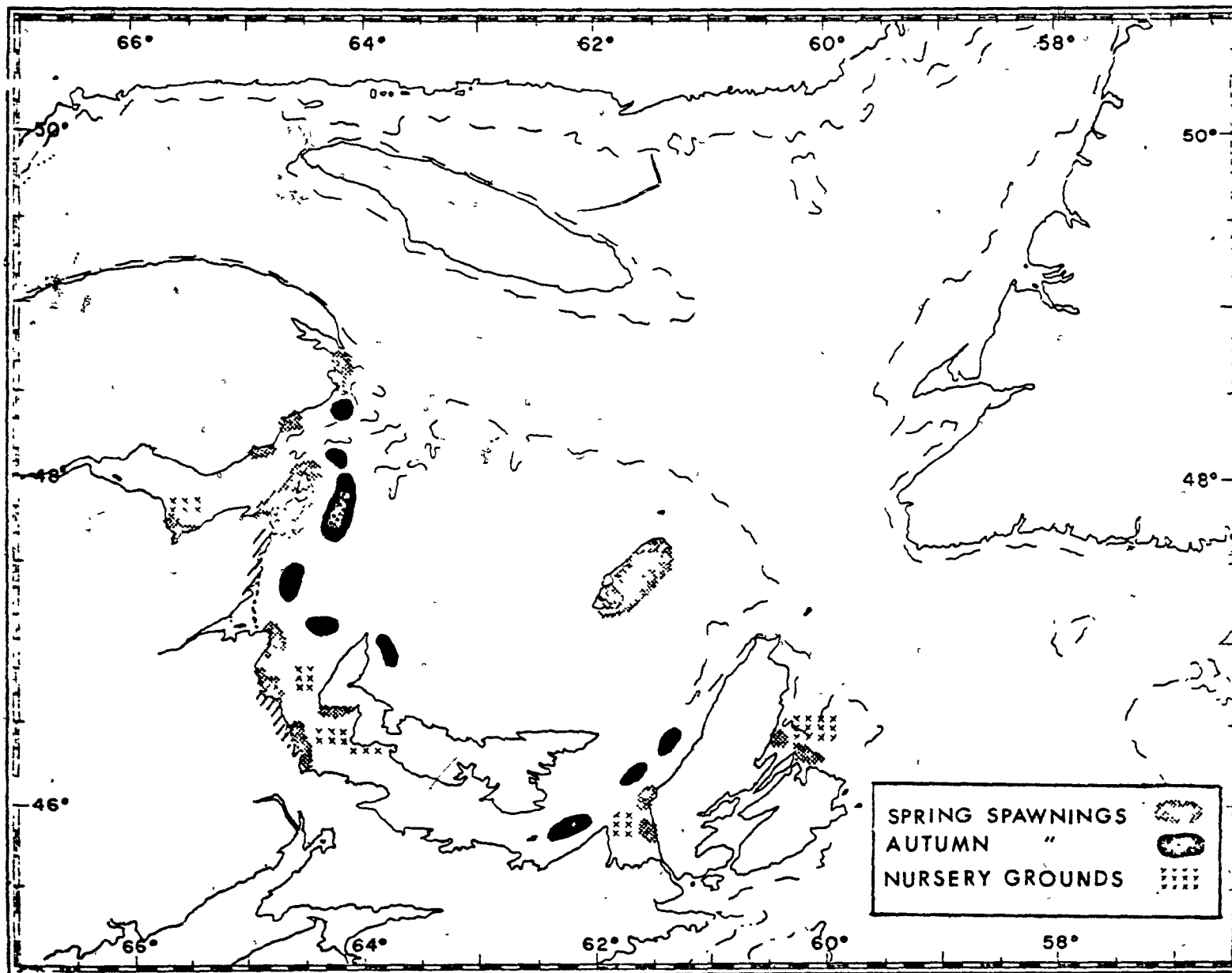


FIGURE 17: Herring spawning grounds in the Gulf of St. Lawrence

the mouth of the Bay of Chaleur. In the latter area, autumn spawning grounds are located in the same general area although in deeper waters.

Discussion

From the distribution of herring spawning localities in the area of Magdalen Shallows, it appears that these localities are numerous and scattered. This is probably an adaptation for survival and greater abundance. In an area such as the Magdalen Shallows which is characterized by erratic hydrographic conditions, the multiplicity of spawning grounds would be necessary for compensating any possible destruction of spawning beds. Destructions of herring spawning beds are not unusual. There have been occasional reports on spawning beds destroyed by wind and tide actions. There were also reports on cases of herring eggs piled on the shore and taken by farmers for use as fertilizers.

Although in general the timing of spawning for both spring and autumn spawners has not changed much from the past (Table 21), the relative strengths of the two spawning groups appear to be shifting towards more abundance for autumn spawners (Figure 18). This is also demonstrated from a comparison of the 1971 catch of herring by fixed fishing gear with those caught in the forties (Figures 19 and 20). The reasons for the shift in abundance between autumn and spring herring population could be that the latter were more vulnerable to the fishermen, as they come closer to the shore for spawning.

Another reason could be that the mass mortalities of herring

TABLE 21

Dates of arrival of herring on the spawning grounds
(1946-63), and peaks of the spawning seasons (1965-69)
of spring and autumn herring in the Gulf of St. Lawrence.

Year	Locality	Spring Fishery	Autumn Fishery
1946	Magdalen Islands	29 April	-
1948	"	30 "	-
1949	"	24 "	-
1950	"	30 "	-
1951	"	4 "	-
1952	Grand River	28 "	14 August
1953	"	18 "	10 "
1954	"	23 "	16 "
1955	Magdalen Islands	18 "	-
1958	"	7 "	-
1960	"	8 "	-
1962	"	30 "	-
1963	"	29 "	-
1965	Caraquet	-	16 August
1966	"	17 May	2 "
1967	"	17 "	24 "
1968	"	6 "	17 "
1969	"	3 "	21 "

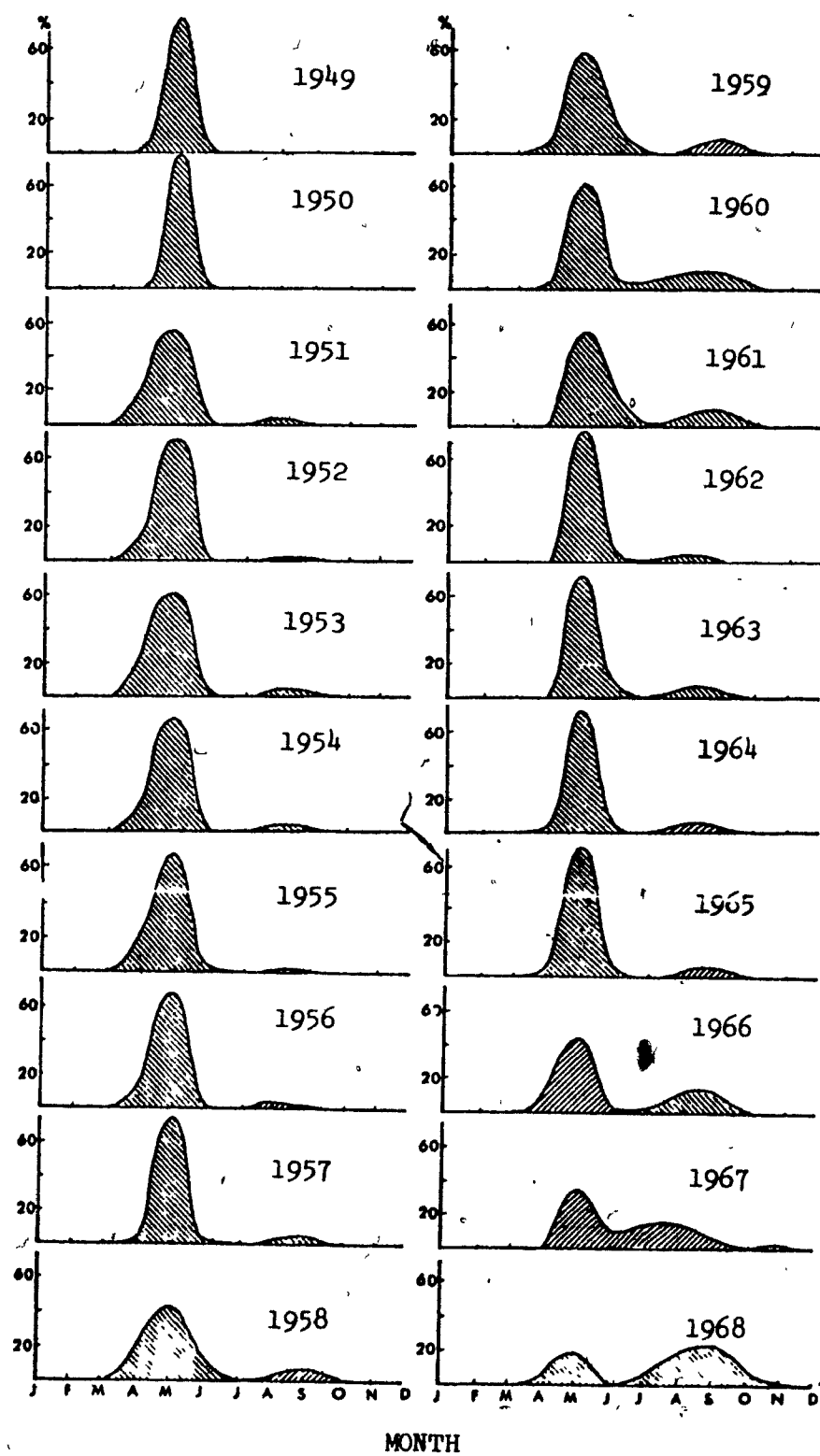


FIGURE 18: Monthly distribution of herring catches showing the shift in seasonal trend of the fishery in 1949 through 1968.

caused by an epizootic '*Ichthyosporidium hoferi*' which apparently affected spring spawners more than autumn spawners. Sindermann (1958) in his description of the disease reported the following: "Widespread herring mortalities, particularly of mature spring-spawning fish, were first reported from the Gulf of St. Lawrence - late spring and early summer of 1954. Dead fish were observed floating in shoals at the surface, were washed up on shores of the Gulf, and were taken in nets of otter trawlers. Mortalities extended from the west coast of Newfoundland to Gaspé coast and from Anticosti Island to Northumberland Strait. Deaths were first apparent in mid-May, reached a peak in June, continued at a reduced rate through July, and apparently ceased in August. Abnormal, lethargic, moribund herring could be seen inshore, particularly near breakwaters, throughout the period. Deaths occurred sporadically in such inshore aggregations, the dying fish sinking to the bottom to become part of an extensive litter of herring carcasses. This pattern was repeated in 1955 as far as number of fish, abnormal behavior, and time were concerned. Mortalities in 1956 were drastically lower, being confined to the Chaleur Bay region and the Magdalen Islands, and to relatively few fish as compared to 1954 and 1955."

Although the Magdalen Shallows support spring and autumn herring spawning populations, reports on herring on the Newfoundland coastal areas indicate that spring spawning herring is the only herring native to Newfoundland (Hourston, 1967; Hodder and Winters, 1972). Olsen (1960) on the basis of the maturation stages of Newfoundland herring was of the opinion that herring in Newfoundland "spawn practically every month of the year," and that there is an "extreme spread

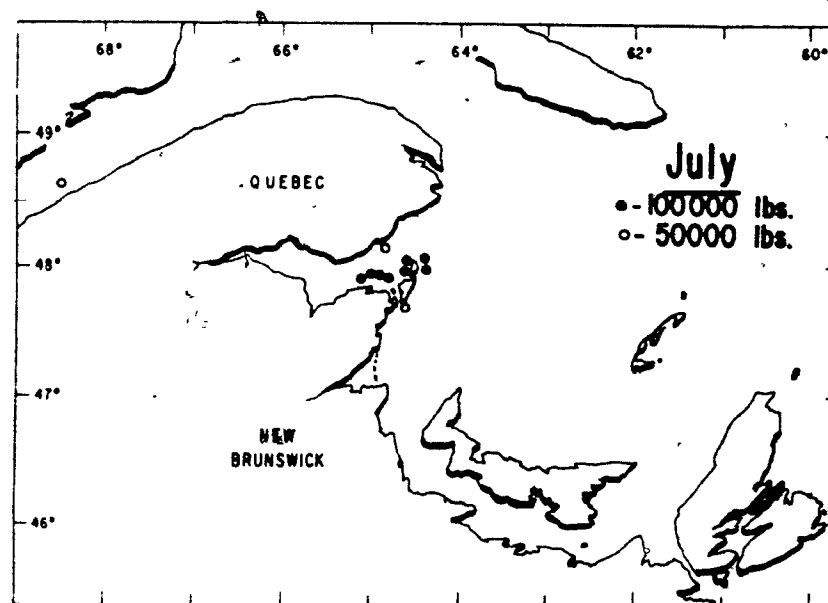
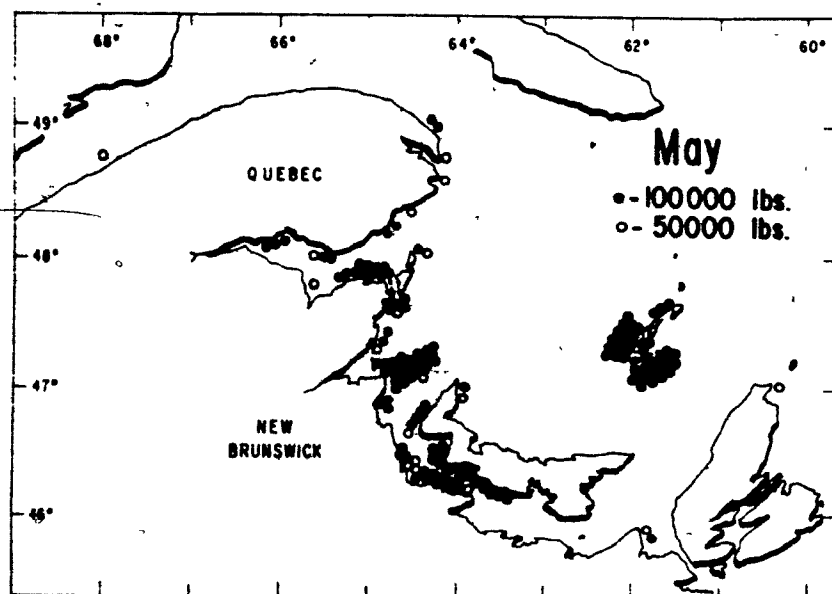
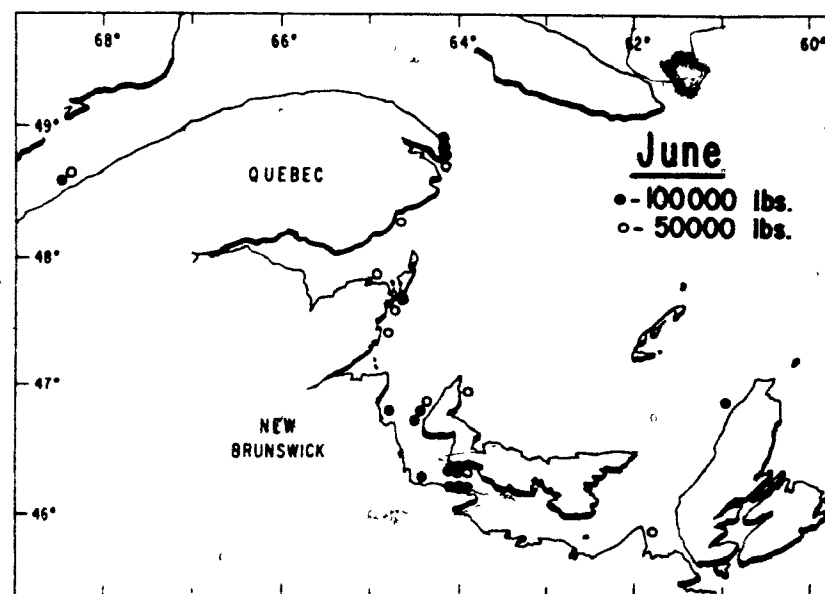
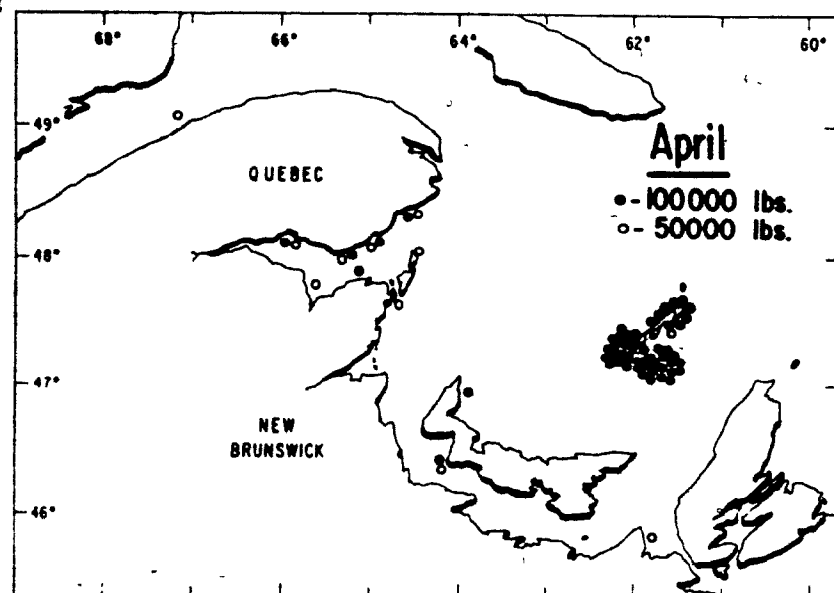


FIGURE 19: Catch of herring by stationary fishing gear (gill nets and traps) in 1971

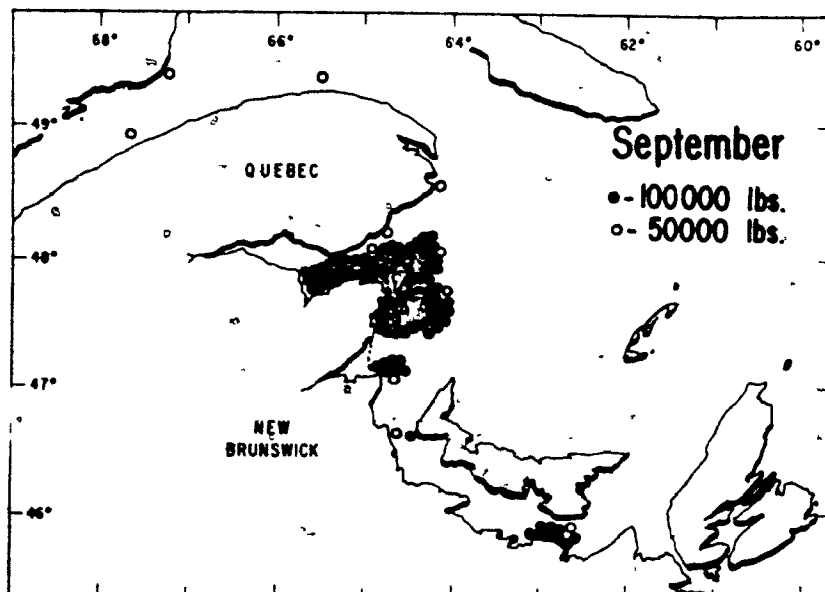
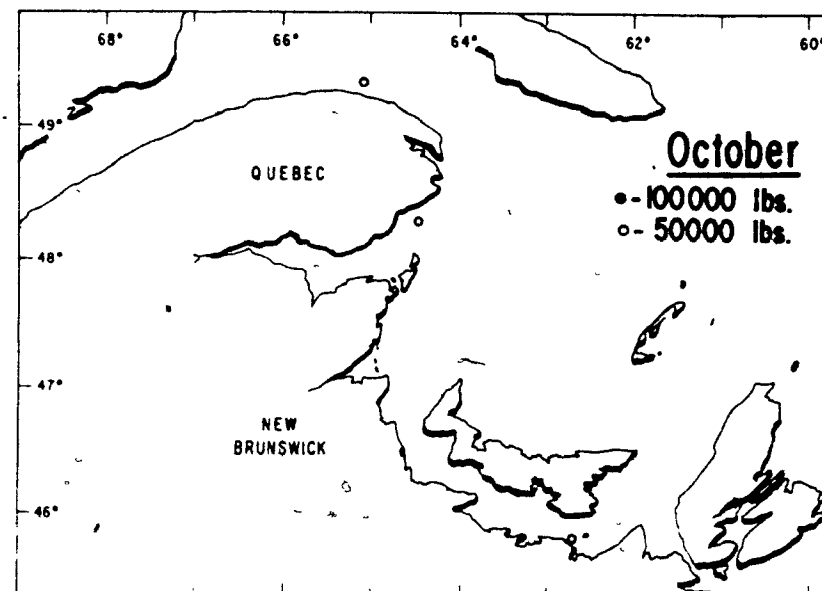
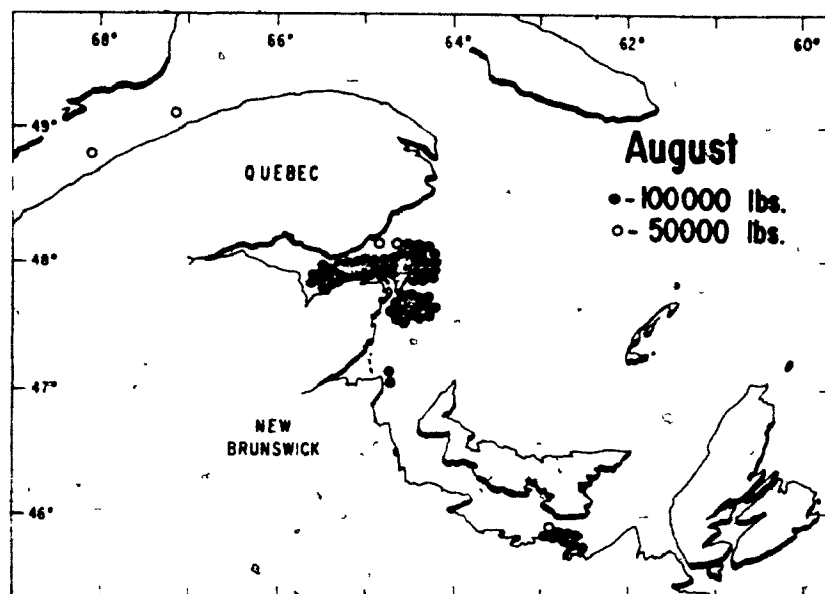


FIGURE 20: Catch of herring by stationary fishing gear (gill nets and traps) in 1971

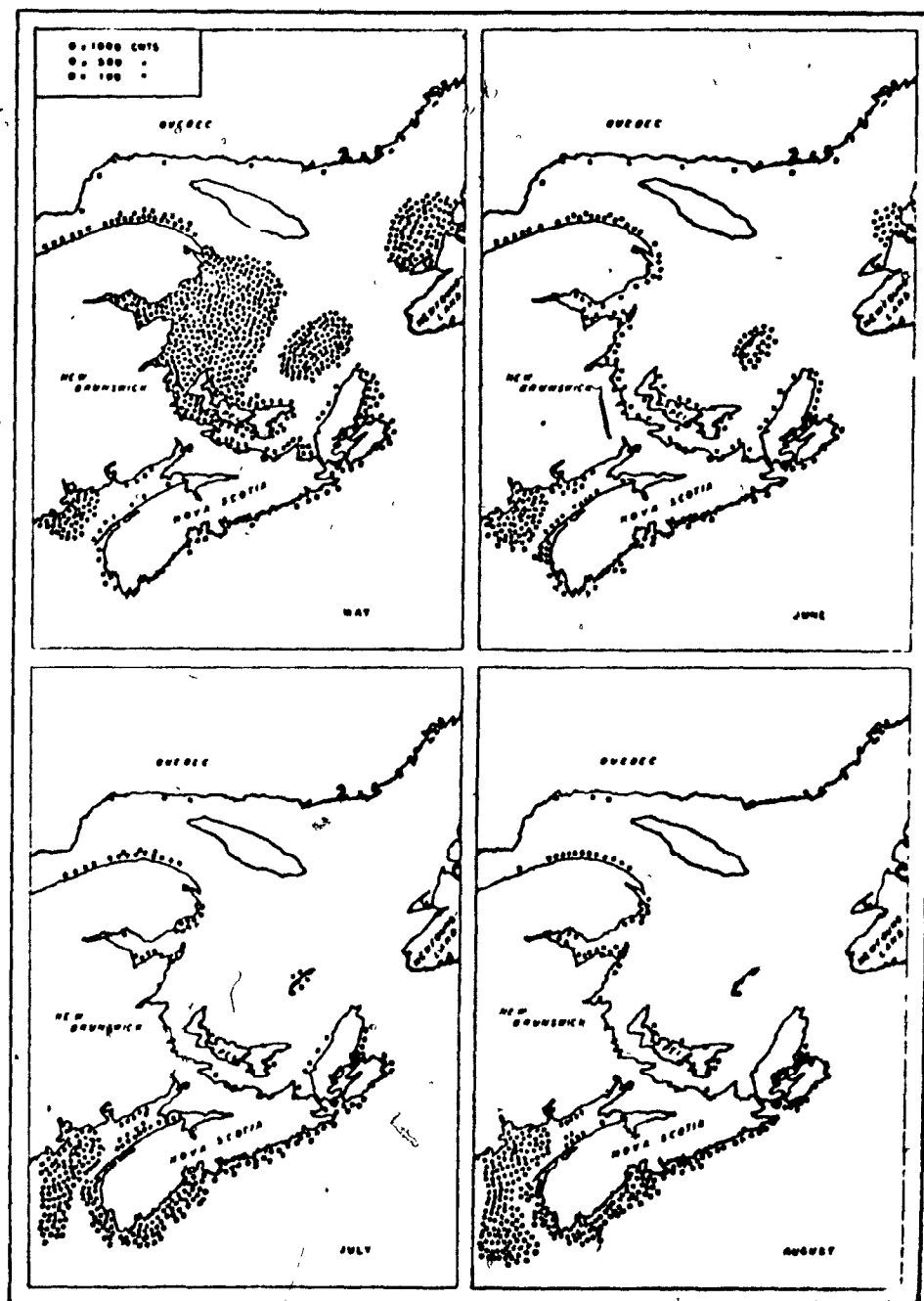


FIGURE 21: Seasonal trend in the catch of herring in the Gulf of St. Lawrence in the Forties (after, Leim *et al.*, 1957)

in spawning time and a considerable winter (December-January spawning)." Olsen apparently was in error. He was misled by the presence of advanced stages of maturation, during winter, not realizing that these were spring spawning population overwintering in this area. Recent reports (Hourston, 1967, 1968; Hodder and Winters, 1972) indicate that no significant spawning of herring occurs in western and southern Newfoundland in the fall.

Records of autumn-spawned herring larvae in Esquiman Channel have been reported by Squires (1957). This has been interpreted by Olsen (1961) as an evidence of the presence of autumn spawning herring in Newfoundland. A different interpretation, however, could be offered on the basis of the pattern of larval herring dispersal and the general surface drift in the Gulf of St. Lawrence (Messieh and Kohler, 1972). It is likely that some larvae which were spawned on the Magdalen Shallows could be drifted passively with the prevailing surface current to the east side of the Gulf across the Laurentian Channel.

USE OF MERISTIC CHARACTERS IN IDENTIFYING HERRING STOCKS

Use of Single Meristic Characters in Separating Spring and Autumn Herring Populations

In 1969, 400 fish were collected from each of the spring and autumn fisheries in the southern Gulf of St. Lawrence. The objective was to investigate the possibility of the use of meristic differences in herring stock identification.

The fish were x-rayed, and the radiographs were examined for vertebral counts. Dorsal and pectoral fins were cut, spread on polyethylene sheets, and x-rayed. The counts were done from radiographs on an illuminated background, and by the aid of a magnifying glass.

Some of the fish were unsuitable for the counts, either because they were badly mounted, unclearly developed, or suspect for loss of rays or fusion of vertebrae. This reduced the number of the fish that were used for comparisons.

Gill arches (first left arch) were collected from a subsample at random from each group. The gill rakers on the lower branch comprising the ceratobranchials and hypobranchials were counted under low magnification (x10).

Results of these meristic counts are shown in Table 22. Of the four examined characters, the vertebral counts of both groups were similar (55.51 and 55.55 for spring and autumn herring respectively).

TABLE 22

Frequency distributions, means, and Z test between the means of some meristic characters of herring from spring and autumn fisheries. Probabilities (P) associated with values of Z are shown.

Gill-rakers	44	45	46	47	48	49	50	51	52	53	N	Mean	S.D.	Z	P
Spring fishery	7	21	39	38	26	15	7				153	46.83	1.47	11.17 < 0.01	
Autumn fishery	2	7	6	12	15	13	19	5	10	3	92	48.73	2.22		
Vertebral count		53	54	55	56	57									
Spring fishery		2	24	162	182	24					394	55.51	0.73	0.78	0.218
Autumn fishery		1	18	162	190	24					395	55.55	0.69		
Dorsal fin		17	18	19	20	21									
Spring fishery		2	95	163	92	6					358	19.01	0.78	2.73 < 0.01	
Autumn fishery		5	59	201	109	12					386	19.17	0.77		
Pectoral fin		16	17	18	19	20	21								
Spring fishery		10	63	153	116	12					354	18.16	0.86	5.69 < 0.01	
Autumn fishery		30	142	130	84	13	1				400	17.78	0.99		

The probability that these fish could have been drawn from the same population was high ($p \geq 0.218$).

For other meristics, however, the differences between the two groups were significant ($p \leq 0.01$). The fish of the two groups were of comparable sizes, so that the differences could not be length-dependent. Of the three meristics, the differences in mean gill-raker counts were most obvious.

To examine the degree of divergence in gill-raker counts between the two spawning groups, frequency distributions of the two samples were calculated and the areas of the distributions were compared according to Ginsburg method (Ginsburg, 1938; Kreft, 1958). The intergradation was calculated as 29.9%; this is the area of overlapping of the two distributions, expressed as percentage of the total area of both distributions.

On this basis, the divergence between the two populations was 70.1% which is very significant, but its level was less than the level (75%-85%) to be considered two subspecies.

The encouraging results of the use of meristic characters led to the expansion of the sampling program in 1970, both in space and time (Tables 23 to 26) and the development of the techniques to take more than one meristic simultaneously. Three meristics, *viz.*, dorsal fin rays, pectoral fin rays and gill-rakers, were used in the analysis. The vertebral counts - due to their similarity and hence limited use - were eliminated from the analysis.

TABLE 23

Frequency distributions, means, standard deviations (SD), and standard errors (SE) of mean vertebral counts of herring in the southern Gulf of St. Lawrence, in 1970.

Vertebral Count	431	432	433	434	Area 435	436	437	438	439	Total
51										
52						1				1
53	2	1		1	2	1	2	4		13
54	16	5	1	9	7	10	17	40	7	112
55	166	26	95	54	86	113	192	421	31	1184
56	258	49	89	74	86	149	233	510	52	1500
57	44	9	6	9	15	18	30	80	5	216
58	2	2		2			1	2		9
59										
60	1									1
Total	489	92	191	149	196	292	475	1057	95	3036
Mean	55.69	55.71	55.52	55.58	55.54	55.58	55.58	55.59	55.58	55.60
SD	0.74	0.84	0.57	0.78	0.73	0.71	0.69	0.71	0.71	0.71
SE	0.03	0.09	0.04	0.06	0.05	0.04	0.03	0.02	0.07	0.01

TABLE 24

Frequency distributions, means, standard deviations (SD), and standard errors (SE) of mean pectoral fin-ray counts of herring in the southern Gulf of St. Lawrence, in 1970.

Pectoral Fin Count	Area									Total
	431	432	433	434	435	436	437	438	439	
15						1		2	1	4
16	38	6	7	7	19	26	24	72	16	215
17	182	21	45	52	83	112	109	287	50	941
18	132	36	42	37	68	98	162	375	21	971
19	37	27	4	1	25	44	158	280	8	584
20	6	5			1	8	30	57	1	108
21						1	2	2		5
22					1					1
23										
24										
Total	395	95	98	97	197	290	485	1075	97	2829
Mean	17.47	18.04	17.44	17.33	17.54	17.64	18.13	17.97	17.23	17.80
SD	0.85	0.99	0.69	0.62	0.91	0.97	1.01	0.02	0.89	0.99
SE	0.04	0.10	0.07	0.06	0.06	0.06	0.05	0.03	0.09	0.02

TABLE 25

Frequency distributions, means, standard deviations (SD), and standard errors (SE) of mean dorsal fin-ray counts of herring in the southern Gulf of St. Lawrence, in 1970.

Dorsal Fin Count	Area									Total
	432	432	433	434	435	436	437	438	439	
17	2	1			2	1	3	13	1	23
18	37	6	13	9	31	34	40	122	19	311
19	193	40	59	58	102	173	212	509	44	1390
20	141	35	27	26	50	82	196	370	23	950
21	5	6		1	.5	4	16	38	1	76
22					1			2		3
23										
24										
25										
26										
Total	378	88	99	94	1911	294	467	1054	88	2753
Mean	19.29	19.44	19.14	19.20	19.14	19.18	19.39	19.29	19.05	19.27
SD	0.68	0.77	0.62	0.61	0.77	0.66	0.72	0.77	0.76	0.73
SE	0.03	0.08	0.06	0.06	0.06	0.04	0.03	0.02	0.08	0.01

TABLE 26

Frequency distributions, means, standard deviations (SD), and standard errors (SE) of mean gill-raker counts of herring in the southern Gulf of St. Lawrence, in 1970.

Gill- Raker Count	Area										Total
	431	432	433	434	435	436	437	438	439	470	
41			1								1
42	2		4					3			9
43	4		11		2		2	5			24
44	16	4	20		5		5	19			69
45	47	7	21		12	1	12	56	7	3	166
46	68	7	23		24	2	24	132	5	7	292
47	88	18	10		43	11	37	169	23	15	414
48	67	18	4		43	22	61	211	21	14	461
49	48	18			27	22	58	200	20	19	412
50	33	12			20	14	53	142	15	16	305
51	7	7			16	12	28	89	5	18	182
52	4	5			6	7	11	41	2	3	79
53	4	1			2	4	3	14		2	30
54	1	1				2	1	5			10
55		1				2	1	1			5
Total	389	99	94		200	99	296	1087	98	97	2459
Mean	47.27	48.32	44.97		47.96	49.43	48.57	48.28	48.19	48.92	48.07
SD	1.93	2.22	1.52		1.97	2.00	1.96	2.03	1.64	1.86	2.12
SE	0.09	0.22	0.16		0.14	0.20	0.11	0.06	0.17	0.19	0.04

Use of Multiple Meristic Characters (Discriminant Function Analysis)

Materials and Methods. Samples of dorsal and pectoral fins and gill-rakers from 2422 fish collected in 1970 were used for the analysis. Herring samples of April and May (459 fish) were taken as representatives of spring-spawning population. These fish were collected on the spawning grounds, and in the spawning season. Their maturation stages support this assumption (Table 27). Herring samples taken in August and September on the spawning grounds (470 fish) were assumed to be representatives of autumn-spawning population. Most of these fish were in ripe and running stage and there is no doubt that they were mostly autumn spawners.

The only exception was a sample taken in Miscou in August where 68% of its fish were in stage 3 of maturation. This stage, however, is usually confused with stage 8 (recovering fish) as indicated earlier in section 5. This sample comprised only 15% of the total autumn herring samples.

The other samples, comprising 1393 fish, were of mixed origin, i.e. spring and autumn spawning fish mixed together. Referring to their maturation stages (Table 27) these fish could not be assigned to a particular spawning group.

Three meristic counts (pectoral fin, dorsal fin and gill-raker counts) were taken for these fish. Examination and counting of these meristics were made in a manner similar to that described in the previous action.

TABLE 27

Maturation stages of herring samples used for
discriminant function analysis

Location	Month	Maturation Stages								Total
		1	2	3	4	5	6	7	8	
<u>Spring Spawners</u>										
Magdalens	May				1	19	65		4	89
Egmont Bay	April				57	34	2			93
N. Rustico	April			2	86	2			1	91
Escuminac	May				43	33	7	7	1	91
Caraquet	May			6	16	31	19	22	1	95
All				8	203	119	93	33	3	459
<u>Autumn Spawners</u>										
Escuminac	Sept.					54	44			98
Maisonete	Aug.				3	70	15			88
Caraquet	Sept.				1	33	56	7	2	99
Miscou	Aug.				1	87	9	1		98
Miscou	Aug.		12	60	9	2		4	1	88
Pt. Jaune	Aug.				1	53	41	4		99
All			12	60	15	299	165	16	3	570
<u>Mixture</u>										
Deadman's Is.	Oct.		3	7	27	13		24	16	90
East Pt., FEI	Sept.		4		2	16		49	19	90
Orphan Bank	Sept.		1	38	12	2		13	34	100
Bradelle Bank	Aug.	1	35	19	6	19	1	11		92
Cape Gaspe	July		1	9	34	15	1	21	4	85
Miscou	July			26	37	16	7			86
American Bank (A)	Aug.			45	7	20	6	16		94
American Bank (b)	Aug.		1	25	7	7		53	6	99
Cape Gaspe	Aug.			42	5	3	37	1		88
American Bank	Sept.			29	16			35	19	99
Shippegan G.	Sept.				11	31	48			90
S.E. Miscou	Oct.		67	11	2	1		5	6	92
Birch Pt.	Oct.		56	21				13	9	99
St. Ann's Bay	May		5	8	37	15	27	3		95
All			1	197	291	204	158	127	134	1393

Statistical Analysis. A set of linear functions is calculated from the three meristic counts of the spring and autumn herring populations. The classification of an individual into a group is performed by reducing the set of counts from the individual to a single value, and evaluating each of the calculated linear functions, then finding the group for which the value is the closest.

The discriminant function is then used to assign other individuals (of unknown origin) to one group or the other. Number of groups (in this case two: spring- and autumn-groups) and number of variables (in this case three variables: pectoral fin, dorsal fin, and gill-raker counts) should not be changed throughout the analysis. Any individual missing one of the counts should be eliminated from further analysis.

The mathematical model on which the analysis is based is a multivariate normal distribution (Mahalanobis, 1936; Rao, 1952; Anderson, 1958).

Results. Means and common means of the three variables of the spring and autumn groups were found as follows:

Variable	Means of Spring Group	Means of Autumn Group	Common Means
Pectoral	17.30	18.37	17.89
Dorsal	19.20	19.41	19.32
Gill rakers	46.10	49.12	47.78

The constant and coefficients of the discriminant function of

the spring group were:

Constant:	-811.809		
Coefficients:	19.252	35.845	13.063

Those of the autumn group were:

Constant:	-881.460		
Coefficients:	20.614	35.957	13.970

Results of the classification of individual fish in spring and autumn groups are presented in Table 28. It can be seen that the spring fishery comprised from 76.8% to 95.7% (average of 85.8%) fish classified in the spring group. In the autumn fishery except for one sample (Point Jauné, Quebec) which comprised a relatively low percentage (50.5%) of fish classified as autumn fish, all samples comprised from 85.7% to 93.2% fish classified as autumn herring (Table 28). In the mixing areas, however, the separation gave a wider range in the percentage occurrence of fish classified as spring and autumn herring.

On the basis of the above classification the percentage ratios of the two groups in various areas were plotted (Figure 22). It is shown that in two areas the spring group was more represented than the autumn group. Thus in the Magdalen Islands (area 431) and Chaleur Bay (area 437) the spring herring were 60% and 52% respectively.

In the other four areas there were more autumn herring than spring herring. Variations between areas were also demonstrated. In

TABLE 28

Numbers and percentages of spring and autumn herring
as classified by the discriminant function analysis

Location	Month	Spring Group No.	%	Autumn Group No.	%	Total
<u>Spring Spawners</u>						
Magdalens	May	71	79.8	18	20.2	89
Egmont Bay	April	89	95.7	4	4.3	93
N. Rustico	April	83	91.2	8	8.8	91
Escuminac	May	78	85.7	13	14.3	91
Caraquet	May	73	76.8	22	23.2	95
All		394	85.8	65	14.2	459
<u>Autumn Spawners</u>						
Escuminac	Sept.	14	14.3	84	85.7	98
Maisonette	Aug.	6	6.8	82	93.2	88
Caraquet	Sept.	8	8.1	91	91.9	99
Miscou (A)	Aug.	9	9.2	89	90.8	98
Miscou (b)	Aug.	7	7.9	81	92.0	88
Pt. Jaune	Aug.	49	49.5	50	50.5	99
All		93	16.3	477	83.7	570
<u>Mixture</u>						
Deadman's Is.	Oct.	54	60.0	36	40.0	90
East Pt., PEI	Sept.	37	41.1	53	58.9	90
Orphan Bank	Sept.	43	43.0	57	57.0	100
Bradelle Bank	Oct.	49	52.1	45	57.9	94
Paspebiac	Aug.	47	50.5	46	49.5	93
Cape Baspe	July	43	43.9	55	56.1	98
Miscou	July	26	30.2	60	69.8	86
American Bank (A)	Aug.	38	40.4	56	59.6	94
American Bank (B)	Aug.	46	46.5	53	53.5	99
Cape Gaspe	Aug.	40	45.5	48	54.5	88
American Bank	Sept.	44	44.4	55	55.6	99
Shippegan Gully	Sept.	20	22.2	70	77.8	90
S.E. Miscou	Oct.	68	73.9	24	26.1	92
Birch Pt.	Oct.	66	66.7	33	33.3	99
St. Ann's Bay	May	32	33.0	65	67.0	97
All		653	46.3	756	53.7	1409

St. Anne's Bay (area 470) and east P.E.I. (area 432) autumn herring was dominant. In the other two areas, Orphan/Bradelle Banks (area 435) and American Bank/Gaspé area (area 438) they were 52% and 56% respectively.

The change in the mixing ratios of spring and autumn herring was followed in the American Bank/Gaspé area in the four months of sampling (Figure 23). It is shown that autumn herring was dominant in July, August and September, while in October the dominance was for the spring herring.

Discussion. The use of meristic characters in discriminating between spring and autumn herring populations in the southern Gulf of St. Lawrence was demonstrated during this study. Similar uses have been reported by various authors (e.g. Hubbs, 1925; Tester, 1938; Runnstrom, 1941; Day, 1957). Some of the reports published on this subject go back to the last century (Heincke, 1898).

From the four meristic characters taken - number of vertebrae, dorsal fin rays, pectoral fin rays, and gill-rakers - the last three characters were useful in separating between the two herring groups. The vertebral counts, however, are of little use in this particular situation.

The similarity of vertebral counts between spring and autumn herring which was demonstrated here has been noted by earlier investigators (Jean, 1956; Day, 1957). Day observed differences in all characteristics examined except vertebral numbers. He ~~was~~ wondered why

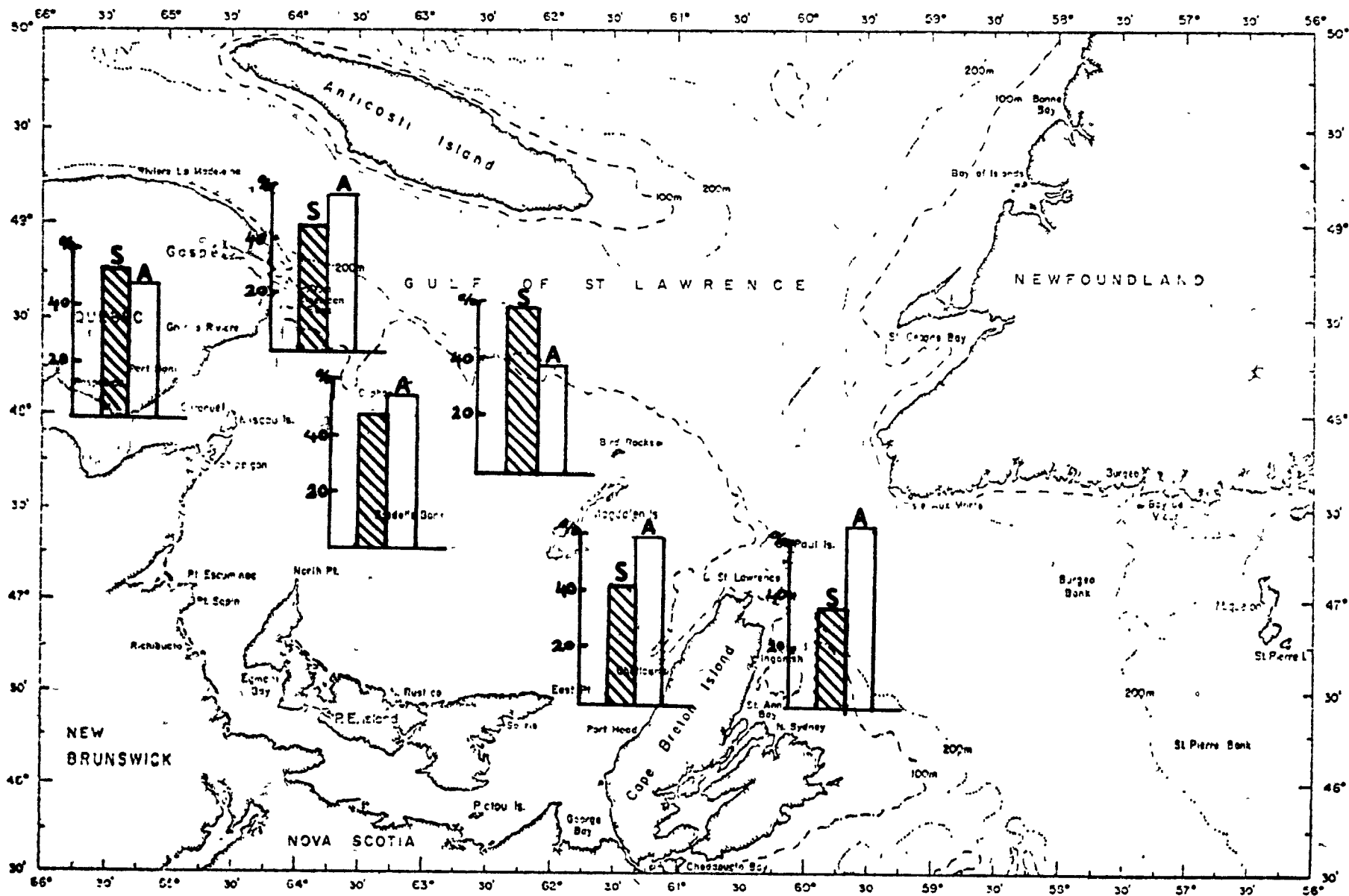


FIGURE 22: Percentage ratios of spring (S) and autumn (A) herring in the Gulf of St. Lawrence

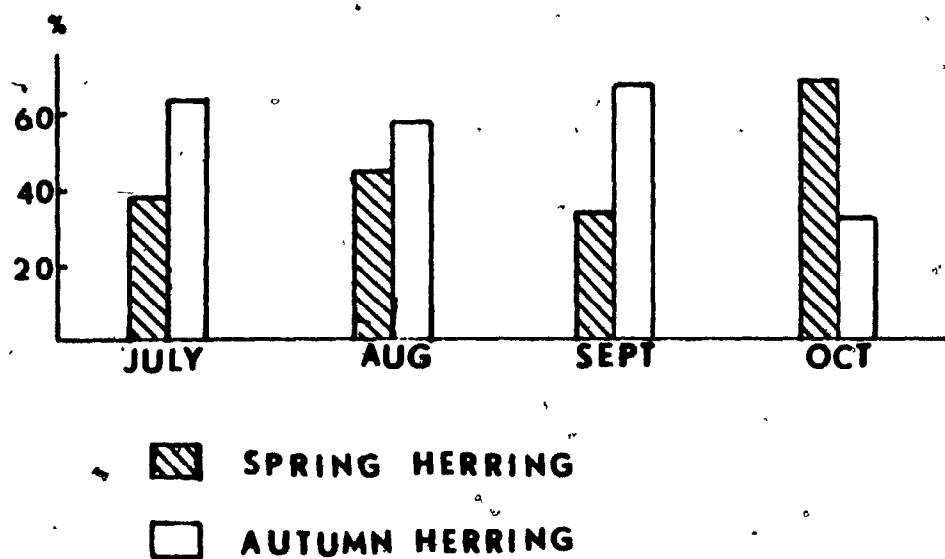


FIGURE 23: Monthly change in percentage ratios of spring and autumn herring on feeding grounds in the American Bank area

there were no significant differences between means of vertebral counts from samples taken in the spring and the fall in spite of the wide differences in temperature (3° to 10°C for May to June, and 9° to 19°C for August to October). He asked the question: Why did the fall-spawning herring differ from spring-spawners in some characteristics yet did not differ in vertebral counts? but unfortunately he did not give an answer to this question.

Jean (1956) on the basis of the similarity in vertebral counts of spring and autumn herring in Chaleur Bay hypothesized that those groups are not biologically isolated, i.e. interbreed freely, but his hypothesis failed to offer a convincing explanation for the differences in their growth rates. Contradictory results also arose when he applied the scale ratio as criterion for separating the groups, especially when this was applied to the autumn spawning group.

Messieh (1969a) questioned Jean's hypothesis, and suggested that the observed variations in herring scale growth could be attributed to the variations in hydrographic conditions which are more pronounced within seasons in this particular area. The water off Grand River, Bay of Chaleur, shows erratic variations of temperature and salinity due to tidal fluctuations in the vertical structure of the water mass (Lauzier, 1957).

In attempting to find the possible factors that might explain the observed similarity in vertebral counts of spring and autumn

spawning herring, data on temperatures on spawning grounds were collected, and the average surface and bottom temperatures during spawning seasons were compared. In the Chaleur Bay area (area 437) average surface temperatures were plotted for the months May through November (Figure 24). The temperature curves showed that surface temperature increased until August when it reached a maximum, and then decreased until November. The temperatures ranged between 2.5° and 5°C for the spring spawning period, and 11° to 13°C for the autumn period.

When bottom temperatures on the spring and autumn grounds in the same area were plotted, taking into consideration the differences in depth of these grounds (10 metres depth range for spring spawners and 20 to 30 metres depth range for autumn spawners), temperatures ranged from 4° to 6°C for spring spawning period and 5° to 7.5°C for the autumn period. Assuming that herring eggs are more affected by bottom temperatures - as they are demersal - than by surface temperatures, and that the number of vertebrae are fixed during the incubation period before hatching (Hubbs, 1940), the overlap in bottom temperature ranges in both spawning seasons might explain the nonsignificant differences between their vertebral counts.

The significant differences in fin rays and gill rakers between the two spawning groups reflect the environmental conditions prevailing in their larval stages. Several investigators (e.g. Rounsefell and Dahlgren, 1932; Tester, 1937; Day, 1947) found that the meristic counts of fish increase with latitudinal decrease in temperature. If this

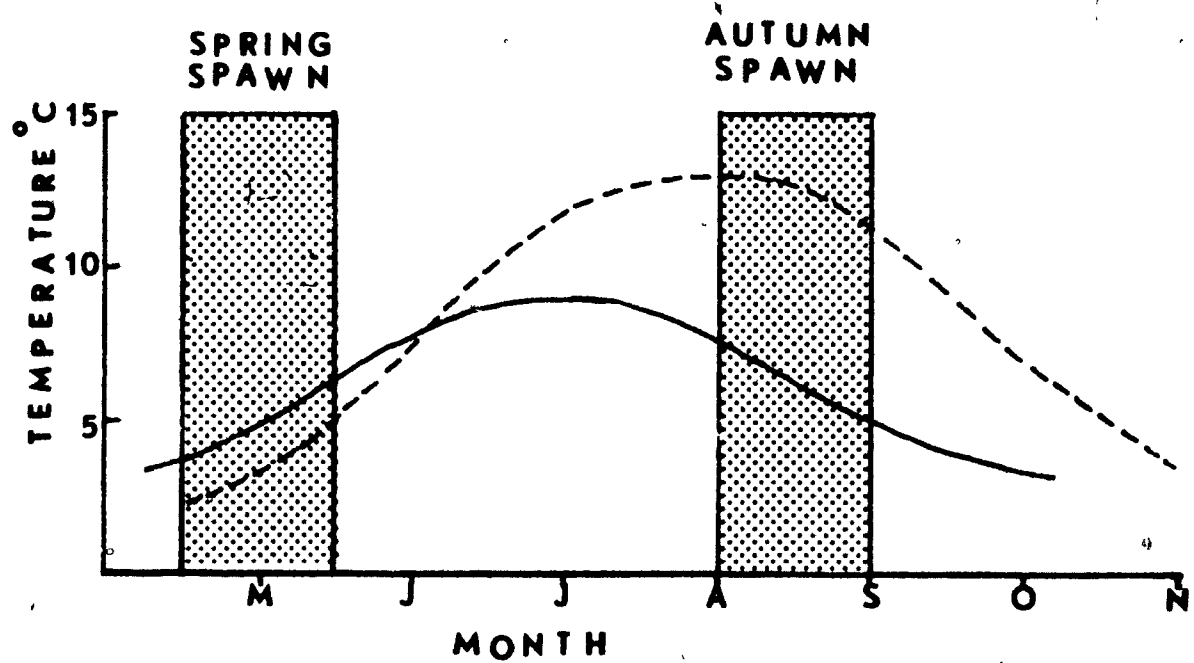


FIGURE 24: Surface (-----) and bottom (——) temperatures on herring spawning grounds in Caraquet area, Gulf of St. Lawrence

hypothesis holds good for the herring in the Gulf of St. Lawrence, then autumn spawned herring having higher meristics than the spring herring should have been subjected to lower temperatures than the spring spawned herring.

Although the time in the ontogeny of Atlantic herring when the numbers of fin rays are fixed is not known, the implication from the work by Taning (1952) indicates that the period of fixation of the fin rays begins in the egg stage but continues after hatching. The dorsal and then the pectoral fins are formed next. Bigelow and Schroeder (1953) gave 15 to 17 mm and Baxter (1962) gave 13 to 14 mm as the lengths at which the dorsal fin is formed.

From Figure 24 it is shown that spring herring larvae hatched in a lower surface temperature than autumn, but the temperature in the spring soon increases rapidly, and the larvae during their development will be subject to an increasing temperature. On the other hand, the autumn larvae will be subject to a continuous decrease in temperature, to the extent that some larvae will fail to metamorphose before their first winter.

Hubbs (1940) related the differences in meristic counts to the different rates of development. He reported that increased numbers of somites, vertebrae, scale rows, fin rays and changes in body form tend to be correlated with retardations of development whatever may be the cause for the slackening of the pertinent stage of development,

so increased salinity has about the same effect as decreased temperature.

Similarly, Hempel and Blaxter (1961) reported that both temperature and salinity may modify meristic characters. The importance of genotype is difficult to judge. It seems likely that it provides a general basis for the number of meristic units, the actual number being controlled by environmental factors.

Taking into consideration temperature and salinity together as factors modifying the meristic counts of herring, the hydrographic conditions in the Gulf give an explanation for the higher meristics in autumn spawning herring. This is clear from the Lauzier (1957) report: "Associated with this change in temperature (increasing from 10° to 18°C) the salinity of the surface water during the summer has generally decreased over the whole southwestern Gulf and the isohaline of 30.0‰ extended from the estuary of the St. Lawrence southeasterly to Newfoundland. By October, the surface salinities have generally increased over the whole area of the Gulf. The general direction of the horizontal temperature gradient is similar to that of the summer, but with temperatures ranging from 7.0°C in the estuary to 12°C off Cape Breton."

In the foregoing, the differences in meristic counts between spring- and autumn-spawning herring except for vertebral counts were clearly demonstrated. This will lead us to the conclusion that relying on one meristic character only might lead to erroneous conclusions.

It should be emphasized that the similarity in one of the characteristics does not necessarily mean homogeneity of the populations. On the other hand, differences in one of the characteristics could be more clearly demonstrated when compared with differences in other characteristics at the same time as has been shown from the method of discriminant function analysis. Three characters were compared at the same time which provided a stronger tool for separating the two herring populations.

- The value of the discriminant function analysis lies not only in providing more reliable separation between the populations, but also in calculating the mixing ratios of these populations in space and time, a problem which is of ultimate value for a fishery biologist who is concerned with the scientific management of fish stocks.

The discrimination between herring stocks should not be restricted only to the use of one or more of the meristic characters. Supporting evidences - preferably based on other characteristics of different nature - should be sought. In the next section the use of otoliths as natural tags will be discussed.

IDENTIFYING HERRING STOCKS BY MEANS OF THEIR OTOLITHS

Materials and Methods

Otoliths from 14 samples including 1423 herring were examined. Samples were collected from various localities during 1968 through 1970 (Table 29). Some of the otoliths were found unsuitable for measurements, either because they were broken, badly mounted or showing irregularities (such as translucences; differences within pairs). This resulted in the discarding of 62 fish from further analysis. Samples of herring otoliths were photographed and traced using camera lucida. Diameters of nuclei were measured using a moving ocular micrometer scaled in equal divisions (one unit = 0.083 mm).

According to their shape, otoliths were classified into two types: the spring type (S) and the autumn type (A). The validity of the differences between the two types was tested by comparing nucleus size, regression of otolith lengths on fish length, maturation stages and fin ray counts. Sizes of otolith nuclei were plotted as frequency distributions and compared by chi-square tests for homogeneity. Mean values of the fin ray counts were tested for probable differences by z-statistic.

Lengths of otoliths were plotted against fish lengths. Data fitted simple regression lines of the form $y = a + bx$, where y = otolith length, x = fish length, a = intercept of regression line with y-axis, and b = slope of regression line. The regression coefficients were

TABLE 29

Summary of herring samples examined for otolith measurements,
maturation stages and meristic counts

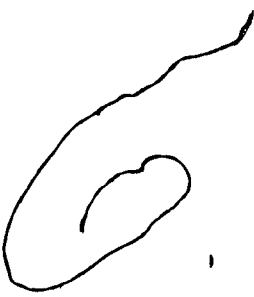
Sampling Locality	Date	No. of fish in sample	Otolith measurements and maturation	Pectoral fin ray counts	Dorsal fin ray counts
Caraquet	May 1968	150	148	124	124
Magdalen I.	May 1968	93	85	85	85
Caraquet	August 1968	150	141	141	141
Escuminac	August 1968	100	96	-	-
American Bank	October 1968	50	42	42	42
American Bank	June 1969	100	90	90	90
Off Shippegan	September 1969	80	75	75	75
Chedabucto Bay	February 1969	100	93	93	93
Chedabucto Bay	April 1969	100	94	-	-
Caraquet	May 1970	100	100	100	99
Magdalen I.	May 1970	100	100	100	100
Georges Bank	July 1970	100	97*	97	97
Caraquet	September 1970	100	100	99	98
Escuminac	September 1970	100	100	100	99
Total		1423	1361	1146	1143

* Maturation stages not available.

calculated by the least squares methods, and their values were compared by *t*-test.

Results

Otoliths of S-Type. The main feature of otoliths of this type (Figure 25a-c) is a well developed pararostrum which in most cases is as long as the postrostrum. The postrostrum is a little wider than the pararostrum (Table 31). The excisura minor is deeply grooved, clearly defined and runs almost parallel to the long axis of the otolith. The postrostrum is rounded. The line joining the tips of the postrostrum and pararostrum runs almost perpendicular to the long axis of the otolith.



There are subdivisions within this type: for example, otolith samples from the Magdalen Islands area (Figure 25b and c) are more slender, their antirostra more pointed dorsally, and the angles between the rostra and antirostra are wider than in samples from Caraquet (Figure 25a).

Otoliths of A-Type. Otoliths of this type (Figure 25d-f), have small pararostra that are always shorter than the postrostra, and the excisura minor are not deeply grooved. The postrostrum is more than twice as wide as the pararostrum. A line extending from the nucleus to the excisura minor usually forms an angle with the long axis of the otolith. The line joining the tips of the postrostrum and pararostrum is obviously not perpendicular to the long axis of the otolith (Table 30).

TABLE 30

Mean values of herring otolith measurements from different fisheries with standard deviations included. (Nucleus size in ocular micrometer units 1 = 0.083 mm.)

Locality	Date	Mean size otolith nucleus	Ratio of postrostrum/ pararostrum width	Angle between rostrum, postrostrum and pararostrum
<u>Spring Fishery</u>				
Caraquet	May 1968	3.08 $\pm$ 1.28	1.39 $\pm$ 0.36	84.4 $\pm$ 5.88
Magdalen I.	May 1968	3.40 $\pm$ 1.02	1.37 $\pm$ 0.30	85.3 $\pm$ 5.72
Caraquet	May 1970	3.12 $\pm$ 0.98	1.32 $\pm$ 0.33	86.2 $\pm$ 5.34
Magdalen I.	May 1970	3.36 $\pm$ 1.10	1.42 $\pm$ 0.31	84.5 $\pm$ 5.82
<u>Autumn Fishery</u>				
Caraquet	Aug. 1968	4.06 $\pm$ 1.25	2.80 $\pm$ 0.84	68.8 $\pm$ 6.11
Escuminac	Aug. 1968	4.22 $\pm$ 1.32	3.12 $\pm$ 0.96	65.7 $\pm$ 5.90
Georges Bank	July 1970	4.27 $\pm$ 1.09	3.95 $\pm$ 1.45	66.9 $\pm$ 5.35
Caraquet	Sept. 1970	4.21 $\pm$ 1.15	3.10 $\pm$ 0.92	65.3 $\pm$ 5.44
Escuminac	Sept. 1970	4.12 $\pm$ 1.21	3.45 $\pm$ 1.05	
<u>Mixed Fishery</u>				
American Bank	Oct. 1968	3.86 $\pm$ 1.13	1.95 $\pm$ 0.60	78.2 $\pm$ 5.93
American Bank	June 1969	3.52 $\pm$ 0.92	2.85 $\pm$ 0.73	73.0 $\pm$ 6.17
Off Shippegan	Sept. 1969	3.74 $\pm$ 1.02	2.75 $\pm$ 0.98	70.2 $\pm$ 5.61
Chedabucto Bay	Feb. 1970	3.70 $\pm$ 1.25	2.93 $\pm$ 1.01	74.9 $\pm$ 5.83
Chedabucto Bay	April 1970	3.62 $\pm$ 0.94	2.45 $\pm$ 0.95	71.4 $\pm$ 6.15

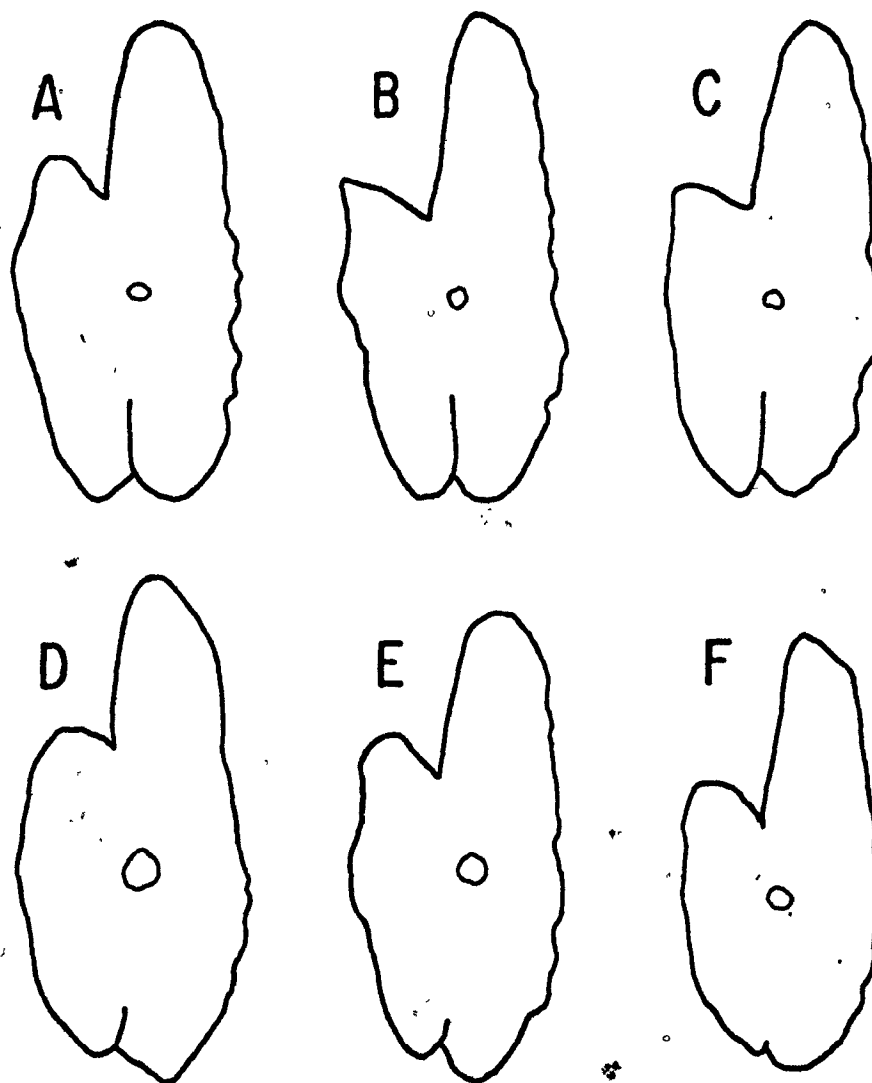


FIGURE 25: Different types of herring otoliths from spring and autumn fisheries.

- a. S-type: Caraquet, May 1968
- b. S-type: Magdalen, May 1968
- c. S-type: Magdalen, April 1970
- d. F-type: Caraquet, August 1968
- e. F-type: Escuminac, August 1968
- f. F-type: Georges Bank, July 1970

There are also subdivisions within this type; samples from Georges Bank (Figure 25f) are obviously different from those in the Gulf of St. Lawrence (Figure 25d,e). In the former, the excisura minor is very short, and the pararostrum is always poorly developed or even absent in some specimens.

Within the Gulf of St. Lawrence, A-type otoliths showed minor differences between spawning groups. Otoliths from Caraquet Island samples (Figure 25d) have more pointed postrostra than those from Escuminac (Figure 25e).

Otoliths of Mixed Types. Samples of otoliths from the American Bank and offshore from Shippegan (Figure 26a) showed a mixture of S- and A-types similar to those characterizing fish from the spring and autumn fisheries in the Gulf of St. Lawrence. Similarly, samples from Chedabucto Bay (Figure 26b) showed a mixture of the two otolith types. However, these otoliths differed from both Gulf of St. Lawrence and Georges Bank samples. Their A-type is similar to the A-type from Nova Scotia, while their S-type has a narrower posterior end and more rounded antirostrum than the S-type from the Gulf of St. Lawrence.

Otolith Nucleus Size. Otolith nuclei of herring from the different fisheries varied in sizes (Table 30). The minimum size was from the Caraquet spring fishery (mean diameter 0.26 mm); the maximum size was from Georges Bank herring (mean diameter 0.35 mm). In all cases mean sizes of nuclei from spring herring were smaller than those from

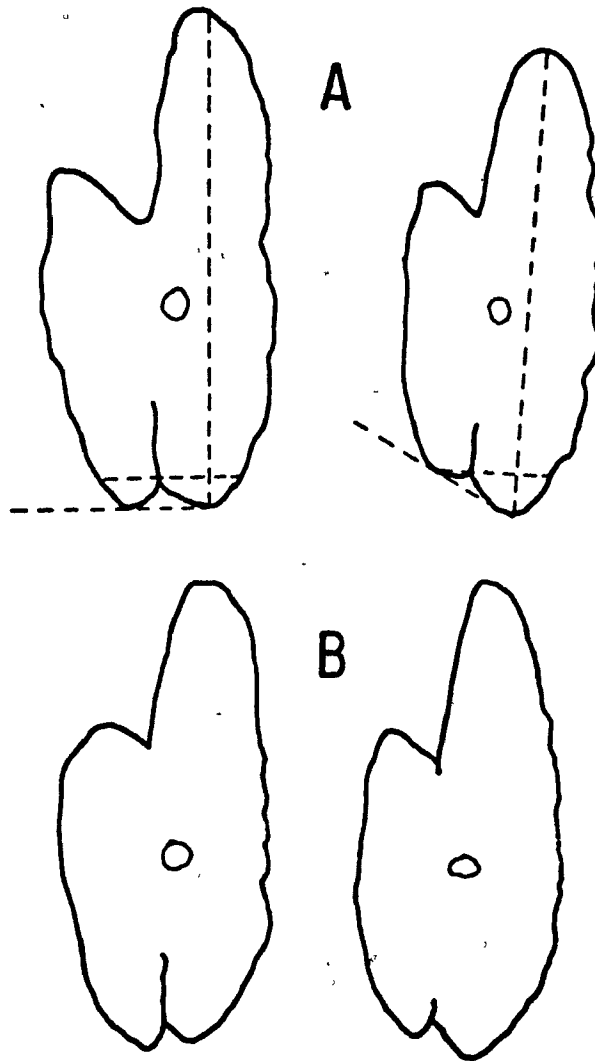


FIGURE 26: Different types of herring otoliths from:

- a. American Bank, June 1969
- b. Chedabucto Bay, April 1970

autumn herring (Table 30). Mean values for herring of mixed types fell in between.

Frequency distributions of otolith nucleus sizes for different fisheries overlapped (Figure 27), but the differences between them were significant. The probability that spring and autumn fish in the Gulf of St. Lawrence were drawn from the same population was small ($p < 0.01$). However, when otoliths from the latter areas were separated by spawning types, the frequency distributions of their nucleus sizes were similar to those of the spring and autumn fish in the Gulf of St. Lawrence (Figure 27). The probability was 0.25 that A-type and S-type otoliths could have been drawn from the autumn- and spring-spawning populations respectively ($\chi^2 = 9.47$, with 7 degrees of freedom, and $\chi^2 = 8.17$, with 6 degrees of freedom respectively).

Relation of Otolith Length to Fish Length. The regression of otolith lengths on fish lengths (Figure 28) showed that, for the length range of fish sampled, the otolith length increased in direct proportion to the body length. However, the regression coefficients differed between fish from different localities. Their values ranged from 0.130 for Georges Bank to 0.163 for Caraquet (Figure 28).

When samples of mixed otolith types were separated by spawning types and the regression of otolith length against fish length was calculated (Figure 28), the S-type regressions were significantly different from those of the A-type ($p < 0.01$). In all cases A-type otoliths grew faster than S-type otoliths.

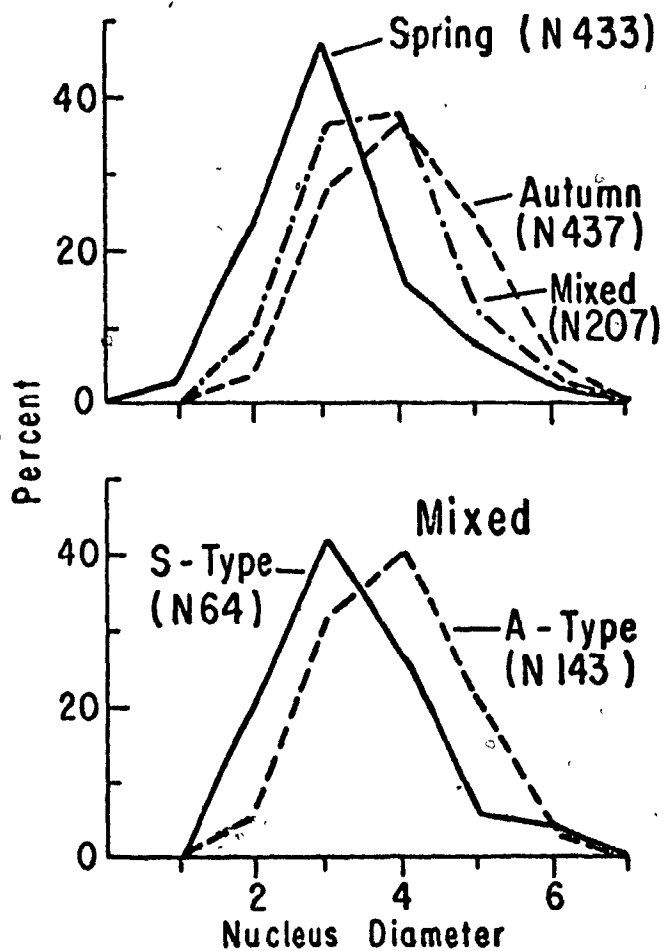


FIGURE 27: Frequency distributions of otolith nuclei sizes of herring from different fisheries in the Gulf of St. Lawrence (1 unit = 0.083 mm)

Maturation Stages of Herring with S- and A-type Otoliths.

Samples of spring-spawning herring, as determined by stages of maturation, usually had S-type otoliths (Table 31). Of the spring spawners in Caraquet and Magdalen Islands, 97.7% had otoliths of this type and the remainder could not be assigned to any particular type. In contrast, A-type otoliths predominated in autumn-spawning herring. In the Caraquet and Escuminac autumn fisheries, 97.1% of the fish had A-type otoliths (Table 31).

In areas where samples of mixed otolith types were found, as in the American Bank, offshore from Shippegan and Chedabucto Bay areas, the maturation stages of the fish were diverse. In American Bank and Shippegan, fish from the same samples had maturation stages from 2 to 8 (Table 31). The distribution of these stages showed two peaks, indicating that the fish had spawned in two different seasons.

When these fish were separated by otolith types, the maturation stages of each type indicated that they belonged to the same spawning group. The S-type represented the spring-spawning fish, and A-type represented the autumn-spawning fish.

Meristic Counts of S- and A-type Herring. Mean counts of pectoral and dorsal fin rays differed significantly ($p < 0.01$) between herring of spring and autumn fisheries and between herring of S- and A-type otoliths (Tables 32 and 33). In all cases, mean fin ray counts were smaller for S-type otoliths than for A-type. However, the

TABLE 31

Maturation stages of herring by otolith type and fishery
(S = spring-type otolith; A = autumn-type; D = doubtful)

Locality	Date	Type of otolith	No. of fish	Maturation Stages						
				2	3	4	5	6	7	8
<u>Spring Fishery</u>										
Caraquet	May 1968	S	148			2	11	120	10	5
		D	2							
Magdalen I.	May 1968	S	85			12	37	36		
		D	8							
Caraquet	May 1970	S	100				9	85	6	
		D	0							
Magdalen I.	May 1970	S	100			3	8	77	12	
		D	0							
<u>Autumn Fishery</u>										
Caraquet	Aug. 1968	A	141		6	2	25	69	34	5
		D	9							
Escuminac	Aug. 1968	A	96				14	82		
		D	4							
Caraquet	Sept. 1970	A	100				7	85	8	
		D	0							
Escuminac	Sept. 1970	A	100				8	67	22	3
		D								
<u>Mixed Fishery</u>										
American Bank	Oct. 1968	S	22	1	13	6				2
		A	20	3	2	3				12
		D	8							
American Bank	June 1969	S	24	1	5	11	1		1	5
		A	66	4	10	46	6			
		D	10							
Off Shippegan	Sept. 1969	S	18	12	1				5	
		A	57	14	2		1		37	3
		D	5							
Chedabucto Bay	Feb. 1970	S	20	6	9	5				
		A	73	25	36	7				5
		D	7							
Chedabucto Bay	Apr. 1970	S	26	2	8	16				
		A	68	20	42	6				
		D	6							

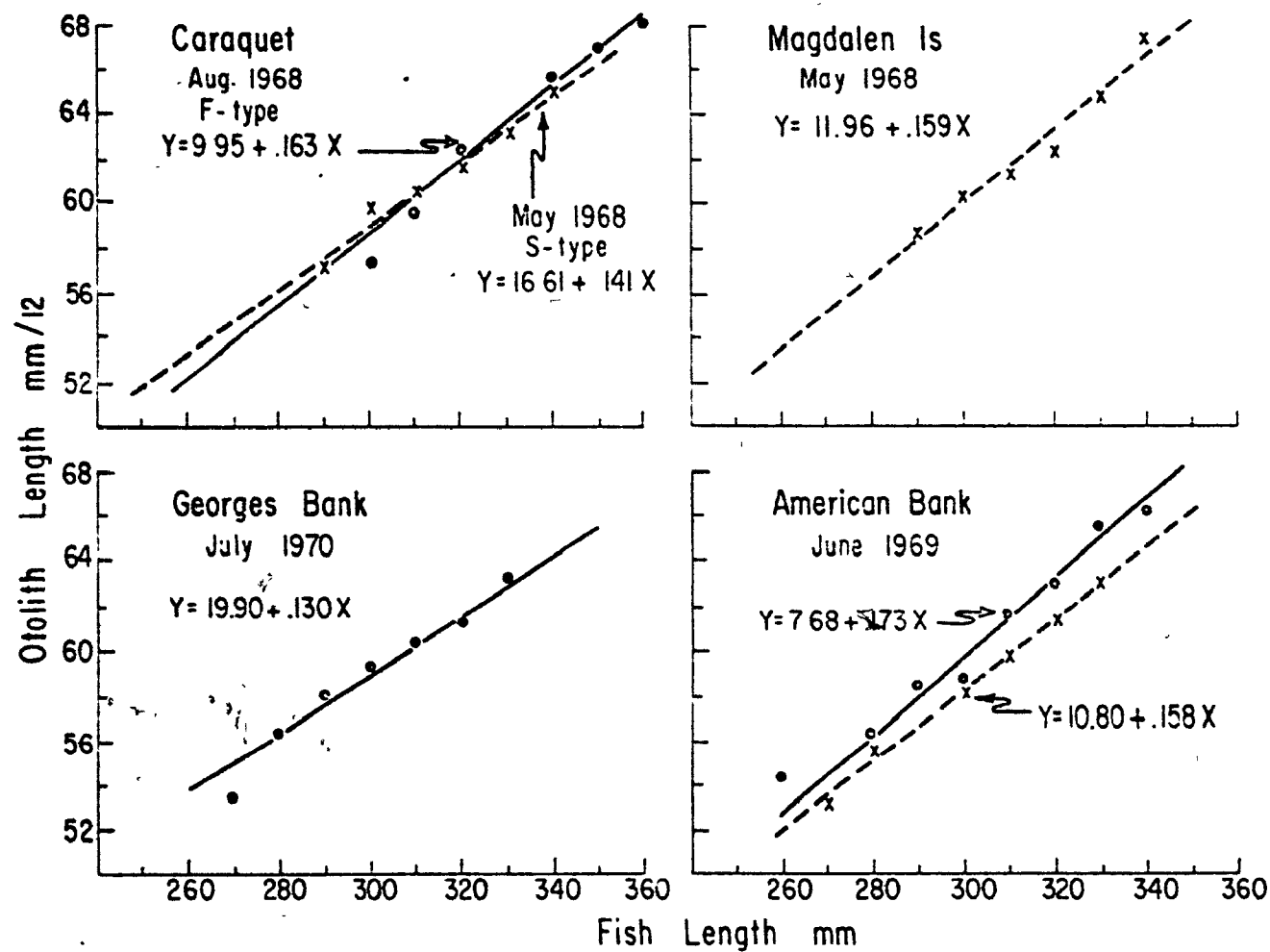


FIGURE 28: Regression of otolith lengths on fish lengths of herring from various areas and spawning groups

differences were more obvious for pectoral than for dorsal fins.

In areas where both otolith types were mixed in the same samples, mean values of fin ray counts, were intermediate between the values for S- and A-types. When these mixed fish were separated according to otolith types, the fin ray counts differed between types, the mean counts being less for S-type than for A-type (Tables 32 and 33).

Discussion

The evidence presented supports the conclusion that otoliths can be used as 'natural tags' for identifying herring stocks in the study area. The S-type otoliths characterize the spring-spawning population, and the A-type characterizes the autumn-spawning population. Although the present data do not demonstrate the genotypic origin of the differences in otolith characteristics, the consistency of differences between the two types, in conjunction with differences in other characteristics, provides good evidence that the two otolith types represent fish of biologically isolated herring populations.

Otolith nucleus sizes have been used by some investigators for distinguishing between herring groups in the northeast Atlantic. For example, Postuma and Zijlstra (1958) used measurements of otolith nuclei as a racial character to distinguish between herring populations in the North Sea. In the present study, a comparison of nuclei sizes of the two otolith types showed that the nuclei were smaller for the S-type than for the A-type. This would be expected, since spring-

TABLE 32

Mean pectoral fin ray counts by otolith type and fishery.

Numbers of fish (N) and standard deviations (SD) included.

Locality	Date	S-type otolith		A-type otolith	
		N	mean $\pm$ SD	N	mean $\pm$ SD
<u>Spring Fishery</u>					
Caraquet	May 1968	124	17.04 $\pm$ 0.70		
Magdalen I.	May 1968	85	17.18 $\pm$ 0.61		
Caraquet	May 1970	100	17.16 $\pm$ 0.65		
Magdalen I.	May 1970	100	17.22 $\pm$ 0.68		
<u>Autumn Fishery</u>					
Caraquet	Aug. 1968			141	18.31 $\pm$ 0.64
Georges Bank	July 1970			97	18.02 $\pm$ 0.78
Caraquet	Sept. 1970			99	18.55 $\pm$ 0.77
Escuminac	Sept. 1970			100	18.49 $\pm$ 0.84
<u>Mixed Fishery</u>					
American Bank	Oct. 1968	22	17.35 $\pm$ 0.64	20	18.23 $\pm$ 0.62
American Bank	June 1969	24	17.76 $\pm$ 0.85	66	18.31 $\pm$ 0.68
Off Shippegan	Sept. 1969	18	17.70 $\pm$ 0.82	57	18.00 $\pm$ 0.75
Chedabucto Bay	Feb. 1970	20	17.55 $\pm$ 0.84	73	17.96 $\pm$ 0.81

TABLE 33

Mean dorsal fin ray counts by otolith type and fishery.

Numbers of fish (N) and standard deviations (SD) included.

Locality	Date	S-type otolith		A-type otolith	
		N	mean $\pm$ SD	N	mean $\pm$ SD
<u>Spring Fishery</u>					
Caraquet	May 1968	124	19.36 $\pm$ 0.78		
Magdalen I.	May 1968	85	19.23 $\pm$ 0.65		
Caraquet	May 1970	99	19.36 $\pm$ 0.72		
Magdalen I.	May 1970	100	19.28 $\pm$ 0.67		
<u>Autumn Fishery</u>					
Caraquet	Aug. 1968			141	19.45 $\pm$ 0.63
Georges Bank	July 1970			97	19.30 $\pm$ 0.72
Caraquet	Sept. 1970			98	19.51 $\pm$ 0.61
Escuminac	Sept. 1970			99	19.38 $\pm$ 0.60
<u>Mixed Fishery</u>					
American Bank	Oct. 1968	22	19.06 $\pm$ 0.78	20	19.21 $\pm$ 0.75
American Bank	June 1969	24	18.75 $\pm$ 0.80	66	19.00 $\pm$ 0.82
Off Shippegan	Sept. 1969	18	19.11 $\pm$ 0.69	57	19.34 $\pm$ 0.72
Chedabucto Bay	Feb. 1970	20	18.45 $\pm$ 0.86	73	18.56 $\pm$ 0.80

hatched larvae have a shorter laraval period than autumn-hatched larvae (Jean, 1956). However, the use of otolith nuclei sizes has limitations, since the actual sizes are sometimes masked by an overgrowing material that increases with age of fish. Moreover, variations in nuclei sizes may arise from variations in environmental conditions that may occur within a season as well as between seasons (Messieh, 1969a). This explains the large overlapping of their frequency distributions (Figure 27).

Differences between otolith types were also evident in their growth. Differences between regression of otolith lengths on fish lengths for both types indicate significant differences between the two populations, but it should be noted that these regressions are based on adult herring of lengths ranging from 260 to 370 mm. No samples of smaller herring were available to determine whether or not otoliths grew differently before attaining sexual maturity. For young herring in the Gulf of Maine, an area adjacent to the study area, Watson (1964) found that otolith lengths increased in direct proportion to fish lengths. His conclusion was based on fish ranging from 80 to 275 mm in length.

Differences between maturation stages of herring of different otolith types showed that each type represents a different spawning group, with a different maturation cycle. The significant differences between fin ray counts of herring of the two otolith types indicate that these fish most likely inhabited different environments in their

early stages of development. The fish with S-type otolith - having smaller number of meristic counts - were probably subjected to warmer water than those fish with A-type.

8

SEPARATION OF HERRING STOCKS IN RELATION
TO HYDROGRAPHIC REGIME AND MIGRATION

In the previous sections it has been shown that the differences between spring and autumn herring populations are significant and consistent. Both populations differ in meristic characters (pectoral fin counts, dorsal fin counts and gill raker counts) and vital parameters (growth rate and year-class strength). These differences could not be achieved without accepting the hypothesis that the two populations are biologically isolated, i.e. separate unit-stocks.

Ideally, differences between stocks should have the same sort of taxonomic differences that are used to separate between species, subspecies or races because they are presumably genotypic. In practice these differences are often meristic characters or vital parameters. The problem of delineating the stocks then arises when there is more than one stock inhabiting the area, and when mixing in one or more stages of the life cycle occurs, as is the case of Atlantic herring. Attempts were made to study the role of the hydrographic regime (water circulation) in maintaining the identity of the spring and autumn herring stocks during their migration. It is assumed that a herring stock depends upon the containment of its migration circuit within a fixed current structure, to maintain itself from spawning to spawning.

Circulation

One of the major factors affecting herring migration is the circulation pattern of waters inhabited by the fish. Water currents have been studied using Lagrangian techniques. Drift bottles and seabed drifters were released from research cruises and recoveries were recorded with pertinent data on their dates and location. Number of releases, recoveries and percentage recoveries by year are presented in Appendix Tables 20 and 21. Recoveries of 1967 and 1968 releases only were used for this analysis. Surface and bottom circulation inferred from these recoveries for each cruise are shown in Appendix Figures 2 to 17. The lines showing the direction of the current are drawn by joining the points of releases and recoveries in the most direct way. In some cases when these lines were congruent or overlapping due to many recoveries in one area, the lines were reduced to avoid complication of the figure.

As it is shown in these figures, the general pattern of the surface circulation is cyclonic. The main features are the Gaspé current extending along the Gaspé coast drifting southward, and a southerly and easterly drift prevailing on Magdalen Shallows forming a huge semicircle crossing the Laurentian Channel towards the Newfoundland side of the Gulf. Comparison of the drift-bottle recoveries by cruise indicates a seasonal trend in the surface circulation. More drift-bottles were stranded on the Newfoundland coast and bays in the spring than autumn which indicates that the current was more offshore

in the latter season. On the other hand, more recoveries have been taken from Prince Edward Island and the Gulf side of Cape Breton Island from the autumn releases. The trend in the seasonal variation of surface currents is shown in Figure 29. Those of the winter (based on geostrophic circulation) are adapted from El-Sabh and Johannssen, 1971.

Another feature of the circulation is the presence of gyres in some areas of the Gulf. These gyres appear in two areas: one southeast of PEI as shown in cruises AF (August 18-20, 1967) and EEP-33 (August 17-30, 1968), and another gyre near the mouth of the Bay of Chaleur (cruises HU-24, August 8-28, 1967; and GRF-94, July 26-August 5, 1968). Similar gyres in these two locations were reported previously by Trites (1968) and Legendre and Watt (1970) respectively. Around Magdalen Islands many drift-bottles were found stranded on the shores. Many sea-bed drifters were also recovered inshore around the Islands, especially from the western side, indicating convergence in this area.

Drift of Herring Larvae

Herring larvae are pelagic and they are carried passively by water currents during at least their early stages before they are able to swim independently of the current. Hence it is presumed that the distribution of herring larvae would be influenced by the circulation pattern. Messieh and Kohler (1972) in their study of herring larvae in the Gulf of St. Lawrence in 1966 through 1970 found a general agreement between the distribution of larvae and the surface circulation.

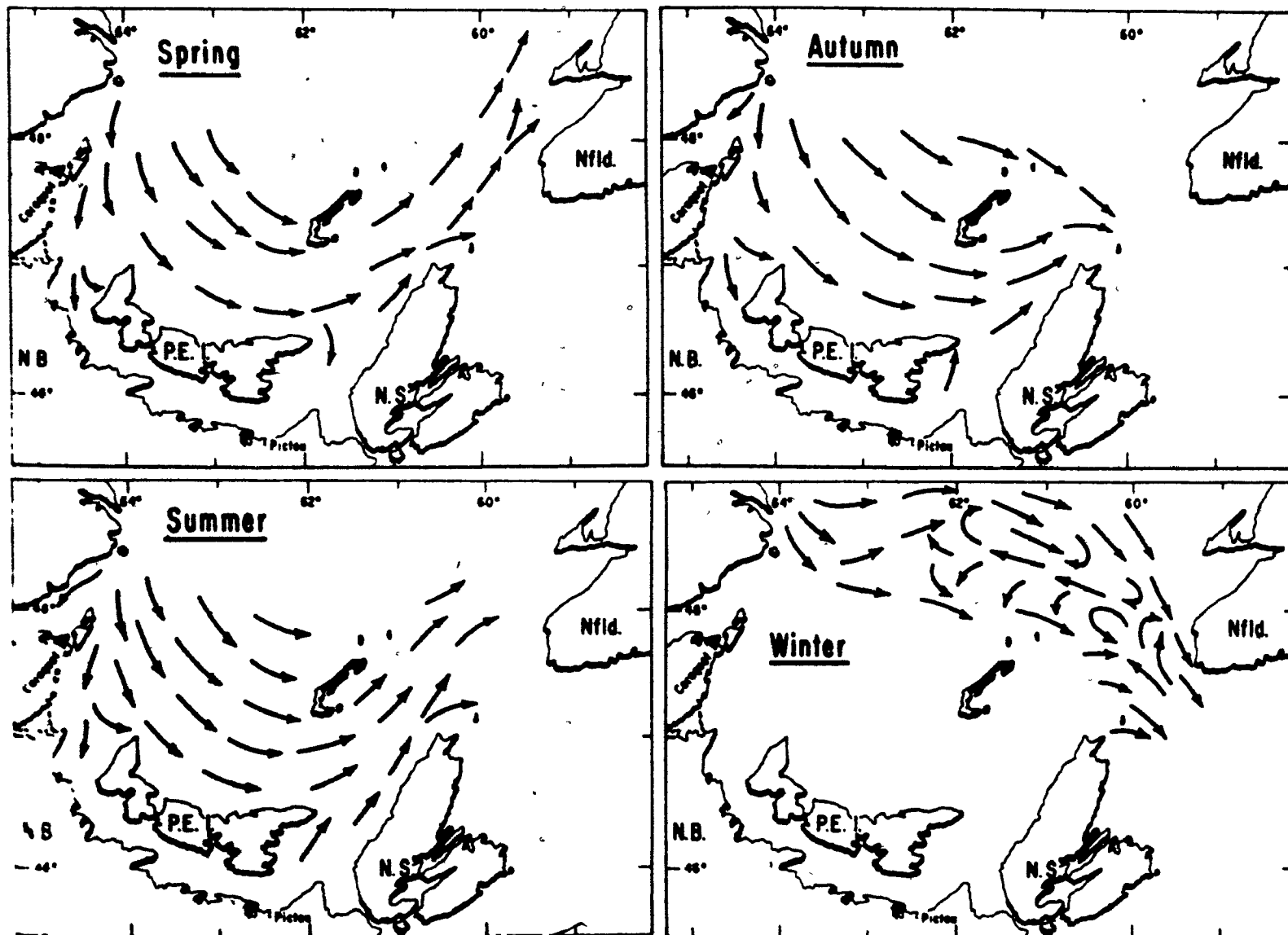


FIGURE 29: Surface currents in the Gulf of St. Lawrence as inferred from the drift-bottle recoveries (spring, summer and autumn) and geostrophic currents (winter).

The distribution of the different sizes of herring larvae made it possible to plot their dispersal pattern and to follow their drift from the spawning centres (Figure 30). It appears that there are seasonal variations in the larval distribution which apparently correspond with the seasonal variation in the circulation pattern. Although the number of larvae collected near the Newfoundland side of the Gulf was relatively small, it gave an indication that spring-spawned larvae were drifted toward St. Georges Bay, southwest Newfoundland, in the spring. This was clear from the larval collection in two cruises made in June 1969 and May 1970. None of the larvae have been collected from the same stations during the autumn cruises. These results agree with the results of drift-bottle recoveries where many of the drift-bottles were found stranded in this bay and along the coast in the nearby areas from releases made during spring cruises.

Unfortunately no stations were made offshore farther to the north to investigate whether autumn-spawned larvae are found there. From a previous report (Squires, 1957), it was found that autumn-spawned larvae were taken from offshore stations during a cruise on the *CNAV Sackville*, September 18 to October 18, 1955. "Plankton tows were taken in the northern part of the Gulf of St. Lawrence and the Strait of Belle Isle where cod eggs and herring larvae were found in fair numbers The greatest number of herring larvae was taken over the northern end of the Esquiman Channel, the deep-water channel running along the west coast of Newfoundland." We recall (see chapter 5) that

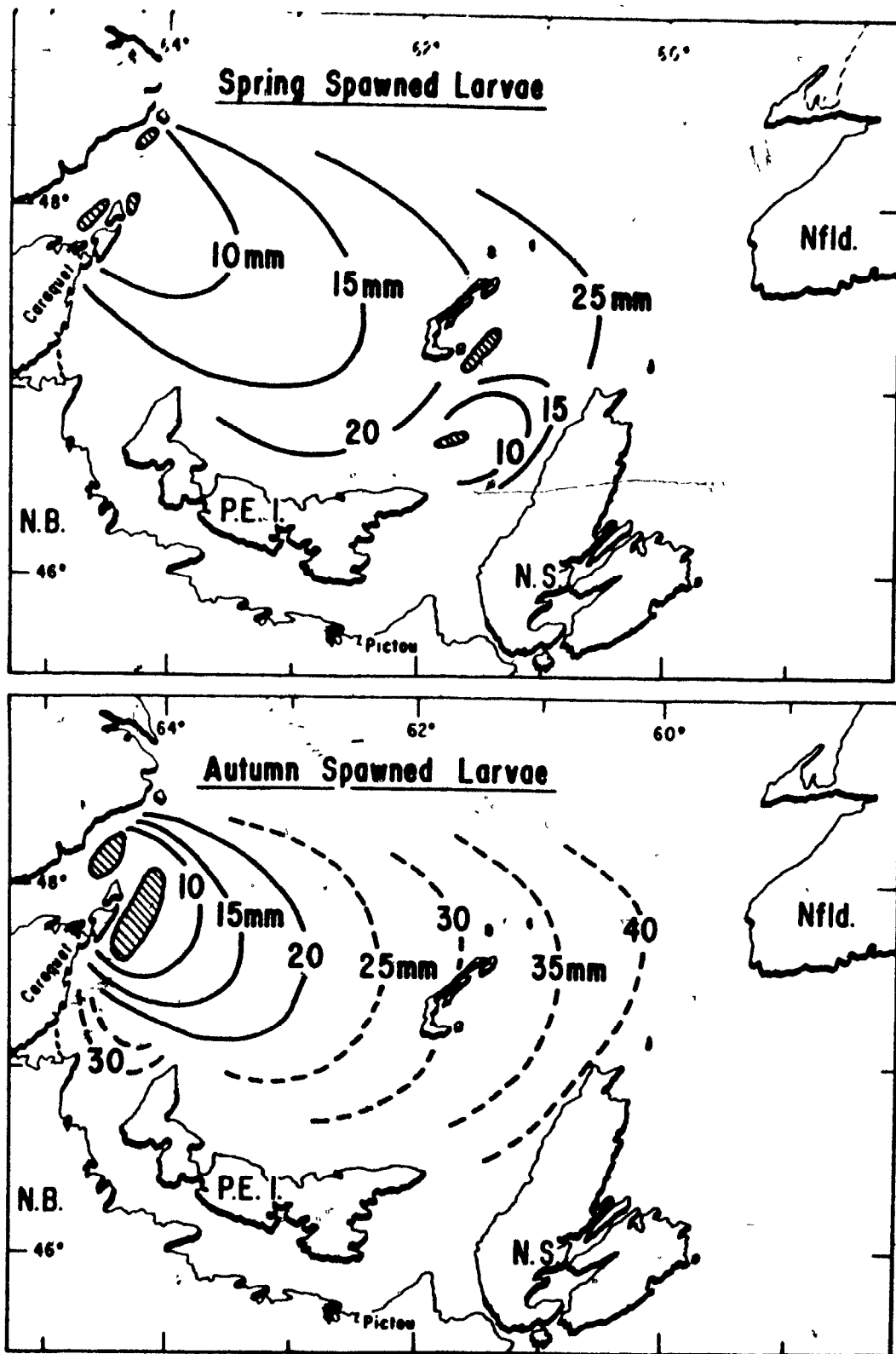


FIGURE 30: Dispersal patterns of spring- and autumn-spawned herring larvae in the Gulf of St. Lawrence, as inferred from their size distribution. Dashed lines represent autumn-spawned larvae caught in succeeding spring.

autumn spawning does not occur on the western coast of Newfoundland and the only source of these autumn spawned larvae would be the Magdalen Shallows.

The influence of the gyres in the differential distribution of spring and autumn spawned herring should not be overlooked. In the foregoing section it has been shown that there is a gyre at the entrance to the Bay of Chaleur. This gyre appears to be a permanent feature in this area (Legendre and Watt, 1970). We recall that some of the major spawning grounds are located in this area near the mouth of the Bay of Chaleur in Caraquet/Miscou area (Figure 17). In this figure it is shown that the spring spawning ground is located west of Miscou Island, while the autumn spawning grounds are located more offshore and east of Miscou Island. Hence, it is to be expected that the spring-spawned larvae would be in the range of this gyre, thus more likely to be retained inside the bay than the autumn-spawned larvae. From the distribution of herring in the Bay of Chaleur (Messieh and Kohler, 1972) the finding of more concentrations of spring-spawned larvae inside the bay during the spring and summer cruises agrees with the above conclusion.

Migration of Adult Herring

The migratory circulation of adult herring appears to provide the fish with the advantage of best benefit from the hydrographic conditions and the production cycle in the area. They move around in the Gulf of St. Lawrence spending the winters in the deep warm waters in

the fjords along the southwest and west coast of Newfoundland, and moving westward - after overwintering - to feed and spawn on the Magdalen Shallows. The area of the Magdalen Shallows is thought to be the region where much of the plant production swept by the Gaspé current from the St. Lawrence estuary is converted to animals (Steven, 1970). This region also supports the most important nursery for major fish stocks and benthic animals.

There is a body of circumstantial evidence which suggests that spring- and autumn-spawning populations separate in their migratory circulation, and probably take different routes. The implication is that the two populations should have separate life cycles. The evidence for this hypothesis is the following:

1. In early spring after the melting of the ice, and the warming up of the water, herring gather in schools in wintering areas (major areas so far known are located on the southwest coast of Newfoundland) and move offshore leaving the area. A few days later the spring-spawning herring appear near Magdalen Island ready for spawning. Tagging results confirmed that these fish are of the same population which overwintered in the southwest coast of Newfoundland (Winters, 1971). On the other hand, there is a delay of autumn herring which do not arrive on the Magdalen Shallows until mid-summer (Messieh and Tibbo, 1971).
2. Hodder (1971) reported that: "About the time that the herring leave the Newfoundland coast in the spring some separation of spring- and autumn-spawning herring is evident from samples

taken from seiner catches near the end of the season in early April. The short fishery at Magdalen Islands in late April and early May is based mostly on herring schools heading for shallow water to spawn, but a few catches consist mostly of autumn spawners. However, the latter probably disperse to a large extent and ultimately move westward to the southwestern part of the Gulf, where they feed during the summer and spawn in late summer and early autumn."

3. Decamps (1971) examined herring samples (400 fish) taken by RV *Thalassa* off Cape St. Lawrence and Cape Smoky (Cape Breton Island) and Burgeo Bank (south of Newfoundland). These fish were apparently a part of the overwintering herring along the southwest coast of Newfoundland and in their way to spawning migrations. Results of his examination indicate a segregation of spring- and autumn-spawning herring. The distinction between 'spring' and 'autumn' spawning herring gives the following results: Cape St. Lawrence 86% 'spring herring', Cape Smoky 98% 'autumn herring', Burgeo 87% 'autumn herring'.
4. Some herring samples - which I have started to collect for a herring feeding study - were used for calculating an index of feeding as follows:

$$\text{Index of feeding} = \frac{\text{wet weight of stomach}}{\text{weight of fish}} \times 1000$$

This index gives a rough estimate of the feeding condition of

TABLE 34

Feeding index of herring samples from Gulf of St. Lawrence taken in May through September 1972. Numbers of fish, means, standard deviations (SD), and stand errors (SE) of the means are included.

Feeding Index	West Point PEI May	St. Georges Bay May	Caraquet May	Borden PEI May	Shediac May	Escuminac June	Egmont June	American (A) July	American (B) July	Caraquet August	Chaleur Bay September
5	6		19	31			9			29	
10	30		27	17	8	10	12			20	1
15	10	1	2	2	11	19	1	3		1	
20	3	8	2	2	5	6	2	4	1		
25		9			2	4	1	5	1	1	1
30	1	7			2			9	6		1
35		8						11	7		1
40		6				1		5	5		1
45		5						9	8		1
50		2						3	5		1
55		2							4		2
60									4		2
65								1	4		1
70									2		1
>70									3		
N	50	48	50	50	28	40	25	50	50	50	13
$\bar{x}$	11.49	32.60	8.70	7.10	16.25	16.13	9.80	34.50	47.60	7.20	46.15
SD	4.50	10.21	3.62	2.87	5.87	5.93	5.30	10.51	14.89	2.70	17.46
SE	0.64	1.47	0.51	0.41	1.11	0.94	1.06	1.49	2.11	0.38	4.84

the fish. A few samples were also examined for the major food items preyed by the fish.

Analysis of feeding index (Table 34) has shown that the fish spend some time in a 'fasting period' before spawning. Almost all fish either spring- or autumn-spawners had empty stomachs when they were in the ripe and running stage of maturation. Shortly after spawning the fish feed vigorously showing a peak in May, continue feeding throughout the summer, and another feeding peak appears in September. From the few stomach samples examined for the kind of food eaten by the fish, Euphausiids appear to be the dominant food in the spring while copepods were dominant during the summer.

Based on the foregoing evidence, it is hypothesized that the two populations have two separate life cycles, with different migratory circulations as presented in the schematic model (Figure 31). The sequence of the migratory phases for the spring spawning population is: wintering + spawning + feeding. For the autumn-spawning population the sequence is: wintering + feeding + spawning. The nursery grounds of the juvenile herring are still not known in spite of the frequent surveys which started in 1966. To discover whether there are separate nursery grounds for the two herring populations or whether there is a common ground shared by herring of various origins - as is the case with the Passamaquoddy herring (Messieh, 1970) - will need further investigation.

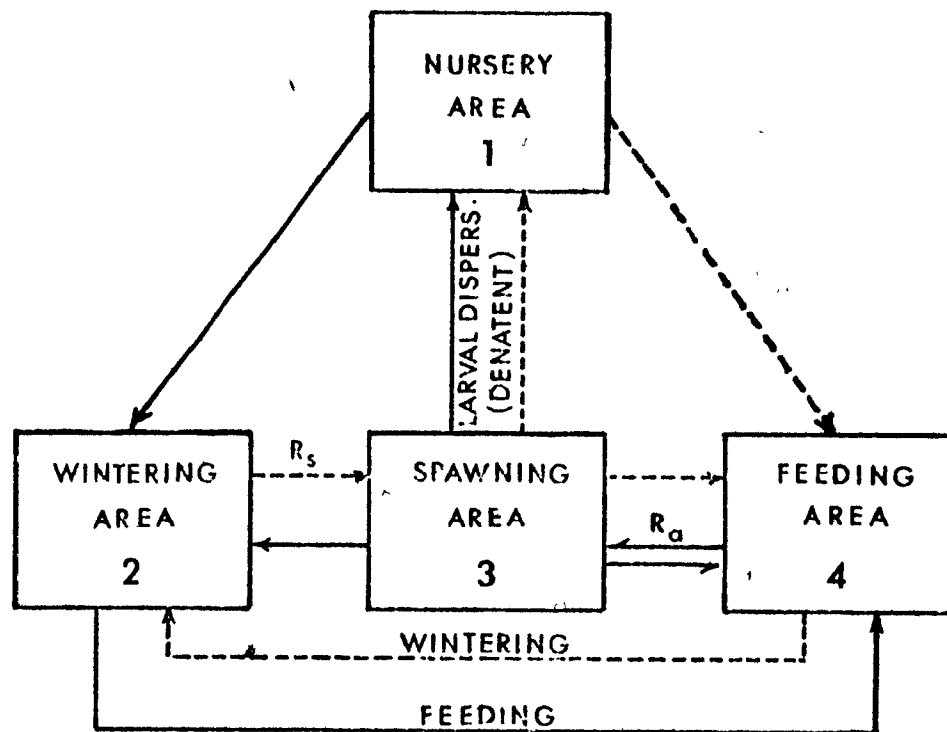


FIGURE 31: A theoretical model of the life cycle of spring (---) and autumn (—) spawning herring in the Gulf of St. Lawrence. R_s : recruitment of spring herring, R_a : recruitment of autumn herring.

REFERENCES

- ALLEN, K.R. 1966. A method of fitting growth curves of the von Bertalanffy type to observed data. *J. Fish. Res. Bd. Canada*, 23: 163-179.
- ANDERSON, T.W. 1958. *Introduction to multivariate statistical analysis*. John Wiley and Sons, New York, Section 6.6-6.8.
- ANON. 1962. Recommendations adopted by the Herring Committee. Rapp. Proces - Verbaux Reunions Cons. Perma. Int. Explor. Mer. Append. 1: 71-73.
- ANON. 1972. Report of the standing Committee on research and statistics, Appendix II. ICNAF Res. Doc. Ser. No. 2886.
- ANON. 1972. International Commission for the Northwest Atlantic Fisheries. ICNAF Statistical Bull. Vol. 21.
- BARRETT, B.E. 1968. The fecundity of Canadian Atlantic herring, ICNAF Res. Doc. 68/62.
- BAXTER, I.G. 1959. Fecundities of winter-spring and summer-autumn herring spawners. *J. Cons. Perm. Int. Explor. Mer.*, 25: 73-80.
- BERTALANFFY, L. VON. 1938. A quantitative theory of organic growth. *Hum. Biol.* 10 (2): 181-213.
- BIGELOW, H.B., and W.C. SCHROEDER. 1953. Fishes of the Gulf of Maine. U.S. Fish and Wildlife Serv., Fish. Bull. 74, Vol. 53: 1-577.
- BOYAR, H.C., and R.A. CLIFFORD. 1967. An automatic device for counting dry fish eggs. *Trans. Amer. Fish. Soc.*, 96: 361-363.

- DAY, L.R. 1957. Populations of herring in the southern Gulf of St. Lawrence. Fish. Res. Bd. Canada Bull. 111: 121-137.
- DECAMPS, P. 1971. Study of the biological characteristics of spring and autumn herring taken off Cape Breton Island and Burgeo Bank. ICNAF Res. Doc. 71/40.
- DUNBAR, M.J. 1960. The evolution of stability in marine environments, natural selection at the level of the ecosystem. The American Naturalist Vol. XCIV, No. 875: 129-136
- EINARSSON, H. 1951. Racial analysis of Icelandic herring by means of the otoliths. Rapp. et Proc. Verb. Reun. Cons. Perm. Int. Explor. Mer., 128: 55-74.
- EL-SABH, M.I., and O.M. JOHANNSEN. 1971. Winter geostrophic circulation in the Gulf of St. Lawrence. Marine Science Centre, McGill University. MS Rept. No. 18.
- GINSBURG, I. 1938. Arithmetical definition of the species, subspecies and race concept, with a proposal for a modified nomenclature. Zoologica 23 (13): 253-286.
- GRAHAM, T.R. 1962. A relationship between growth, hatching and spawning season in Canadian Atlantic herring (*Clupea harengus* L.). J. Fish. Res. Bd. Canada 19: 985-987.
- HEINCKE, F. 1898. Naturgeschichte des herings. Teil I. Die Lokalformen und die Wanderungen des herings in den europaeischen Meeren. Abh. dtsh. Seefisch, Ver. 2: 128-223.
- HEMPEL, G., and J.H.S. BLAXTER. 1961. The experimental modification of meristic characters in herring (*Clupea harengus* L.). J. Cons. Perm. Int. Explor. Mer., 28: 336-46.

- HJORT, J. 1915. Investigations into the natural history of the herring of the Atlantic waters of Canada, 1914, Preliminary Rept. Dept. of the Naval Service, Ottawa, 38 pp.
- HJORT, J. 1919. Investigations in the Gulf of St. Lawrence and Atlantic waters of Canada. Canadian Fisheries Expedition, 1914-1915. Dept. of the Naval Service, Ottawa.
- HODDER, V.M. 1971. Status of the southwest Newfoundland herring stocks 1965-70. ICNAF Redbook 1971: 105-114.
- HODDER, V.M. 1972. The fecundity of herring in some parts of the Newfoundland area. ICNAF Res. Bull. No. 9: 99-107.
- HODDER, V.M., and G.H. WINTERS. 1972. Distribution and size of larval of herring and capelin, southern Gulf of St. Lawrence and southwestern Newfoundland, November 1969 and 1970. Fish. Res. Bd. Canada, Tech. Rept. No. 315, 25: 25 pp.
- HOURSTON, A.S. 1968. Herring landings and catches by fishing seasons in Newfoundland waters - herring spawnings in 1967. Fish. Res. Bd. Canada, Biol. Sta. St. John's, Newfoundland. Circ. No. 15: 1-17.
- HOURSTON, A.S. 1969. Distribution and migratory movements of major herring stocks in Newfoundland waters. Fish. Res. Bd. Canada, Biol. Sta. St. John's, Newfoundland. Circ. No. 16: 8-9.
- HOURSTON, A.S., and L.S. PARSONS. 1969. Opaque and hyaline otolith nuclei as indicators of spring and autumn spawning herring in Newfoundland waters. Fish. Res. Bd. Canada, Tech. Rept. 138: 26 pp.

- HUBBS, C.L. 1925. Racial and seasonal variation in the Pacific herring, California sardine, and California anchovy. Calif. Fish Game Comm. Fish. Bull. No. 8, 23 pp.
- HUBBS, C.L. 1940. Speciation of fishes. *The American Naturalist*, 74: 198-211.
- HUMPHREYS, R.D. 1965. Biological characteristics of herring population on the south coast of Newfoundland. *J. Fish. Res. Bd. Canada*, 23: 97-804.
- JEAN, Y. 1956. A study of spring and fall spawning herring (*Clupea harengus* L.) at Grande-Riviere, Bay of Chaleur, Quebec. Dept. Fish. Que. Contrib. 49: 76 pp.
- KREFT, G. 1958. Counting of gill rakers as a method of morphological herring investigation. *Rapp. et Proc. Verb.* Vol. 143 (2): 22-25.
- LAUZIER, L.M. 1957. Variations of temperature and salinity in shallow waters of the southwestern Gulf of St. Lawrence. *Bull. Fish. Res. Bd. Canada* 111: 251-268.
- LAUZIER, L.M. 1957. Bottom temperatures on the Magdalen Shallows. *Fish. Res. Bd. Canada Bull. No. 111*: 269-285.
- LEA, E. 1919. Report on age and growth of the herring in Canadian waters. *Can. Fish. Exped.* 75-164.
- LEE, R.M. 1920. A review of the methods of age and growth determination in fishes by means of scales. *Fish. Invest. London* (2) 4 (2): 1-32.

- LEGENDRE, L., and W.D. WATT. 1970. The distribution of primary production relative to a cyclonic gyre in the Bay of Chaleur. *Marine Biol.*, 7: 167-170.
- LEIM, A.H. 1946. Herring investigations conducted by the Atlantic Herring Investigation Committee. Fish. Res. Bd. Canada, Biol. Sta. St. Andrews, Ann. Rept. 1946: 34-38.
- LEIM, A.H. 1954. Atlantic Investigation Committee, Final Report, Vol. 1: 15-45.
- LEIM, A.H., S.N. TIBBO, and L.R. DAY. 1957. Explorations for herring in Canadian Atlantic waters, 1945-1950. Fish. Res. Bd. Canada Bull. No. 111: 35-83.
- MAHANALOBIS, P.C. 1936. On the generalized distance in statistics. Proc. Nat. Inst. Sciences (India) 2 (1): 49-55.
- MESSIEH, S.N. 1969a. Similarity of otolith nuclei in spring- and autumn-spawning Atlantic herring in the southern Gulf of St. Lawrence. *J. Fish. Res. Bd. Canada* 26: 1889-1898.
- MESSIEH, S.N. 1969b. Growth of immature herring populations in Passamaquoddy area - Bay of Fundy. ICNAF Res. Doc. 69/48: 11 pp.
- MESSIEH, S.N. 1970. Immature herring populations in the Bay of Fundy ICNAF Res. Bull. No. 7: 59-66.
- MESSIEH, S.N. 1972. Use of otoliths in identifying herring stocks in the southern Gulf of St. Lawrence and adjacent waters. *J. Fish. Res. Bd. Canada* 29: 1113-1118.

- MESSIEH, S.N., and S.N. TIBBO. 1971. Discreteness of Atlantic herring (*Clupea harengus* L.) populations in spring and autumn fisheries in the southern Gulf of St. Lawrence. *J. Fish. Res. Bd. Canada* 28: 1009-1014.
- MESSIEH, S.N., and A.C. KOHLER. 1972. Distribution, relative abundance and growth of larval herring (*Clupea harengus* L.) in the southern Gulf of St. Lawrence. Fish. Res. Bd. Canada, Tech. Rept. No. 318: 31 pp.
- MORICE, J. 1971. French Research Report to ICNAF Subarea 3 and 4. ICNAF Redbook 1971: 46-64.
- OLSEN, S. 1961. Contribution to the biology of herring (*Clupea harengus* L.) in Newfoundland Waters. *J. Fish. Res. Bd. Canada*, 18: 31-46.
- PARRISH, B.B. 1964. Notes on the identification of subpopulations of fish by serological and biochemical methods. The status of techniques and problems of their future application. FAO Fish. Tech. Pap. 30: 9 pp.
- PARRISH, B.B., and D.P. SHARMAN. 1958. Some remarks on methods used in herring racial investigation with special reference to otolith studies. *Rapp et Proc. - Verb. Reun. Cons. Perm. Intern. Explor. Mer*, 143: 66-80.
- PARRISH, B.B., and D.P. SHARMAN. 1959. Otolith types amongst summer-autumn spawning herring in the northern North Sea. *J. Cons. Perm. Int. Explor. Mer*, 25: 81-92.

- PARRISH, B.B., and A. SAVILLE. 1965. The biology of Northeast Atlantic herring populations. In: Oceanog. Mar. Biol. Ann. Rev. Harold Barnes (ed.) Vol. 3: 323-373.
- PARSONS, L.S., and G.H. WINTERS. 1972. ICNAF herring otolith exchange 1971-72. ICNAF Res. Doc. 72/92, 23.
- POSTUMA, K.H., and J.J. ZIJLSTRA. 1958. On the distinction between herring races in the autumn- and winter-spawning herring of the North Sea and English Channel by means of otoliths and an application of this method in tracing the offspring of the races along the continental coast of the North Sea. Rapp. et Proc. Verb. Vol. 143 (2): 130-145.
- RAO, R.C. 1952. *Advanced statistical methods in biometric research*. John Wiley and Sons, Inc., New York, 390 pp.
- ROUNSEFELL, G.A., and E.H. DAHLGREN. 1932. Fluctuations in the supply of herring, *Clupea pallasii*, in Prince William Sound, Alaska. Bull. U.S. Bur. Fish., Vol. 47: 263-291.
- RUNNSTROM, S. 1941. Racial analysis of the herring in Norwegian waters. Fiskeridir. Skr. Ser. Havunders. 6 (7): 1-110.
- SAMEOTO, D.D. 1971. The distribution of herring (*Clupea harengus* L.) larvae along the southern coast of Nova Scotia with some observations on the ecology of herring larvae and the biomass of macrozooplankton on the Scotian Shelf. Fish. Res. Bd. Canada, Tech. Rept. No. 252: 72 pp.

- SINDERMAN, C.J. 1958. An epizootic in Gulf of St. Lawrence fishes.
Trans. 23rd North American Wildlife Conference, 349-360.
- SQUIRES, H.J. 1957. Cod eggs and herring larvae in late September
an indication of fall spawning in the Gulf of St. Lawrence.
Prog. Rept. of the Atlant. coast stations, Fish. Res. Bd.
Canada, No. 67: 31-33.
- STEVEN, D. 1970. International Biological Programme Study of the
Gulf of St. Lawrence. In: Second Gulf of St. Lawrence Work-
shop, Bedford Inst., Dartmouth, N.S.: 146-159.
- TANING, A. 1952. Experimental study of meristic characters in fishes.
Biol. Rev. 27: 169-193.
- TESTER, A.L. 1937. Populations of herring (*Clupea pallasii*) in the
coastal waters of British Columbia. *J. Fish. Res. Bd. Canada*,
3 (2): 108-144.
- TESTER, A.L. 1938. Variation in the mean vertebral count of herring
(*Clupea pallasii*) with water temperature. *J. Cons. Perma. Int.*
Explor. Mer 13: 71-75.
- TIBBO, S.N., and T.R. GRAHAM. 1963. Biological changes in herring
stocks following an epizootic. *J. Fish. Res. Bd. Canada*, 20:
435-39.
- TRITES, R.W. 1968. Are gyres a common feature of the Gulf? Gulf of
St. Lawrence Workshop Rept., Bedford Inst., Dartmouth, N.S.,
34-36.

TRITES, R.W. 1970. The Gulf of St. Lawrence from a pollution viewpoint.

FAO Technical Conference on marine pollution and effects on
living resources and fishing, 23 pp.

VLADYKOV, V.D. 1956. Fecundity of wild speckled trout (*Salvelinus
fontinalis*) in Quebec lakes. *J. Fish. Res. Bd. Canada*, 13:
799-841.

WALFORD, L.A. 1946. A new graphic method of describing the growth of
animals. *Biol. Bull. (Woods Hole)* 90: 141-147.

WATSON, J.E. 1964. Determining the age of young herring from their
otolith. *Trans. Amer. Fish. Soc.* 93: 11-20.

WINTERS, G.H. 1971. Migration of the southwest Newfoundland stock of
herring as indicated by tag recaptures. *ICNAF Res. Doc.*
71/108, 6 pp.

ZIJLSTRA, J.J. 1958. On the herring 'races' spawning in the southern
North Sea and English Channel (preliminary report). *Rapp. et
Proc. Verb. Reun. Cons. Perm. Intern. Explor. Mer.* 142:
134-145.

APPENDIX 1

REPORT ON HERRING SPAWNING TIME, DURATION AND LOCALITIES

BASED ON INTERVIEWS BY DR. A.H. LEIM

WITH THE FISHERIES OFFICERS AND FISHERMEN DURING 1943/44

Sydney, N.S.

Early in May there was a spring run of small poor fish. All are caught by gill-nets. Four miles offshore would be the extreme limit to which they are set. No herring ever being taken offshore around Cape Breton. Very few herring are taken in the Bras d'Or Lakes. A few are caught in winter in nets set through the ice, and in early spring. At present no trap nets are set in Sydney Harbour because a more regular supply is available at St. Ann's. Outside Sydney Harbour the catch around the shore has been fairly constant. The herring are spring spawners. There are no fall spawners here at all.

In the last 6 to 7 years the herring seem to have left Sydney Harbour and gone to St. Ann's Bay. The spring fish at St. Ann's, Sydney and Ingonish are all spawners; the next herring arriving about December first, and running on for four months.

Baddeck, N.S.

Herring can be caught at any time of the year in Whycogomagh Bay. These are all small fat herring. The fishing in the Bras d'Or Lakes is all done by gill-nets. Some years there are so many herring in the inland waters that they do not know what to do with them.

Appendix 1 continued:

Herring spawn at the head of St. Ann's Harbour. The herring are all spring spawners here. Fat July herring are scarce now. They were quite plentiful 20 or more years ago. All were caught outside - from Cape Smoky along the shore. In March and April some fish are caught through the ice. All the 'inside' netting is fairly close to the shore. In Whycogomagh Bay they set at different depths depending on the season. Whenever the ice moves off outside the herring come. In the Bras d'Or Lakes they are under the ice. Fishermen claim that there are three schools of herring come in. In St. Ann's Bay they get a lot of small herring (6 inches or less) in the traps in May.

Terre Noire, N.S.

Herring are taken all along the district. As a rule the area from Broad Cove to Margaree Harbour is good for herring. Pleasant Bay is fairly good. Cheticamp is not as good. The runs do not seem to last as long as they formerly did. From May 20th to June 15th there is a fairly regular supply of spawning herring. Usually by the last week of June to mid-July there is a run of fat herring - both larger and fatter than the spring fish. The July fish are caught farther offshore - $\frac{1}{2}$ to 2 miles.

Margaree Harbour, N.S.

The first herring are caught in May. They are very thin spawning fish. The spring run of herring is not large since 12 to 15 years ago. Formerly there were a lot of spring herring although they were

Appendix 1 continued:

not fished very hard. The fat July herring are used for cod bait or salted for mackerel bait. This year they are getting quite a few September herring, are mostly spawned out.

Cheticamp, N.S.

May and July are the only herring months here.

Port Hood, N.S.

Herring are taken chiefly in the Judique and Port Hood area in the summer months. The spring run is about equally distributed all along the coast, although there are more from Inverness to Judique. In an ordinary spring the herring come during the second week in May and spawn. These fish are just a medium size. All caught in gill-nets. Six years ago and before there was one trap at Port Hood Island. A run of fairly lean herring, in small quantities, comes in July. The fish are a little larger than the spring run.

There is a run of herring along in the latter part of August and into September - very large fish - which spawn. This fall run is taken in quantity only at Port Hood Island. There is a bank with 14 fathoms of water off Port Hood Island. They used to fish just inside that bank. The fall run usually ends in September.

There is not very much herring in the Bras d'Or Lakes; a large run comes about the time the ice is breaking up. The bulk are in the West Bay area. No quantity taken in the Bras d'Or Lakes during the

Appendix 1 continued:

summer, and not many in the autumn.

Antigonish County, N.S.

In the spring the herring are caught first in George Bay. This is in the latter part of April when the ice is leaving. The next big run is from the 15th to the 24th of May. It lasts until the second week in June. There are very few July or August herring. Used to get some in former years. The next run is about this time of the year and only lasts about 10 days. The spring run are all spawners and very thin. From Pictou County line to Cape George the herring strike later than in George Bay. The July fish are fatter than the spring fish but are not very fat. The only fat herring they get are caught in the latter part of September. September herring are taken all the way from Harbour Boucher to Pictou County line. The best spring herring fishing in this county is around Harbour Boucher and Cape Jack. Years ago they used to get fat July herring but not now.

Pictou, N.S.

They are getting a few herring now (Sept. 17, 1943) outside Pictou Island. They were spawning or spawned out - just like the Port Hood lot. Do not get many herring in spring. There are more at this time of year than any other. Those shown in statistics for November were probably taken in September or October.

Appendix 1 continued:

New Mills, N.B.

The ice usually does not go out until the 1st to 5th of May and there are herring in then. They are larger fish but are not spawning. Then there is a second run of spawning fish in June. They are also large. They come from down the Bay where they catch them earlier. In summer they get a small very fat fish. In September there is a short run of large fat fish, from 14 to 15 inches long.

Jacquet River, N.B.

Never get any herring before the 20th of April. The first fish are as large as the last but the last fish are soft. The last of the fishing comes in late May or early June. Herring spawn around the 20th to 25th of May. No one fishes herring here in the summer.

Petit Rocher, N.B.

The first herring in 1943 were taken on May 8th, the last on June 4th. They get herring first about 4 miles from Bathurst, a week earlier than here at Beresford and a week later at Belle Dune. They get them up there when they are finished at Petit Rocher. Only get a few fall herring in September. The spring herring are not spawning when they arrive - they remain 3 to 4 days and then spawn, then disappear to be followed by other schools. Has observed cycles of unripe and ripe herring for a month. Herring were late this year. Usually they are here last week in April. They used to catch herring here under the ice about April 15th. As soon as the ice goes there are lots

Appendix 1 continued:

of herring. Herring spawn about two weeks after the ice goes or when the warm water strikes.

Grand Anse, N.B.

The spring fish are all caught within $\frac{1}{4}$ to $\frac{1}{2}$ mile from shore. The August-September catch is taken about the same place and some off on Caraquet Bank, - 6 to 7 miles east of Caraquet Island. Herring spawn in both spring and fall. The fall fish are fatter than the spring ones. In the spring, after storms, the spawn is sometimes a foot deep on the beach. Farmers haul it up for fertilizer.

Shippegan, N.B.

The first of the herring fishing is in April or May depending on the ice. It lasts through until June 10th. The June catches are small. Fish in spring all around both islands about equally distributed. The fall herring stay farther off in 5 to 8 fathoms of water which places the fishing about $1\frac{1}{2}$ to 2 miles offshore. Fall fishing is on the north side from Caraquet to Miscou Point - none on the outside to speak of. The fall fish are spawning too, but are large and fat. There is a run of $7\frac{1}{2}$ -inch to 8-inch fat herring in July.

Tracadie, N.B.

Fall herring are only caught in mackerel nets. They are not spawners. Spring herring are on from 25th of April to 1st of May. Years ago they used to miss the run by fishing too far offshore. In

Appendix 1 continued:

April and up to May 15th the fish are not spawning. They spawn after that. Disappear soon after spawning. The spawn is sometimes cast up on shore in quantity.

Bay du Vin, N.B.

From Bay du Vin to Portage River herring are about equally abundant. They get them a mile or so above Bay du Vin. They get herring in late April (25th) around Point Sapin but somewhat later at Bay du Vin. Some seasons the herring hang around until the last of May. At other times the wind takes them out earlier. They usually stay about a month. The herring spawn a short time after they arrive. They disappear soon after they spawn. There are no herring here in late June or July. The first fall herring come in August. The fall herring are never inside Escuminac settlement, but are on the outer coast.

Richibucto, N.B.

The fishery is concentrated at Richibucto Head and Harbour. They work north in the spring and south in the fall. Strike the latter part of April but usually the 1st of May - depends on the ice. May is usually the big month. They do not spawn until a little while after they arrive. The September herring sometimes hit on the shore. One year they tried with drift-nets about halfway between PEI and Richibucto. Got large quantities. Small herring were seen about 6 inches long, caught in the smelt gill-nets in October. Has not seen any in recent

Appendix 1 continued:

years. The spring fish appear as soon as the ice goes. There is always a little school of herring here in April. Large quantity in May. Sometimes get a good catch for a day or so in June. Spring fish spawn after May 15th - very close to shore then spawn is sometimes washed ashore. The fall fishery never amounted to much in this district. Small herring, 5 to 6 inches long in the smelt nets, were seen in December - in bag nets right in the river during the smelt fishing season (early December). Some years they get tons of them and other years none at all.

Shediac, N.B.

Bulk of herring catch is from the Shemogue River to Cape Binet. Practically none in Shediac Bay and none from Cape Tormentine to N.S. boundary. Get no herring in the fall. They had small herring in smelt net (4 to 5 inches long). The first herring here this year on the 25th of April. Get an odd herring in the mackerel nets in July.

Souris, PEI.

They catch more herring in the spring; they are smaller than the fall fish.

Carleton, Que.

Herring are caught from 15th to 31st of May. In September they usually get a few but there were not many in September 1943. There are herring up as far as St. Omer in spring.

Appendix 1 continued:

Port Daniel, Que.

The herring come on the shore line here in April and last until the 15th or end of May. They get large quantities within a quarter of a mile of shore. Then there are none along shore until the 10th to 15th of August when there is another run of herring - just as large as the spring fish. This run lasts through August.

Paspebiac, Que.

The spring run of herring is the only worthwhile thing here. It occurs in April and May. The fish are caught close to shore. He has seen the spawn four feet deep at Port Daniel. Herring come first then the capelin. The best section for herring is from Bonaventure to Caplan. This year the August run of fish lasted only 2 to 3 days and not over. The August fish are just part of a school that passes by. The spring run of herring is not as great in recent years as formerly.

Grand River, Que.

Most of the fish are taken close to shore - up to a mile or so off, sometimes get herring out at Orphan Bank. Said that the fall fishing for herring is very erratic - they may get a few or none for 8 to 10 days and then load the nets in a single night. The bulk of the spring herring fishing is in Bonaventure County. He thinks that just as much herring could be caught in Gaspé County if the fishermen went after them. He thinks, but is not certain, that the spring fish

Appendix 1 continued:

are the largest that are caught. The spring fishing here is all within a few miles of shore.

Fox River, Que.

The fishermen were getting a few small herring. The summer fish are smaller than the spring fish and are fairly fat as are the fall fish.

APPENDIX 2

[illegible]

APPENDIX 2

LENGTH COMPOSITION PER MILE		MEAN LENGTHS AND WEIGHTS					
year 1969 - area 436		JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
LENGTH		JUNE	MAY				TOTAL
70-79MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
80-89MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90-99MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
100-109MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
110-119MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
120-129MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
130-139MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
140-149MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
150-159MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
160-169MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
170-179MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
180-189MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
190-199MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
200-209MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
210-219MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
220-229MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
230-239MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
240-249MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
250-259MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
260-269MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
270-279MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
280-289MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
290-299MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
300-309MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
310-319MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
320-329MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
330-339MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
340-349MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
350-359MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
360-369MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
370-379MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
380-389MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
390-399MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
400-409MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
410-419MM	0.30	0.00	0.00	0.00	0.00	0.00	0.00
TL-PENNVILLE	0.30	0.00	0.00	0.00	0.00	0.00	0.00
TL-MEASURED	0.30	0.00	0.00	0.00	0.00	0.00	0.00
TL-EASY LENGTH	0.30	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX 2
TABLE 6

LENGTH	LENGTH COMPOSITION PER MILE --- MEAN LENGTHS AND WRIGHTS												TOTAL
	year 1969 - area 438												
	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	
70-79MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80-89MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90-99MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100-109MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
110-119MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
120-129MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
130-139MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
140-149MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150-159MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
160-169MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
170-179MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
180-189MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
190-199MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
200-209MM	0.00	0.00	0.00	0.00	0.00	1.23	0.00	0.00	2.94	0.00	0.00	0.00	0.00
210-219MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.41	0.00	0.00	0.00	0.00
220-229MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.47	0.00	0.00	0.00	0.00
230-239MM	0.00	0.00	0.00	0.00	0.00	1.23	5.90	0.00	1.47	0.00	0.00	0.00	0.00
240-249MM	0.00	0.00	0.00	0.00	0.00	3.91	0.00	0.00	20.61	0.00	0.00	0.00	0.00
250-259MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.45	0.00	0.00	0.00	0.00
260-269MM	0.00	0.00	0.00	0.00	0.00	30.97	5.00	0.00	108.98	0.00	0.00	0.00	0.00
270-279MM	0.00	0.00	0.00	0.00	0.00	48.32	25.00	0.00	223.85	0.00	0.00	0.00	0.00
280-289MM	0.00	0.00	0.00	0.00	0.00	69.39	70.00	0.00	184.39	0.00	0.00	0.00	0.00
290-299MM	0.00	0.00	0.00	0.00	0.00	89.21	140.00	0.00	125.18	0.00	0.00	0.00	0.00
300-309MM	0.00	0.00	0.00	0.00	0.00	121.53	155.00	0.00	88.35	0.00	0.00	0.00	0.00
310-319MM	0.00	0.00	0.00	0.00	0.00	110.28	145.00	0.00	41.23	0.00	0.00	0.00	0.00
320-329MM	0.00	0.00	0.00	0.00	0.00	144.98	165.00	0.00	41.23	0.00	0.00	0.00	0.00
330-339MM	0.00	0.00	0.00	0.00	0.00	171.00	125.00	0.00	32.40	0.00	0.00	0.00	0.00
340-349MM	0.00	0.00	0.00	0.00	0.00	121.43	115.00	0.00	50.57	0.00	0.00	0.00	0.00
350-359MM	0.00	0.00	0.00	0.00	0.00	40.89	35.00	0.00	32.40	0.00	0.00	0.00	0.00
360-369MM	0.00	0.00	0.00	0.00	0.00	13.63	5.00	0.00	6.83	0.00	0.00	0.00	0.00
370-379MM	0.00	0.00	0.00	0.00	0.00	1.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
380-389MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
390-399MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400-409MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
410-419MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TL-PERVILLE	0.00	0.00	0.00	0.00	0.00	999.99	1000.00	0.00	999.99	0.00	0.00	0.00	999.99
TL-MEASURED	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00
MEAN LENGTH						31.6	31.6	0.00	29.1	0.00	0.00	0.00	30.5

APPENDIX 2

[illegible]

APPENDIX 2

LENGTH	COMPOSITION PER MILE --- MEAN LENGTHS AND WEIGHTS														
	JANUARY		FEBRUARY	MARCH	APRIL	YEAR 1970 -		JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
							1970 -								
						</									

APPENDIX 2
TABLE 15

LENGTH	COMPOSITION PER MILE --- MEAN LENGTHS AND WEIGHTS												TOTAL
	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	
70-79MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80-89MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90-99MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100-109MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
110-119MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
120-129MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
130-139MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
140-149MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150-159MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
160-169MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
170-179MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
180-189MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
190-199MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
200-209MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
210-219MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
220-229MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
230-239MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
240-249MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
250-259MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
260-269MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
270-279MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
280-289MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
290-299MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
300-309MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
310-319MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
320-329MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
330-339MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
340-349MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
350-359MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
360-369MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
370-379MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
380-389MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
390-399MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400-409MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
410-419MM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TL PERMILLE	0.00	0.00	0.00	0.00	0.00	0.00	999.99	999.99	1000.00	1000.00	0.00	0.00	999.99
TL MEASURED	0.0	0.0	0.0	0.0	0.0	0.0	304	1729	400	200	0	0	2633
MEAN LENGTH	0.0	0.0	0.0	0.0	0.0	0.0	32.0	33.8	33.5	27.5	0.0	0.0	33.1

APPENDIX 2

TABLE 18

Back-calculated lengths for various ages of a spring herring sample

DIRECT PROPORTIONAL METHOD

DATE 68/ 9/ 8

FISH NO	TOTAL LENGTH	SEX	MAT	SCALE AGE	L(1)	L(2)	L(3)	L(4)	L(5)	L(6)	L(7)	L(8)	L(9)	L(10)	L(11)	L(12)
10	296	2	6	4	129.16	231.41	274.47	296.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	309	1	6	6	125.27	233.83	272.81	289.51	300.64	309.00	0.00	0.00	0.00	0.00	0.00	0.00
25	316	1	6	6	53.10	156.67	238.99	276.16	308.03	316.00	0.00	0.00	0.00	0.00	0.00	0.00
62	314	1	6	6	85.63	186.84	254.31	295.83	306.21	314.00	0.00	0.00	0.00	0.00	0.00	0.00
96	314	1	6	6	120.36	230.26	272.13	298.30	306.15	314.00	0.00	0.00	0.00	0.00	0.00	0.00
72	311	2	6	6	128.34	232.01	276.44	291.25	301.12	311.00	0.00	0.00	0.00	0.00	0.00	0.00
88	308	2	6	6	114.17	231.00	265.51	292.06	300.03	308.00	0.00	0.00	0.00	0.00	0.00	0.00
13	340	1	6	7	117.69	235.38	279.84	303.38	320.12	330.58	340.00	0.00	0.00	0.00	0.00	0.00
48	317	1	6	7	127.36	205.48	243.41	271.71	288.69	308.50	317.00	0.00	0.00	0.00	0.00	0.00
50	327	1	6	7	109.96	202.56	245.97	283.59	306.74	318.31	327.00	0.00	0.00	0.00	0.00	0.00
58	315	1	6	7	111.46	222.92	256.84	283.50	298.03	306.27	315.00	0.00	0.00	0.00	0.00	0.00
69	318	1	6	7	93.35	204.22	247.98	274.23	297.57	309.24	318.00	0.00	0.00	0.00	0.00	0.00
76	320	1	6	7	108.84	201.36	244.89	266.66	288.43	310.20	320.00	0.00	0.00	0.00	0.00	0.00
94	324	1	6	7	91.80	156.60	221.39	278.10	298.08	315.90	324.00	0.00	0.00	0.00	0.00	0.00
99	325	1	6	7	95.90	186.47	239.75	266.39	298.36	317.00	325.00	0.00	0.00	0.00	0.00	0.00
29	327	2	6	7	91.78	183.57	266.76	286.84	304.05	318.39	327.00	0.00	0.00	0.00	0.00	0.00
39	330	2	6	7	125.08	234.19	276.77	292.74	308.70	319.35	330.00	0.00	0.00	0.00	0.00	0.00
57	331	2	6	7	111.17	222.35	271.87	293.09	308.25	320.89	331.00	0.00	0.00	0.00	0.00	0.00
79	326	2	6	7	122.91	208.42	253.85	280.57	299.27	315.31	326.00	0.00	0.00	0.00	0.00	0.00
95	325	2	6	7	110.00	210.00	250.00	275.00	300.00	312.50	325.00	0.00	0.00	0.00	0.00	0.00
5	332	1	6	8	127.69	214.52	255.38	296.24	306.46	316.67	324.33	332.00	0.00	0.00	0.00	0.00
14	328	1	6	8	75.69	158.95	262.40	282.58	295.20	310.33	320.43	328.00	0.00	0.00	0.00	0.00
18	331	1	6	8	84.33	173.93	224.00	258.26	289.88	306.75	321.51	331.00	0.00	0.00	0.00	0.00
19	347	1	6	8	119.11	227.88	274.49	305.56	321.10	332.49	341.92	347.00	0.00	0.00	0.00	0.00
24	334	1	6	8	140.06	210.09	247.80	274.74	296.29	308.14	323.22	334.00	0.00	0.00	0.00	0.00
28	331	1	6	8	120.36	191.48	251.66	270.81	297.23	300.90	317.32	331.00	0.00	0.00	0.00	0.00
32	314	1	6	8	125.49	204.89	261.23	279.16	287.87	298.63	308.87	314.00	0.00	0.00	0.00	0.00
33	333	1	6	8	96.57	206.55	265.57	295.07	311.17	323.51	332.63	338.00	0.00	0.00	0.00	0.00
34	322	1	6	8	144.90	214.66	249.55	268.33	281.75	295.16	311.26	322.00	0.00	0.00	0.00	0.00
35	326	1	6	8	101.54	197.73	240.49	272.55	291.26	304.62	317.98	326.00	0.00	0.00	0.00	0.00
36	330	1	6	8	95.08	204.15	251.69	274.06	290.84	304.83	321.61	330.00	0.00	0.00	0.00	0.00
37	323	1	6	8	120.79	210.08	267.85	280.98	294.11	304.61	315.12	323.00	0.00	0.00	0.00	0.00
43	322	1	6	8	97.50	204.08	260.77	278.91	296.14	308.39	317.46	322.00	0.00	0.00	0.00	0.00
47	337	1	6	8	102.56	192.92	239.31	283.27	305.25	322.34	332.11	337.00	0.00	0.00	0.00	0.00
53	317	1	6	8	134.84	216.69	255.49	276.78	286.24	298.07	309.90	317.00	0.00	0.00	0.00	0.00
59	327	1	6	8	112.25	190.34	258.23	283.07	297.71	309.91	319.47	327.00	0.00	0.00	0.00	0.00
68	330	1	6	8	135.24	216.39	259.67	281.31	292.13	308.36	319.18	330.00	0.00	0.00	0.00	0.00
77	328	1	6	8	104.45	208.91	261.14	282.03	289.87	302.92	315.98	328.00	0.00	0.00	0.00	0.00
83	327	1	6	8	94.52	181.18	235.03	266.12	306.56	316.78	321.77	327.00	0.00	0.00	0.00	0.00
86	344	1	6	8	113.87	196.91	251.47	289.43	317.90	332.13	339.24	344.00	0.00	0.00	0.00	0.00
87	336	1	6	8	102.50	182.23	250.57	284.74	302.96	314.35	324.61	336.00	0.00	0.00	0.00	0.00
90	330	1	6	8	71.50	156.75	231.00	264.00	286.00	308.00	324.50	330.00	0.00	0.00	0.00	0.00

DATE 68/ 5/ 8					SCALE												
FISH NO	TOTAL LENGTH	SEX	MAT	AGE	L(1)	L(2)	L(3)	L(4)	L(5)	L(6)	L(7)	L(8)	L(9)	L(10)	L(11)	L(12)	
93	328	1	4	8	113.53	209.41	258.86	277.53	292.67	310.33	320.43	328.00	0.00	0.00	0.00	0.00	
328	328	1	4	8	145.77	229.88	260.71	285.94	299.96	313.98	322.39	328.00	0.00	0.00	0.00	0.00	
100	328	2	6	8	89.23	168.00	230.09	273.22	280.93	297.45	308.47	325.00	0.00	0.00	0.00	0.00	
3	338	2	6	8	76.57	126.75	235.01	290.44	306.91	321.10	330.07	338.00	0.00	0.00	0.00	0.00	
30	321	2	6	8	77.66	178.62	222.62	269.22	287.34	300.29	313.23	321.00	0.00	0.00	0.00	0.00	
52	337	2	6	8	124.01	210.28	256.12	283.08	291.16	304.64	323.52	337.00	0.00	0.00	0.00	0.00	
56	339	2	5	8	103.13	198.53	262.99	283.62	294.96	309.40	319.71	329.00	0.00	0.00	0.00	0.00	
61	335	2	6	8	119.25	205.58	262.90	290.00	306.27	319.82	327.95	335.00	0.00	0.00	0.00	0.00	
91	331	2	6	8	75.36	173.06	223.30	267.96	285.82	301.46	312.62	321.00	0.00	0.00	0.00	0.00	
-2	341	1	6	9	111.80	195.65	254.35	279.50	297.95	310.25	321.22	328.61	341.00	0.00	0.00	0.00	
4	340	1	6	9	75.00	165.00	225.00	261.00	289.00	309.00	321.00	324.30	340.00	0.00	0.00	0.00	
6	326	1	6	9	126.19	215.58	252.38	270.79	283.93	297.08	310.22	316.53	326.00	0.00	0.00	0.00	
8	328	1	6	9	83.45	160.83	218.46	255.58	279.05	294.70	308.78	319.21	326.00	0.00	0.00	0.00	
11	333	1	6	9	80.12	160.24	220.33	265.39	287.93	302.95	320.48	327.99	333.00	0.00	0.00	0.00	
15	330	1	6	9	121.44	190.08	243.93	278.78	290.40	299.90	316.80	324.72	330.00	0.00	0.00	0.00	
17	332	1	6	9	100.53	205.75	252.51	275.89	292.26	311.61	310.97	320.32	325.00	0.00	0.00	0.00	
20	322	1	6	9	98.32	191.72	233.51	262.02	285.12	299.87	309.70	317.08	322.00	0.00	0.00	0.00	
22	331	1	6	9	110.33	180.54	253.26	278.84	293.38	303.92	320.96	325.98	331.00	0.00	0.00	0.00	
26	332	1	6	9	102.15	183.87	245.16	273.81	296.24	308.46	318.67	324.93	332.00	0.00	0.00	0.00	
27	321	1	6	9	71.35	152.17	202.11	252.04	275.82	297.22	316.73	313.56	321.00	0.00	0.00	0.00	
31	326	1	6	9	99.08	180.83	230.37	262.58	284.87	299.74	313.11	319.55	326.00	0.00	0.00	0.00	
38	326	1	6	9	100.08	205.89	251.64	274.52	288.82	300.26	311.70	320.28	326.00	0.00	0.00	0.00	
49	334	1	6	9	119.23	212.54	264.38	274.75	285.12	300.67	311.04	319.81	324.00	0.00	0.00	0.00	
55	335	1	6	9	124.96	202.06	244.60	276.50	289.80	303.75	313.73	324.36	335.00	0.00	0.00	0.00	
60	344	1	6	9	98.99	212.83	272.23	292.02	314.30	324.20	331.62	336.57	344.00	0.00	0.00	0.00	
64	327	1	6	9	81.75	164.55	226.79	263.70	284.80	297.99	313.81	321.72	329.00	0.00	0.00	0.00	
65	329	1	6	9	70.76	167.24	224.81	260.45	282.39	301.58	312.55	322.42	327.00	0.00	0.00	0.00	
67	328	1	6	9	95.22	179.87	230.12	264.51	283.03	301.54	314.77	322.70	328.00	0.00	0.00	0.00	
75	324	1	6	9	137.11	218.36	256.45	276.77	292.00	302.16	312.31	318.41	324.00	0.00	0.00	0.00	
78	330	1	6	9	91.96	210.98	254.26	281.31	297.54	308.36	316.47	324.59	330.00	0.00	0.00	0.00	
81	335	1	6	9	92.19	171.52	236.52	262.64	284.08	308.20	321.60	325.03	335.00	0.00	0.00	0.00	
82	335	1	6	9	113.66	215.35	254.24	278.16	296.11	311.07	321.83	329.01	335.00	0.00	0.00	0.00	
92	335	1	6	9	96.52	198.72	249.83	272.54	292.41	308.61	314.83	326.48	335.00	0.00	0.00	0.00	
16	340	2	6	9	111.56	218.87	276.25	297.50	318.75	336.68	346.37	357.00	340.00	0.00	0.00	0.00	
40	337	2	6	9	104.38	204.58	259.46	292.26	307.17	316.12	322.08	331.03	337.00	0.00	0.00	0.00	
41	332	2	6	9	93.16	180.68	231.49	265.37	282.31	296.42	316.19	324.65	332.00	0.00	0.00	0.00	
43	339	2	6	9	98.94	190.47	231.53	257.26	291.89	304.26	314.15	321.57	329.00	0.00	0.00	0.00	
44	337	2	6	9	95.48	174.11	219.04	247.13	275.21	302.17	320.15	324.64	337.00	0.00	0.00	0.00	
51	335	2	6	9	109.22	207.79	245.08	269.06	282.38	296.36	314.35	322.34	333.00	0.00	0.00	0.00	
54	348	2	6	9	129.25	186.91	231.17	273.62	298.28	313.20	330.60	343.02	348.00	0.00	0.00	0.00	
85	324	2	6	9	75.34	160.74	220.01	248.85	271.25	286.32	297.37	316.46	324.00	0.00	0.00	0.00	
98	341	2	6	10	123.28	209.84	257.06	278.94	291.16	303.32	320.01	333.13	341.00	0.00	0.00	0.00	
12	325	1	6	10	81.50	178.79	241.96	265.90	280.17	297.90	305.64	315.93	327.00	0.00	0.00	0.00	
46	328	1	6	10	72.00	160.00	218.66	250.66	272.00	290.66	304.00	314.66	322.00	0.00	0.00	0.00	
46	326	1	6	10	125.59	165.67	208.42	251.18	275.22	293.93	304.62	315.31	320.65	324.00	0.00	0.00	
73	331	1	6	10	101.04	206.25	244.43	272.45	290.26	304.99	313.17	320.81	325.90	331.00	0.00	0.00	
80	357	1	6	10	96.48	190.56	253.77	303.93	323.22	339.29	342.52	351.21	354.58	357.00	0.00	0.00	
97	330	1	6	10	64.89	153.85	234.18	258.64	276.48	289.86	313.24	314.39	321.08	330.00	0.00	0.00	
9	343	2	6	10	74.44	175.48	233.98	260.57	284.50	303.11	316.41	327.04	335.02	343.00	0.00	0.00	

APPENDIX 2

TABLE 19

Back-calculated lengths for various ages of a spring herring sample

LEES METHOD
(A = 40.)

DATE 68/5/8

FISH NO TOTAL LENGTH SEX MAT AGE SCALE

FISH NO	TOTAL LENGTH	SEX	MAT	AGE	SCALE	L(1)	L(2)	L(3)	L(4)	L(5)	L(6)	L(7)	L(8)	L(9)	L(10)	L(11)	L(12)
10	296	2	6	4		151.70	240.14	277.38	296.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	309	1	6	6		149.05	243.56	277.49	292.03	301.72	309.00	0.00	0.00	0.00	0.00	0.00	0.00
25	316	1	6	6		86.28	176.84	248.73	283.21	309.04	316.00	0.00	0.00	0.00	0.00	0.00	0.00
62	314	1	6	6		114.72	203.04	261.91	298.14	307.20	314.00	0.00	0.00	0.00	0.00	0.00	0.00
96	314	1	6	6		145.03	240.93	277.46	300.30	307.15	314.00	0.00	0.00	0.00	0.00	0.00	0.00
72	311	2	6	6		151.84	242.17	280.88	293.79	302.39	311.00	0.00	0.00	0.00	0.00	0.00	0.00
88	308	2	6	6		139.34	241.00	271.03	294.13	301.06	308.00	0.00	0.00	0.00	0.00	0.00	0.00
13	340	1	6	7		143.44	247.69	286.92	307.69	322.46	331.69	340.00	0.00	0.00	0.00	0.00	0.00
48	317	1	6	7		151.29	219.55	252.69	277.42	292.26	309.58	317.00	0.00	0.00	0.00	0.00	0.00
50	327	1	6	7		136.51	217.78	255.88	288.90	309.22	319.32	327.00	0.00	0.00	0.00	0.00	0.00
58	315	1	6	7		137.30	234.61	264.23	287.50	300.19	307.34	315.00	0.00	0.00	0.00	0.00	0.00
69	318	1	6	7		121.61	218.53	256.78	279.74	300.14	310.34	318.00	0.00	0.00	0.00	0.00	0.00
76	320	1	6	7		135.23	216.19	254.28	273.33	292.38	311.42	320.00	0.00	0.00	0.00	0.00	0.00
94	324	1	6	7		120.66	177.26	234.06	283.76	301.28	316.90	324.00	0.00	0.00	0.00	0.00	0.00
99	325	1	6	7		124.09	203.52	250.24	273.60	301.63	317.99	325.00	0.00	0.00	0.00	0.00	0.00
29	327	2	6	7		120.56	201.12	274.13	291.75	306.85	319.44	327.00	0.00	0.00	0.00	0.00	0.00
39	330	2	6	7		149.91	245.80	283.22	297.25	311.29	320.64	330.00	0.00	0.00	0.00	0.00	0.00
57	331	2	6	7		137.74	235.48	279.01	297.67	311.00	322.11	331.00	0.00	0.00	0.00	0.00	0.00
79	326	2	6	7		147.83	222.85	262.70	286.14	302.55	316.62	326.00	0.00	0.00	0.00	0.00	0.00
95	325	2	6	7		136.46	224.15	259.23	281.15	303.07	314.03	325.00	0.00	0.00	0.00	0.00	0.00
5	332	1	6	8		152.30	228.67	264.61	300.55	309.53	318.52	325.26	332.00	0.00	0.00	0.00	0.00
14	328	1	6	8		106.46	179.56	270.40	288.12	299.20	312.49	321.35	328.00	0.00	0.00	0.00	0.00
18	331	1	6	8		114.14	192.91	236.93	267.05	294.89	309.68	322.65	331.00	0.00	0.00	0.00	0.00
19	347	1	6	8		145.38	241.61	282.89	310.34	324.08	334.17	342.41	347.00	0.00	0.00	0.00	0.00
24	334	1	6	8		163.29	224.93	258.12	281.83	300.80	311.23	324.51	334.00	0.00	0.00	0.00	0.00
28	331	1	6	8		145.81	208.34	261.25	278.09	292.52	304.54	318.97	331.00	0.00	0.00	0.00	0.00
32	314	1	6	8		149.51	218.79	267.96	283.60	291.20	300.59	309.53	314.00	0.00	0.00	0.00	0.00
33	338	1	6	8		125.14	222.11	274.14	300.15	314.34	325.22	333.26	338.00	0.00	0.00	0.00	0.00
34	322	1	6	8		166.90	228.00	258.55	279.00	286.75	298.50	312.60	322.00	0.00	0.00	0.00	0.00
35	326	1	6	8		129.08	213.47	250.98	279.11	295.52	307.24	318.96	326.00	0.00	0.00	0.00	0.00
36	330	1	6	8		123.55	219.40	250.84	295.59	307.88	322.62	330.00	0.00	0.00	0.00	0.00	0.00
323	323	1	6	8		145.83	224.06	274.68	286.18	297.69	306.69	318.09	323.00	0.00	0.00	0.00	0.00
45	322	1	6	8		125.39	218.75	268.38	284.26	299.36	310.08	318.02	322.00	0.00	0.00	0.00	0.00
47	337	1	6	8		130.39	210.02	250.91	289.65	309.02	324.08	332.69	337.00	0.00	0.00	0.00	0.00
53	317	1	6	8		137.82	229.15	263.25	281.85	290.12	300.46	310.79	317.00	0.00	0.00	0.00	0.00
59	327	1	6	8		138.52	207.05	264.88	288.44	301.29	312.00	320.50	327.00	0.00	0.00	0.00	0.00
68	330	1	6	8		158.85	230.16	268.19	287.21	296.72	310.98	320.49	330.00	0.00	0.00	0.00	0.00
72	328	1	6	8		131.71	223.43	264.29	287.44	294.52	311.45	324.00	330.00	0.00	0.00	0.00	0.00
83	327	1	6	8		122.96	199.19	248.28	291.12	309.06	318.03	322.51	327.00	0.00	0.00	0.00	0.00
86	344	1	6	8		140.63	214.01	262.23	295.77	320.93	333.51	339.80	344.00	0.00	0.00	0.00	0.00
87	336	1	6	8		130.30	200.54	260.74	290.84	306.90	316.93	325.96	336.00	0.00	0.00	0.00	0.00
90	330	1	6	8		102.83	177.75	243.00	272.00	291.33	310.66	325.16	330.00	0.00	0.00	0.00	0.00

APPENDIX 2

TABLE 20

Number and percentage of drift-bottles (DB) and sea-bed drifters (SBD) released in the Gulf of St. Lawrence area in 1967 through 1969.

Cruise	Date	DB			SBD		
		Rel.	Rec.	%	Rel.	Rec.	%
<u>1967</u>							
ATC-132	May 14-23	252	96	38.1	252	25	9.9
EEP-6	May 25-June 6	450	170	37.8	450	133	29.6
HU-24	Aug. 8-28	611	161		306	16	5.2
AF	Aug. 18-20	180	51	28.3	188	77	47.2
<u>1968</u>							
EEP-27	May 23-June 4	428	111	25.9	324	82	25.3
EEP-29	June 19-26	306	84	27.4	162	42	25.9
GRF-94	July 26-Aug. 5	252	28	11.1	---	---	---
EEP-33	Aug. 17-30	342	46	13.4	324	69	21.3
ATC-153	Oct. 20-Nov. 4	252	44	17.5	252	14	5.6
<u>1969</u>							
ATC-155	Jan. 17-22	---	---	---	234	15	6.4
EEP-45	May 12-26	468	142	30.8	240	15	6.2
EEP-47	June 12-20	396	135	34.1	246	8	3.2
GRF-97	July 22-28	396	112	28.3	246	11	4.5
EEP-52	Aug. 20-28	402	65	16.2	252	19	7.5

APPENDIX 2

TABLE 21

Percentage recoveries* of drift bottles (upper line)
and sea-bed drifters (lower line) by years of recovery.

Cruise	Month	Percentage recoveries by year						Total	
		1	2	3	4	5	6		
<u>1967</u>									
ATC-132	May	93.7	3.1	3.1					96
		32.0	12.0	20.0	8.0	8.0	8.0	12.0	25
EEP-6	May	90.6	5.9	2.4		1.6			170
	June	36.8	37.6	15.8	5.3	3.0	0.8°	0.8	133
HU-24	Aug.	93.8	4.9		1.2				161
		50.0	12.5	12.5		6.3	6.3	12.5	16
AF	Aug.	94.1	2.0	3.9					51
		70.1	18.1	5.2	3.4	2.6			77
<u>1968</u>									
EEP-27	May	97.2	1.8	0.7					111
	June	42.7	35.4	17.1	2.4	1.2		1.2	82
EEP-29	June	98.8		1.2					84
		33.3	26.2	14.3	16.7	2.4		7.1	42
GRF-94	July	82.1	17.9						28
	Aug.								
EEP-33	Aug.	93.5	2.2	4.3					46
ATC-153		47.8	21.7	17.4	8.7	1.4		2.9	69
ATC-153	Oct.	100.0							44
	Nov.	35.7	14.3	42.9	7.1				14
<u>1969</u>									
ATC-155	Jan.								
EEP-45	May	33.3	53.3	6.7					15
		95.8	3.5	0.7					142
EEP-47	June	40.0	33.3	6.7	20.0				15
		96.3	2.2	1.5					135
GRF-97	July	50.0	25.0	12.5				12.5	8
		93.7	2.7	3.6					112
EEP-52	Aug.	63.6	18.2					18.2	11
		90.8	9.2						65
		26.3	42.1	21.1	5.3			5.3	19

* Recoveries after December 1972 - if any - are not included.

APPENDIX 3

Figure 1 shows a map of the Gulf of St. Lawrence and major fishing localities. Figures 2 to 17 show the surface and bottom drifts as inferred from the recoveries of drift-bottles and sea-bed drifters released during various cruises in 1967 and 1968.

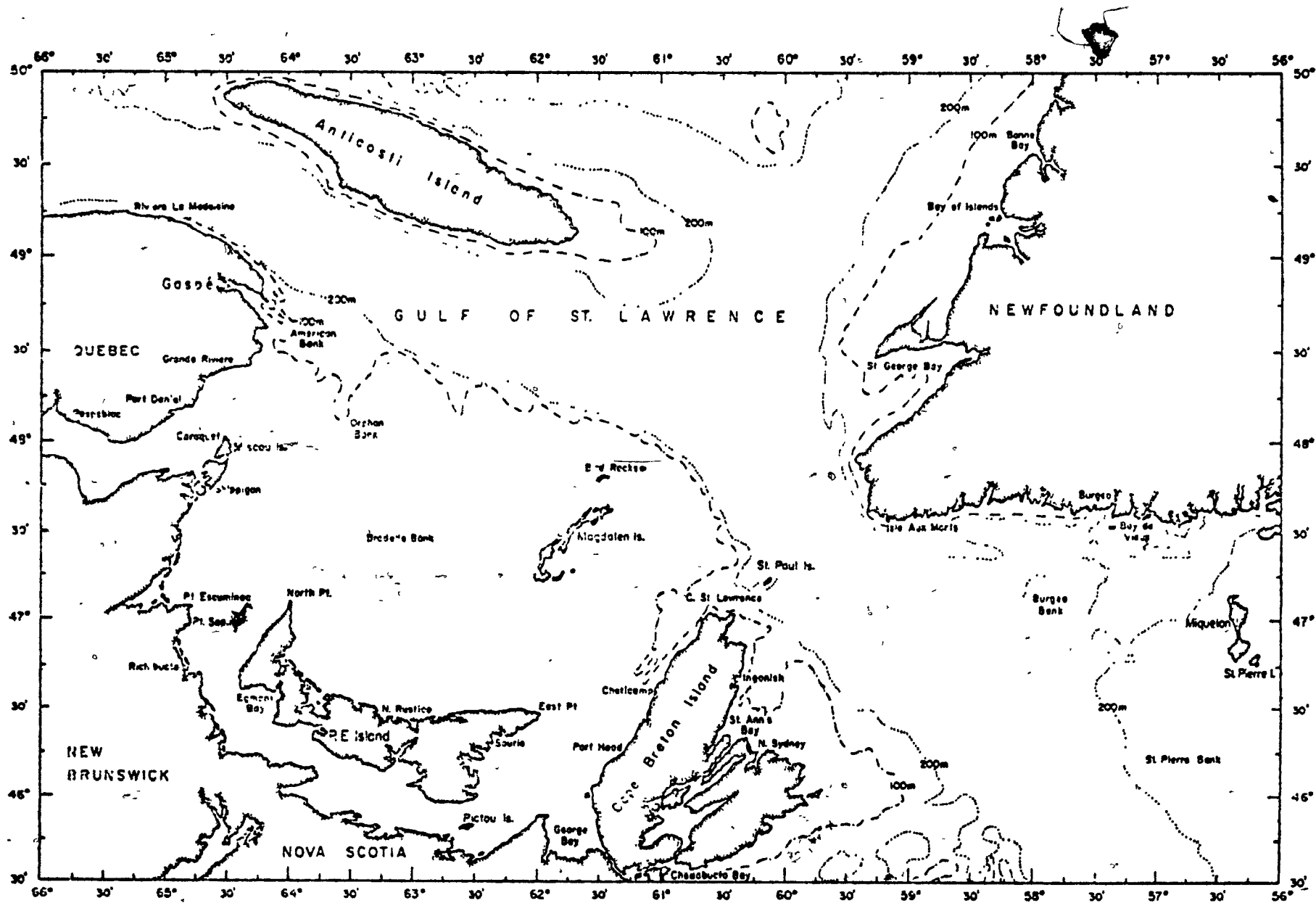


FIGURE 1: Gulf of St. Lawrence showing the major fishing localities

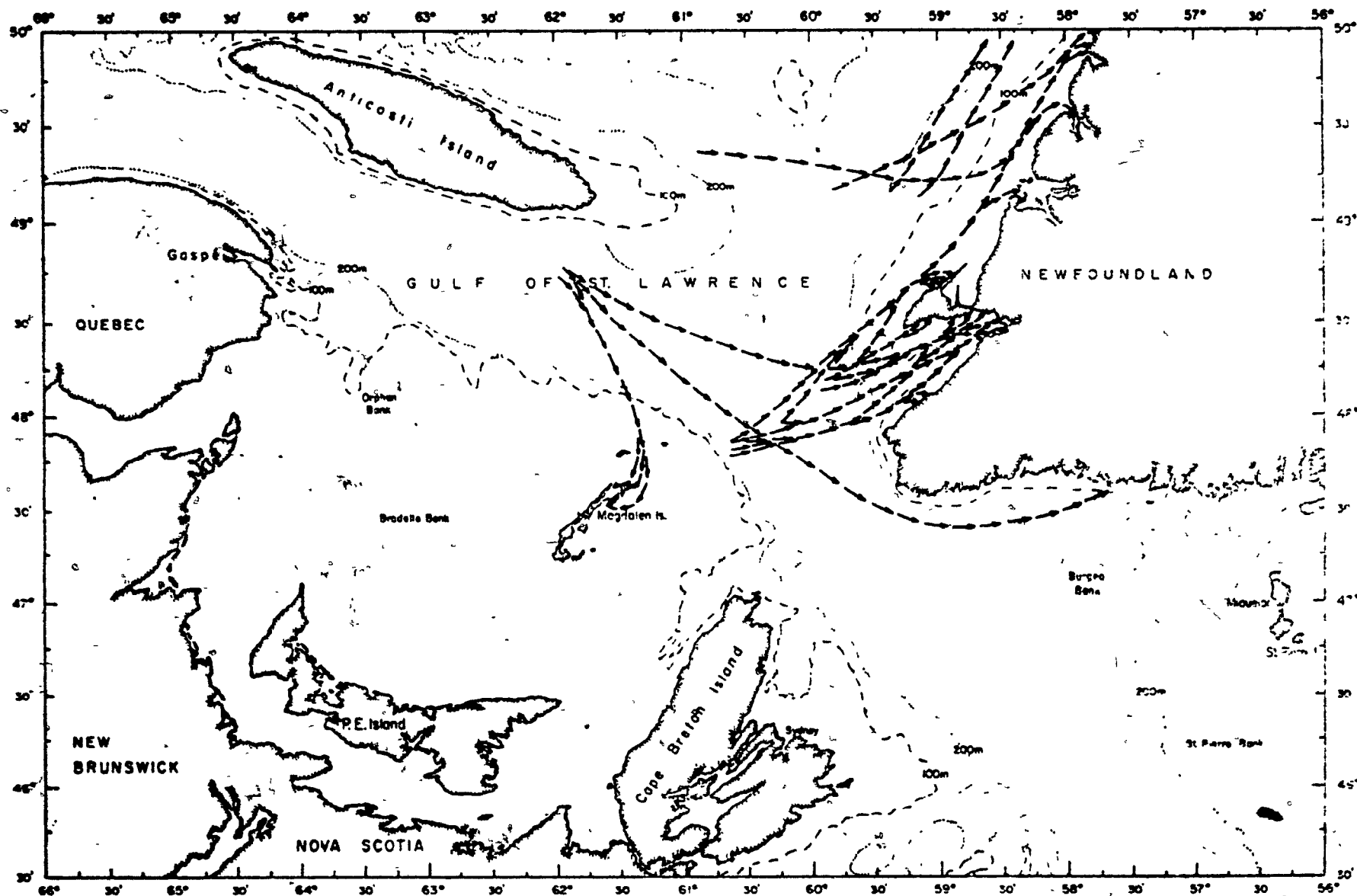


FIGURE 2: Surface drift as inferred from recoveries of drift-bottles released from May 14 to 23, 1967

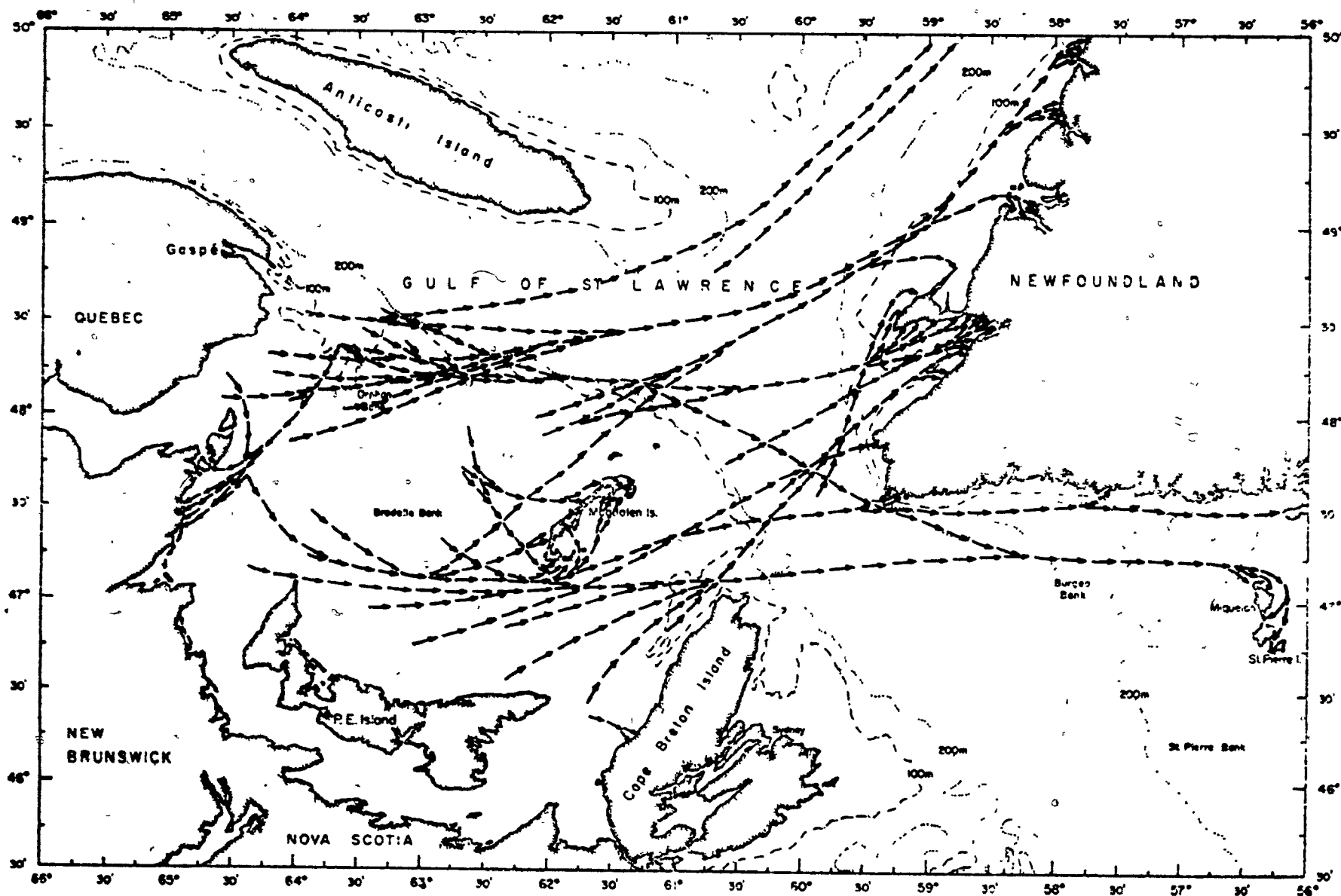


FIGURE 3: Surface drift as inferred from recoveries of drift-bottles released from May 25 to June 6, 1967

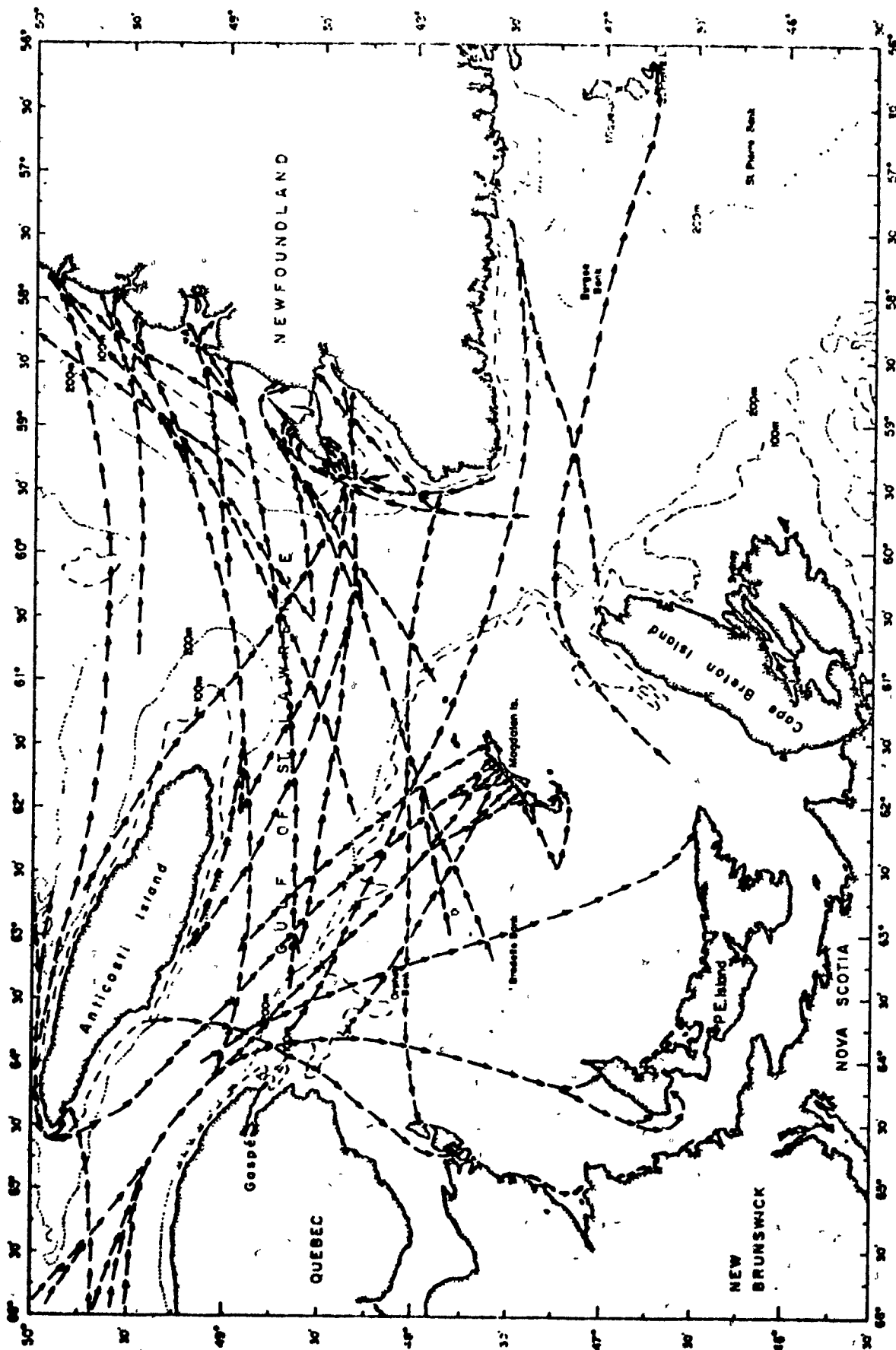


FIGURE 4: Surface drift as inferred from recoveries of drift-bottles released from August 8 to 28, 1967

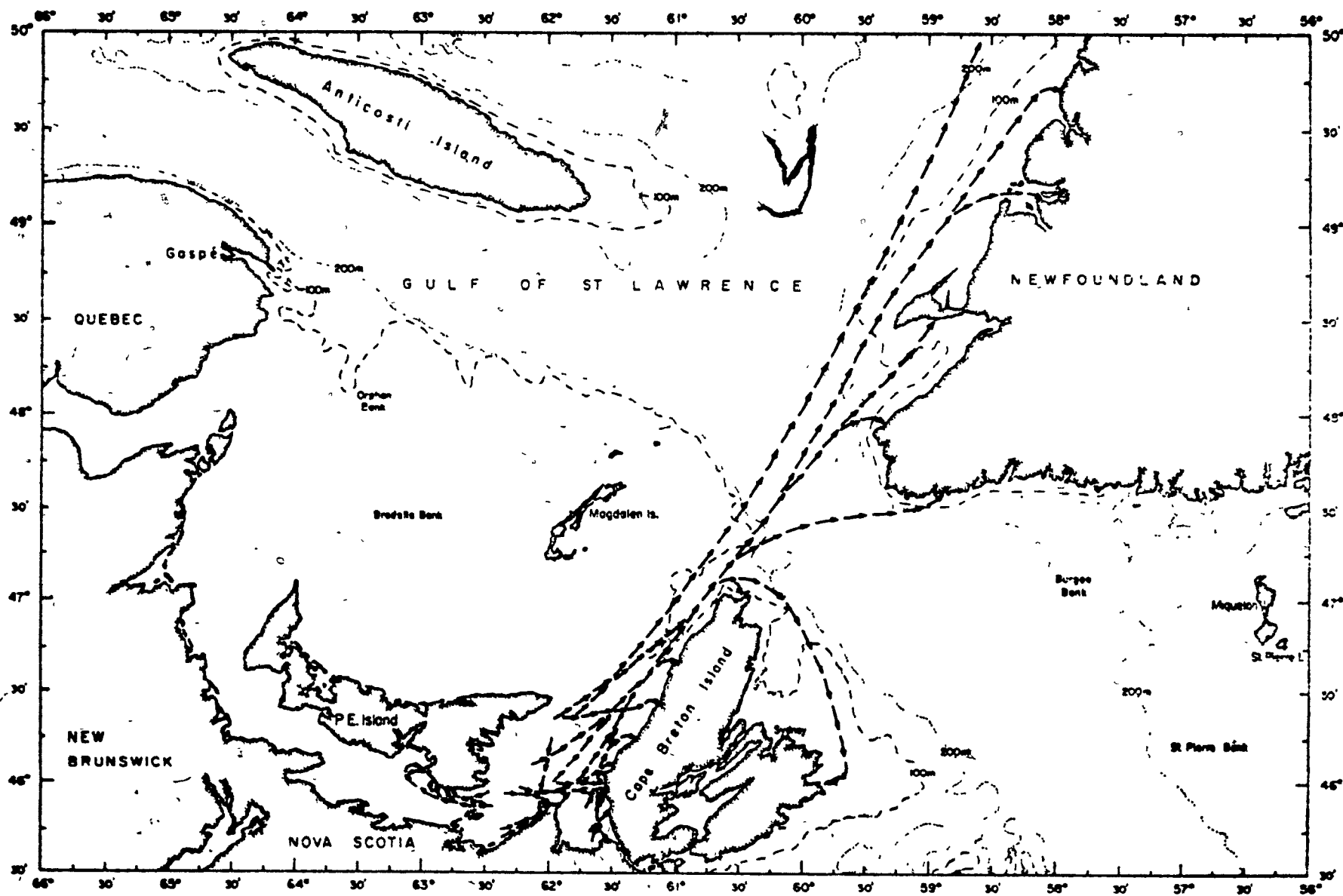


FIGURE 5: Surface drift as inferred from recoveries of drift-bottles released from August 18 to 20, 1967

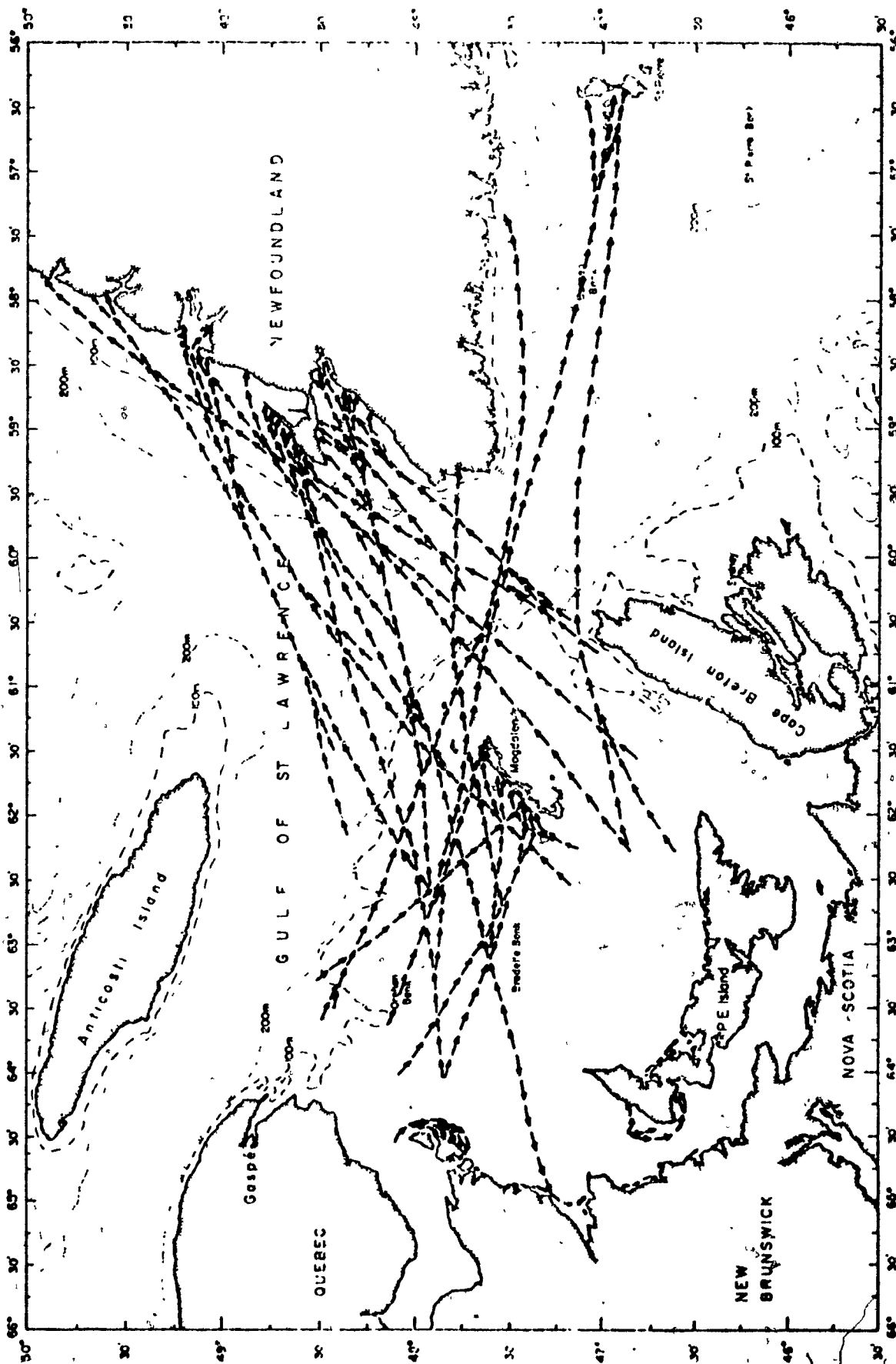


FIGURE 6: Surface drift as inferred from recoveries of drift-bottles, released from May 23 to June 4, 1968

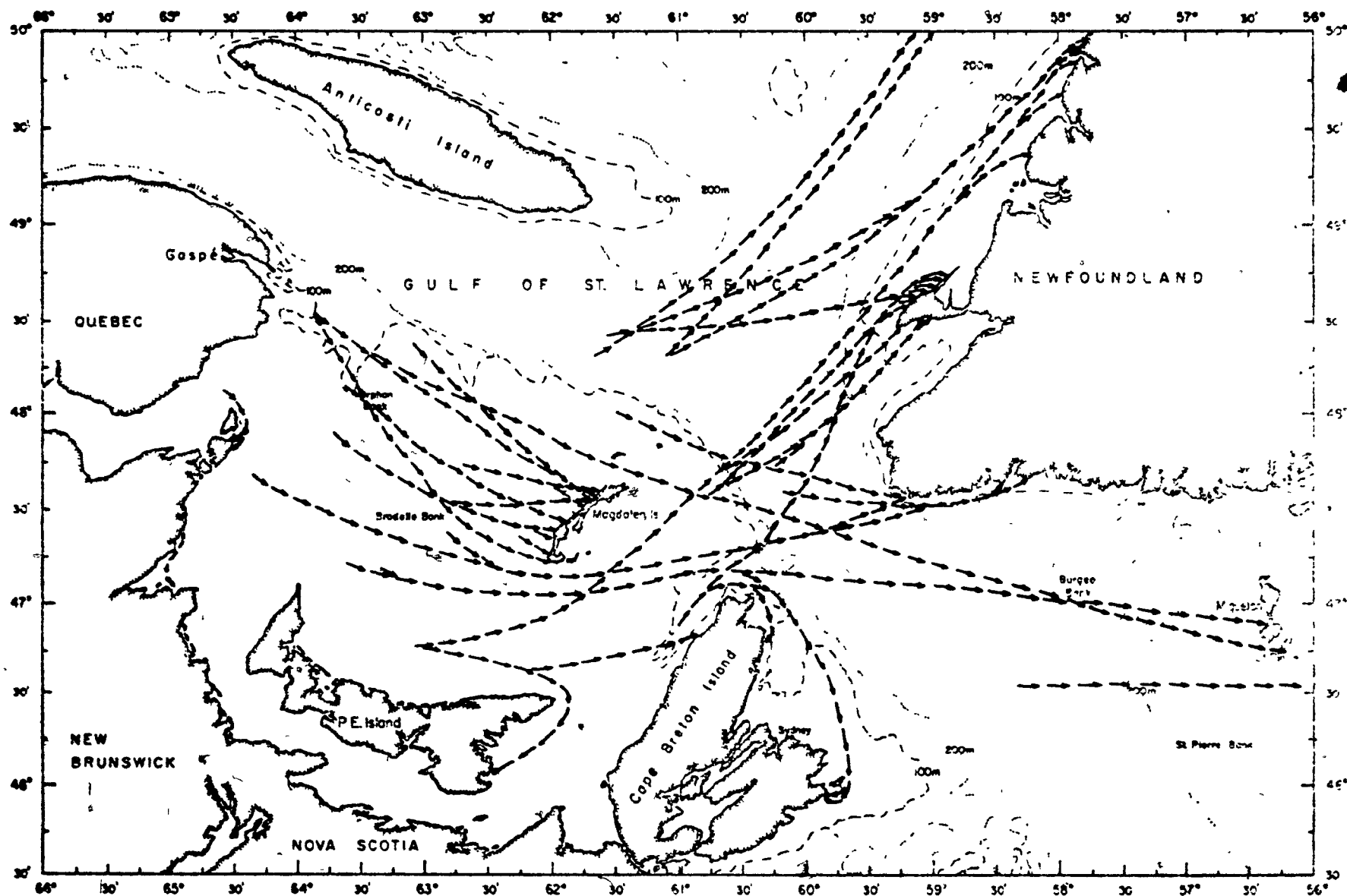


FIGURE 7: Surface drift as inferred from recoveries of drift-bottles released from June 19 to 26, 1968

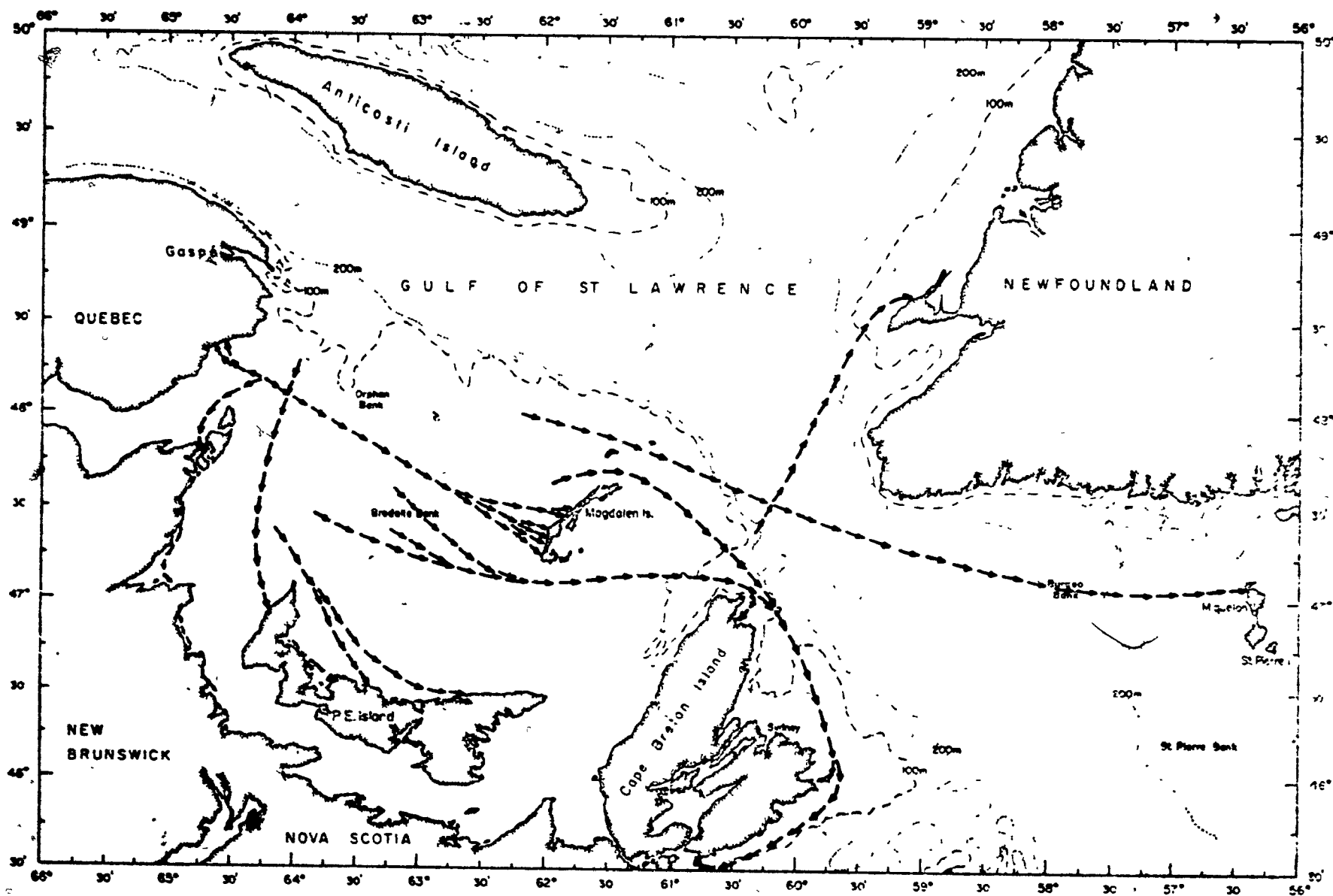


FIGURE 8: Surface drift as inferred from recoveries of drift-bottles released from July 26 to August 5, 1968

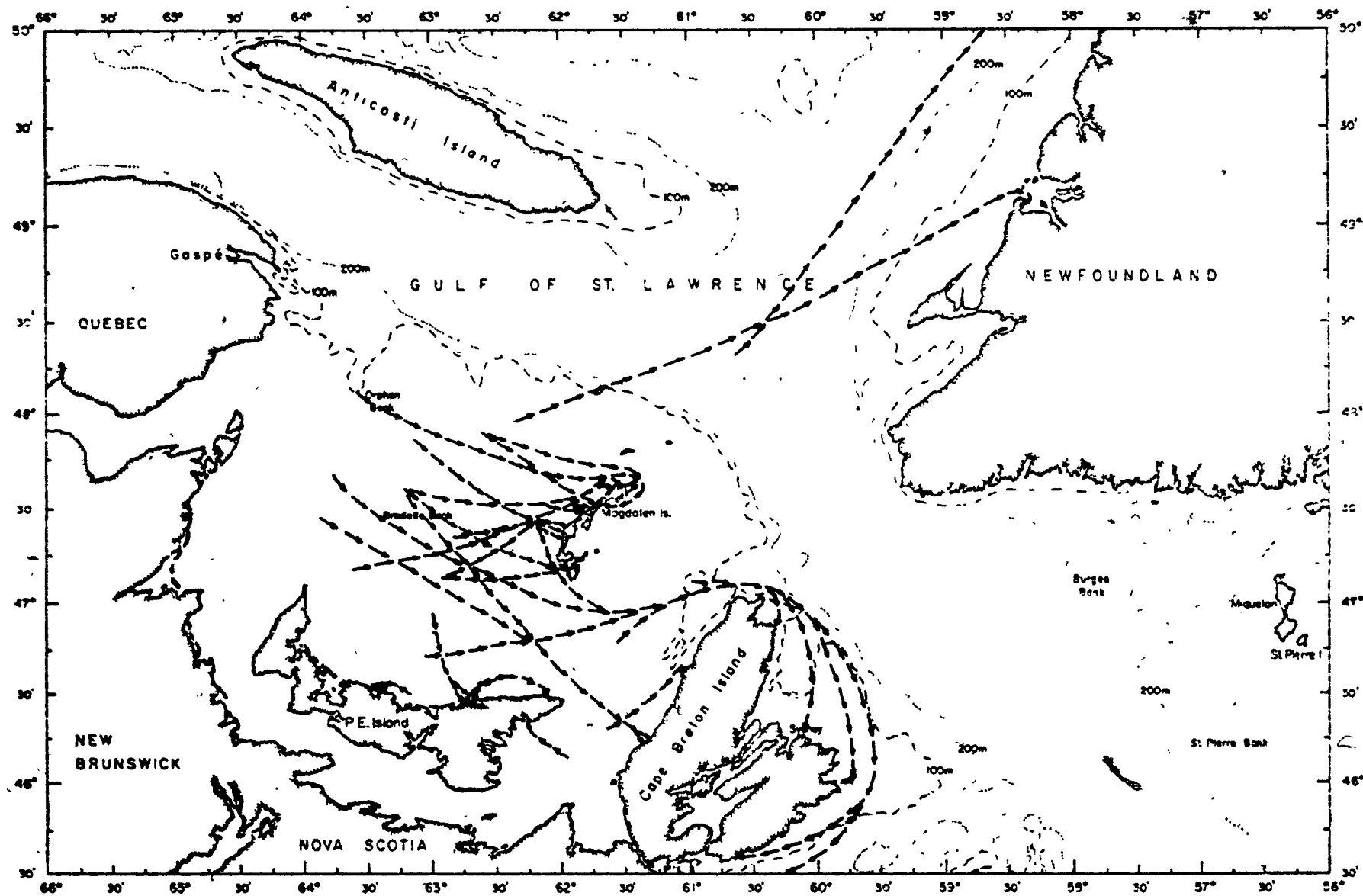


FIGURE 9: Surface drift as inferred from recoveries of drift-bottles released from August 17 to 30, 1968

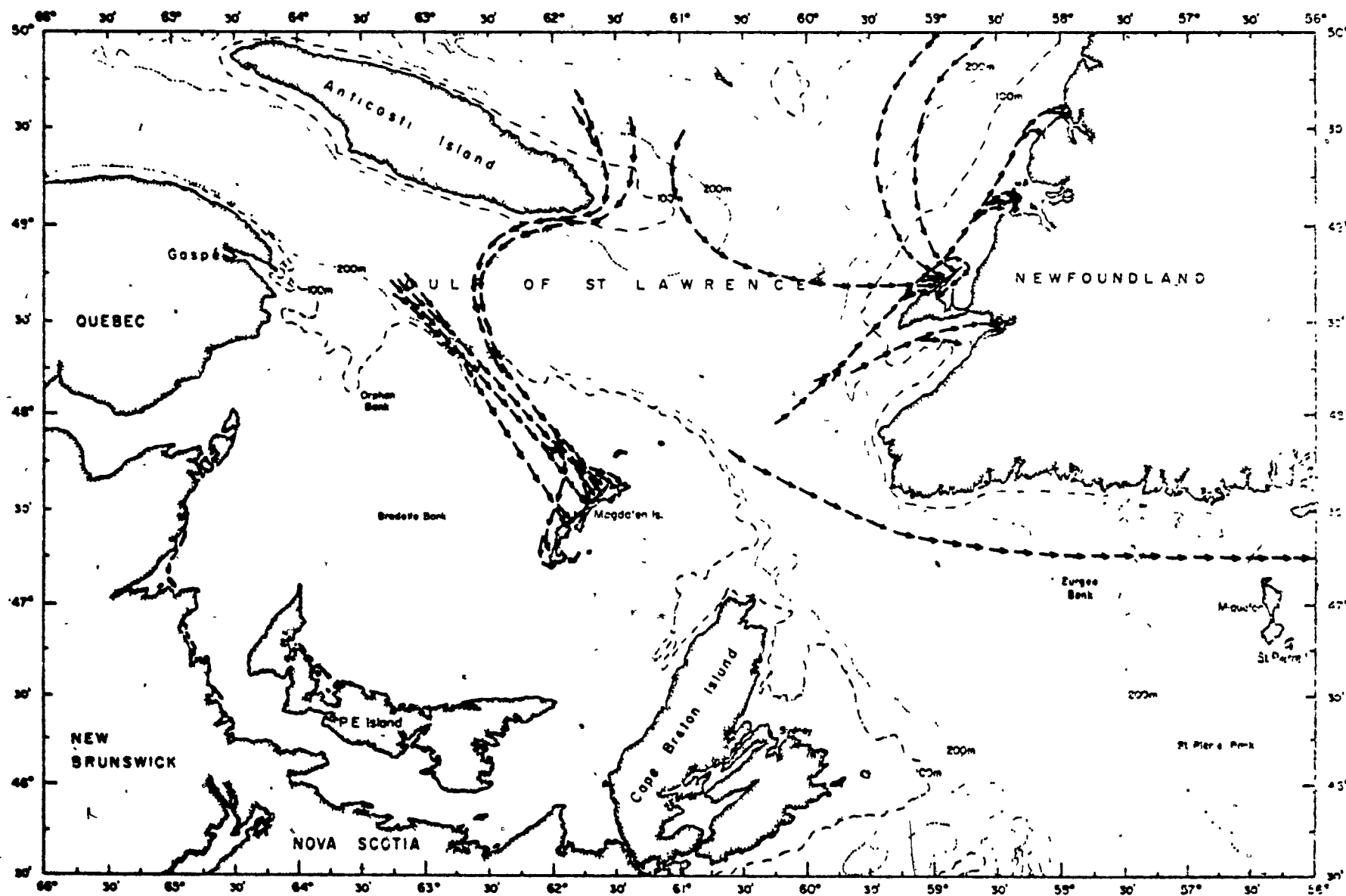


FIGURE 10: Surface drift as inferred from recoveries of drift-bottles released from October 20 to November 4, 1968

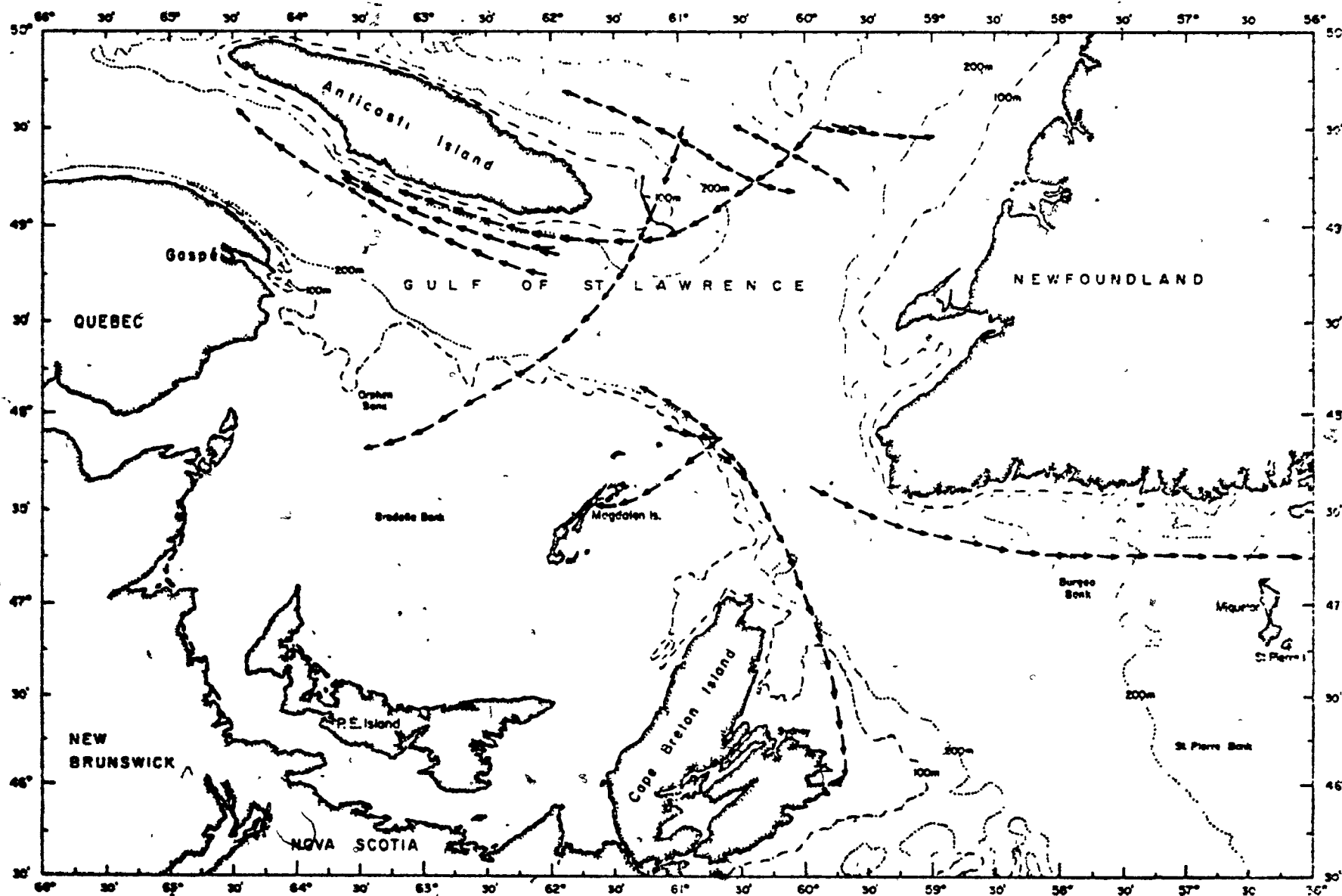


FIGURE 11: Bottom drift as inferred from recoveries of sea-bed drifters released from May 14 to 23, 1967

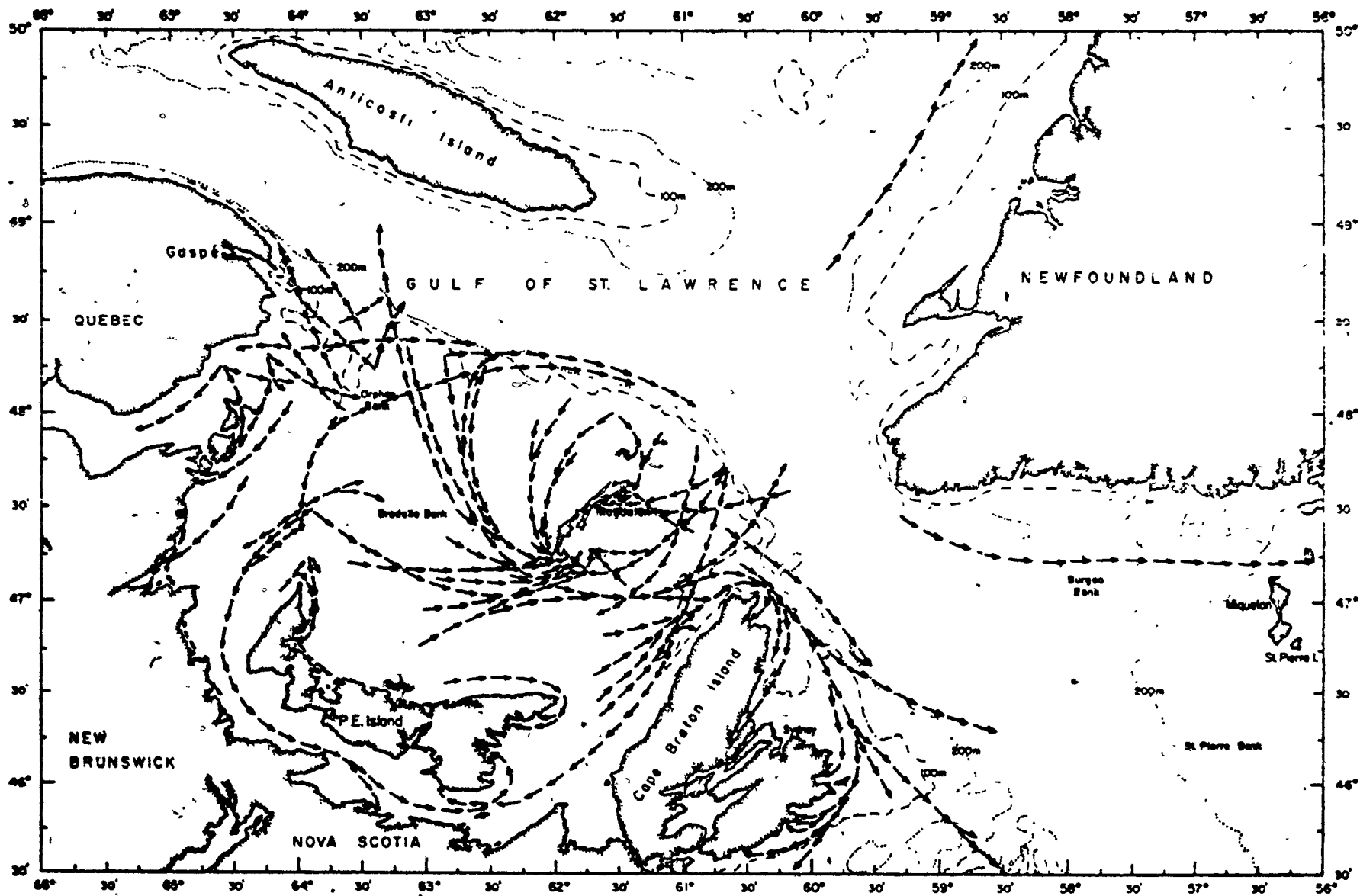


FIGURE 12: Bottom drift as inferred from recoveries of sea-bed drifters released from May 25 to June 6, 1967

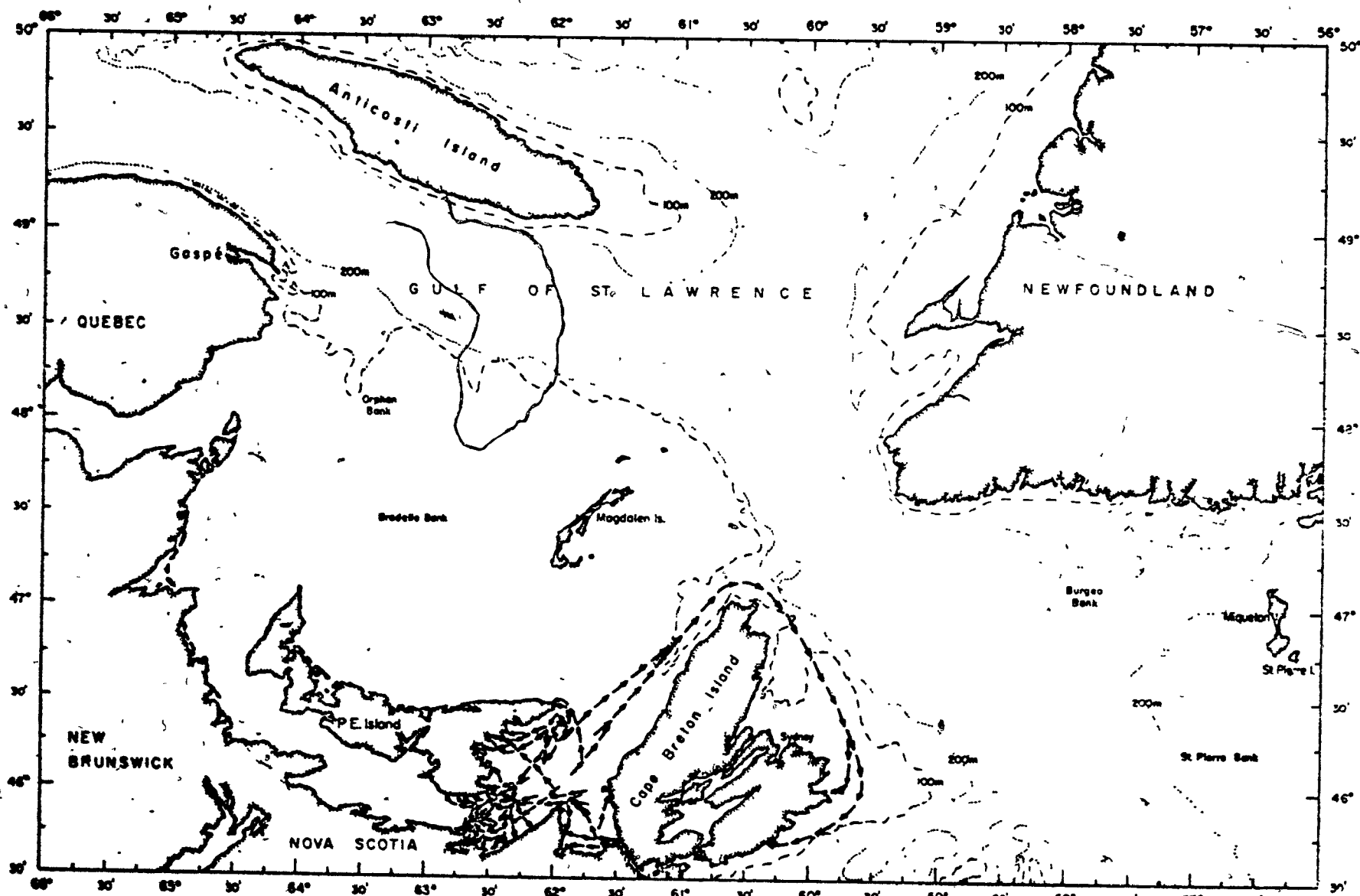


FIGURE 13: Bottom drift as inferred from recoveries of sea-bed drifters released from August 18 to 20, 1967

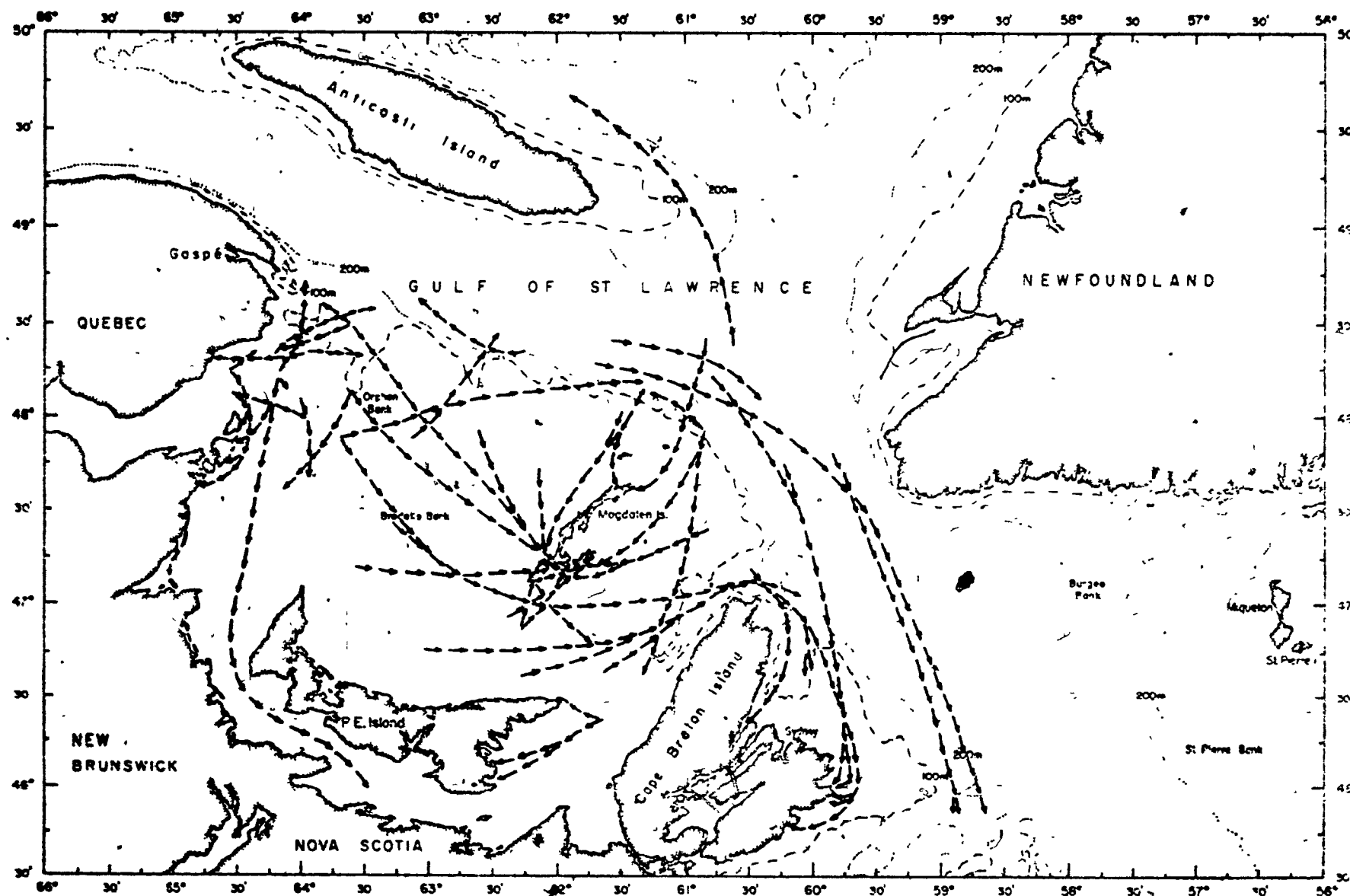


FIGURE 14: Bottom drift as inferred from recoveries of sea-bed drifters released from May 23 to June 4, 1968

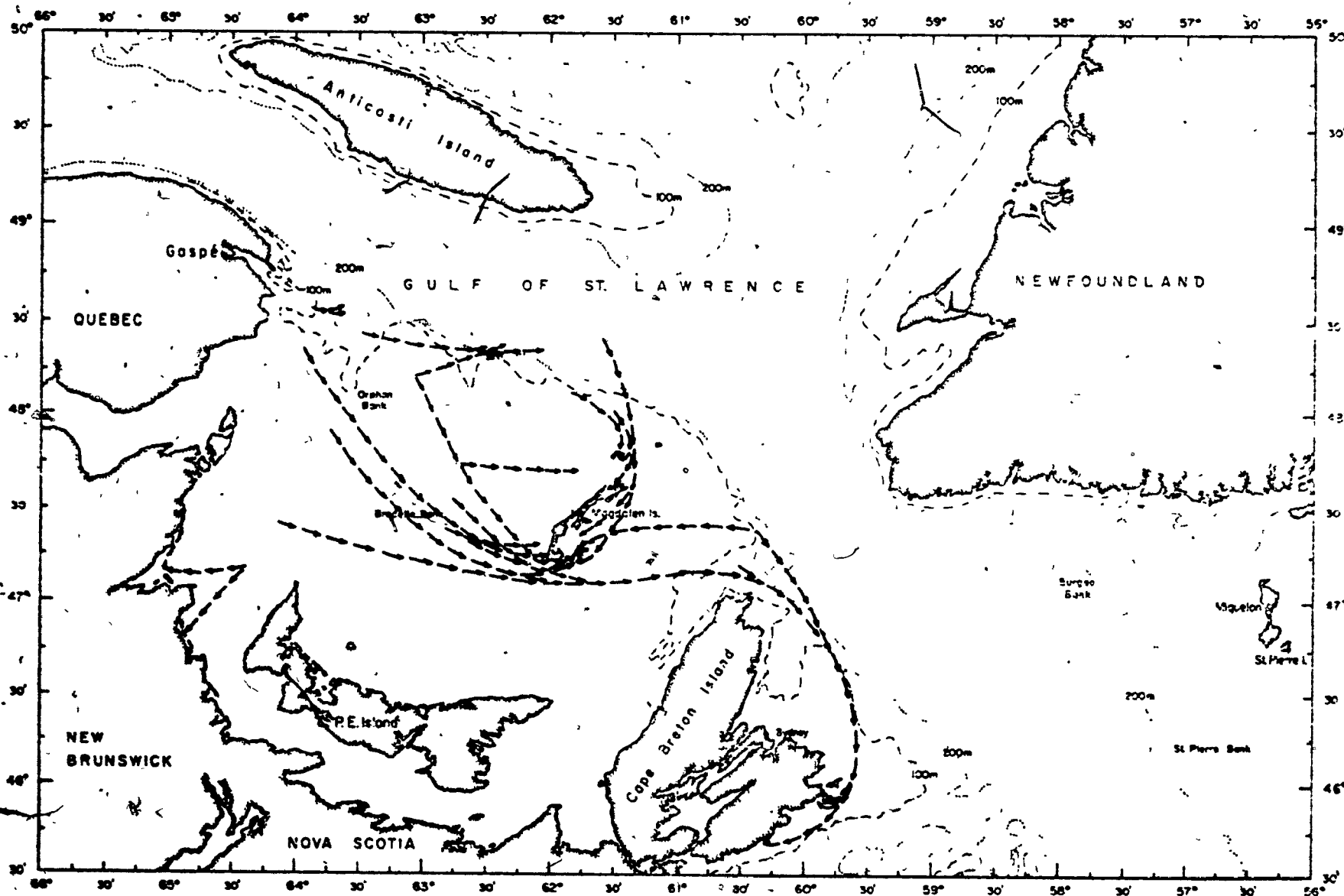


FIGURE 15: Bottom drift as inferred from recoveries of sea-bed drifters released from June 19 to 25, 1968

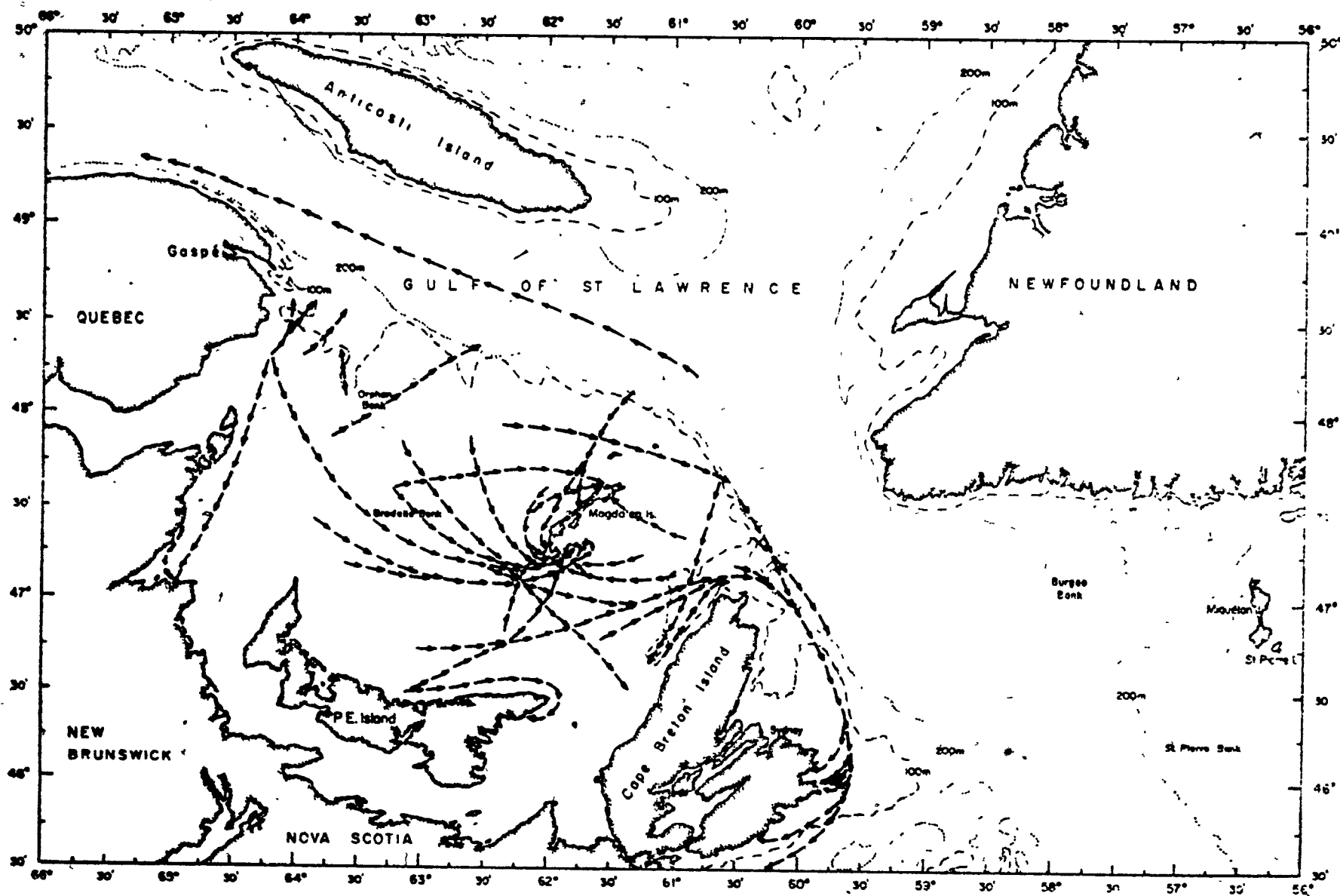


FIGURE 16: Bottom drift as inferred from recoveries of sea-bed drifters released from August 17 to 31, 1968

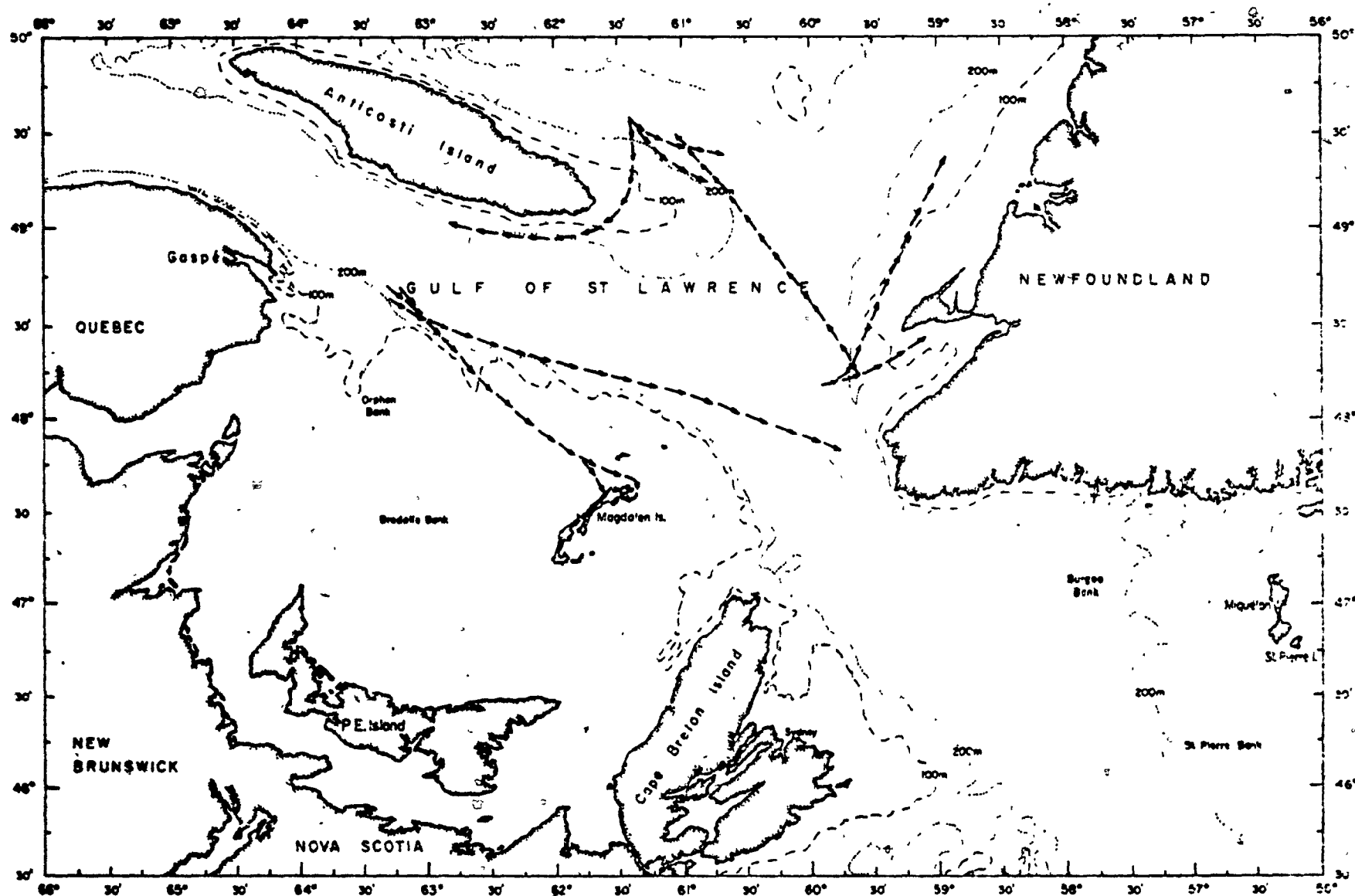


FIGURE 17: Bottom drift as inferred from recoveries of sea-bed drifters released from October 21 to November 5, 1968