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The Decline of the Herring Fishery in Northern Northumberland Strait and its Possible Causes

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In a report to the Canso Marine Environment Workshop, Dartmouth, November 1977, on "the possible effect of the Canso causeway on the herring fishery" (Messieh and Moore 1977), catch data showed a dramatic decline in the northern Northumberland Strait herring landings in the 1950's. A discussion on the interpretation of the decline in this fishery and its possible causes led to two different views: one that the decline is a part of a general phenomenon common to other herring fisheries in the Gulf, particularly the spring inshore fisheries, and the other that it is caused by the closure of the Canso Strait.

Accepting the latter hypothesis, i.e., a decline due to the closure of the Canso Strait, implies the presence of a connection between the herring populations in the Gulf and those in Nova Scotia through the Canso Strait, a connection which has been broken by the construction of the causeway. Some questions naturally arise in this respect: (1) why did the disconnection, if it happened, affect the northern Northumberland Strait differently from other areas in the Gulf? and (2) why was there no similar decline on the other side of the causeway, i.e., in Chedabucto Bay? The serious implication of the situation, if this hypothesis could be substantiated, is that the present herring fisheries management decisions, currently based on the assumption that the herring populations in the Gulf of St. Lawrence and the Atlantic coast of Nova Scotia are separate unit-stocks, should be changed.

The purpose of this report is to show that the dramatic decline in the northern Northumberland Strait fishery in the 1950's is not an isolated event. It reflects rather a general phenomenon which affected all spring herring fisheries in the Gulf, particularly those of the inshore fishermen, caused by an epizootic disease in the mid-1950's. Based on data from pre- and post-causeway periods, there is no evidence that the herring populations in northern Northumberland Strait and Chedabucto Bay were connected prior to the construction of the causeway.

More data on sea and air temperatures are also presented. These data confirm the evidence for a relationship between temperatures and date of arrival of herring on spawning grounds - the colder the temperature, the later the arrival.

Catch statistics

Figure 1 shows herring catches in the southern Gulf of St. Lawrence (Div. 4T), separated by fishing gear. Since its inception in 1966, the mobile fleet exerted much effort in catching herring and the catches in their second year of operation by far exceeded the long-term average catch of the inshore fishermen. However, a dramatic decrease in their catch occurred since 1970.

The catches of the fixed gear (inshore fishery) were relatively stable until the early 1950's when a major decline occurred. Catches declined from more than 40,000 mt in 1955 to 18,000 mt in 1961. A recovery of the fishery took place by 1965, after which a steady decline down to 12,000 mt in 1975 was shown.

To examine the effect of the decline in different fisheries, landings were separated by area and fishing season. Those of April, May and June comprise the spring fishery; July, August and September, the autumn fishery. The 3-year running means of herring landings are shown in Figures 2-6. Historical catch records are incomplete as to area and method of capture. However, landings before 1966 were almost all taken by fixed gear and they represent locations of catches.

From these figures it is shown that autumn fisheries were subjected to fluctuations, but there was an increasing trend in catches of all these areas. The increase was much more dramatic in Caraquet landings (Fig. 2), particularly since 1966. This reflects the landings by the mobile fleet which do not necessarily operate in the vicinity of the area. Caraquet-Shippegan harbours provide facilities and major centers of activities of the large purse-seiners in the Gulf.

Landings from the spring fisheries showed a general phenomenon common to all areas, i.e., a decline in the mid-1950's until 1960, after which a recovery of the fisheries occurred by 1964. The Gaspé fishery was an exception where the recovery started to show up in 1958. A comparison of herring landings in 1950-65 (Fig. 7) shows the similarity of these trends in the spring fisheries.

Comparison of herring landings in the spring fisheries of the Magdalen Islands (Fig. 3) and that of the northern Northumberland Strait (Fig. 4) shows similar trends of the decline in the mid-1950's. In the Magdalen Islands, mean landings declined from about 18,000 mt in 1955 to 6,000 mt in 1960, compared to a decline in northern Northumberland Strait from 8,500 mt to 3,500 mt over the same period. Landings of the two areas in more recent years followed a similar trend. Landings in the Magdalens declined from 15,000 mt in 1965 to 2,500 mt in 1974, compared to a decline from 8,500 mt to 700 mt in the same period for northern Northumberland Strait.

The trends in landings in the two areas, however, differed in the early 1950's. So, while a decline from 14,500 mt in 1950 to 8,000 mt in 1955 was shown in the northern Northumberland Strait, an increase from 8,000 mt to 18,000 mt was shown for the same period in the Magdalen Islands.

Separation of herring stocks in Div. 4T and 4W

Studies based on direct (tagging) and indirect (biological characteristics; morphometric and meristic characters) methods of stock identification showed that the herring stocks in the Gulf of St. Lawrence (ICNAF Div. 4T) are distinct and separate from those in the Chedabucto Bay-Nova Scotia area (ICNAF Div. 4W). Results of studies by various investigators in this respect are summarized by Messieh and Moore (1977). However, this summary only includes results of recent studies, i.e., in the post-causeway period.

Evidence of discreteness of herring populations in the Gulf of St. Lawrence and along the Atlantic coast of Nova Scotia in the pre-causeway period is also available. Results based on comparisons of growth, length and age compositions, and meristic characters of herring collected in 1914-15 and 1943-48 indicate that the two populations were separate before the completion of the Canso causeway.

Lea (1919) compared back-calculated growth of herring samples from the Gulf and Nova Scotia, and found them different (Fig. 8). He reported that "herring in the Magdalen Islands and Northumberland Strait exhibit a type of growth differing from that noted among the herring from West Adroise (Chedabucto) and Nova Scotia, which appear to form in this respect a group apart." The differences between the Nova Scotia and the Gulf of St. Lawrence populations were also shown in their age compositions. An exceptional sample from W. Adroise, however, composed of young fish (ages 3 and 4) had an age similar to a sample from Port Hood. Being aware of the small sample size, Lea *(op. cit.)* did not conclude - or even suggest - homogeneity of the populations in the two areas. It is known that ages 3 and 4 are the ages of "recruit-spawners" entering the fishery for their first time, regardless of their origin. This phenomenon has been observed in other situations where herring samples were collected from widely separated areas.

Differences between herring populations in the Gulf of St. Lawrence and the Chedabucto Bay area were also shown in some of their meristic characters (data presented by Lea 1919). The mean counts of the dorsal rays (D), anal rays (A), keeled-scales (K), and vertebrae (V) were found as follows (Lea 1919):

Locality	D	A	K	V*
Northumberland Strait	18.3	16.7	12.5	55.3
Magdalen Islands	18.3	16.6	12.5	55.5
W. Adroise (Chedabucto)	18.5	17.3	12.9	55.3

*Adjusted to exclude the basi-occipitals

The differences in the anal-ray counts and keeled-scale counts between the Northumberland Strait and Magdalen Islands on the one hand and the Chedabucto Bay on the other are significant.

Herring data collected in 1943-48 (Day 1957; Tibbo 1957) provide further evidence for separation between the Gulf of St. Lawrence and the Nova Scotia populations. Results of Day's investigation corroborate Lea's findings and indicate similarity between herring populations in Shediac and North Rustico on the one hand and the Magdalen Islands and Cheticamp on the other.

Results of examination of more than 14,000 herring, from 28 localities on the Atlantic coast of Nova Scotia, including 3000 fish from Chedabucto Bay collected in 1943-48 were reported by Tibbo (1957). He found that herring in Nova Scotia were larger and older than in the Gulf of St. Lawrence. There were some dominant year-classes in the area but not to the same extent as in the Gulf. Although he did not find differences in their vertebral counts, he considered the two groups distinct geographically.

Figure 9 shows a comparison of the length and age compositions of herring from Westmorland and Inverness Counties in the Gulf and Chedabucto Bay in Nova Scotia. All these samples were collected in June 1948.

Factors involved in the decline of the fishery

As shown in the catch statistics (Fig. 7), the decline in the northern Northumberland Strait fishery was not an isolated event. Rather, it was a part of a general phenomenon common to all spring herring fisheries in the Gulf of St. Lawrence; in particular, the inshore fisheries.

The inshore spring fishery in the northern Northumberland Strait was subjected to three successive major events since the early 1950's. These were the aerial forest spraying with DDT in the vicinity of the Miramichi estuary in 1952, the widespread epizootic disease, *Ichthyosporidium hoferi*, in 1954, and the dramatic increase in the fishing effort by the mobile fleet since 1966.

In the catch curve (Fig. 4), the observed decline coincides with these three events. The catch declined from about 15,000 mt in 1951 to 8,000 mt in 1954; from 8,500 mt in 1955 to 3,000 mt in 1961, followed by a sharp increase up to 9,000 mt in 1965, and a dramatic decrease from 7,000 mt in 1966 to 700 mt in 1975.

The DDT forest spraying in the early 1950's

Much of the forest area in New Brunswick, especially that in the northeast area comprising the Miramichi River system, was subjected to DDT spraying between 1952 and 1967, inclusive. When DDT-in-oil was sprayed, some of it got into drainage systems lying in the spray zone. As a result, many young salmon were killed and stocks were endangered. Reduction in number of young salmon was followed by declines in numbers of adults taken in fisheries and returning as spawners (Elson 1967). There were reports that the first spraying of the Northwest Miramichi with DDT was followed by virtual elimination of gaspereaux, shad and smelt runs in the streams above the Curventon counting fence. Extensive killing of suckers and cyprinids was also observed (Elson et al. 1972).

While direct effects of DDT and other organochlorine compounds on salmon and trout have been well established, little is known about accumulation of pesticide residues in the marine food chain in the Gulf of St. Lawrence. Because of its persistence in the environment - a half life about 13 years - it is assumed that DDT derivatives, mostly DDE and some DDD, are still recycling in the waters (Sprague et al. 1969; Trites 1970).

Other pollutants entering the Miramichi estuary originate mainly from two sources. These are the discharge of municipal effluents into the estuary, and industrial effluents from a variety of manufacturing industries located on or near the estuary. Pulp mills carried large volumes of toxics containing high BOD, suspended solids and oxygen-demanding wastes. Until 1969 a wood preserving plant discharged large quantities of organic compounds containing mineral oil, polynuclear hydrocarbons, such as benzopyrene, cresols, pentachlorophenol, etc., directly into the Miramichi via a small stream. Elson et al. (1970) reported that effluents associated with pulp mills and other urban waste so contaminated the Miramichi estuary as to delay upstream migration of salmon. The contaminated effluents are quite likely to have had adverse effects on herring spawning beds and nursery grounds in this area.

Water circulation in the northern Northumberland Strait

To better understand the effect of pollution on the northern Northumberland Strait herring fishery, a knowledge of water circulation and larval transport in this area is essential. Lauzier (1965) reported on results of drift bottles released from fixed stations and during cruises in Northumberland Strait from 1960 to 1963. Most recoveries inferred a drift to a certain point along the Strait but very seldom further. There seems to be a drift from northwest to southeast at various points along the Strait. More recoveries were made on the Prince Edward Island side than on the New Brunswick side, indicating an easterly component of the drift of surface waters. Within the northern segment, the recoveries infer a cyclonic eddy with a southerly drift along the New Brunswick coast and a northeasterly drift along the Prince Edward Island coast in a "U-turn" direction and out into the Gulf again (Fig. 10). This northeasterly movement of the surface waters is no doubt the main avenue for bottles drifting out of the northern Northumberland Strait toward the Magdalen Islands and Newfoundland (Lauzier, *op. cit.*). Lauzier reported also that the Northumberland Strait receives on the average a rather small "share" of the surface water just north of it.

It should be kept in mind that the small contribution of outside waters to the Northumberland Strait is not a recent phenomenon resulting from the closure of the Canso Strait. Farquharson's (1959) results indicate that any possible change in the flow in the Northumberland Strait is much less than the wind-driven residual currents.

Studies on larval herring distribution in the Gulf of St. Lawrence (Messieh and Kohler 1972; Messieh, unpublished) showed large concentrations of herring larvae in the northern Northumberland Strait. Very few larvae were found in the middle and southern segments of the Strait (Fig. 11). The dispersal pattern indicates larval retention in the northern Northumberland Strait, and larval drift on the Gulf side of Prince Edward Island.

Mass mortalities of herring in the mid-1950's

In spring of 1954 dead herring were seen in large quantities floating at the surface and washed up on the beaches throughout most of the inshore areas of the southwestern Gulf of St. Lawrence and along the west coast of Newfoundland. Dead and dying fish were first reported near the mouth of Chaleur Bay and Magdalen Islands, and after a few days in the northern Northumberland Strait area.

Mortalities started about mid-May near the end of the fishery for spring-spawning herring. They reached a peak in June, continued through July, apparently ceased in August before the autumn fishery. Similar mortalities occurred in 1955 throughout the same area and period. In 1956 fewer herring died than in either of the two previous years and only the Chaleur Bay and Magdalen Islands areas were involved.

The spring fishery appears to have suffered most from mortalities, with average landings decreasing 46% in 1955-59

(Tibbo and Graham 1963). The autumn fishery declined 25% over the same period. Sinderman (1958) estimated that at least half of the mature herring in the Gulf were destroyed during the period 1954-56, and he considered his estimate to be conservative. From the data presented here, herring catches in the spring fishery of the northern Northumberland Strait declined 65% in 1955-61, whereas the autumn fishery increased more than twice over the same period.

Tibbo and Graham *(op. cit.)* reported that disease resulted in substantial decreases in the production of herring larvae. Comparisons of the catches of larvae for periods before (1951-53) and after (1957-61) the disease epidemic showed that the average catch of spring-hatched larvae decreased from 589.1 to 8.4 per tow, whereas the average catch of autumn-hatched larvae increased from 0.03 to 4.6 per tow.

The decline of the fishery in the mid-1960's

Traditionally, the herring fishery in northern Northumberland Strait was based almost exclusively on inshore spring spawning populations caught by fixed gear. Since 1966 the fishing pattern on this stock has changed from a predominantly inshore fishery to a predominant purse-seine offshore fishery operating in spring, summer and fall. Introduction of the mobile fleet to the fishery and the increased exploitation rate resulted in inevitable changes in population structure, particularly in old fish on which many inshore fisheries depend.

Moreover, the mobile fleet exploits not only spawning concentration but also pre-spawning, post-spawning and feeding concentrations. A major operation of the herring purse-seiners is concentrated in Shippegan-Caraquet, where harbour and landing facilities are available. However, their activities extend through the entire Gulf area, and it is permissible to assume that a large percentage of fish in the northern Northumberland Strait could be caught by the mobile fleet before reaching their spawning grounds. It appears most likely that this is the major factor in reduced inshore catches.

A similar situation is the decline of the inshore fishery in the Magdalen Islands (Messieh 1978). Examination of this problem by CAFSAC Pelagic Subcommittee showed that the 'edge' fishery by mobile fleet is most probably the primary factor in reducing the catches of inshore fixed gear fishery in the Magdalen Islands.

The decline of the northern Northumberland Strait fishery appears to be a part of an overall decline in the Gulf. Winters and Hodder (1975) showed that the precipitous decline in catches during the early 1970's was due to a combination of high fishing mortalities and successively poor recruitment.

A special situation which might have aggravated the problem is the fact that the northern Northumberland Strait area is the only area in the Gulf of St. Lawrence where lobster fishing is prohibited in the spring. So, while fishermen in other areas are attracted to fish the more lucrative lobsters, the inshore fishermen of northern Northumberland Strait have no alternative, during spring, except to catch herring and other species. This no doubt resulted in a sustained fishing effort on the spring spawning herring population in this area, compared to a decrease in fishing effort in spring in other areas.

Effect of temperature on herring date of arrival

Examination of the relationship between date of herring arrival on spawning grounds near the Magdalen Islands and mean surface sea temperatures showed a significant negative correlation between date of arrival and April temperature (Messieh 1977). The colder the temperature, the later was the arrival. This study was based on observations on actual arrival of the spawners recorded for 25 years during 1933-73. Similar results were found for herring in Antigonish and Inverness Counties in relation to sea temperatures in the nearest Record Station (Sambro Lightship) (Messieh and Moore 1977). In spite of the shortcoming of the data source, results showed good correlations. Correlation coefficients were -.73 and -.81 for Antigonish in March and April, respectively, and -.69 and -.78 for Inverness (Table 1).

Long-term similarities between air temperatures and sea temperatures in a wide geographic area have been reported by various investigators (e.g., Sutcliffe et al. 1976). There is a strong relationship between air temperatures and sea surface temperatures in the Magdalen Islands area (Messieh 1978).

Data on air temperatures from two meteorological stations, Grindstone I. (one of the Magdalen Islands) and Charlottetown, Prince Edward Island, are available. Comparison of mean annual temperatures from these stations with mean date of arrival showed an inverse relationship (Fig. 12). The higher the temperature, the earlier was the date of arrival. This relationship is very pronounced in the early 1950's where the highest mean temperatures and the earliest day of arrival in the period of observations were recorded.

The linear regressions of date of arrival in Antigonish on mean air temperatures of March and April in Grindstone I., and Charlottetown, P.E.I., are shown (Figs. 13 and 14). Results of analyses are presented in Table 1. It can be seen that the correlation coefficients for Antigonish County are higher than those for Inverness County. This may be explained by the fact that data from Inverness County included catches from wider geographic areas, and in some years landings in the two fishery districts 2 and 3 in this county were not separated.

The study of the relationships of air temperatures to date of arrival on spawning grounds near the Magdalen Islands (Fig. 15) showed good correlations (Messieh 1978). The correlation coefficients were -.75 and -.78 for March and April, respectively (Table 1). These values are higher than those for Antigonish and Inverness Counties - a result which could be expected since the dates of arrival in these counties, unlike the Magdalen Islands observations, were calculated from commercial catches. These calculations were based on the assumption that these fish were adult spawners, an assumption which is not true in all cases, and the calculations may include a bias resulting from differences in spatial and temporal distribution of fishing effort resulting from factors other than biological ones.

The effect of temperature on spawning time of herring and other species has been studied by various investigators and is generally accepted. Berenbeim and Sigaev (1977) showed a correlation between water temperatures and spawning time of herring in the Georges Bank (Fig. 16). Intensive surveys in the Georges Bank spawning grounds were made annually by AtlantNIRO from 1963 to 1973. Locations of spawning grounds and the time of beginning, peak and termination of massive spawning were determined, along with sea temperature records at different depths. Results showed good correlations between summer sea temperature anomalies and mean sea bottom temperatures in August on the one hand, and day of peak spawning in September on the other. They concluded that August temperature contributes significantly to the formation of the summer anomalies in the Georges Bank area where highly developed dynamic processes exclude thermal inertia. The established relationship indicated that relatively high heat content of water before spawning determines the earlier dates of peak spawning.

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Table Results of correlation analysis of herring date of arrival (peak spawning) and air and sea temperatures.

Location of spawning ground	Station of temp. record	Kind of temp. data	Arrival date	N	a	b	r	Source of data
Antigonish	Grindstone I.	Mean March air °F	Calculated	18	224.23	-3.01	-.71	Present report
		Mean April air °F	"	18	273.49	-3.74	-.66	" "
Inverness	Grindstone I.	Mean March air °F	"	18	187.93	-1.29	-.40	" "
		Meal April air °F	"	18	219.54	-1.92	-.44	" "
Antigonish	Charlottetown, PEI	Mean March air °C	"	18	130.71	-5.88	-.68	" "
		Mean April air °C	"	18	166.79	-6.93	-.74	" "
Inverness	Charlottetown, PEI	Mean March air °C	"	18	145.17	-3.42	-.52	" "
		Mean April air °C	"	18	166.26	-4.07	-.57	" "
Antigonish	Sambro Lightship	Mean March surface °C	"	18	155.04	-6.31	-.73	Messieh & Moore (19
		Mean April surface °C	"	18	161.81	-5.04	-.81	" " " "
Inverness	Sambro Lightship	Mean March surface °C	"	18	160.14	-4.49	-.69	" " " "
		Mean April surface °C	"	18	165.20	-3.68	-.78	" " " "
Magdalen I.	Grindstone I.	Mean March air °F	Observed	23	157.77	-1.75	-.75	Messieh (1978)
		Mean April air °F	"	23	227.48	-3.42	-.78	" "
Georges Bank	Georges Bank	Sept. anomaly 50 m depth °C	"	10	20.6	-6.50	-.81	Berenbeim and Sigae (1977)
		Mean Aug. bottom °C	"	11	64.1	-3.62	-.71	Berenbeim and Sigae (1977)
Magdalen I.	Entry I.	Mean April surface °C	"	15	29.56	-6.61	-.86	Messieh (1977)

N = number of years of observations
a = constant
b = regression slope
r = correlation coefficient

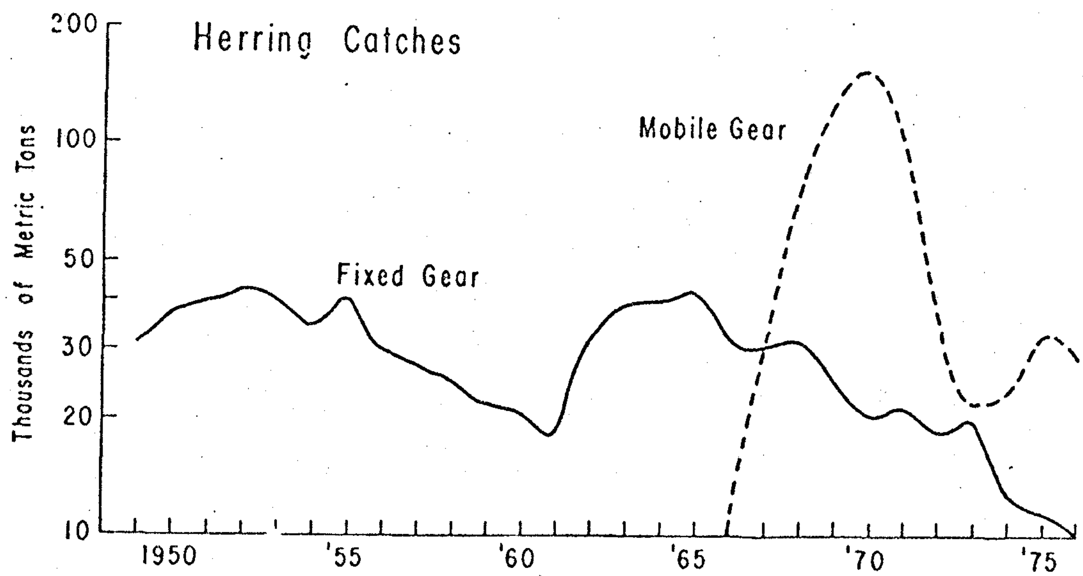

Figure 1. Herring catches ('000 MT) in the southern Gulf of St. Lawrence (Div. 4T) by fishing gear, 1949-76.

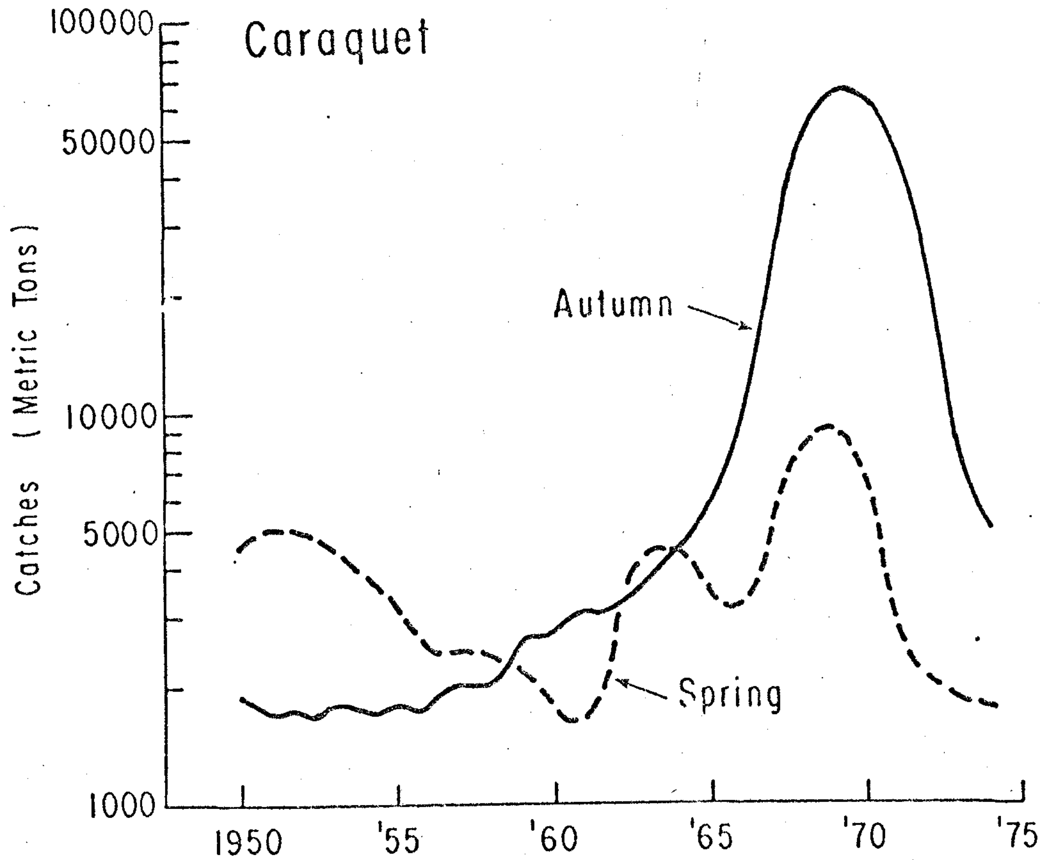

Figure 2. Herring landings (mt) of the spring and autumn fisheries in the Caraquet-Shippegan area, 3-year running means, centered.

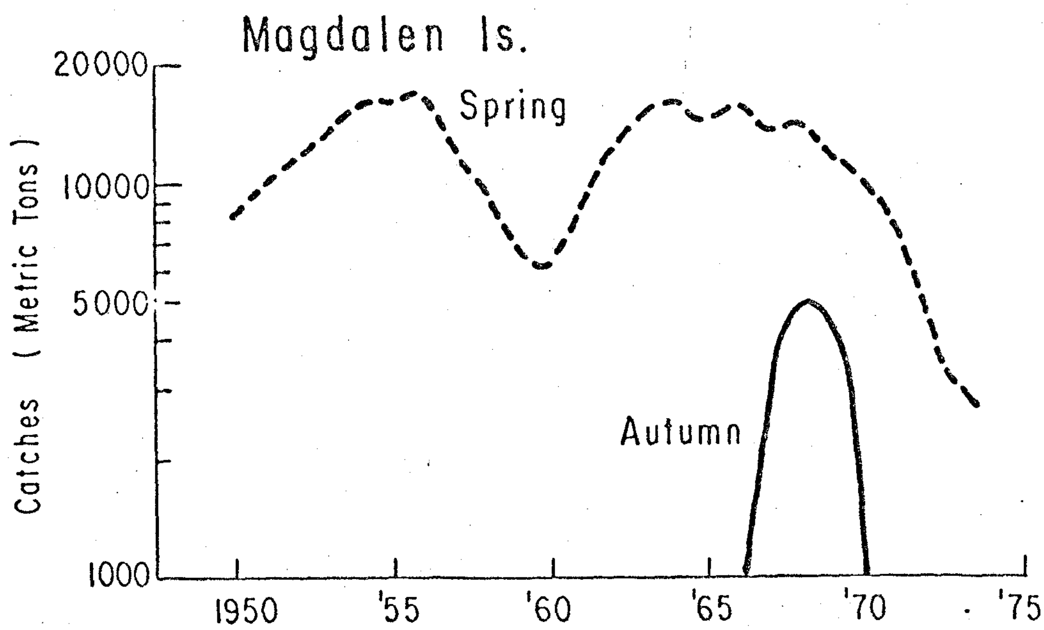

Figure 3. Herring landings (mt) of the spring and autumn fisheries in the Magdalen Islands area, 3-year running means, centered.

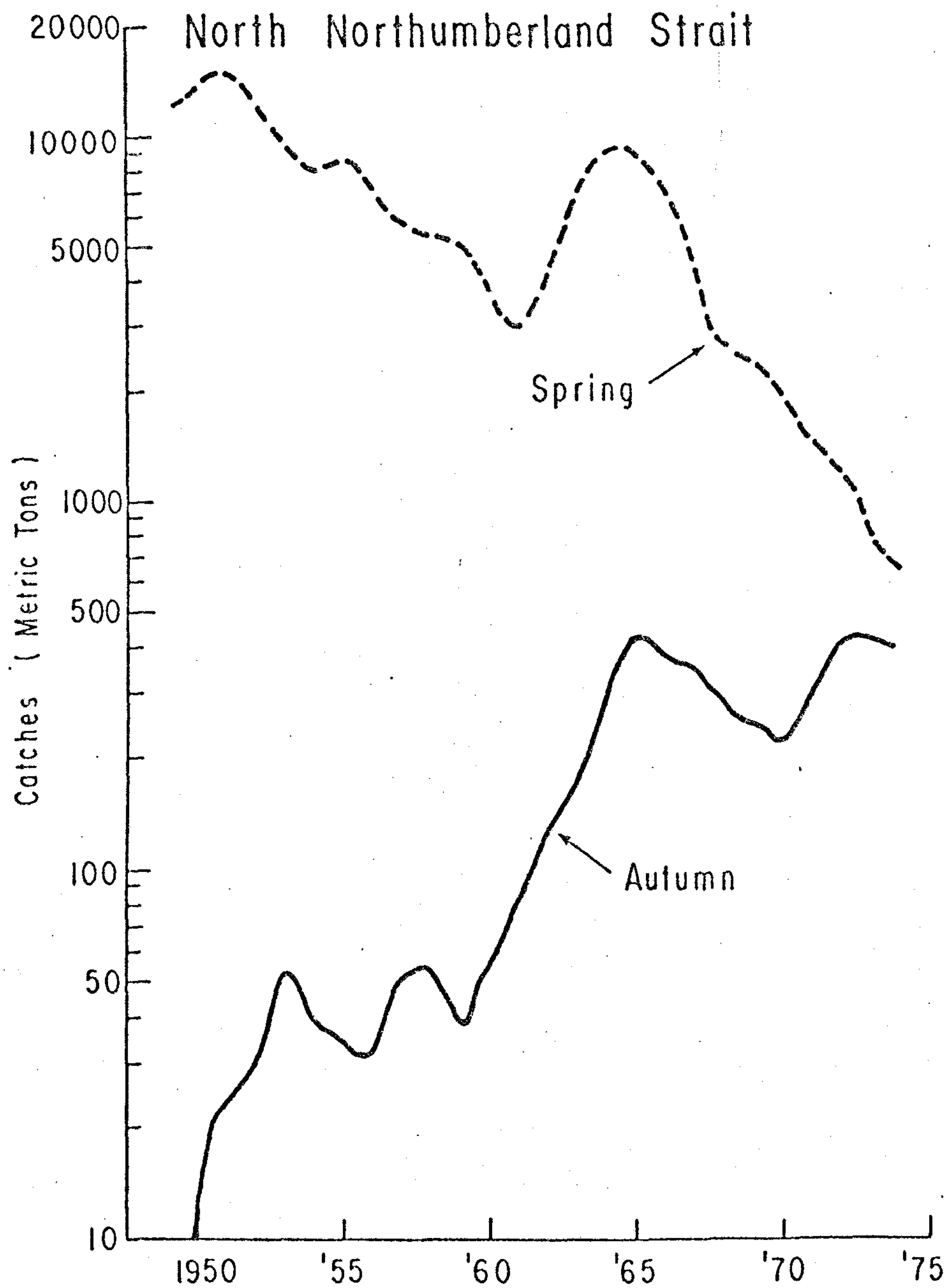

Figure 4. Herring landings (mt) of the spring and autumn fisheries in the northern Northumberland Strait area, 3-year running means, centered.

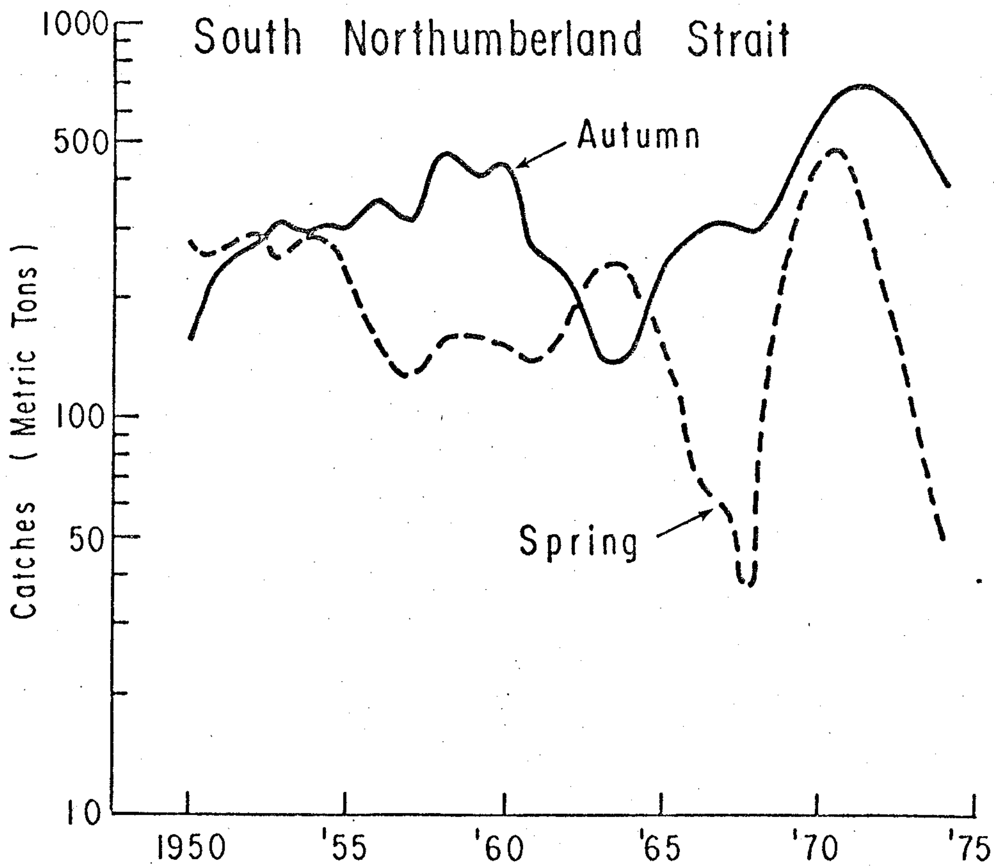

Figure 5. Herring landings (mt) of the spring and autumn fisheries in the southern Northumberland Strait area, 3-year running means, centered.

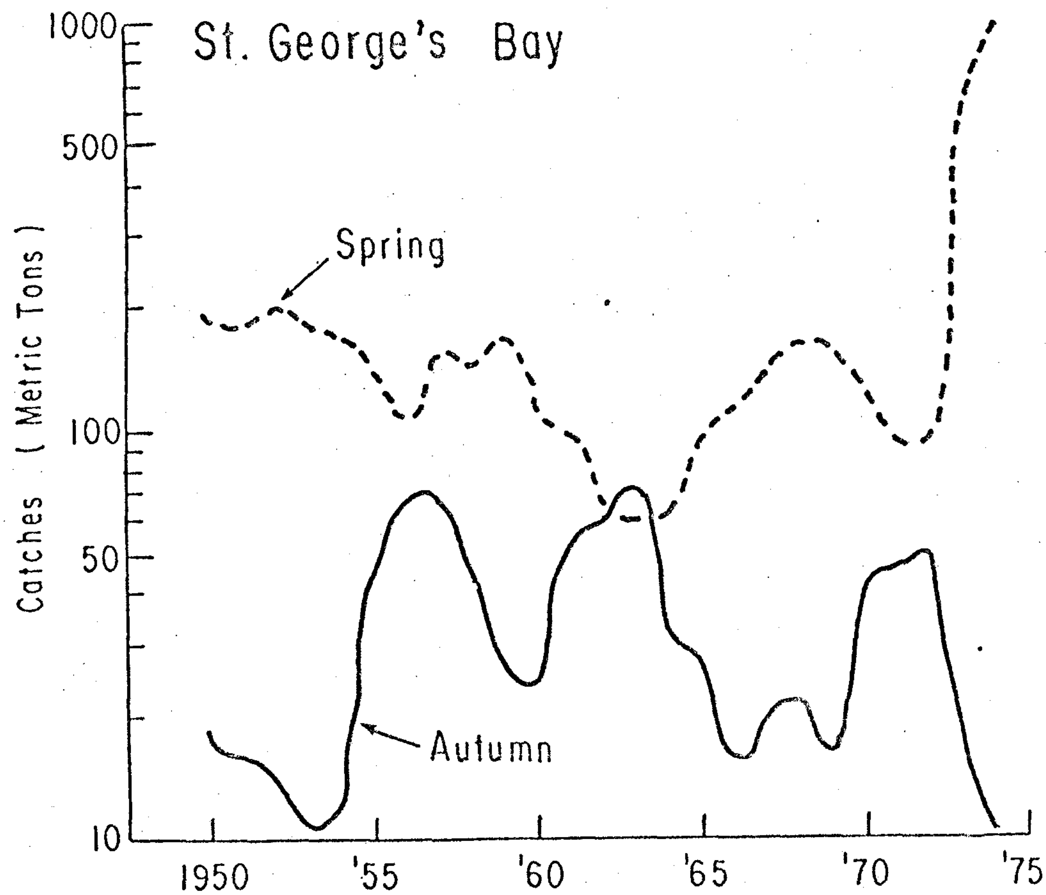

Figure 6. Herring landings (mt) of the spring and autumn fisheries in St. Georges Bay, 3-year running means, centered.

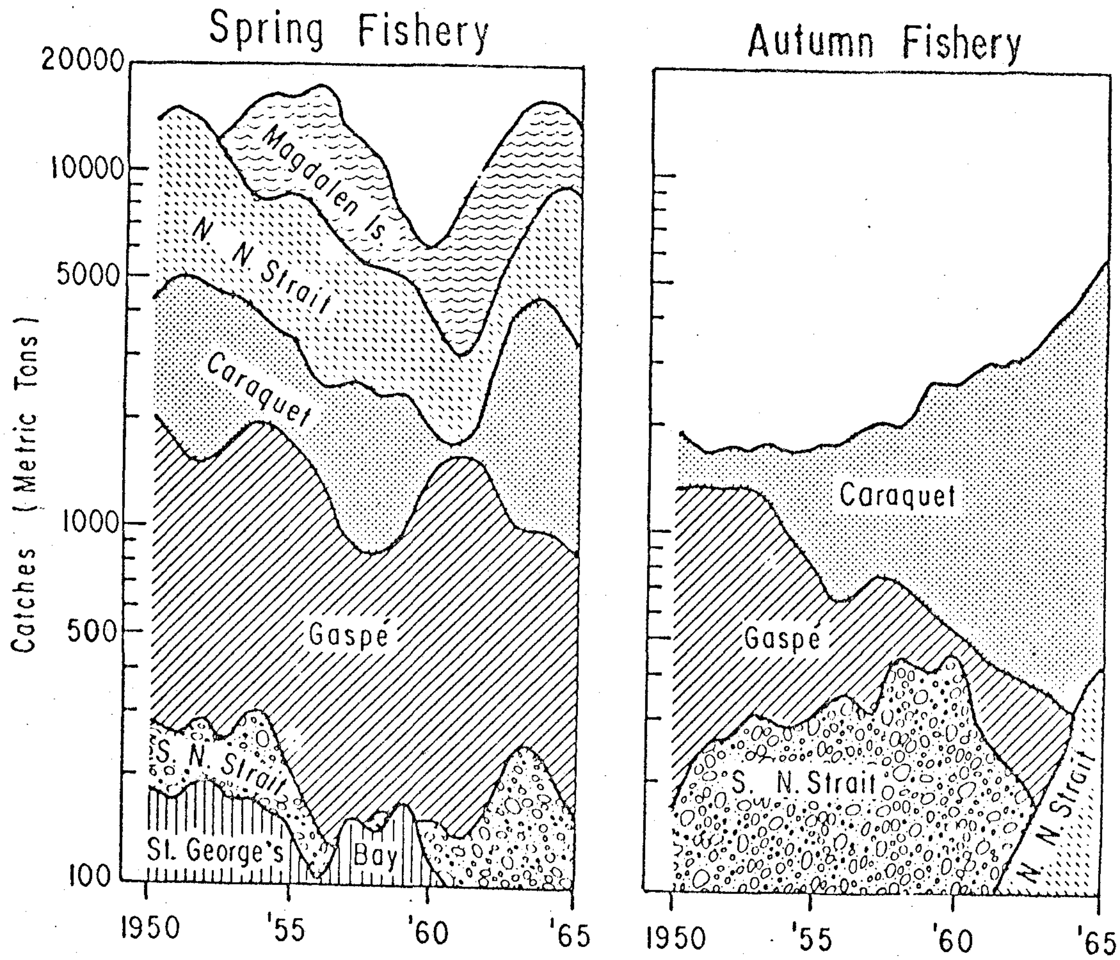

Figure 7. Comparison of herring landings (mt) of the spring and autumn fisheries in different areas of the southern Gulf of St. Lawrence, 3-year running means, centered.

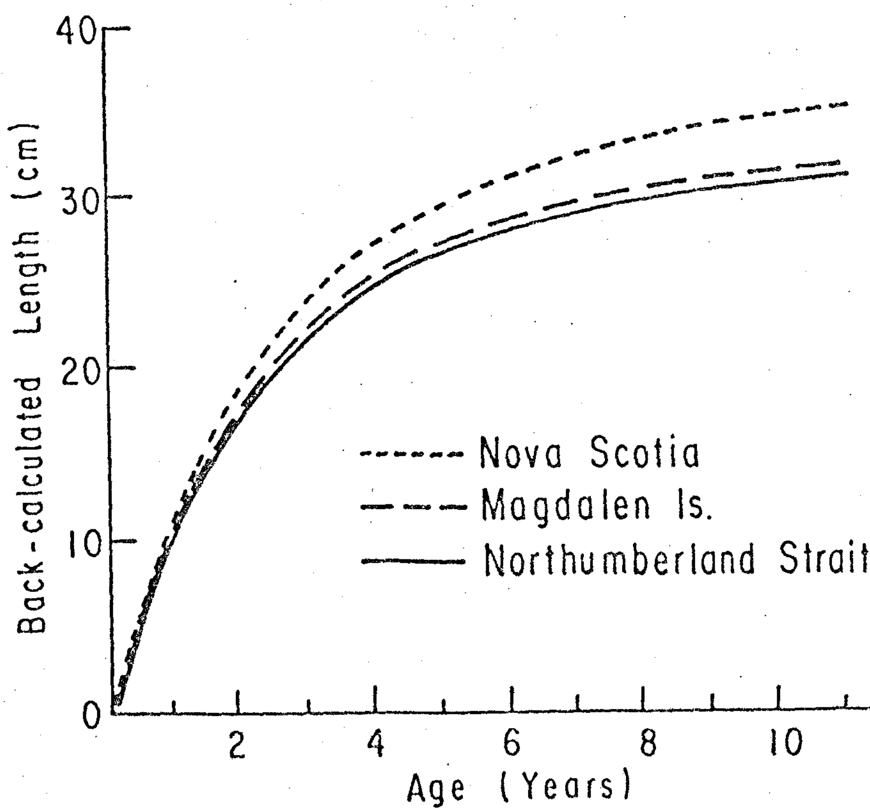

Figure 8. Back-calculated growth of herring from the Magdalen Islands and Northumberland Strait, Gulf of St. Lawrence, and along the Nova Scotia coast (from Lea 1919).

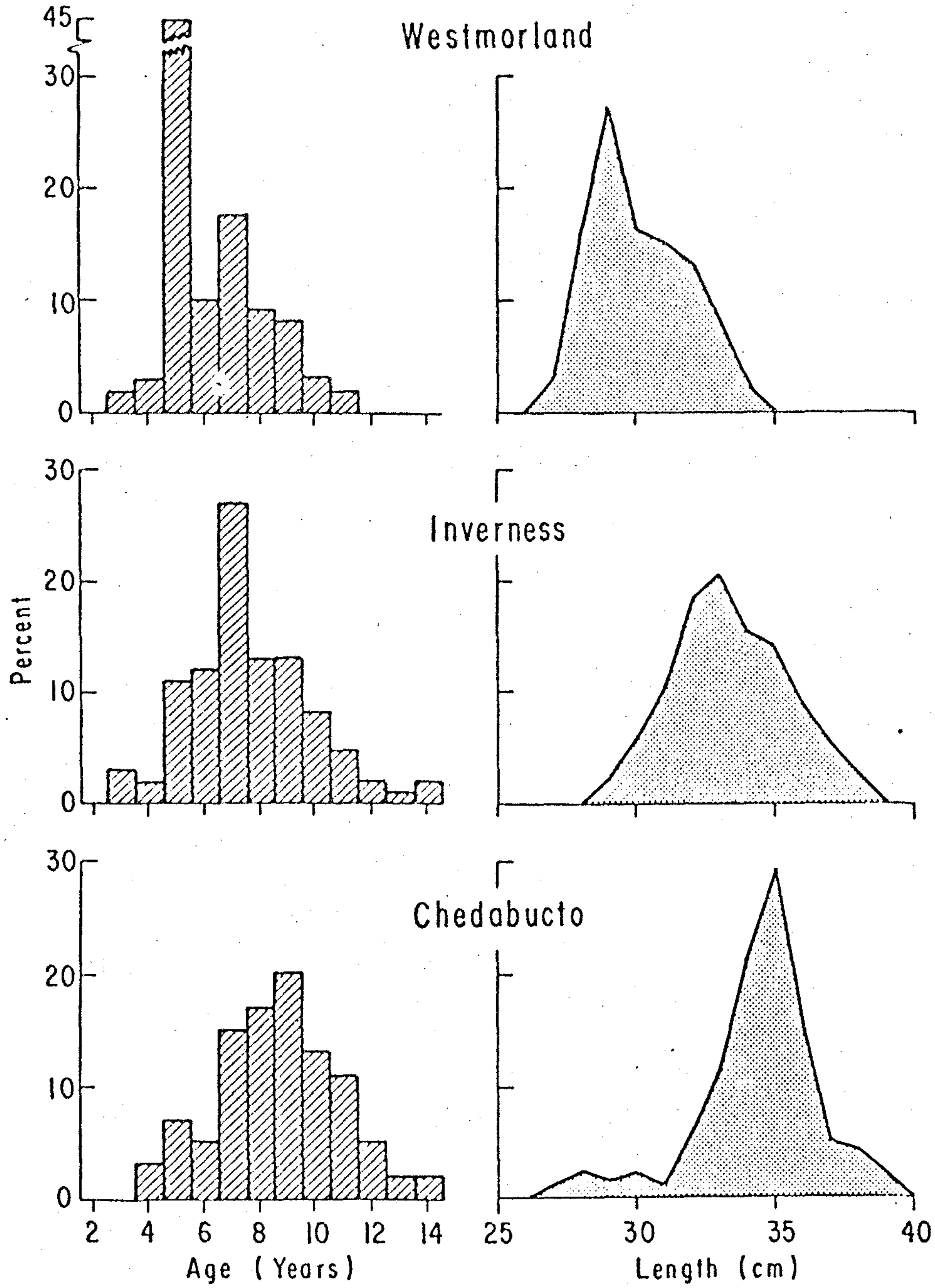

Figure 9. Length and age compositions of herring from Westmorland and Inverness Counties, Gulf of St. Lawrence, and Chedabucto Bay, Nova Scotia (from Day 1957; Tibbo 1957).

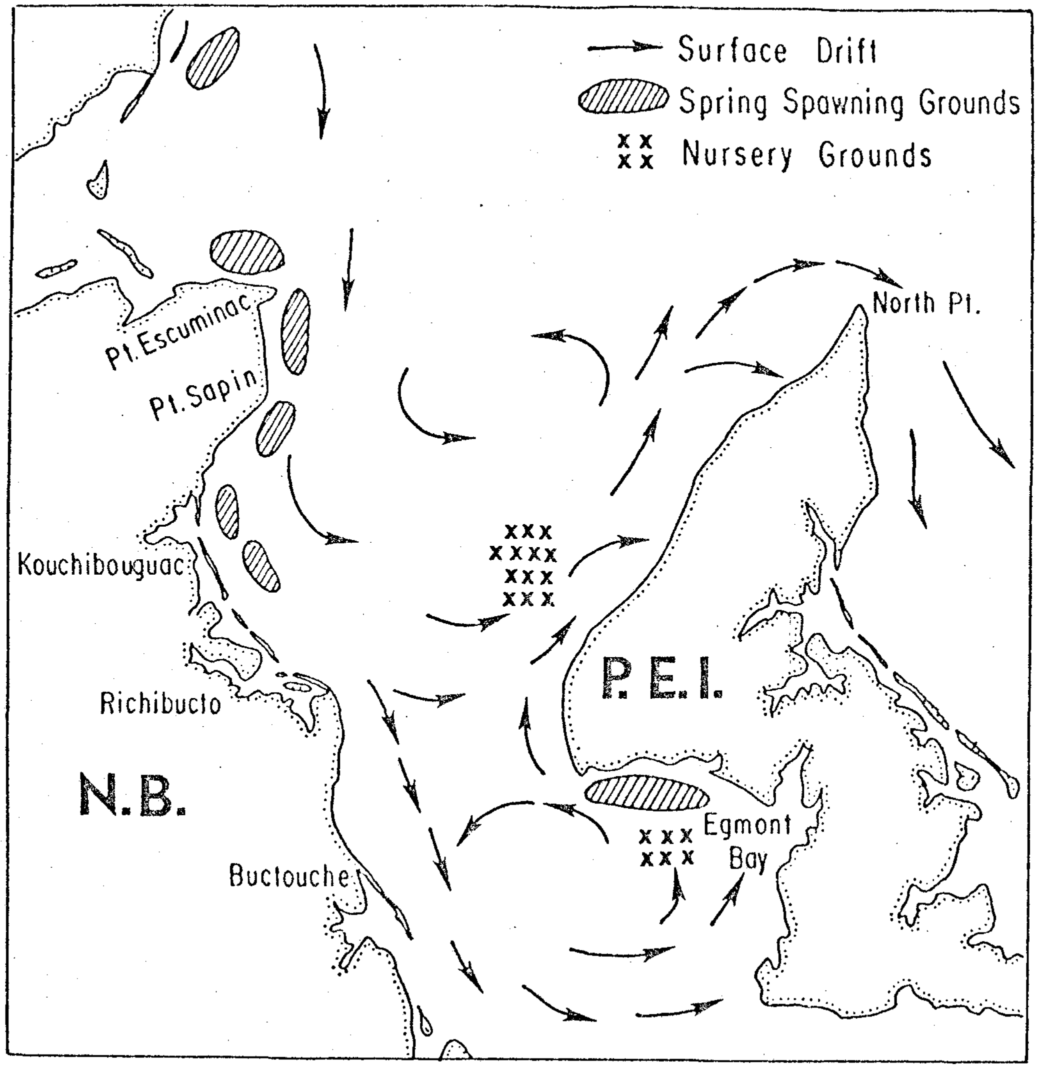

Figure 10. Map of the northern Northumberland Strait showing inferred surface drift, spring-spawning grounds, and nursery grounds of herring (surface drift from Lauzier 1965).

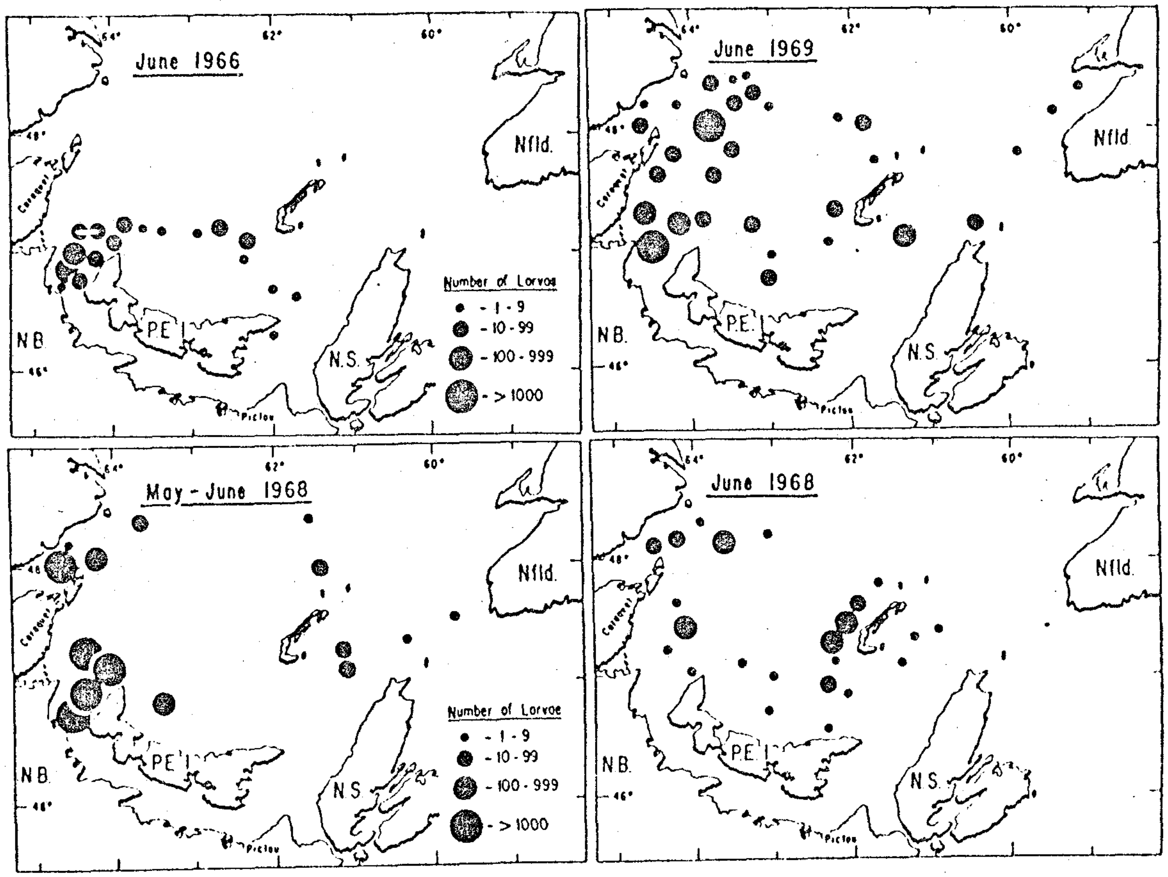

Figure 11. Distribution of spring-spawned herring larvae in the southern Gulf of St. Lawrence in 1966, 1968 and 1969.

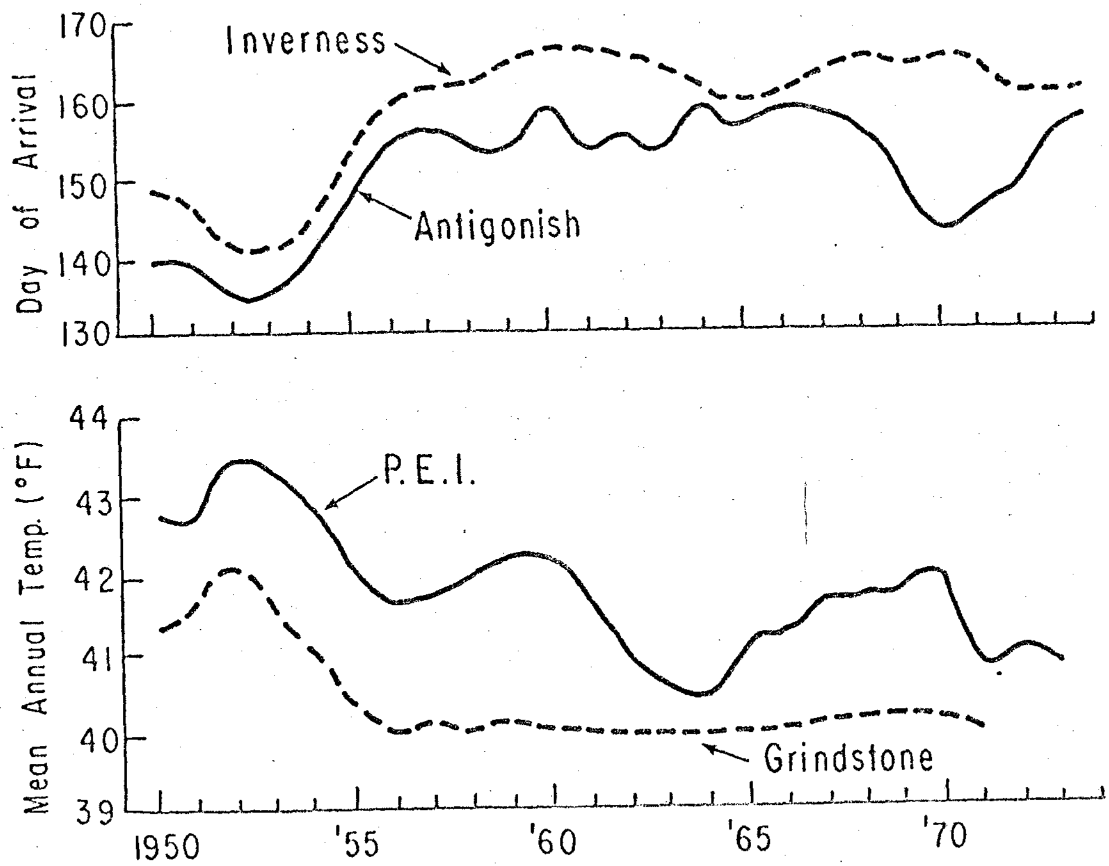

Figure 12. Mean day of herring arrival in Inverness and Antigonish Counties (upper figure), and mean annual air temperatures in Charlottetown, P.E.I., and Grindstone Island weather stations (lower figure), 1950-74.

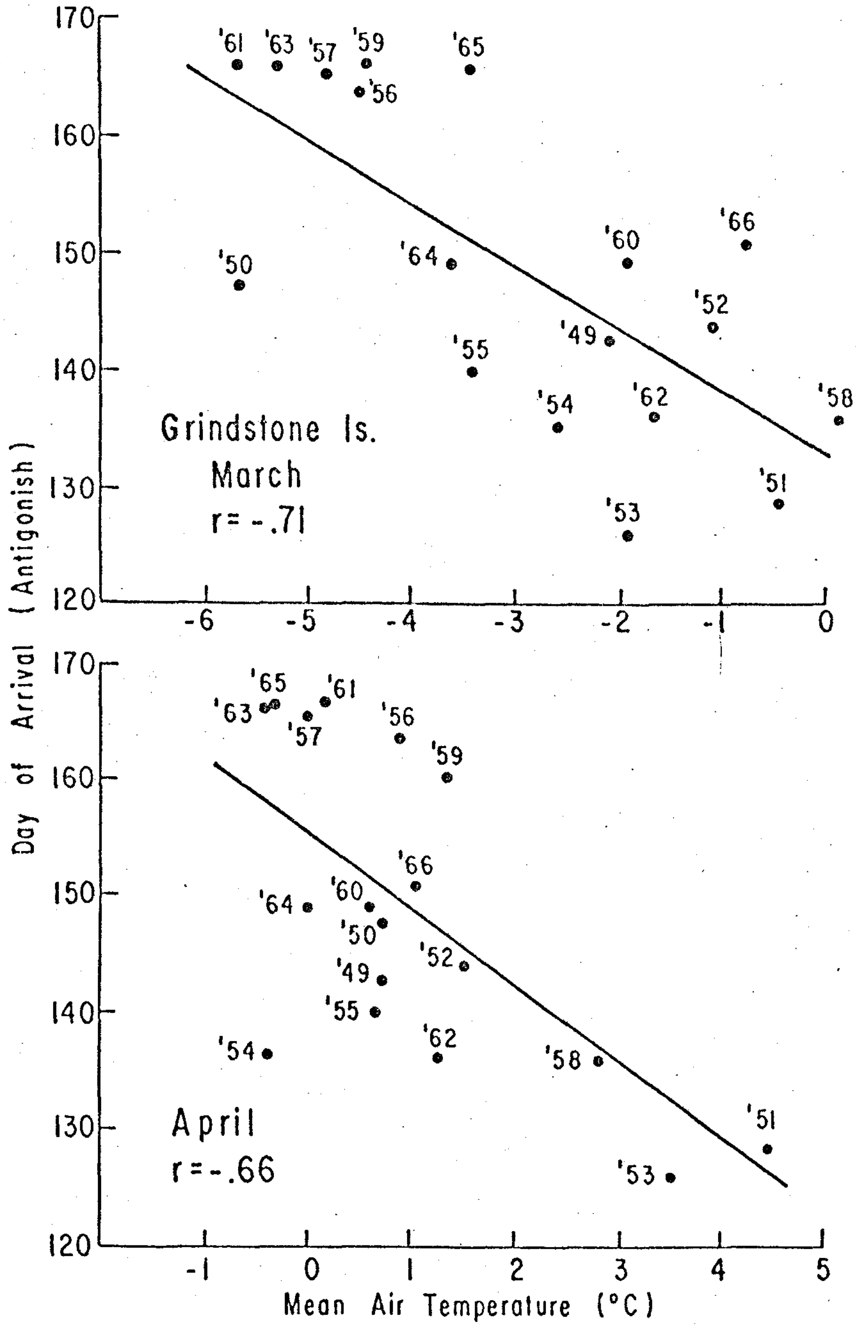

Figure 13. Relationship between days of herring arrival in Antigonish County and mean air temperatures in March and April at Grindstone Island. Years of observations are shown.

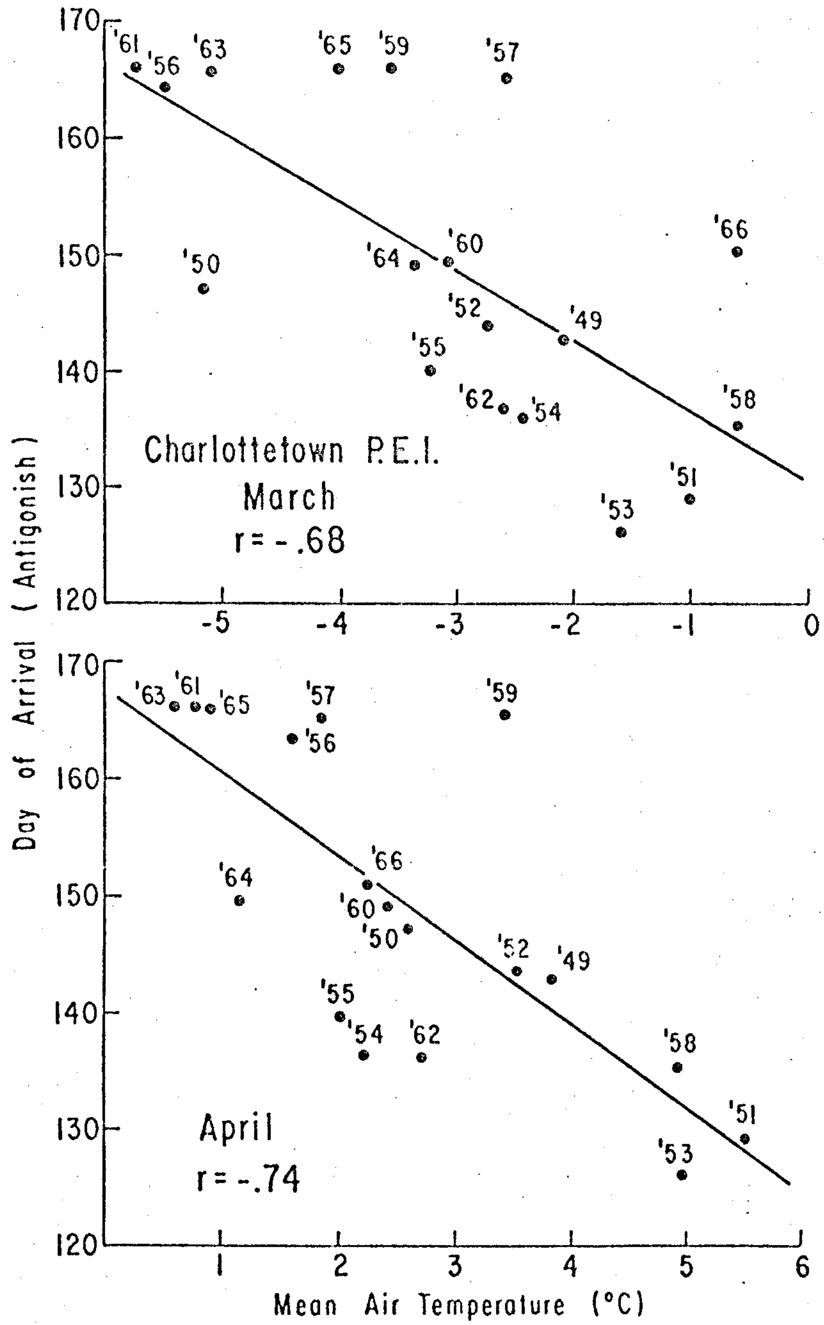

Figure 14. Relationship between days of herring arrival in Antigonish County and mean air temperatures in March and April, Charlottetown, P.E.I.

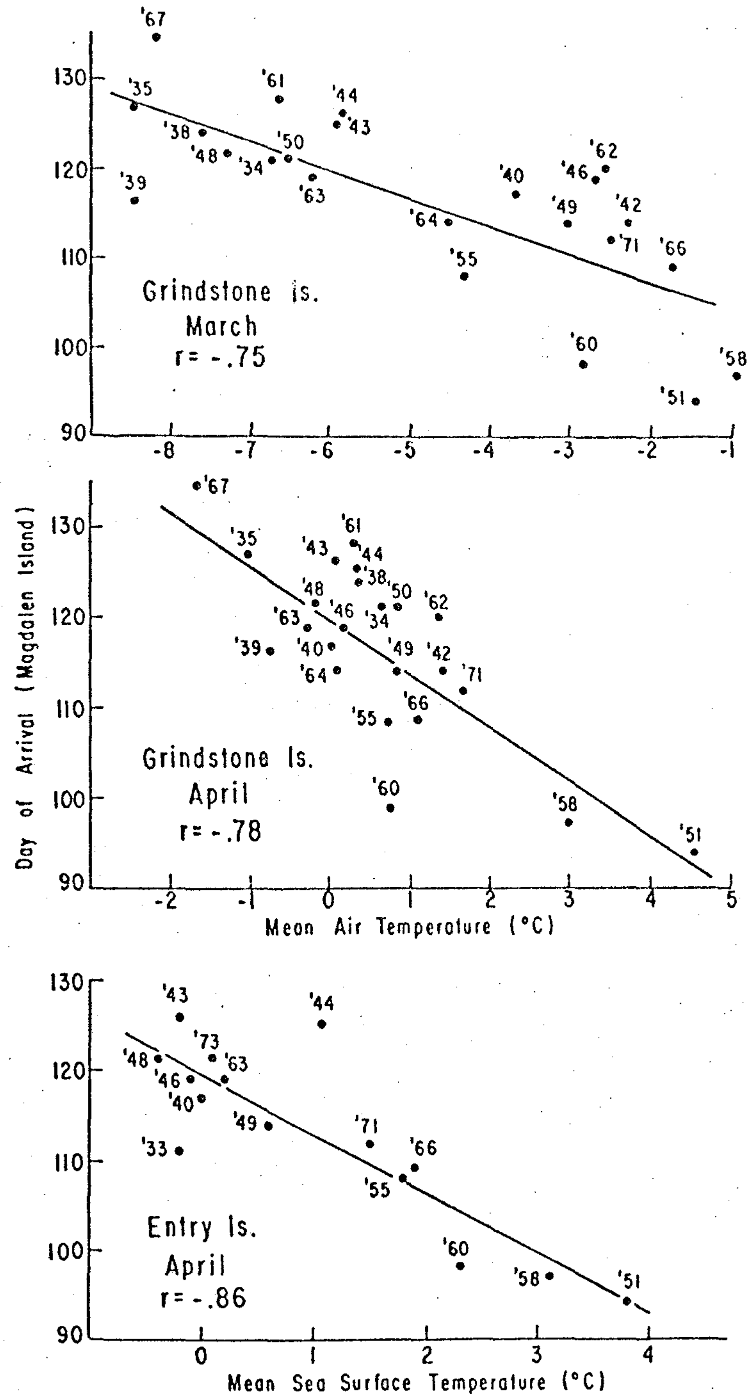

Figure 15. Relationship between days of herring arrival in the Magdalen Islands and mean air temperatures at Grindstone Island (upper two figures from Messieh 1978), and mean sea surface temperatures at Entry Island (lower figure from Messieh 1977).

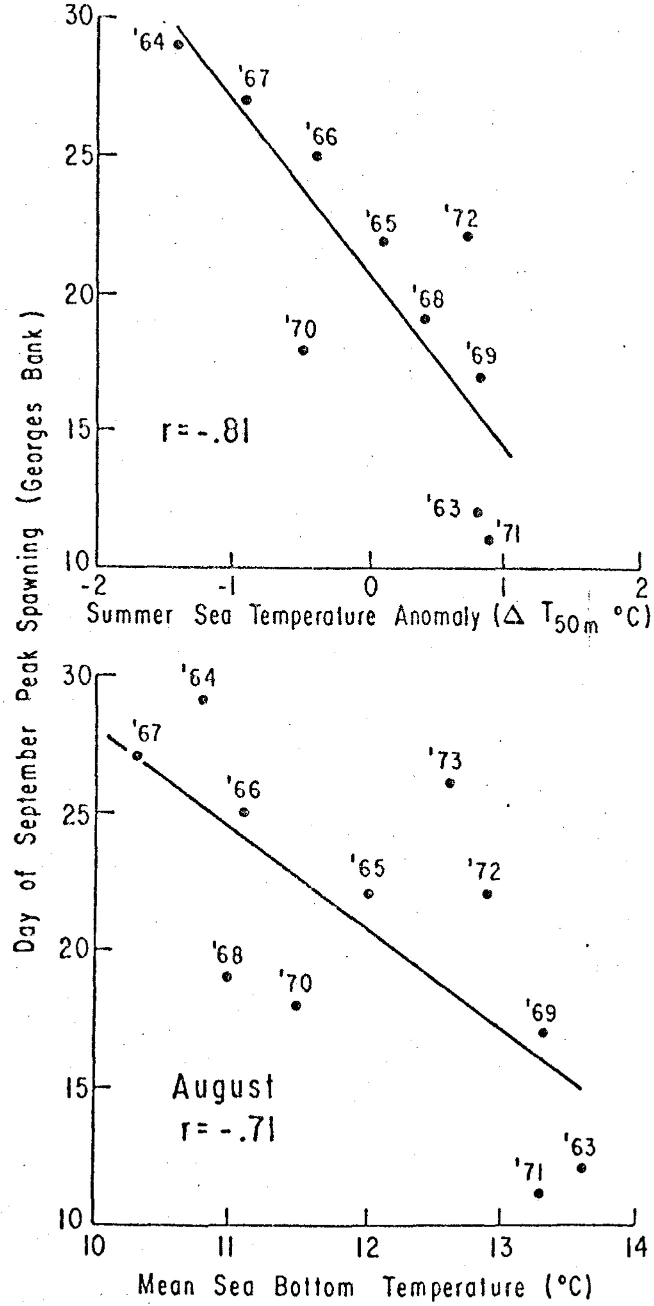

Figure 16. Relationship between date of herring spawning in Georges Bank in September and summer sea temperature anomalies (50-m depth) and mean sea bottom temperatures in August (from Berenbeim and Sigaev 1977).