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THE REGULARITY OF SPAWNING TIME OF ATLANTIC HERRING IN THE GULF OF ST. LAWRENCE

by

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ABSTRACT

Analysis of maturity stages of a large number of herring samples from the southern Gulf of St. Lawrence showed regularity of their spawning seasons. Several peak spawnings were shown, indicating different stocks within each of the spring and autumn spawning groups. Peak spawning times varied from year-to-year and between areas, but the spawning seasons did not change.

The relation of time of herring arrival on a spring spawning ground near the Magdalen Islands and water temperatures for 25 years was examined. Significant correlations between time of fish arrival and anomalies from normal March and April temperatures were found.

INTRODUCTION

The Gulf of St. Lawrence is one of the few areas in the Northwest Atlantic where both spring and autumn spawning herring are still caught in abundance. Each of these spawning groups comprises a complex of stocks spawning in different areas of the Magdalen Shallows (areas 431 to 439; Figure 1) (Messieh, 1975a).

The water round the Magdalen Islands, a group of small islands near the edge of the Magdalen Shallows (area 431) provide major herring spawning grounds, mainly for the spring spawning populations. These fish have become well known for the regularity of their spawning migration. In the early spring, shortly after the ice disappears, the fishermen set up their nets inshore, awaiting the arrival of herring schools in their westward migration from the overwintering area in Newfoundland fjords (Messieh and Tibbo, 1971); Parsons, 1972).

In this report, the regularity of spawning times of spring and autumn herring populations, and the relation of dates of herring arrival on the Magdalen Islands spawning grounds to water temperatures are discussed. The Magdalen Islands herring fishery provides a unique opportunity for the study of spring spawning herring, which are relatively pure stocks and separated from other "mixed" fisheries of the Magdalen Shallows.

MATERIALS AND METHODS

A large number of herring samples, collected routinely from different areas in the southern Gulf of St. Lawrence was available. Among the several biological observations taken, maturity stages were recorded according to the maturity scale recommended by the Herring Group of the International Council for Exploration of the Sea (Anon., 1962). Maturity is divided into eight (8) stages according to the size and appearance of the gonads. Differences between some of these stages are not clear-cut. However, fish at maturity stages 5, 6 and 7 (ripe , running and recently spent) are undoubtedly spawners, spawning in the same season as that in which they were caught.

Spawning peaks were estimated on a weekly basis as the time when 50% or more of the fish are in spawning condition. Weeks were numbered according to the calendar year, starting with January 1-7 as the first week of the year.

Length and age at sexual maturity were estimated by the normal distribution separator using steepest descent method (Modified Computer Program NORMSEP). The output included observed and predicted frequencies, and estimated values at which 50% of the fish are sexually mature.

A series of pairs of observations of surface water temperatures and dates of herring arrival at spawning grounds near the Magdalen Islands was available for 25 years between 1933-73. The relation between these variables were examined by fitting linear regressions to the data, using the least squares method.

RESULTS AND DISCUSSION

Herring Spawning Seasons

Figure 2 shows the relative abundance of spring and autumn herring fisheries in the southern Gulf of St. Lawrence during 20 years (1949-68). During this period of observations, the spring fishery extended for 2-3 months between April and June; and the autumn fishery for a similar period between August and October. The distribution of maturity stages, presented in Table 1 for 1968-73, and for earlier years as reported by Jean (1956), Tibbo (1957), Day (1957) and Messieh and Tibbo (1971) show that high percentages of the catch were in spawning condition. Highest percentages of spawning fish were in April and May for the spring fishery, and August and September for the autumn fishery.

The shift in relative abundance from spring to autumn fishery, which occurred in recent years (Figure 2) coincides with the drastic changes in fishing methods which were introduced into the fisheries in the mid-sixties. Until 1965, most of the catch were taken by fixed gear. By 1967, a large mobile purse-seine fleet had expanded the fishing activities to include more off-shore areas, and operated in almost all months of the year. The discreteness of the spawning groups has been already established (Parsons, 1972; Messieh, 1975a; Winters and Hodder, 1975). The apparent shift in relative abundance of the spawning groups cannot be explained by a change in the spawning season of one of the spawning groups.

An alternative hypothesis is that the spring spawning group consists of several stocks (sub-populations) - some of which could not reach their spawning grounds and hence failed to spawn. The distribution of maturation stages (Table 1) and peak spawning times (Figure 3) support this hypothesis.

A shift in time or location of spawning has been described for herring in other areas. For example, Devold (1963) showed that the Atlanto-Scandian herring shifted spawning between 1930 and 1960 from early February to late February. In Newfoundland, Hourston (1968) reported that in 1967 the herring failed to spawn in traditional spawning areas and shifted from the major inshore spawning locations.

In spite of the recent changes in fishing activities, it appears that the seasonal trend in the herring fishery has not changed since the nineteenth century. Perley (1852), in his Reports on the Sea and River Fisheries of New Brunswick (p. 2) stated that "the common herrings appear in the Gulf of St. Lawrence at the end of April, or early May, and the fishing continues until about 10th June, when they retire to deep water, having deposited their spawn...Another herring (group) appear on the coast about the 20th August and remain inshore for a month..."

Peak Spawning Times

Table 2 shows the distribution of peak spawnings (50 or >50% ripe and running) of spring and autumn herring estimated from the maturity stages during 1966-73. The duration of peak spawnings varied from year-to-year; in the spring from one week in 1969 and 1971 to four weeks in 1967. In the autumn, peak spawnings lasted two weeks in 1967, 1971 and 1972, and three weeks in 1968 and 1970. It is worth noting that, in all years, peak spawnings in both seasons were well separated.

Between-area comparisons of peak spawnings are shown in Figure 3. It can be seen that the number of peak spawnings declined in more recent years. This is particularly noticeable in the spring fishery. It is also remarkable that in 1973 no peak spawnings were shown. The disappearance of peak spawnings in the spring of 1972 and both seasons in 1973 shows a change in spawning activity of this fishery during these years.

Maturity ogives (Figure 4) showed differences in herring sizes in different spawning areas. Similar differences in their ages (not shown) were also noted. Mean lengths varied between 29.25 ± SD 1.59 cm (area 437-1972) to 32.00 ± 1.26 cm (area 431-1971) for spring spawners. The autumn spawners ranged from 31.24 ± 2.93 cm (area 432-1973) to 33.70 ± 1.47 cm (area 435-1972). Between-area differences of length at maturity provide supporting evidence that these fish were drawn from different spawning groups. Meristic differences of these groups, shown in a previous study (Messieh, 1975a) agree with this conclusion.

The multiplicity of peak spawnings (Figure 3) reflects the multiplicity of the spawning stocks on the various spawning beds. This agrees with earlier observations (Messieh, 1975b) on the sporadic nature of herring spawning as an adaptation to ensure success of spawning in an area characterized by erratic hydrographic conditions.

Relation of Herring Arrival to Water Temperature

Dates of herring arrival on one of the spawning grounds near Entry Is., one of the Magdalen Islands (area 431; Figure 1), for 25 years between 1933-73 are shown in Table 3 together with the surface water temperatures and anomalies from normal April temperature in the same area.

The linear regression of herring arrival on April temperatures (Figure 5) showed significant negative correlations. The equations describing the relationship between the two sets of variables were as follows:

$$Y = 29.56 - 6.61X_1 \qquad (r = -0.86)$$

and

$$Y = 21.83 - 6.61X_2 \qquad (r = -0.86)$$

where Y = date of herring arrival on spawning grounds in days

X_1 = mean surface water temperature of April (°C) at Entry Island

X_2 = anomaly from normal April temperature (°C) at Entry Island

Because of the ice conditions around the Island during winter and early spring, mean April water temperatures were not available during some years. Also, no temperature records were available prior to April (Lauzier and Hull, 1969). Hence, water temperatures of March and April from St. Andrews, N. B., Station, about 300 miles southwest of Entry Island were used to examine the relation between these temperatures and dates of herring arrival at Entry Island. It is known that trends of surface temperatures at St. Andrews, N. B., represent surface temperature variations over a large area of the Atlantic Seaboard (Lauzier, 1965). This led Sutcliffe et al., (1977) to use sea temperatures at St. Andrews to correlate temperature variations with fish catch from areas as far as the waters of southern New England.

Fitting linear regressions of dates of herring arrival at Entry Island and anomalies of temperatures from normal March and April at St. Andrews (Figure 6) resulted in the following equation:

$$Y = 25.18 - 7.70X_3 \qquad (r = -0.70)$$

and $$Y = 25.50 - 5.87X_4 \qquad (r = -0.52)$$

where X_3 = anomalies of surface water temperatures from normal March at St. Andrews, N. B.

and X_4 = anomalies of surface water temperatures from normal April at St. Andrews, N. B.

Both relations are significant, however, the correlation coefficient for March was higher than that for April.

It is important to note that a correlation by itself does not necessarily prove that a relationship is causal. Gulland (1965) discussed the problems involved in using the correlation techniques. However, it is of practical interest to show that the results reported here can be used for prognostic purposes. Having temperature anomalies from normal March at St. Andrews, dates of herring arrival at Entry Island in the spring (April-May) can be predicted.

The influence of water temperature on herring behaviour, spawning and catch has been documented by several authors on both sides of the Atlantic. In the Gulf of St. Lawrence, Lauzier and Tibbo (1965) found a relationship between water temperatures during the second half of April and herring landings during April. They reported that the start of the fishery at the Magdalen Islands was usually preceded by a rapid warming of the water to 2.1°C. Hourston (1968) related the marked changes in the distribution and timing of spawning of herring in Newfoundland waters during 1967 to deviations from the 'normal' environmental conditions on the traditional spawning grounds. Sutcliffe et al., (1977) showed a relation between temperature and catches of several commercial fish species, among which was herring in New England waters. Lett and Kohler (1976) showed that herring growth rate, coupled with adult stock size and environmental effects, mediated through temperature were the prime determinants of larval abundance in the Gulf of St. Lawrence.

On the eastern side of the Atlantic, Penin (1966) and Lyamin (1966) showed that herring react to shifts of the isotherms in the Norwegian Sea, and all spawning grounds of the Norwegian herring come under the influence of the warm Atlantic water of the Norwegian current.

The observed variations in herring arrival with variations in water temperature, as reported in this study and its possible effects on spawning times do not contradict the concept of regularity of spawning season in relation to production cycle as presented by

Cushing (1969). The small variations of peak spawning of herring, influenced with water temperature suggests that a fish population can adapt to environmental changes. However, this does not imply that herring populations shift spawning from one season to another. If they spawn at a fixed season, the population has the best chance of profiting by the variability of the production cycle.

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Table 1. Maturity frequency distribution of herring in the southern Gulf of St. Lawrence, 1968-73.

YEAR AND MONTH	Percent of fish at maturity stage							
	1	2	3	4	5	6	7	8
1968								
May			1.2	11.3	21.9	62.9	.1	2.6
June	.8	7.2	34.2	20.6	10.6	4.0	2.6	20.0
August	.1		8.7	6.4	24.7	46.0	7.9	6.1
October	1.5	6.0	26.5	20.5				45.5
1969								
April			1.0		60.0	39.0		
May		.2	3.9	5.2	60.5	20.9	.1	9.2
June	2.5	7.8	12.5	52.6	5.3	.1	6.6	2.7
July		3.5	2.0	6.6	87.9			
September	4.5	37.4	7.6	2.6	6.2	.6	32.5	8.6
1970								
April			.6	47.0	49.0	1.8	.4	1.2
May			1.6	21.4	28.9	34.9	12.9	.4
July	.5	1.4	20.7	40.4	19.7	4.3	11.1	1.9
August	.1	6.8	26.1	5.3	34.0	9.8	15.3	2.8
September		.8	9.3	9.5	28.4	26.5	15.2	10.3
October	.6	33.9	13.7	12.9	4.2		19.5	15.3
1971								
January		13.8	44.7	7.4				34.0
April	.5	1.0	3.0	25.6	50.3		10.1	9.5
May	.07	.22	6.3	30.2	21.9	29.4	6.6	5.4
June	.2	13.7	24.8	45.2	9.9	1.5	1.2	3.6
July	.1	17.4	16.0	27.1	37.1	1.9	.1	.1
August		6.0	17.1	17.1	37.0	8.3	.6	14.0
September			40.9	13.6	9.1			36.4
November	1.5	3.5	8.5	2.5			2.0	82.0
December	.5	.5	17.0	1.5	.5			.5
1972								
May			6.0	34.9	43.1	12.0	2.9	1.1
July	.3	35.0	35.3	29.0				.3
August	.5	4.0	5.5	10.5	40.0	29.0	1.0	9.5
September			9.8	9.3	45.0	24.5		11.5
October	1.0	5.1	32.7	24.5	2.0			34.7
November	1.5	11.3	9.6	2.8	1.0			73.9
December	3.9	17.2	6.5	6.8	2.5			63.1
1973								
January	27.1	26.1	3.5	4.0	1.5			37.7
May			37.6	26.6	21.1	3.9	3.2	7.6
June		.5	25.9	48.7	20.7	4.1		
August		1.2	6.0	73.8	19.0			
September	.3	32.3	1.7	13.5	49.8	1.3	.3	.7
October	13.2	41.5	18.9	9.4				17.0
November	58.3	37.5	4.2					
December		21.4	21.4					57.1

Table 2. Distribution of weeks of peak spawning of spring and autumn spawning herring in the southern Gulf of St. Lawrence, estimated from the maturity stages. Each entry represents a week of spawning.

	Weeks of Peak Spawning												
	Spring Spawning						Autumn Spawning						
Year	17	18	19	20	21	22	32	33	34	35	36	37	38
1966			1	1									
1967			1	1	1	1			1				1
1968	1	1	1				1	1	1				
1969		1											
1970		1	1		1				1	1	1		
1971			1						1				1
1972							1				1		
1973													

Table 3. Dates of herring arrival for spawning near Entry Island, Gulf of St. Lawrence, 1933-73, with mean surface temperatures and temperature anomalies at Entry Island and St. Andrews[1]

Year	Date of arrival	Temp. °C at Entry Is. Mean April	ΔT(April)	Temp. °C at St. Andrews ΔT(March)	ΔT(April)
1933	April 21	-0.2	-1.4	0.2	0.2
1934	May 1			-1.7	-0.1
1935	May 7			-1.6	-1.0
1938	May 4			-0.3	0.3
1939	April 26			-0.6	-1.0
1940	April 27	0.0	-1.2	-0.9	-1.2
1942	April 24			0.1	0.1
1943	May 6	-0.2	-1.4	-1.3	-1.4
1944	May 5	1.1	-0.1	-0.9	-0.7
1946	April 29	-0.1	-1.3	0.3	0.1
1948	May 1	-0.4	-1.6	-0.8	-1.1
1949	April 24	0.6	-0.6	0.8	1.5
1950	May 1			0.3	0.5
1951	April 4	3.8	2.6	1.9	1.8
1955	April 18	1.8	0.6	1.1	1.2
1958	April 7	3.1	1.9	1.5	1.3
1960	April 8	2.3	1.1	0.5	0.2
1961	May 8			-0.4	-0.9
1962	April 30			0.2	0.4
1963	April 29	0.2	-1.0	0.5	0.5
1964	April 24			0.5	-0.1
1966	April 19	1.9	0.7	0.7	0.3
1967	May 15			-1.0	-1.2
1971	April 22	1.5	0.3	0.3	0.5
1973	May 1	0.1	-1.1	0.4	0.9

1 No temperature observations for years with no data.

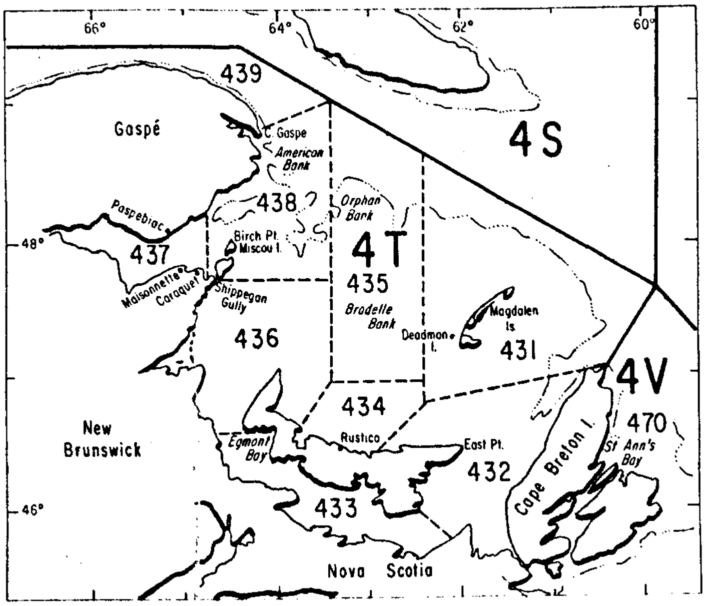

Figure 1. Map of the southern Gulf of St. Lawrence showing ICNAF Statistical areas, and herring fishing unit-areas.

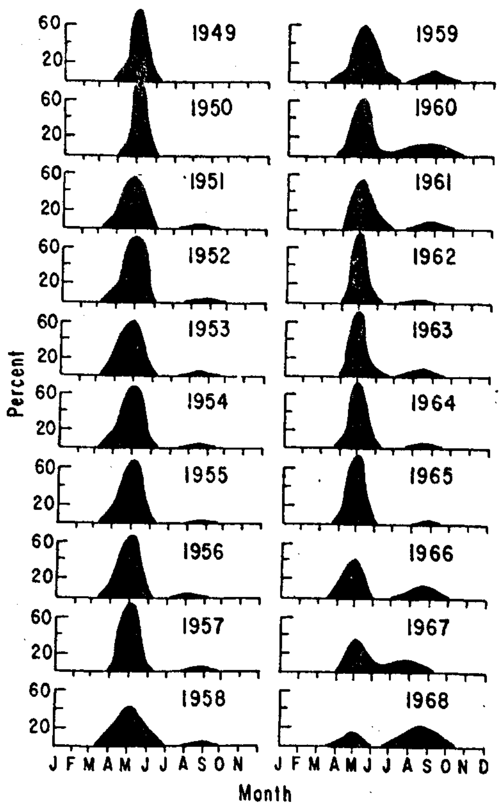

Figure 2. Seasonal pattern of herring catches in the southern Gulf of St. Lawrence.

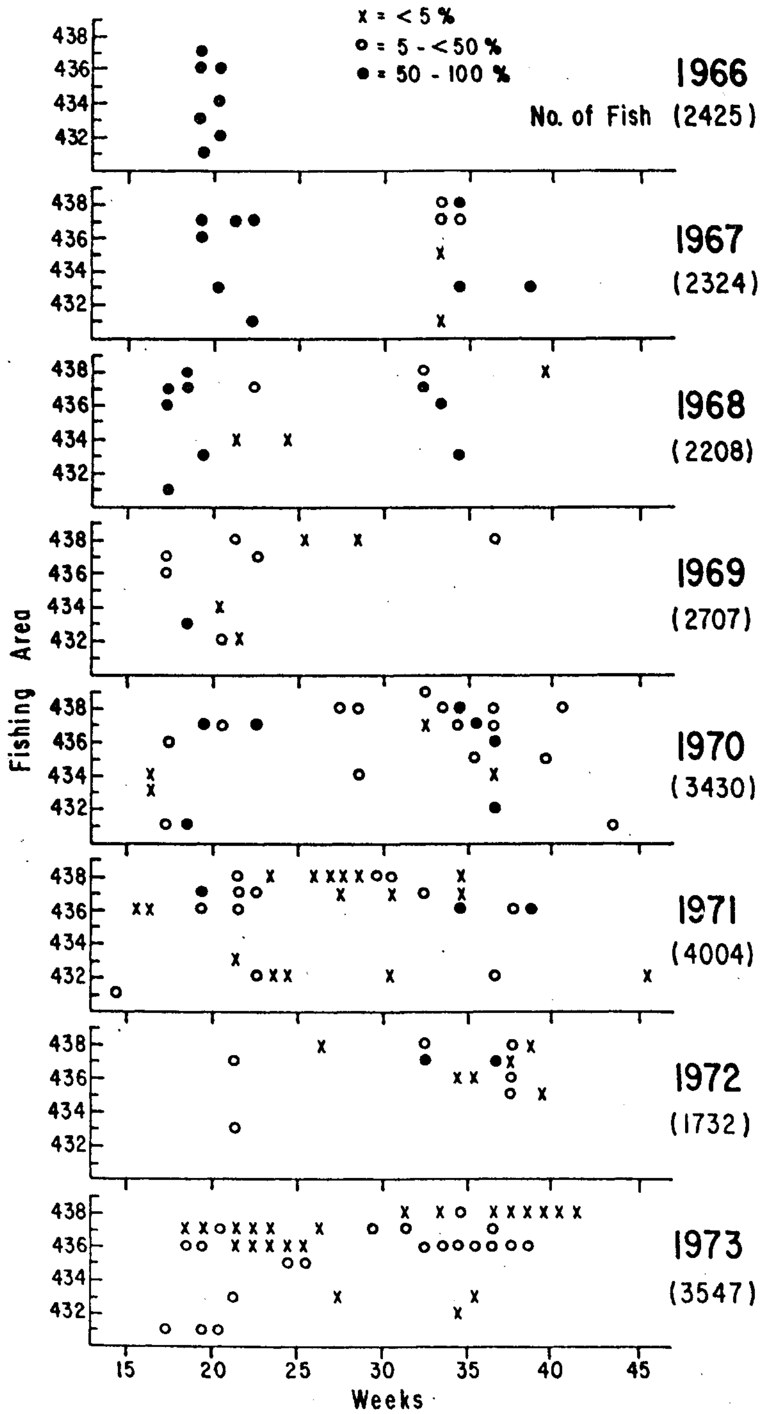

Figure 3. Distribution of weeks of peak spawning of herring in different unit-areas in the southern Gulf of St. Lawrence, 1966-73. Numbers of fish sampled are shown in parentheses.

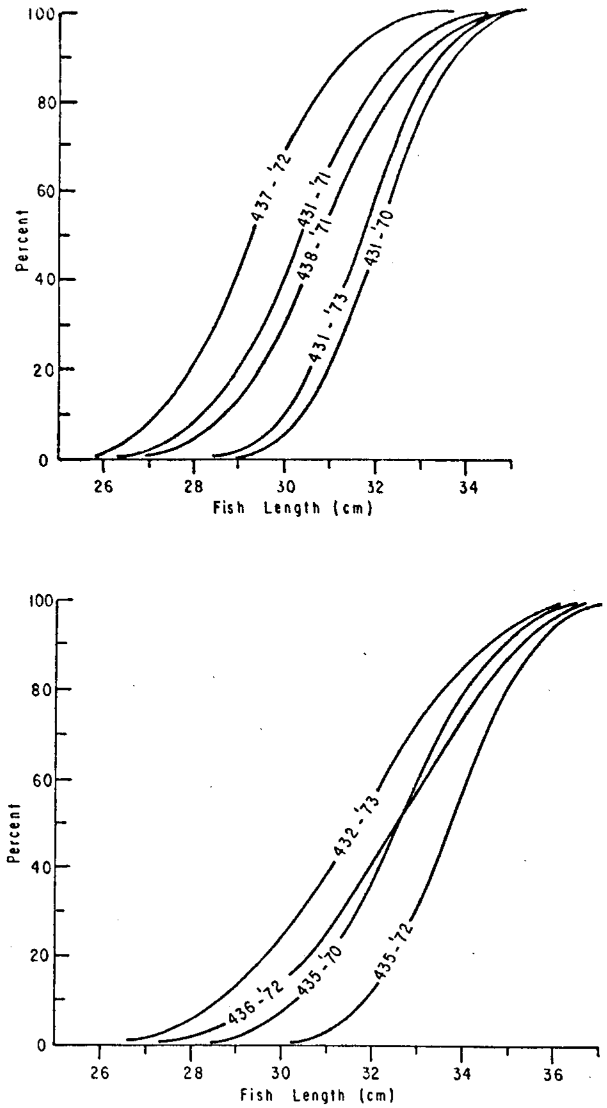

Figure 4. Maturity ogives of spring spawning (upper Figure) and autumn spawning herring (lower Figure) in different unit-areas and years.

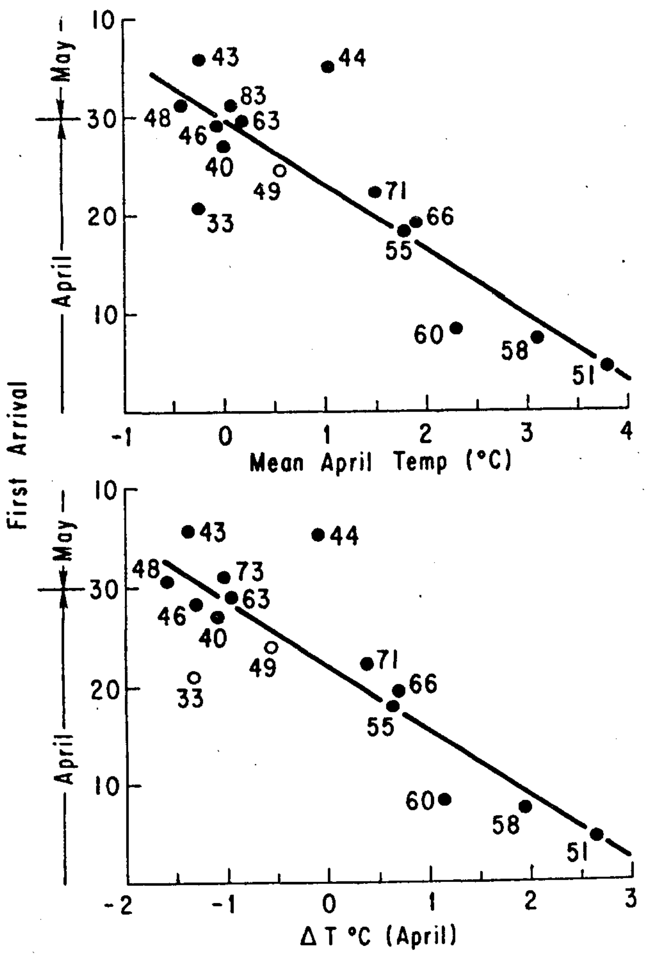

Figure 5. Linear regressions of dates of herring first arrival on spawning grounds at Entry Island and water surface temperatures in the same area. Years of observations are shown.

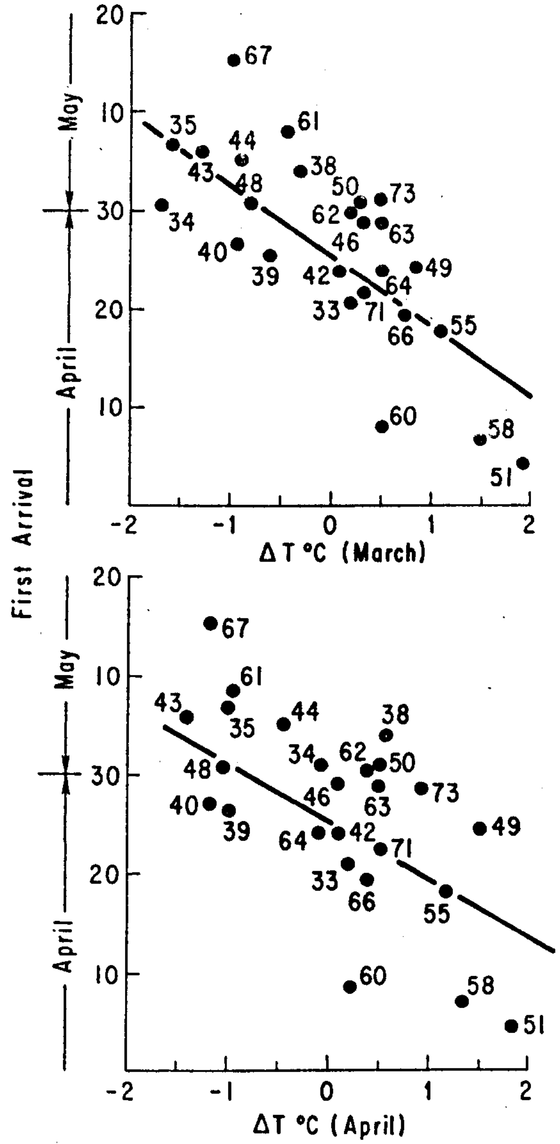

Figure 6. Linear regressions of dates of herring first arrival on spawning grounds at Entry Island and temperature anomalies from normal March and April at St. Andrews Station. Years of observations are shown.