

## Seasonal distribution and growth of larval herring (*Clupea harengus* L.) in the Georges Bank-Gulf of Maine area from 1962 to 1970

H. C. BOYAR<sup>1</sup>, R. R. MARAK<sup>2</sup>, F. E. PERKINS<sup>1</sup>, and R. A. CLIFFORD<sup>1</sup>

This study reports observations made on the seasonal distribution of larval herring in the western North Atlantic from November 1962 through April 1970. It summarizes observations made during all months of the year except January and provides a more complete picture than previous studies conducted in autumn, winter, and spring of the 1950's. The seasonal distribution of larval herring from the autumn through the spring (combined with maturity, meristic and biochemical studies of adult herring in the 1960's) provides evidence of at least three discrete major spawning areas in the western North Atlantic: Georges Bank, coastal Gulf of Maine and Nova Scotia. The presence of a clockwise gyre, although it may at times break down in the winter, on Georges Bank retains the majority of larvae spawned on the Bank. The presence of a counter-clockwise current in the coastal Gulf of Maine appears to retain the larvae in these waters and the circulation off the coast of Nova Scotia results in the larvae remaining close to the spawning site or being carried into the Bay of Fundy. Larvae grow at least to a length of 50 to 55 mm (TL) before becoming post-larvae. They grow on the average of 5 mm per month from September through June.

### Introduction

This paper covers the seasonal distribution of larval herring (*Clupea harengus* L.) in the Georges Bank-Gulf of Maine area from 1962 through 1970. The onset of spawning on Georges Bank and in the coastal Gulf of Maine usually occurs during late August or early September. The peak of spawning is during late September or early October, decreasing in intensity in November and is completed by December and early January. In Nova Scotia spawning takes place from May through December, the peak is reached in September and October. Spawning during the spring and summer takes place on the western part of the coast (Boyar, 1968).

Studies in the 1950's on the distribution of herring larvae of the western North Atlantic (Tibbo et al., 1958; Tibbo and Legare, 1960) covered only the autumn and winter, although Tibbo et al. (1958) mention the capture of herring larvae in April 1955 by the "T. N. Gill" from Penobscot Bay, Maine. Tibbo et al. (1958) reported that the abundance of newly hatched larvae in the plankton collections of the 1960's provided evidence that major spawning occurred on Georges Bank, along the southern coast of Nova Scotia and on a lesser scale along the in-shore waters of the Gulf of Maine. Tibbo and Legare (1960) reported that almost 90% of the larvae taken in plankton tows in October and November were found chiefly on the Northern Edge of Georges Bank and in the Bay of Fundy. Marak and Colton (1961), Marak, Colton and Foster (1962) and Marak et al.

(1962), in their studies of fish eggs and larvae in the Georges Bank-Gulf of Maine area provide information on the distribution of herring larvae in the spring. They collected herring larvae in March, April and May from Georges Bank, Gulf of Maine and Nova Scotia (Bay of Fundy) areas. Boyar (1966; 1970) presented preliminary reports on the distribution and abundance of larval herring on Georges Bank and adjacent waters from September through June. The collecting gear used in the studies of the 1950's were Hardy continuous plankton recorders and one-metre nets. These investigations covered the entire area of Georges Bank, coastal and central Gulf of Maine, the southern tip of Nova Scotia and the Bay of Fundy (Tibbo et al., 1958; Tibbo and Legare, 1960). The present investigation provides a more complete picture of the seasonal distribution of herring larvae since we have data for all months of the year except January.

Tibbo et al. (1958) postulated that spawning on Georges Bank could contribute herring to the waters of coastal Gulf of Maine. Tibbo and Legare (1960) stated that "the drift of larvae from the spawning

<sup>1</sup> National Marine Fisheries Service, Northeast Fisheries Center, National Oceanic and Atmospheric Administration, Department of Commerce, W. Boothbay Harbor, Maine 04575.

<sup>2</sup> National Marine Fisheries Service, Northeast Fisheries Center, National Oceanic and Atmospheric Administration, Department of Commerce, Narragansett, Rhode Island 02882.

grounds as indicated by increasing size and distribution of non-tidal drift surface currents suggested that the Bay of Fundy herring stocks are chiefly from the Nova Scotia spawning." Studies with drift bottles suggested that the progeny of the Georges Bank spawning would be carried south, east and west but not north during late autumn and early winter (Bigelow, 1927; Day, 1958; Bumpus, 1960). Bumpus (1960) indicated there would be little possibility for surface drift to carry larvae from Georges Bank to the Bay of Fundy. Colton and Temple (1961) stated on the basis of the non-tidal drift, it would be unlikely that larvae from Georges Bank would contribute to the coastal fishery for juvenile herring in the Gulf of Maine. In general, the evidence from previous studies was that the ultimate fate of the larvae was not known. Although detailed analysis of the origin of juvenile herring in the Georges Bank-Gulf of Maine area is beyond the scope of this paper, we believe that the data indicate that populations of herring, from Georges Bank, the coastal Gulf of Maine, and Nova Scotia are discrete.

## Methods

In 1962 personnel of the Bureau of Commercial Fisheries Biological Laboratory, Department of the Interior (now National Marine Fisheries Service, Department of Commerce) Boothbay Harbor, Maine, initiated surveys to obtain additional information on the distribution of larval herring in the Georges Bank-Gulf of Maine area. Step oblique plankton tows of 15 minutes (5 min at 20 m, 5 min at 10 m and 5 min at the surface) were made with a one-metre plankton net. The mesh number, number of meshes per cm, and the size of the open mesh aperture were 0, 15 and 0.0569 cm respectively. Post-larvae obtained in 1967 and 1969 were not collected by a plankton net, but were found meshed in the twine of an otter trawl. Larvae were collected from autumn through spring from 1962 through 1970. Vessel time was limited and we were, therefore, unable to study the temporal distribution of larvae for every year. Because the cruises were designed primarily for other research, plankton tows were made only when

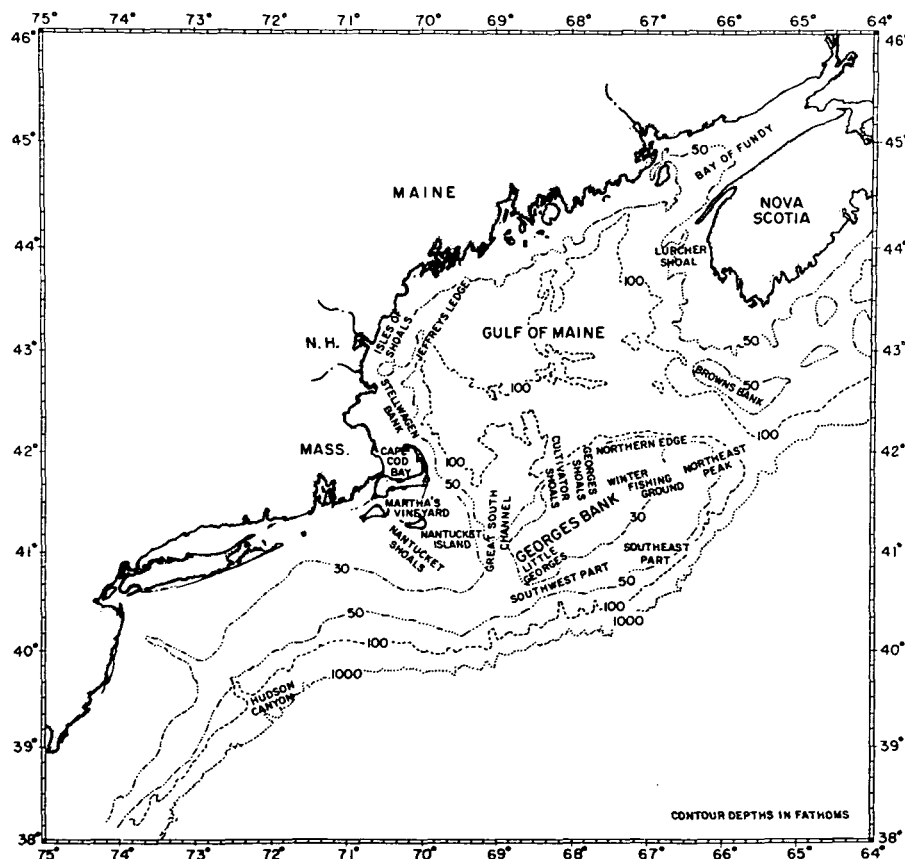


Figure 1. Chart of Georges Bank, Gulf of Maine and Nova Scotia.

time was available. We were, consequently, unable to duplicate plankton stations from year to year for a specific month. In the autumn the majority of the plankton tows were made on the northern part of the Bank. In April and June 1966 and October 1964 and 1967, in addition to sampling various parts of Georges Bank, we made transects from the northern part of the Bank to the coast of the Gulf of Maine.

In 1967 personnel at the Bureau of Commercial Fisheries Biological Laboratory, Department of the Interior (now National Marine Fisheries Service, Department of Commerce) in Woods Hole, Massachusetts in conjunction with groundfish surveys commenced studies to determine the distribution of fish eggs and larvae in the Georges Bank-Gulf of Maine area. In all but one cruise (Posgay and Marak, 1967) they used 20 cm Bongo nets towed for 5 min at 50 m, 5 min at 25 m and 5 min at the surface. (Mesh number, number of meshes per cm, and the size of the open mesh aperture were 3, 23, and 0.0333 cm, respectively.) Data on the distribution of the herring larvae obtained during the Woods Hole cruises were from the autumn through spring of 1967 to 1970. The cruises covered the area from Cape Hatteras, North Carolina, northward to Georges

Bank, into the Gulf of Maine, up to the Bay of Fundy and then to the southern tip of Nova Scotia. In addition, during some months only, special cruises to test the efficiency of Bongo nets were made. These were concentrated on the northern and central part of Georges Bank in a  $80.5 \times 80.5$  km square which included the Northern Edge, Northeast Peak and Winter Fishing Ground of the Bank.

The areas concerned in this paper are shown in Figure 1. Since the type of gear, depths at which the gears were towed and the time of day at which the tows were made were not similar in the studies by the two laboratories, no attempt was made to present a statistical analysis of the relative abundance of herring larvae. We have merely shown the stations where larvae were and were not obtained, although at the stations where larvae were collected, a rough measure of relative abundance is presented.

## Distribution of larval herring

### Results

Three major spawning areas have been reported for the Georges Bank-Gulf of Maine area; namely

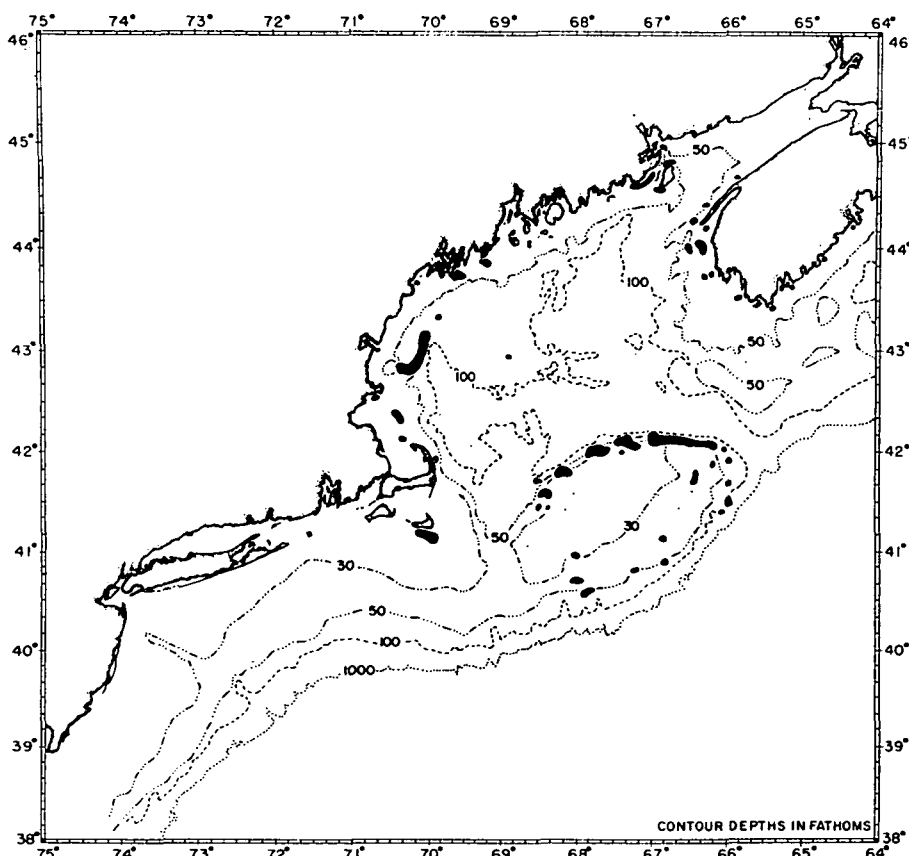


Figure 2. Spawning areas of herring (based on collections of stage VI adults) in the Georges Bank-Gulf of Maine area.

Table 1. Occurrence of yolk-sac larvae at various locations by year in the Georges Bank-Gulf of Maine area from 1962 through 1969 (+ = presence of yolk-sac larvae, 0 = no larvae, - = no tow)

	September					October					November					December				
	1963	1964	1965	1966	1967	1968	1964	1965	1966	1967	1968	1969	1962	1963	1964	1965	1968	1969	1962	1963
Georges Bank																				
Northern Edge.....	0	+	+	0	0	+	+	-	+	0	+	+	0	0	+	0	+	0	+	0
Winter Fishing Ground....	-	-	+	-	0	+	+	0	+	+	+	-	-	-	-	0	+	0	-	-
Northeast Peak.....	-	-	-	0	-	+	+	-	+	0	+	+	-	-	-	-	0	-	-	-
Georges Shoals.....	-	0	0	0	-	0	+	-	+	+	+	+	0	0	-	0	0	0	+	-
Cultivator Shoals.....	0	0	-	-	0	-	0	0	+	+	+	+	0	0	0	0	0	0	0	-
Southeast Part .....	-	-	-	0	0	0	-	0	-	+	-	-	-	-	-	0	+	0	+	-
Little Georges.....	-	-	-	-	-	-	-	-	-	0	0	+	-	-	-	-	+	0	+	-
Coastal Gulf of Maine																				
Nantucket Shoals.....	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	+	+	-	-
Area between Isles of Shoals and Stellwagen Bank.....	-	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	0	0	-	0
Jeffreys Ledge.....	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	0	0	-	-

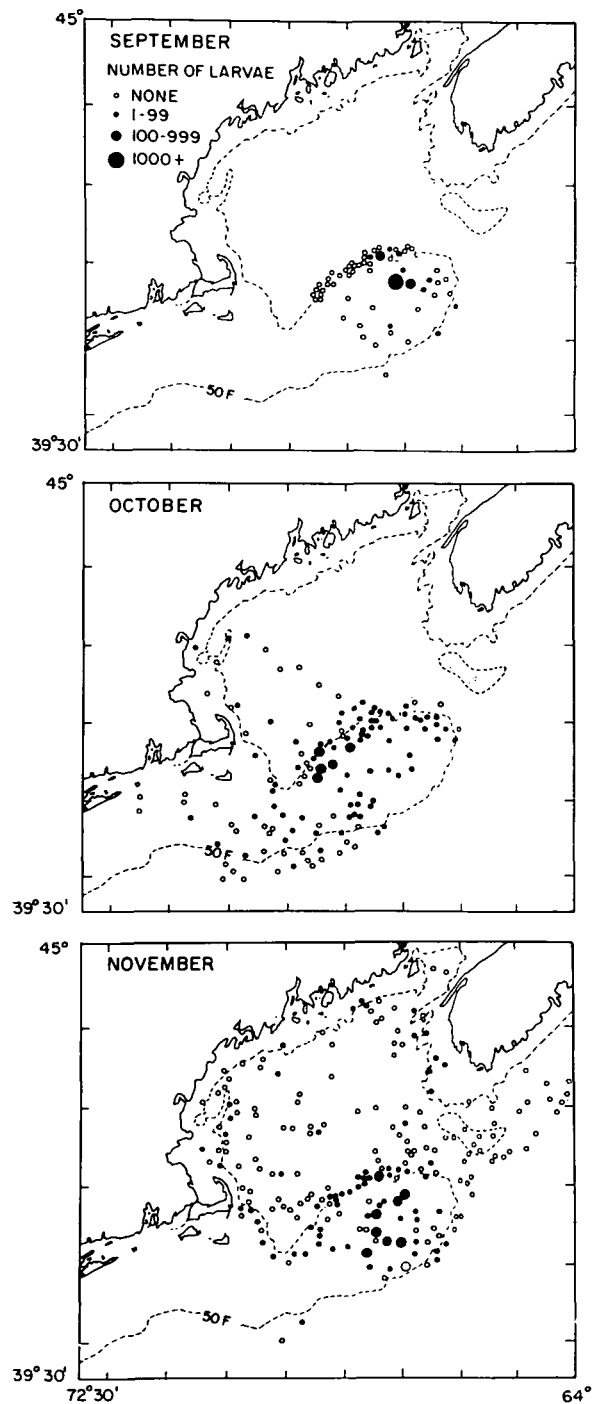


Figure 3. Plankton stations showing absence and presence of larval herring in the Georges Bank-Gulf of Maine area in September 1963–1968, October 1964 and 1966–1969, and November 1962–1965 and 1968–1969.

Georges Bank, coastal Gulf of Maine and Nova Scotia (Boyar, 1968 and 1970). The areas where ripe and running herring (gonadal stage VI) were obtained from research cruises since 1961 (Boyar, unpublished data) are shown in Figure 2. In addition, areas and times where yolk-sac larvae have been taken, also defining and delimiting spawning, are shown in Table 1. (The size and stages of all larvae and the duration of staging of larvae in the samples are presented in Tables 2–4 on “growth of larval herring.”) The dates, stations showing absence and presence, and range in number of all larvae by month and year are shown in Figures 3–5.

We obtained larvae in September 1964, 1965 and 1968 primarily from the eastern part of Georges Bank (Figure 3). We failed to obtain larval herring in September of 1963, 1966 and 1967, but this is directly related to the time of spawning. Examination of the gonads of adult herring collected by trawling in these years indicated that spawning had not yet taken place (Boyar, 1968).

In October larvae were collected at many of the stations where plankton tows were made (Figure 3). During our cruise in October 1964 we made a transect between Georges Bank and the coastal Gulf of Maine. Larvae were not obtained northwest of the Bank until we reached Jeffreys Ledge.

In November through March the stations where larvae were obtained are shown in Figures 3 and 4.

In April larvae were collected throughout various parts of the Georges Bank-Gulf of Maine area. The larvae were most abundant in the north and central eastern part of Georges Bank (Figure 5).

In May larvae were concentrated between latitudes 67° and 66°W, but were not found east of 66°W (Figure 5).

In June plankton tows were made only on the Bank (Figure 5). In the years in which larvae were obtained, they were collected from various parts of the Bank. In 1966 sampling was conducted primarily on Georges, but a few tows were made on a transect to the coastal Gulf of Maine.

### Discussion

Larval herring are found in the Georges Bank-Gulf of Maine area from autumn through the spring. The collection of fewer larvae during the winter on Georges Bank may be due in part to limited sampling during these months, and possibly because larvae at this time of the year may be in waters deeper than 50 m. The available data on the distributions of larval herring from September through February of the 1960's on the Bank are similar to those reported

by Tibbo et al. (1958) and Tibbo and Legare (1960) for the late 1950's. The distributions of larvae in the spring of the 1960's on the Bank were similar to those found by Marak and Colton (1961), Marak, Colton and Foster (1962) and Marak et al. (1962) during 1953, 1955, and 1956.

During September 1963, 1966 and 1967 when we failed to obtain larvae the majority of adult herring taken were in late stage V of gonad development. Tibbo et al. (1958) reported similar information for September 1957 and stated that the absence of herring larvae on Georges Bank at that time of the year was either because the herring had not spawned or because the eggs of herring that had spawned had not hatched. The majority of larvae from the spawnings along the northern part of the Bank remain in close proximity to the spawning site for a few days and then become dispersed, many being carried by the southerly drift toward the Southeast Part of the Bank. In October and November when larvae are found dispersed throughout various parts of the Bank, their distribution suggests that they have been carried clockwise by the current. Larvae found dispersed throughout the Bank in December further suggest that those from the spawnings on the northern part are carried in a clockwise manner. Some of the larvae, however, found on the southern part of the Bank in December may be the offspring from the minor spawnings in this area. The few larvae found between Nova Scotia and the northern part of the Bank may be from the minor spawnings on Brown's Bank (Tibbo et al., 1958) or result from an occasional breakdown in the southerly drift away from Georges, while those found in the middle of the Gulf of Maine are either from the occasional breakdown in the southerly drift away from the Bank or are from spawnings in the Gulf of Maine, itself.

Our findings of larvae for these months are similar to those of Tibbo et al. (1958) for 1956 and 1957. The distribution of larvae on various parts of the Bank and off Cape Cod, Massachusetts in the 1960's is similar to that found by Tibbo et al. (1958) for the same areas in 1956 and 1957. In February larvae are found throughout the Bank. Although during this month we collected larvae only from the Northern Edge, Northeast Peak and Winter Fishing Ground, Tibbo et al. (1958) did obtain some from the southwest part in 1957 and in 1958 they obtained larvae from the Northern Edge and other parts of the Bank, even though they failed to obtain any from the Northern Part of the Bank. In March the distribution of larvae on the Bank is similar to our findings for November and December and also agree with the findings of Marak and Colton (1961), Marak, Colton and Foster (1962) and Marak et al. (1962).

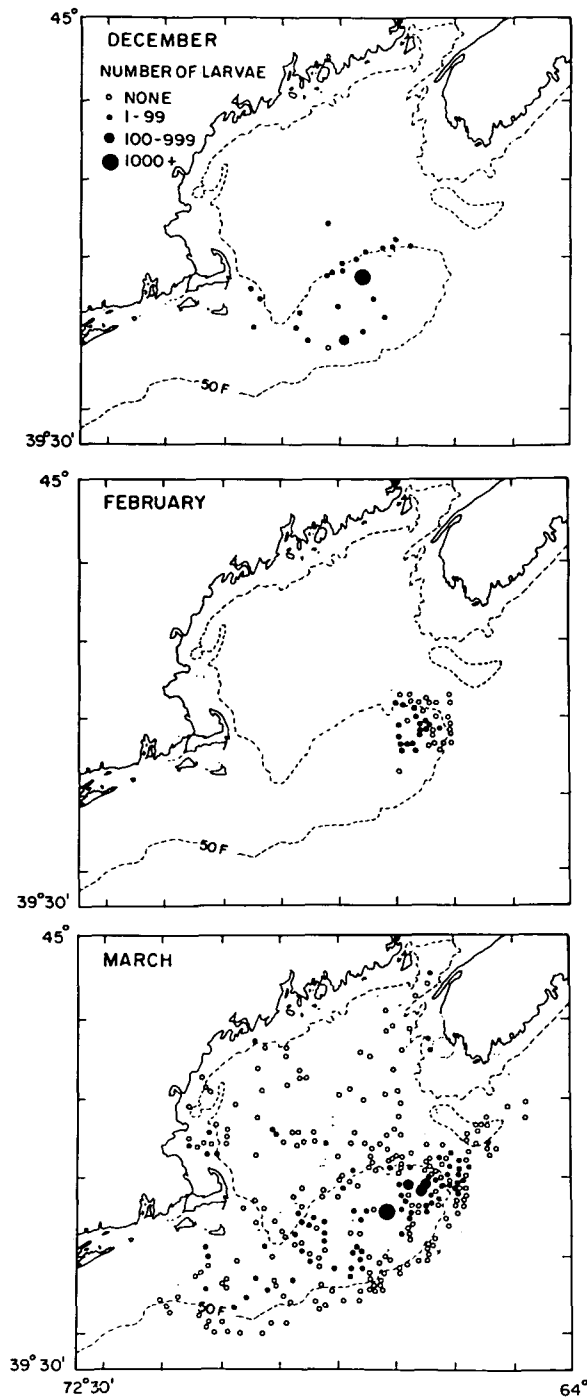


Figure 4. Plankton stations showing absence and presence of larval herring in the Georges Bank-Gulf of Maine area in December 1962-1963, February 1968, and March 1967-1970.

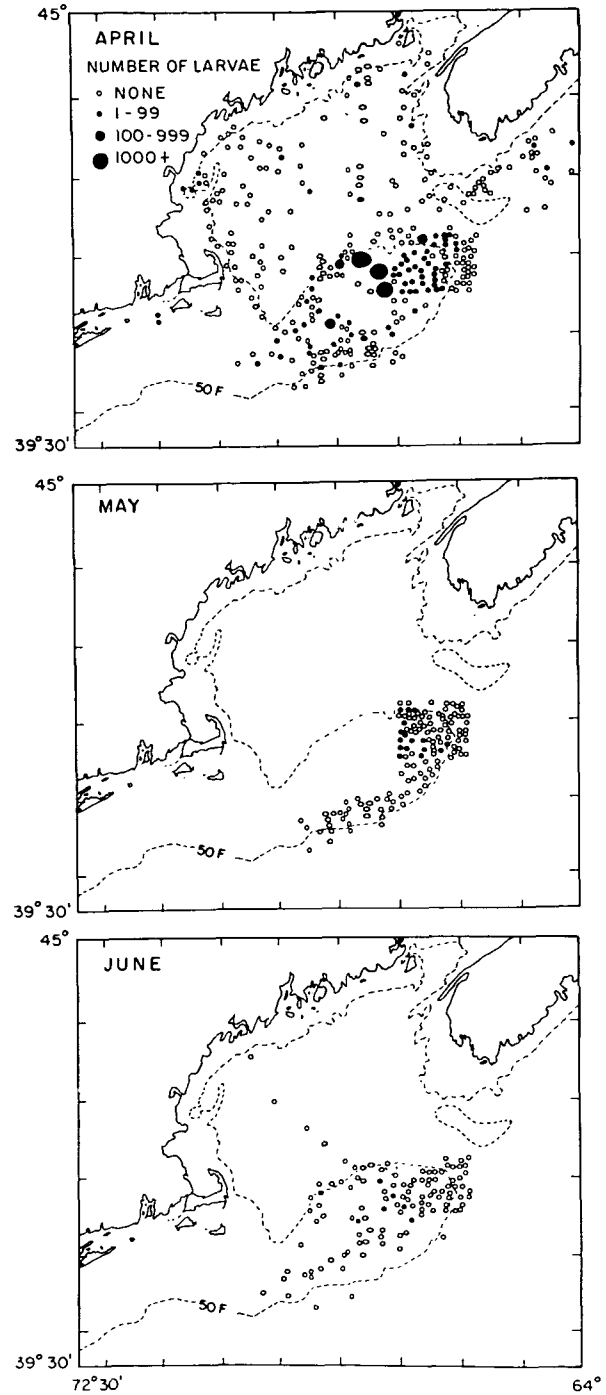


Figure 5. Plankton stations showing absence and presence of larval herring in the Georges-Bank-Gulf of Maine area in April 1965-1970, May 1968-1969, and June 1963 and 1965-1969.

The distribution of larvae in the spring in the three major spawning areas is as well defined as the distribution of the larvae during the autumn. The larvae are, however, still at the mercy of the drift on the Bank, but may be now large enough to maintain their position, at least for a short period of time. Our findings of larvae in April from the three areas differ from the data of Marak and Colton (1961), Marak, Colton and Foster (1962), and Marak et al. (1962) in that we obtained larvae from Georges Bank, coastal Gulf of Maine and Nova Scotia while they sampled the three areas and collected larvae only from Georges Bank. In May we obtained larvae from the northern and central eastern parts of the Bank only, although we made plankton tows in several other parts of the Bank. In June we obtained larvae from several parts of the Bank. We made no attempt to sample the coastal Gulf of Maine and Nova Scotia, but Marak and Colton (1961), Marak, Colton and Foster (1962), and Marak et al. (1962) did collect larvae from these areas.

Larval herring are still present in large numbers in late April and May in Georges Bank and can be occasionally found as post-larvae in June. In July and August the fish are now juvenile herring (approximately 6–8 cm in length) and our plankton sampling gear is not adequate to catch them. Since larval herring and juvenile herring of comparable length are collected in the inshore waters of the Gulf of Maine and Nova Scotia at the same time of the year (Graham and Boyar, 1965; and Das, 1968), it seems likely that the major distribution of larval herring of Georges Bank is restricted to the Bank and its contiguous waters.

Our interpretation differs from that of Das (1968) who stated that based on the work of Tibbo et al. (1958) and Boyar (personal communication), larvae spawned in late autumn on the Northern Edge of the Bank would “be carried across Brown’s Bank northward toward the southern coast of Nova Scotia in the following spring” and that in the spring there would be “a contribution of herring larvae from the northern Georges Bank area to the herring population in the Fundy area”. Larvae found in the middle of the Gulf of Maine could have come from spawnings along the coasts of Massachusetts, New Hampshire and Maine (Figure 2). Tibbo (1968) reported that there may be cases in which larvae from Nova Scotia spawnings might be carried, because of the open circulatory system, southward along the coast of Maine as far as Cape Cod, Massachusetts and beyond.

Data on larvae collected in the 1950’s and 1960’s lend support to the hypothesis that there are three major spawning areas in the Georges Bank-Gulf of

Maine area (Boyar, 1968). Parasitological and serological studies (Sindermann, 1959) and parasitological studies only (Boyar and Perkins, 1971), meristic studies (Anthony and Boyar, 1968) and biochemical studies (Ridgway, Lewis and Sherburne, 1971) of herring also indicate the possible discreteness between the populations of herring of Georges Bank and the coastal Gulf of Maine. Ridgway et al. (1971) demonstrated that there are definite differences in gene frequencies between Gulf of Maine-Nova Scotia herring and herring from Georges Bank. Their findings imply that the larvae from the Bank do not contribute to the Gulf of Maine-Nova Scotia stocks. Our findings of large numbers of larvae on Georges Bank and the findings of Graham and Boyar (1965) and Graham and Venno (1968) of large numbers of larvae in the coastal Gulf of Maine and the virtual absence of larvae between the two areas from September through May–June suggests that the resulting larvae from spawnings on the Bank and along the coastal Gulf of Maine do not mix significantly. Tibbo and Legare (1960) suggested that the larvae found in the Bay of Fundy are primarily from Nova Scotia spawnings. We question the significance of the contribution of larval herring from the Northern Edge of Georges Bank to the Bay of Fundy, as reported by Das (1968). We believe the larvae of Nova Scotia either mature off Nova Scotia or in the Bay of Fundy and contribute to the future stocks of juvenile herring in these waters and possibly to the stocks of juvenile herring along the coast of Maine and perhaps southward. It appears that because of the counter-clockwise circulation in the coastal Gulf of Maine the majority of the larvae from the central and western part of the Gulf of Maine (November and March, Figures 3 and 5) are the offspring from the numerous spawnings along the coast (Figure 2). Although it is also possible, due to a breakdown in this circulation, that larvae could have come from Nova Scotia as postulated by Tibbo (1968).

The majority of the larvae obtained in the Georges Bank-Gulf of Maine area were from stations where the depth was 50 fathoms or less. Although most of our effort was concentrated on Georges Bank where the depth is 70 fathoms or less (exclusive of the Northeast Peak), most of the larvae obtained from the central and coastal Gulf of Maine and Nova Scotia were also obtained at depths of 50 fathoms or less.

Tibbo et al. (1958) reported that more larvae were obtained at night than during the day. Our data agree with their findings. Brawn (1960) and Colton, Honey and Temple (1961) presented data that clearly indicate that larval herring exhibit vertical migration. The question remains as to whether the larvae during the

daytime are close to the bottom (as are adult herring) and attempt to use the bottoms as a visual reference point for maintenance against the current. Larvae obtained in the early autumn would be unable to stem the prevailing currents. Bishai (1960) demonstrated that the critical current velocity for yolk-sac larvae would be between 0.58 and 1.03 cm per second. Larvae of the size obtained during the winter and spring would also be unable to stem any current for a prolonged time (Rosenthal, 1968). The post-larvae we obtained on the Bank, found meshed in the cod end of the otter trawl lined with fine mesh, were probably collected from near or on the bottom. They were caught in waters of 30 fathoms or less and our one-metre net tows, although made only to a depth of 11 fathoms, did not catch any. Even though the post-larvae were at the bottom, they too would be at the mercy of a current, although there could be occasions when they could stem certain minimal currents for short periods (Boyar, 1961).

Questions regarding the vertical distribution of larval herring and whether they can maintain their position on the bottom remain unanswered. Boyar (1961) demonstrated a direct relationship between the size of herring (juveniles) and their ability to maintain their position against various water velocities. Herring of 60 to 79 mm were able to maintain their position against a current of 85.3 cm/s for no more than 30 s. Juvenile herring of 200 to 220 mm were able to maintain their position against a current of 140.2 cm/s for no more than 30 s. Yet post-larvae as well as juvenile herring have been obtained in waters of 30 fathoms or less: at least on Georges Bank. Juvenile herring (2 and 3 years old) have been collected from Little Georges in 1962, from Cultivator Shoals in 1964, from Little Georges and Cultivator Shoals in 1965 and from Cultivator Shoals in 1967 (Boyar, 1968). The juvenile herring occur primarily in shallow waters; all collections were made in depths of 20 to 30 fathoms. Gill net sets made in deeper waters of the Bank failed to yield herring. Apparently post-larvae eventually reach the shallow waters of the Bank and contiguous waters where they develop into juvenile herring.

During our cruises in March and April 1970 we collected larvae southwest of Martha's Vineyard and approximately 80 km south of Nantucket Island. Herring larvae have been obtained off the coasts of Massachusetts (Martha's Vineyard) southward to Maryland-Virginia (Kendall, A., manuscript in preparation). The larvae from the above mentioned areas and those that we obtained from Hudson Canyon (January, 1971) because of the circulatory system, would appear to be the offspring of spawners from the Nantucket Shoals area.

## Growth of larval herring

### Results

The actual length frequencies and the mean lengths of larvae from the research vessel samples on the three major spawning areas by months in 1962 to 1970 are shown in Tables 2 to 4. Histograms of the length frequencies based on 3 mm length intervals for the three areas are shown in Figure 6. An examination of Tables 2 to 4 and Figure 6 show the larval growth rate. On Georges Bank the larvae reach a length of about 55 mm by the June following spawning; in the coastal waters of the Gulf of Maine the larvae reach a length of about 47 mm by April; off Nova Scotia 38 mm by April.

The length frequency data substantiates the results of gonad examination (Boyar, 1968) indicating that spawning is from late August through December with the peak occurring from late September to mid-October. The frequency distributions are, for the most part, unimodal suggesting that the fish are the products of a single spawning.

Muench (unpublished manuscript based on data of sea bed drifters set by Woods Hole Oceanographic Institute) has reported that the residual currents on the bottom on Georges Bank were similar to those on the surface in May as reported by Bumpus and Lauzier (1965), i.e. on the order of 4.8 km per day. Bumpus (personal communication) stated that the tidal current at the bottom on the Northeast Peak was 0.9 that of the surface tidal current. It is reasonable to assume (Bumpus, personal communication) that this condition prevails over all of the Bank. Data on the strong tidal currents (30 to 100 cm/s; Tidal Current Tables, 1962-1970 inclusive) suggest that the current on the bottom and surface would be too great for larvae to swim against. Net movement of larvae would be largely controlled by the current, thus the clockwise gyre on Georges Bank will retain the majority of them on the Bank. At the same time, the counter-clockwise gyre in the coastal Gulf of Maine and Nova Scotia will also retain the majority of the larvae in these waters. Adequate evidence of this fact is that larvae and post-larvae are found in large numbers on the Bank, in the coastal Gulf of Maine (Graham and Boyar, 1965; Graham and Venno, 1968) and in Nova Scotia (Das, 1968). This evidence would suggest that there are three discrete spawning populations in the Georges Bank-Gulf of Maine area. It would seem unlikely, therefore, that larvae would leave the Bank in the fall to return in the spring. Such a phenomenon would suggest a voluntary migration. Larvae for all practical purposes are trapped in the gyre on the Bank and this would explain the "enigma" discussed by Colton and Temple (1961).

Table 2. Length frequencies and mean length of larval herring

Length mm	1964	Sept 1965	1968	1964	1966	Oct 1967	1968	1969	1962	1963	Nov 1964	1965	1968	1969	Dec 1962	1963
4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-
5	15	104	220	-	-	-	-	10	-	-	-	-	51	-	53	-
6	22	93	401	-	2	1	3	11	-	-	-	-	50	-	88	-
7	1	109	1178	24	14	9	21	5	-	-	1	-	137	-	57	-
8	-	112	745	42	94	30	33	31	-	-	-	-	105	-	-	-
9	-	-	468	89	147	69	42	60	-	-	-	-	133	4	-	-
10	-	-	224	46	118	141	90	142	-	1	3	-	170	14	-	-
11	-	-	106	30	64	147	76	175	-	-	5	-	193	47	-	-
12	-	1	123	30	87	139	119	222	-	2	17	1	155	92	-	-
13	-	-	40	26	86	91	100	250	-	3	14	2	135	130	-	-
14	-	1	24	25	51	56	43	159	-	9	11	10	104	193	1	-
15	-	-	21	28	49	38	40	95	-	3	11	2	75	223	10	-
16	-	-	4	11	9	26	49	39	1	4	6	9	94	248	9	-
17	-	-	3	6	14	30	42	17	-	4	10	8	132	229	18	-
18	-	1	-	1	1	12	60	18	1	2	6	6	116	182	28	-
19	-	-	-	-	1	9	56	19	3	4	2	1	99	106	33	-
20	-	-	1	1	-	6	51	17	4	-	1	3	85	95	43	-
21	-	-	-	-	-	-	25	13	2	1	1	7	43	60	52	-
22	-	-	-	-	-	1	22	8	1	-	-	3	32	40	39	-
23	-	-	-	-	1	3	11	10	-	-	1	6	19	22	33	1
24	-	-	-	-	-	2	5	6	-	-	-	7	11	10	28	2
25	-	-	-	-	-	2	3	3	1	-	-	3	6	3	19	1
26	-	-	-	-	-	-	1	10	-	-	-	-	4	4	11	-
27	-	-	-	-	-	-	-	7	-	-	-	-	2	2	7	-
28	-	-	-	-	-	-	-	3	-	-	1	1	3	-	3	2
29	-	-	-	-	-	-	-	2	-	-	-	-	-	1	2	-
30	-	-	-	-	-	1	-	3	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1
32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
57	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total...	41	421	3558	356	738	813	892	1335	13	33	90	69	1954	1706	544	7
Mean...	5.5	6.9	7.9	10.8	11.0	12.1	14.1	13.0	20.0	15.4	14.5	18.8	13.2	16.3	15.4 (21.0)*	26.1

obtained from Georges Bank (\*excluding yolk-sac larvae)

Feb 1968	1967	Mar 1968	1969	1970	1965	1966	Apr 1967	1968	1969	1970	May 1968	1969	1965	June 1967	1969	Length mm
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21
-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22
-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23
-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24
-	12	-	-	1	-	-	-	-	-	-	-	-	-	-	-	25
-	27	-	1	-	-	-	-	-	-	-	-	-	-	-	-	26
1	39	1	-	2	1	-	-	-	-	-	-	-	-	-	-	27
1	60	-	1	-	3	-	-	1	-	-	-	-	-	-	-	28
2	96	4	3	6	5	-	1	3	-	-	-	-	-	-	-	29
7	175	4	5	11	6	3	2	3	-	-	-	1	-	-	-	30
4	258	7	9	15	10	13	3	8	-	-	-	-	-	-	-	31
5	348	9	10	26	13	23	5	17	-	-	-	-	-	-	-	32
4	419	7	10	29	18	68	6	25	-	-	-	-	-	-	-	33
10	410	7	16	22	25	101	7	44	-	-	2	-	-	-	-	34
7	392	19	15	39	31	165	9	48	-	-	4	-	-	-	-	35
3	378	21	18	24	46	260	16	68	-	-	5	-	-	1	-	36
1	280	19	15	22	49	407	15	58	1	-	4	-	-	-	-	37
1	226	14	8	17	41	839	13	55	-	-	5	-	-	-	-	38
3	149	12	10	18	38	1241	15	55	-	-	8	-	-	-	-	39
-	135	7	10	5	32	1263	9	49	-	-	10	-	1	-	-	40
-	89	9	3	4	30	835	8	29	-	-	10	-	-	-	-	41
-	57	2	2	1	28	602	5	22	-	1	4	-	-	1	-	42
-	40	5	2	1	24	446	9	19	-	-	3	-	-	1	-	43
-	14	-	1	-	11	246	2	10	-	-	4	-	-	1	-	44
1	12	-	1	1	11	137	1	6	-	-	3	-	-	-	-	45
-	2	-	-	-	5	48	-	1	-	-	-	1	-	1	-	46
-	2	-	-	-	6	26	-	-	-	-	-	2	-	-	-	47
-	2	-	-	-	6	8	-	-	-	-	-	1	-	1	-	48
-	-	-	-	-	4	3	-	-	-	-	-	1	-	1	-	49
-	-	-	-	-	-	5	-	-	-	-	-	2	-	-	-	50
-	-	-	-	-	2	2	-	-	-	-	-	-	-	1	-	51
-	-	-	-	-	2	2	-	-	-	-	-	1	-	1	-	52
-	-	-	-	-	-	5	-	-	-	-	-	-	-	1	1	53
-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	3	54
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	55
-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	1	56
-	-	-	-	-	-	1	-	-	-	-	-	-	-	2	1	57
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	58
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	59
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	60
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	61
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	62
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	63
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	64
50 33.4	3637 34.4	147 36.1	140 35.5	244 34.7	447 38.3	6751 39.8	126 36.3	521 37.4	1 37.0	1 42.0	62 39.6	9 47.4	1 40.0	14 49.1	25 58.0	

Table 3. Length frequencies and mean lengths of larval herring obtained from the coastal Gulf of Maine

Length mm	Oct		1969	1962	Nov			Dec	Mar		1970	1965	1966	Apr	1969	1970	
	1964	1968			1965	1968	1969		1968	1969							
6	-	3	-	-	-	3	-	-	-	-	-	-	-	-	-	-	
7	-	6	-	-	-	8	2	-	-	-	-	-	-	-	-	-	
8	-	20	1	-	-	21	1	-	-	-	-	-	-	-	-	-	
9	-	25	2	-	-	28	-	-	-	-	-	-	-	-	-	-	
10	-	11	1	-	-	13	-	-	-	-	-	-	-	-	-	-	
11	1	7	3	-	-	9	3	-	-	-	-	-	-	-	-	-	
12	3	3	3	-	-	5	1	-	-	-	-	-	-	-	-	-	
13	-	-	11	-	-	-	1	-	-	-	-	-	-	-	-	-	
14	-	1	9	-	-	2	3	-	-	-	-	-	-	-	-	-	
15	-	-	8	-	-	1	2	-	-	-	-	-	-	-	-	-	
16	-	-	3	-	-	-	2	-	-	-	-	-	-	-	-	-	
17	-	-	-	-	-	4	3	-	-	-	-	-	-	-	-	-	
18	-	-	1	1	-	2	2	-	-	-	-	-	-	1	-	-	
19	2	-	1	1	-	2	1	-	-	-	-	-	-	-	-	-	
20	-	-	2	1	-	4	3	-	-	-	-	-	-	1	-	-	
21	-	-	2	-	-	2	2	-	-	-	-	-	-	-	-	-	
22	-	-	2	-	-	-	2	-	-	-	-	-	-	-	-	-	
23	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	
24	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	
25	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	
26	-	-	-	1	-	1	1	-	-	-	-	-	-	1	-	-	
27	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	
28	-	-	-	-	-	-	-	-	-	1	1	-	-	-	1	-	
29	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	1	
30	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	1	
31	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	
32	-	-	-	-	-	1	-	-	-	1	2	-	1	-	-	-	
33	-	-	-	-	-	-	-	-	-	1	3	-	-	-	-	-	
34	-	-	-	-	-	-	-	-	-	3	5	-	-	-	-	-	
35	-	-	-	-	-	-	-	-	-	-	4	-	1	-	1	4	
36	-	-	-	-	-	-	-	-	-	-	1	-	3	-	1	-	
37	-	-	-	-	-	-	-	-	-	2	6	-	4	-	-	-	
38	-	-	-	-	-	-	-	-	-	3	5	-	-	-	-	-	
39	-	-	-	-	-	-	-	-	-	3	-	-	5	-	-	-	
40	-	-	-	-	-	-	-	-	-	1	-	-	5	-	-	2	
41	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	
42	-	-	-	-	-	-	-	-	-	1	-	-	6	-	-	-	
43	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	
44	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	
45	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	
46	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	
47	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	
48	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	
Total.....	6	76	50	3	3	109	31	18	36	22	36	3	2	55	3	5	17
Mean.....	13.7	9.0	14.5	21.0	20.0	11.2	16.0	20.1	34.5	33.2	34.5	35.0	30.0	40.8	21.0	32.8	35.4

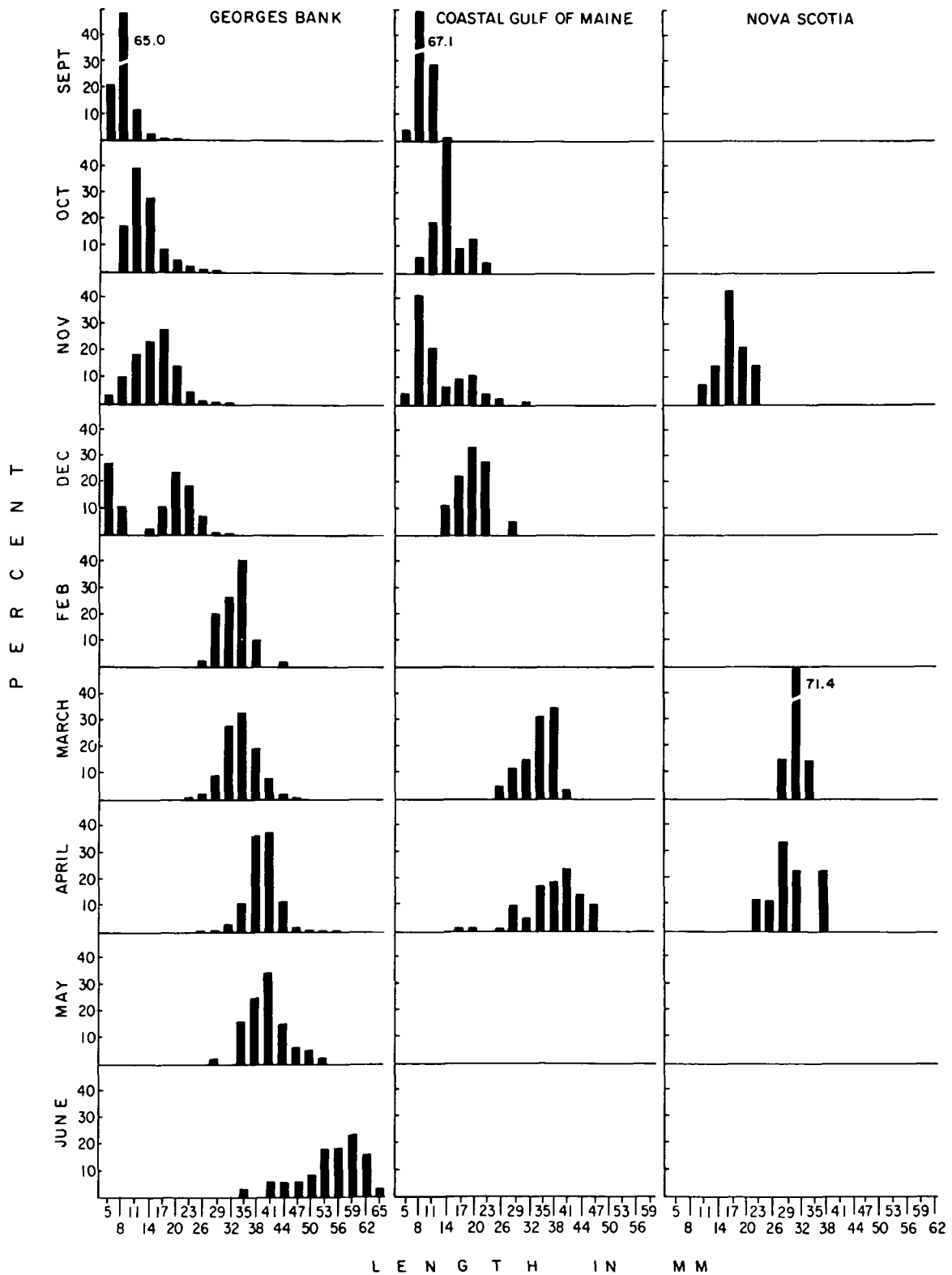


Figure 6. Length frequency distributions of larval herring from September to June for Georges Bank, coastal Gulf of Maine, and Nova Scotia. Data are combined in 3 mm size groups.

Table 4. Length frequencies and mean lengths of larval herring obtained from Nova Scotia.

Length mm	Nov		Mar		Apr	
	1968	1969	1968	1968	1969	1970
11	-	1	-	-	-	-
12	-	-	-	-	-	-
13	-	-	-	-	-	-
14	1	-	-	-	-	-
15	-	1	-	-	-	-
16	1	1	-	-	-	-
17	1	-	-	-	-	-
18	1	2	-	-	-	-
19	2	-	-	-	-	-
20	1	-	-	-	-	-
21	-	-	-	-	-	-
22	1	-	-	-	-	-
23	1	-	-	-	1	-
24	-	-	-	-	-	-
25	-	-	-	-	-	-
26	-	-	-	-	-	-
27	-	-	-	1	-	-
28	-	-	-	-	-	-
29	-	-	1	1	-	-
30	-	-	-	2	-	-
31	-	-	1	-	-	-
32	-	-	2	1	-	-
33	-	-	2	-	1	-
34	-	-	-	-	-	-
35	-	-	1	-	-	-
36	-	-	-	-	-	-
37	-	-	-	-	1	-
38	-	-	-	-	-	1
Total	9	5	7	5	3	1
Mean	18.7	15.6	32.1	29.6	31.0	38.0

A comparison of mean lengths by month of larvae from the present study with data from Tibbo et al. (1952), Tibbo and Legare (1960), Marak and Colton (1961), Marak, Colton and Foster (1962), and Marak et al. (1962) (Table 5) is shown in Figure 7. The growth variations are small.

### Discussion

There was a gradual increase in the length of larvae from September through June. Our data show that the monthly increase in larval length ranged from 4.1 to 7.4 mm. The greatest increase in length occurred between November and January, the least occurred between January and March. The larvae we collected in February and those taken by the investigators of the 1950's in January-February would appear to be the offspring of the early spawners in the autumn for at least 1956 and 1968.

The larvae we obtained from Georges Bank, coastal Gulf of Maine and Nova Scotia are similar in length to those obtained by Graham and Boyar (1965), Graham and Venno (1968) in the inshore waters of the Gulf of Maine and by Das (1968) in the inshore

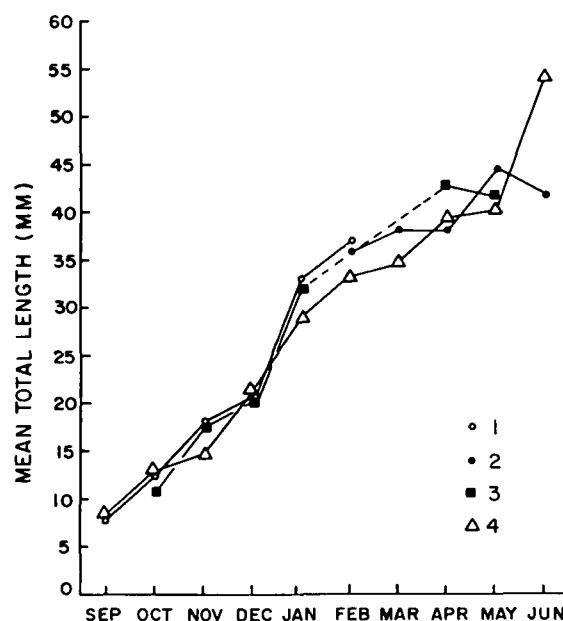


Figure 7. Comparison of growth of larval herring in the Georges Bank-Gulf of Maine area. Mean length of larval herring collected by month (all years combined) by (1) Tibbo et al. (1958); (2) combined data of Marak and Colton (1961), Marak, Colton and Foster (1962), and Marak, Colton, Foster and Miller (1962); (3) Tibbo and Legare (1960); and (4) combined data of Boothbay Harbor and Woods Hole (Data from Table 4).

waters of Nova Scotia (Bay of Fundy) at the same time of the year.

Our findings and the findings of Marak and Colton (1961), Marak, Colton, and Foster (1962) and Marak et al. (1962) of post-larvae on Georges Bank appear well worth emphasizing. None of the collections of Tibbo et al. (1958) and Tibbo and Legare (1960) contained post-larval herring. Marak et al. (1962), however, in May of 1956 collected post-larvae of 60 mm (Lurcher Shoals), 57 mm (off Monhegan Island), 63 mm (Great South Channel) and 66 mm (Nantucket Shoals) (Figure 1), with the Hardy continuous plankton recorder. In June 1967 we collected 8 post-larvae with a mean length of 54 mm and a range of 49 to 57 mm from Cultivator Shoals. On the same cruise 6 larval herring, with a mean length of 43 mm and a range of 36 to 48 mm, were collected from the Northern Edge of the Bank (Table 2). In a cruise in June 1969, 26 post-larvae with a mean length of 58 mm and a range of 50 to 65 mm were collected from the Winter Fishing Ground (Figure 1). Das's (1968) reference to Boyar (unpublished data) finding post-larval herring north of Georges Bank in April 1965 and 1966 is inaccurate. The post-larvae

Table 5. Number and mean length of larval herring collected by month (all years combined) from Georges Bank-Gulf of Maine area. (1) Tibbo et al. (1958); (2) Combined data of Marak and Colton (1961), Marak, Colton and Foster (1962) and Marak, Colton, Foster and Miller (1962); (3) Tibbo and Legare (1960) and (4) Combined data of Boothbay Harbor and Woods Hole.

Month	Years of Collection	Number of larvae	Mean length mm
Sept	(1) 1956 and 1957	517	7.8
	(4) 1964, 1965 and 1968	4020	7.7
Oct	(1) 1956 and 1957	1957	12.3
	(3) 1958	974	10.5
	(4) 1964 through 1969	4266	12.5
Nov	(1) 1956 and 1957	860	17.9
	(3) 1958	456	17.8 <sup>1</sup>
	(4) 1963, 1964, 1965, 1968 and 1969	4025	14.6
Dec	(1) 1956 and 1957	3452	20.6
	(3) 1959	11	20.3
	(4) 1962 and 1963	364	21.2 <sup>1</sup>
Jan	(1) 1957 and 1958	274	33.2
	(3) 1959	129	32.4
	(4) 1971	11	29.0 <sup>2</sup>
Feb	(1) 1957 and 1958	260	37.0
	(2) 1955 and 1956	39	36.0
	(4) 1968	50	33.4
Mar	(2) 1953, 1955 and 1956	160	38.3
	(4) 1967 through 1970	4236	34.7
Apr	(1) 1955	17	—
	(2) 1953, 1955 and 1956	160	38.3
	(3) 1958	1	43.0
	(4) 1965, and 1967 through 1970	7938	39.5
May	(2) 1953, 1955 and 1956	58	44.7
	(3) 1958	7	42.0
	(4) 1958 and 1969	71	40.5
Jun	(2) 1953, 1955 and 1956	28	42.7
	(4) 1965, 1967 and 1969	40	54.5

<sup>1</sup>Mean length minus yolk-sac larvae. <sup>2</sup>Data obtained from cruise in January 1971

referred to by Das were collected on the Northern Edge of the Bank and not north of the Bank and only one (57 mm) obtained in April of 1966, as already mentioned, had metamorphosed into a post-larva. On occasion we have found larvae 50 to 55 mm long that have not metamorphosed into post-larvae. We have also found larvae 49 mm long which had metamorphosed into post-larvae.

Since juvenile herring of 75 mm or greater are collected in the early summer, the major growth of post-larvae into juvenile herring occurs from late June to late August or early September.

Additional concentrated efforts to collect post-larval herring and further investigations, particularly with juvenile herring from the three major spawning areas, are needed to confirm the discreteness of the populations of herring in the western North Atlantic. Plankton tows, particularly quantitative, should be made deeper than 20 m, actually from the bottom to the surface, and we should use gear (Bongo nets

or Isaacs-Kidd trawls) that have closing devices and that can be towed at relatively high speeds. Perhaps the post-larval and juvenile herring of Georges Bank occur in great numbers in the shallow waters of the Bank westward to the Cape Cod area. We have gill-netted for juvenile herring on various parts of the Bank and have never collected them further east than Georges Shoals. We have, however, observed them on the surface (at night) in the shallow waters of the Northern Edge of the Bank.

## Summary

1. Investigations were conducted on the distribution of larval herring in the western North Atlantic for 1962 through 1970.
2. Statistical quantitative analysis of the relative abundance of larvae was not possible since various types of gear were used.

3. Larval herring were collected from September through June (exclusive of January).
4. The distribution of larval herring in the study area indicates three discrete spawning populations for the following reasons:
  - a. Yolk-sac larvae are found in close proximity to known spawning sites on Georges Bank, the Gulf of Maine and Nova Scotia.
  - b. The presence of a clockwise gyre on Georges Bank figuratively traps the larvae on the Bank and retains them there. Larval herring spawned along the western and central part of the coastal Gulf of Maine because of the circulatory system appear to be restricted to these waters although on occasion some may drift into the middle of the Gulf of Maine. The majority of larval herring from Nova Scotia spawnings either remain in close proximity to the spawning grounds, because of the circulatory system, or are carried in high concentrations into the Bay of Fundy. Some of the larvae from the Bay of Fundy, however, may drift to the eastern part of the coastal Gulf of Maine where they mix with the larvae from local spawnings and they may also be carried as far southward as Cape Cod, Massachusetts.
  - c. Our data on the distribution of larval herring agree with the results of meristic and biochemical studies on the discreteness of the populations of herring from the three areas.
5. Yolk-sac larvae were collected from Georges Bank from September through December. The extended spawning season in some years also occurs in the coastal Gulf of Maine and may on occasion occur in Nova Scotia.
6. Larvae from Georges Bank can increase in size from 4 to 65 mm from early September through June. Larvae from Georges Bank were similar in length to those collected by other workers at the same time of the year from the inshore waters of the Gulf of Maine and Nova Scotia.
7. The differences in the mean lengths for the various years within a specific month are undoubtedly due to differences both in time of spawning and collecting. Larvae grow on the average 5 mm per month.
8. Post-larvae living on the Bank appear to prefer shallow waters. Larval herring on Georges Bank usually metamorphose into post-larvae by the time they are 50 to 55 mm long. On occasion, however, we have found larvae 55 mm long that had not metamorphosed and have also collected larvae 49 mm long which had metamorphosed.

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