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A STUDY OF THE SPAWNING AND EARLY LIFE HISTORY OF HERRING (CLUPEA HARENGUS HARENGUS L.) ON JEFFREYS LEDGE IN 1972

by

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INTRODUCTION

This study presents data on the spawning and early life history of herring (Clupea harengus harengus L.) obtained from Jeffreys Ledge in the autumn of 1972. It is the first attempt to investigate details on spawning and early life history of herring in a specific locality in the coastal waters of the Gulf of Maine. The information could increase our understanding of the ecological factors that determine year class strength and may permit an assessment of the relative value of a major spawning site to the maintenance of this fishery.

Location of spawning sites of herring in the Georges Bank-Gulf of Maine area have been reported by Tibbo, Legare, Scattergood and Temple (1958), Tibbo and Legare (1960), Tibbo (1968), Boyar (1968), Boyar (1970a and 1970b), and Boyar, Marak, Perkins and Clifford (1973). Boyar et al. (1973) refer to several spawning sites along the coastal Gulf of Maine and suggest that larvae from these sites are the major contributors to the future herring fisheries in the coastal waters. Sindermann (1961) and Boyar (1968) indicate that herring from the coastal waters of the Gulf of Maine may consist of a western and eastern population. None of these investigators refer to the relative importance of any one spawning site in the Gulf of Maine to the maintenance of the coastal populations.

Although quantities of pre-spawning, spawning and spent herring are caught commercially from the Georges Bank-Gulf of Maine area, little is known of the size of the stocks, the distribution of the spawning beds, the amount of spawned eggs and the number of larvae that survive after the eggs have hatched. In recent years attempts have been made to study some of the spawning beds in the Northwest Atlantic; namely, in the waters of Canada and Georges Bank. Tibbo, Scarratt and McMullon (1963) used free-diving techniques to study a spawning bed (spring-May) of herring near Blanchard Point, Chaleur Bay, New Brunswick. Noskov and Zinkevich (1967), Anthony, Sauskan and Sigaev (1970) and Graham and Chenoweth (1971) investigated specific spawning beds on Georges Bank.

The overall objective of this preliminary study was to understand the ecological factors that affect survival of the sea herring. We have speculated that herring spawning on Jeffreys Ledge results in a major source of recruitment to the fishery of coastal Maine. The presence of an intensive fishery for herring since 1967 on Jeffreys now supports this contention. A major gap in our understanding the potential yield of the herring resource of Jeffreys Ledge has been our ignorance of the early life history of the fish and the factors that affect its survival. Our effort in the fall of 1972 was directed towards (1) locating the spawning site/sites, (2) describing the egg bed-substrate relationship, (3) determining the kinds and number of predators, and the degree to which they reduce the hatching potential, (4) observing the dispersal of larvae after hatching, and (5) defining the physical characteristics of the water mass in which spawning occurs. These objectives were to be accomplished by shipboard and SCUBA diver operations.

METHODS AND MATERIALS

Collection of larval herring from Jeffreys by Boyar et al. (1973) and by Graham, Davis and Bickford (1973) indicated spawning activity on Jeffreys Ledge. The actual spawning site/sites, however, were not determined. To locate spawning activity, we designed a sampling grid of 142 stations placed one nautical mile apart over a major portion of Jeffreys (Figures 1 and 2). Rough weather and heavy seas did not permit sampling at all stations. We were able to work only 50 percent of our allotted time. Discussions with commercial trawl fishermen, however, led to the selection of certain portions of the sampling grid. In addition, local lobster fishermen referred us to historical herring spawning areas along the shore of Cape Ann and at the southwestern end of Jeffreys.

Two commercial fishing vessels were chartered for the study. M.V. MISS PAULA, a 23-meter side trawler, was modified to trawl for herring, dredge for eggs, tow plankton nets and collect hydrographic data. M.V. BARBARA L, a 17-meter stern trawler, was modified to dredge for herring eggs and serve as a platform for SCUBA diving operations. The accuracy of position location using a combination of Loran A and depth soundings was + 0.50 km. We planned to dredge and trawl for evidence of herring spawning at depths in excess of 45 meters and make direct observations of the ocean bottom at depths less than 45 meters. SCUBA diving at greater depths requires certain surface support hardware which was not available to the diving team during this field investigation.

Trawling for herring. Initially we used the location of active purse seiners as a reference to concentrations of adult herring. Eight trawl sets were made on Jeffreys Ledge and three on Stellwagen Bank (Figure 1). The otter trawl was fished at 2 to 2.5 knots for 1 to 2 hours. Tows were made only when herring-like traces were seen on the fish finder, usually between depths of 45 and 110 meters. The gonads of the herring obtained were examined aboard ship. Whenever possible, 100 fish were frozen for future examination in the laboratory for data on age composition, length, weight and maturity. Age determinations were made from otoliths. The age was recorded as the number of actual or virtual summer growth

zones on the otolith. The year class of the fish was recorded and refers to the year of deposition and hatching of the eggs (Boyar, 1968). Juvenile and adult herring were measured (in cm.) from the tip of the lower jaw to the end of the longest lobe of the tail, with the fish lying in a natural position (natural total length). The maturity scale proposed by ICES in 1964 was used in the classification of the various gonadal stages (Boyar, 1968).

The stomachs of all other fish obtained from the trawls were examined aboard ship to determine whether herring, herring and their eggs, or merely the eggs of herring were eaten. Eggs obtained from the stomachs of predators were preserved in three percent buffered formalin or were frozen for later determination of egg fertilization and cell cleavage.

Dredging for eggs. A 1-meter Naturalist dredge was used to obtain samples of the substrate and attached herring eggs. Samples of associated macrofauna were also collected and preserved in five percent buffered formalin. The dredge was fished as the vessel drifted for 5-10 minutes. All tows were made in daylight because of the presence of purse seiners and mid-water trawlers on our sites of sampling during the evening. A bull-hide was secured to both outer sides of the net to prevent tear ups. The mesh size of the net (stretched) was four mm. Sixty-one dredge tows were made by M.V. MISS PAULA and 36 by M.V. BARBARA L. at selected stations (Figures 1 and 2). Some stations were sampled more than once. An examination of the substrate and its fauna was made during the search for herring eggs. The eggs obtained from dredging were preserved in three percent buffered formalin for examination in the laboratory. Buoys were set at stations where eggs were found. Additional tows in close proximity to stations where eggs were obtained were made in the vicinity of these buoys to determine the extent of the egg mass.

Towing for larvae. Paired bongo nets were used to collect larval herring (Posgay and Marak, 1971). The bongo nets had a mouth diameter of 61 cm and a mesh size of 0.505 and 0.333 mm. Duration of tow depended upon water depth. The net was let out at 50 meters per minute to approximately 1 to 2 meters above the bottom and was retrieved at 20 meters per minute. Vessel speed was two knots. Flow meters were mounted inside the central rim of the bongos. The meters were calibrated prior to and at the completion of this field study and both differed only by 0.0050 meters ^{3}/revolution. The calibrations for practical purposes were identical. The meters were read prior to and at the completion of the tow and provided a measure of the volume of water strained in cubic meters. All larvae obtained were counted and measured (T.L. in mm) in the laboratory. The number of larvae obtained was divided by the cubic meters of water strained and multiplied by 1000 giving a larval herring concentration per 1000 cubic meters of water.

Prior to the peak of spawning, plankton tows were made at 25 of the 141 stations. Once the spawning site was defined and the peak of spawning had occurred, a second sampling grid was designed. Stations were positioned at four nautical mile intervals along the imaginary spokes of a wheel radiating from the center of spawning. The central point was sampled six times while traversing the eight transect lines. Forty-six tows were made. The contents of the plankton nets were preserved in a 10 percent buffered formalin solution. The majority of tows were made during daylight. Bathythermograph casts were made at selected stations.

SCUBA survey of ocean bottom. Surveys with SCUBA and photographic documentation of the sea bed was accomplished in potential spawning areas on Jeffreys to depths of 45 meters (Figure 3). Dive sites corresponded with (1) historical spawning sites as determined from conversations with local fishermen and (2) location of the fleet of purse seiners. Each dive station was buoyed. Two divers searched approximately 1000 square meters of ocean bottom and recorded their observations of substrate type and the resident fauna. Total area of ocean bottom examined on Jeffreys Ledge was approximately 6000 m^2.

An extensive survey with SCUBA was also conducted on historical spawning grounds in the vicinity of Cape Ann (Figure 3). A pair of divers were towed over the ocean bottom by a 7-meter power boat at two to three knots for distances of 0.46 to 2.8 km. The dive team examined a band of ocean bottom approximately six meters wide. Total area of sea bed examined was approximately 75,000 m^2.

RESULTS

Samples of adult herring were collected from eleven locations during September and October (Figure 1).

Age and length. Herring obtained in September were dominated by fish of age-group IV (1968 year class), followed in percentage occurrence by fish of age-groups V, III, VI, VIII+, VII, VIII and II, respectively (Figure 4). In October, fish of age-groups III, IV and V (1969 - 1967 year classes, respectively) were dominant, followed in percentage occurrence by fish of age-groups VI, II, VII, VIII+ and VIII, respectively (Figure 4).

Herring obtained in September ranged in length from 22.0 to 35.5 cm, and from 20.0 to 38.0 cm in October. The length frequency distribution of these fish are presented in Figure 5. The mean lengths of herring of a particular age-group collected in September and October were similar (Table 1). A higher percentage of fish of age-groups II and III were obtained in October.

Table 1. Mean lengths (T.L. in cm) of herring of various age-groups from Jeffreys Ledge, September and October, 1972.

Age group	Month of Capture: September Number	September mean length	October Number	October mean length
II	2	22.4	66	22.1
III	23	25.9	126	26.0
IV	45	27.3	120	27.5
V	34	29.1	126	29.2
IV	13	30.5	69	30.9
VII	3	32.3	54	32.2
VIII	3	33.2	25	33.2
VIII+	10	34.1	32	34.4
Total	133		618	

Gonadal development: An examination of gonads of adult herring collected by commercial vessels fishing Jeffreys Ledge was made in the first and second weeks of September. In both examinations, at least 95 percent of the fish had not spawned, the remaining five percent were recently spent. Examination of the gonads of herring collected on M.V. MISS PAULA also indicated that the onset of spawning on Jeffreys occurred in early September. Gonadal development of all herring samples obtained on M.V. MISS PAULA are shown in Table 2.

Fish of gonadal stages I and II are immature herring (juveniles) and the majority of these would not spawn for two to three years from their time of capture. Fish of gonad stage III obtained in the autumn, although maturing, would not spawn until 1973. To simplify the comparison of gonadal development of spawning herring obtained from Jeffreys, we have presented the data using only full (stages IV and V), spawning (stage VI), recently spent (stage VII) and recovering spent (stage VIII). We have also combined the data from the samples collected on the same day (Table 3).

Table 2. Percentage occurrence of gonadal stages of all herring for each sample obtained from Jeffreys Ledge in September and October, 1972.

Gonadal stage	PERCENTAGE OCCURRENCE BY DATE										
	SEPTEMBER			OCTOBER							
	22	25	27	2	2	5	9	11	18	18	18
	SAMPLE SIZE										
	100	33	55	32	68	26	100	122	100	82	88
I	2.0	----	9.1	2.9	34.4	3.8	10.0	----	35.0	4.9	1.1
II	27.0	21.2	9.1	41.2	31.2	----	57.0	1.6	4.0	40.2	46.6
III	6.0	6.1	3.6	1.5	3.1	----	3.0	----	3.0	2.4	5.7
IV	18.0	12.1	14.5	7.8	3.1	----	----	1.6	2.0	----	1.1
V	39.0	48.5	52.8	28.0	3.1	23.1	----	59.9	----	1.3	2.3
VI	1.0	9.1	1.8	7.8	6.3	15.4	----	29.5	3.0	----	4.5
VII	6.0	----	9.1	11.8	12.5	26.9	18.0	6.6	14.0	23.2	23.9
VIII	1.0	3.0	----	----	6.3	30.8	12.0	0.8	39.0	28.0	14.8

Table 3. Percentage occurrence of gonadal stages of mature and spawning herring obtained from Jeffreys Ledge in September and October, 1972. (Samples obtained on same day have been combined).

Gonadal stage	PERCENTAGE OCCURRENCE BY DATE							
	SEPTEMBER			OCTOBER				
	22	25	27	2	5	9	11	18
IV	27.7	16.7	18.6	12.8	----	----	1.7	2.1
V	60.1	66.7	67.5	42.6	24.0	----	60.8	2.1
VI	1.5	12.5	2.3	14.9	16.0	----	30.0	5.0
VII	9.2	----	11.6	25.5	28.0	60.0	6.7	38.0
VIII	1.5	4.1	----	4.2	32.0	40.0	0.8	52.8

In September 86 percent of the fish of gonadal stages IV to VIII were full (stages IV and V), four percent were spawning, eight percent were recently spent and two percent were recovering. In the first two weeks of October, 49 percent of the fish were full, 21 percent were spawning, 20 percent were recently spent and 10 percent were recovering. The mean lengths of herring of maturity stage IV and V were 28.2 and 30.9 cm, respectively; the ranges in length were 25.9-33.5 and 28.0-34.5, respectively. In the samples obtained in the third week of October, only six percent of the fish were full, five percent were spawning, 38 percent recently spent and 53 percent recovering. The actual peak of spawning, therefore, probably occurred during the first two or three weeks of October. Additional evidence for the above spawning time was provided by information from the captains of purse seiners fishing for herring who described the condition of the fish to us. In addition, we noted that their vessels were most active between these dates, and by October 21, the majority of the vessels had ceased fishing, suggesting that the spawning concentrations of fish had dispersed. A fleet of about 40 vessels from Europe, engaged in mid-water trawling, replaced the departed seiners. These vessels were active for a few days, but our observation was that they were spending most of their time looking for herring. We did not trawl for herring after October 18.

Egg-beds: It was assumed that the major concentration of herring was where the purse seiners were actively fishing (between stations 66-67 and 106-142, approximately 42°46'; 70°11' and in an area where we did most of our trawling (Figures 1 and 2). A second concentration of herring was southwest of the above-mentioned area at approximately 42°40'; 72°25', in the vicinity of station 27 (Figures 1 and 2). We did not collect herring at the latter site, but were informed of their presence by commercial fishermen. In addition, the fishermen gave us large samples of eggs of herring obtained from the stomachs of codfish taken in this area. These eggs were fertilized and cell division had begun. We did not obtain eggs from any of the groundfish caught by M.V. MISS PAULA, but did note that in many cases, cod, monkfish and whiting had eaten entire herring.

Dredging for eggs began on September 25. The station numbers, depths, types of substrate and presence of eggs are shown in Table 4. A total of 15 stations were sampled before eggs were found at station 57 on October 5. The eggs were on scales of herring which led us to believe that they must have been squeezed out of females during the previous night's purse seining operation. None of the eggs were fertilized.

Table 4. Stations where dredge sets were made on Jeffreys Ledge, September-October 1972 (*refers to a set between 2 stations).

Station	Date	Depth (meters)	Type of substrate	Eggs +	Eggs -
111	Sept. 25	48	sand-gravel		-
10	" 29	46	gravel-rock		-
25	" 29	73	clay-gravel		-
66	Oct. 4	51	bedrock		-
67	" 4	55	gravel-rock		-
68	" 4	59	sand-gravel		-
69	" 4	57	gravel-rock		-
106	" 4	62	sand		-
142	" 4	44	sand		-
46	" 5	48	sand-gravel		-
47	" 5	49	bedrock-rock		-
48	" 5	46	bedrock		-
49	" 5	59	bedrock-rock		-
40	" 5	60	rock-boulder		-
38	" 5	60	rock-boulder		-
57	" 5	57	gravel-rock	+	
37	" 5	48	sand-gravel		-
133	" 5	38	rock-boulder		-
24	" 5	51	sand		-
63	" 5	95-101	sand		-
64	" 5	57	sand-rock		-
65	" 5	59	bedrock-rock		-
108	" 5	55	bedrock		-
54	" 5	53	gravel-rock		-
55	" 5	51	clay-rock		-
56	" 5	55	bedrock		-
57	" 5	60	sand-rock		-
57	" 5	57	gravel		-
57	" 5	59	gravel	+	
64	" 5	58	sand		-
57	" 5	60	sand-gravel		-
66	" 6	51	gravel-rock		-
66	" 6	35	bedrock		-
142	" 6	33	bedrock		-
106	" 6	77-81	gravel-rock		-
105	" 6	66	sand-gravel		-
104	" 6	66	sand		-
101	" 6	77	sand		-
100	" 6	70	gravel-rock		-
107	" 6	64	gravel-rock		-
52	" 6	123	mud		-
98	" 6	59	sand-gravel		-
97	" 6	60	rock-boulder		-
96	" 6	71	gravel-rock		-
95	" 6	59	bedrock-rock-boulders		-

Table 4. cont.

Station	Date	Depth (meters)	Type of substrate	Eggs +	Eggs -
94	Oct. 6	104	mud		-
93	" 6	55	bedrock-rock		-
92	" 6	57	sand-rock		-
91	" 6	93	sand		-
70	" 6	53	sand-rock		-
69	" 6	55	sand-rock		-
57	" 10	55	clay-gravel		-
38	" 10	64	mud-gravel		-
38	" 11	49	rock-boulder		-
39	" 11	48	rock-boulder		-
62	" 11	64	sand		-
*25-121	" 11	55	gravel		-
121	" 11	44	gravel		-
121	" 11	38	bedrock-rock		-
135	" 11	42	gravel		-
*26-121	" 11	49	gravel		-
135	" 11	38	gravel		-
136	" 11	49	gravel		-
28	" 11	51	sand		-
29	" 11	55	sand		-
30	" 11	59	sand		-
31	" 11	51	gravel		-
32	" 11	48	gravel		-
142	" 14	35-37	bedrock		-
142	" 14	37	bedrock		-
57	" 14	51	rock-boulder	+	
66	" 14	59	sand	+	
64	" 14	59	rock-boulder		-
64	" 14	59	rock-boulder		-
40	" 14	48	rock-boulder		-
62	" 14	59	gravel		-
63	" 14	57	clay-gravel		-
64	" 14	53	bedrock-rock-boulder	+	
* 64	" 14	53	rock-boulder	+	
* 64	" 14	55	rock-boulder	+	
65	" 14	48	gravel		-
108	" 14	56	sand-gravel		-
99	" 14	58	sand-gravel		-
68	" 14	55	sand-rock	+	
67	" 14	66	clay-rock		-

Table 4. cont.

Station	Date	Depth (meters)	Type of substrate	Eggs +	Eggs -
*67-64	" 14	58	clay-rock	+	
56	" 14	53	rock-boulder	+	
135	" 14	56	gravel-rock		-
63	" 21	57	gravel		-
57	" 21	55	gravel		-
56	" 21	55	gravel		-
55	" 21	53	gravel-rock		-
68	" 21	55	sand		-
67	" 21	62	sand		-
64	" 21	51	gravel		-
64	" 21	50	gravel		-
64	" 21	51	gravel		-
64	" 21	51	gravel		-
64	" 21	50	gravel		-

On October 14, we obtained our first sample of fertilized eggs at station 57. We continued dredging at adjacent stations and collected samples of eggs from stations 66, 64, 68, and 56; water depth at these stations ranged from 53 to 59 meters. In addition, eggs were collected between stations 64 and 67, the water depth was approximately 58 meters. Eggs collected were in clumps, and the layers were never more than five mm thick (deep). The most eggs collected in a tow were approximately 500, A shipboard examination indicated that these eggs had been fertilized; cell cleavage was visible and in many cases the beginning of the formation of the larvae could be seen inside the egg. Bottom temperatures ranged from 7° to 8.5° C.

The eggs from our collections with the dredge were from substrate comprised of boulders, rocks and gravel. The bottom where fertilized eggs were obtained from the stomachs of cod was examined by the SCUBA team. Evidence of spawning was not found. It, too, was a rock-boulder substrate. SCUBA observations of the substrate and attached eggs were not possible at station 64 and immediate vicinity because of excessive depths.

Herring eggs were not found on the 75,000 m^2 of sea bed examined by the divers in the vicinity of Cape Ann. Substrate ranged from bedrock to rock to sand and mud; depth from 10 to 30 meters. Discussions with 12 fishermen fishing lobster traps along the shores of Cape Ann gave our research team the impression that herring spawning here had been a common phenomenon until about 1967. Since that time evidence of spawning, eggs attached to lobster fishing gear, was non-existent. Neither was there evidence of spawning during September and October of 1972.

Plankton tows for larval herring: Larval herring (yolk-sac and post yolk-sac) were first collected at three stations (42, 65 and 110) on September 27. These larvae were considered to be from the onset of spawning on Jeffreys (Table 5). On October 3 and 4, we collected larvae at all seventeen stations sampled (Figure 6). The length frequencies of larvae obtained on September 27 and October 3, 4, 18 and 21 are given in Table 5.

The number of larvae collected at each station, date of collection, mean length, range in length, volume of water filtered and the number of larvae per 1000 meters^3 of water strained are presented in Table 6.

The larvae collected ranged in length from 6 to 28 mm. Mean length ranged from 7 to 15 mm. Tows from September 27 to October 4 yielded only a few-yolk-sac larvae. By 9 mm the yolk-sac had been absorbed in almost 100 percent of the larvae. Larvae collected on October 18 and 21 ranged in length from 5 to 29 mm with means from 8 to 15 mm. As shown in Table 5, considerable numbers of larvae were obtained on October 18 and 21.

Table 5. Length frequencies and mean lengths of larvae obtained from Jeffreys Ledge during September and October.

Length (TL in mm)	September 27	October 3	October 4	October 18	October 21
5				11	1
6	1			214	12
7	2			267	244
8	2			179	198
9	2		1	139	18
10	--		--	133	15
11	4	16	2	124	9
12		40	8	93	5
13		35	9	18	2
14		7	4	19	--
15		6	4	23	--
16		1	--	8	1
17		3	1	5	2
18		2	1	8	1
19		3	--	13	1
20		--	1	18	1
21		--	--	18	2
22		--	1	7	--
23		3		5	--
24		1		1	1
25		--			2
26		--			--
27		--			--
28		1			--
29					1
30					
Mean	9	13	14	9	8

Table 6. Larval catch data for herring samples taken from Jeffreys Ledge in September and October 1972.

Station Number	Date	Number of larvae	Mean length	Range in length	Volume H_2O strained (m^3)	Number of larvae /1000m^3
110	27-9	6	8	6-11	348	17
42	27-9	3	9	8-11	436	7
65	27-9	2	10	9-11	532	4
66	3-10	8	12	11-17	327	24
56	3-10	19	13	12-19	364	52
38	3-10	41	12	11-16	189	217
40	3-10	18	15	11-24	377	48
54	3-10	16	15	12-19	573	28
68	3-10	10	13	11-15	393	25
105	3-10	6	13	12-28	491	12
142	3-10	27	14	11-22	735	37
63	4-10	4	13	9-17	446	9
26	18-10	120	10	5-22	341	352
133	18-10	63	9	6-16	357	176
13	18-10	385	9	5-23	430	895
138	18-10	192	10	5-24	411	467
7	18-10	129	7	5-23	290	445
8	18-10	72	10	6-23	337	214
137	18-10	56	10	6-22	342	164
13	18-10	159	10	6-22	319	498
10	18-10	62	12	7-23	549	113
9	18-10	65	10	7-21	338	192
63	21-10	44	8	6-13	321	137
57	21-10	108	8	6-25	320	338
56	21-10	161	8	5-17	265	608
55	21-10	16	9	7-19	320	50
68	21-10	2	15	8-21	180	11
67	21-10	26	7	6-24	466	56
64	21-10	153	8	6-21	274	558
142	21-10	6	13	7-29	264	23

The number of larvae/1000 m^3 of water was considerably higher for the samples taken during October 18 and 21 than those taken on September 27 and October 3 and 4 with the exception of station 38 on October 3. We assumed that the peak of spawning had subsided by October 20 and the grid shown in Figure 7 was designed.

Plankton tows on all the stations of the eight tracts were completed in eight days (October 22-29, 1972). The length frequencies, range in lengths and mean lengths during this period are shown in Table 7.

The date of collection, number of larvae, mean length, range in length, volume of water filtered, and the number of larvae per 1000 m^3 of water strained are shown for each station in Table 8.

Table 7. Larval catch data (combined) for herring obtained from Jeffreys Ledge and adjacent waters during October 1972.

Length (TL in mm)	Length frequencies of larval herring sampled between 22 and 29 October				
	22	25	26	27	29
5	--	1	1	8	--
6	7	18	6	185	14
7	63	49	43	624	292
8	68	42	75	154	168
9	15	6	33	51	23
10	16	11	13	40	24
11	22	3	8	25	19
12	21	4	11	16	7
13	32	5	12	8	7
14	11	3	15	22	4
15	11	1	11	18	11
16	3	1	6	21	13
17	2	--	7	6	3
18	2	1	4	4	4
19	3	--	3	3	3
20	--	3	--	2	2
21	2	1	--	2	2
22	4	1	--	3	1
23		1	1	1	--
24		1	1	2	1
25				--	
26				1	
27				--	
28				3	
29					
30					
X	10	9	10	8	8

The range in mean length of larvae collected from the stations was 7 to 24 mm; the range in length was 5 to 28 mm. The range in length of their mean for each date of sampling was 8 to 10 mm. As previously stated, by 9 mm the yolk-sac had been absorbed in the majority of larvae. If we use only larvae collected with a range in length of 5 to 8 mm, the percentages of yolk-sac specimens collected on each of the sampling days for October 22, 25, 26, 27 and 29 were 48.9, 72.4, 50.0, 81.0 and 79.2, respectively.

The distribution and relative abundance of the larvae are shown in Figure 7. Reference to Figure 7 and to Table 8 show that very few larvae were obtained east of longitude 70°08'. In addition, relatively few larvae were obtained at stations F1-F3. The majority of the larvae were collected west of longitude 70°08' and between latitudes 42°30' and 42°52'. Specimens collected at stations between the following coordinates: northern - 42°51'; eastern - 42°47'; southern - 42°38' and western - 42°51' and bounded by 70°10' and 70°22' had a mean length of 7 to 8 mm (except at the center point on 29 October when the mean length was 12 mm).

Table 8. Larval catch data by sampling station for herring collected on Jeffreys Ledge in October, 1972.

Station no.	Date	Number of larvae	Mean length (TL in mm)	Range in length	Volume H_2O /m^3	No. of larvae /1000 m^3
A1	22-10	61	14	9-22	443	138
A2	22-10	43	11	8-16	325	132
A3	22-10	15	12	7-22	1089	14
A4	22-10	46	8	6-15	288	160
A5	22-10	10	7	6-8	493	20
Center Pt.	22-10	51	8	6-13	417	122
B4	22-10	0	--	--	468	0
B3	22-10	12	8	7-11	327	37
B2	22-10	24	9	6-21	342	70
B1	22-10	20	9	7-14	447	45
Center Pt.	25-10	73	7	5-13	288	253
C5	25-10	29	9	6-14	1075	27
C4	25-10	42	9	7-16	943	46
C3	25-10	0	--	--	1033	0
C2	25-10	0	--	--	740	0
C1	25-10	0	--	--	764	0
D1	25-10	0	--	--	770	0
D2	25-10	0	--	--	1265	0
D3	25-10	1	18	18	1021	1
D4	25-10	6	21	20-23	981	6
D5	25-10	1	24	24	792	1
Center Pt.	26-10	60	8	6-19	307	195
H5	26-10	35	10	7-18	362	97
H4	26-10	41	12	5-19	772	53
H3	26-10	39	10	7-23	713	55
H2	26-10	17	11	7-17	975	17
H1	26-10	58	10	7-24	568	102
Center Pt.	27-10	170	8	6-20	342	497
G5	27-10	474	8	5-28	299	1585
G4	27-10	99	9	6-28	349	284
G3	27-10	17	14	9-22	790	22
G2	27-10	27	13	8-18	541	50
G1	27-10	13	13	8-24	353	37
F1	27-10	4	20	18-21	1040	4
F2	27-10	0	--	--	747	0
F3	27-10	4	12	9-14	627	6
F4	27-10	209	7	5-16	284	736
Center Pt.	27-10	177	8	6-24	425	416
D5	27-10	6	7	6-7	412	15
Center Pt.	29-10	97	12	6-22	454	214
E6	29-10	486	8	6-16	237	2051
E5	29-10	6	9	7-15	345	17
E4	29-10	5	19	11-24	534	9
E3	29-10	1	18	18	725	1
E2	29-10	1	20	20	814	1
E1	29-10	2	13	12-14	735	3

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The percentage of the length frequency distributions of the larvae collected at each station are shown in Tables 9 and 10. The lengths have been combined into four millimeter groupings.

Table 9. Percentage occurrence of lengths (4 mm groupings) of larval herring from Jeffreys Ledge, September 27, October 3, 4, 18 and 21, 1972.

Date	Station number	Total no. of larvae	Percentage of Length Groups						
			5-8	9-12	13-16	17-20	21-24	25-28	29-32
27/9	110	6	67	33					
27/9	42	3	33	67					
27/9	65	2	--	100					
3/10	66	8	--	50	38	12			
3/10	56	19	--	53	42	5			
3/10	38	41	--	61	39	--			
3/10	40	18	--	33	44	--	23		
3/10	54	16	--	25	38	37	--		
3/10	68	10	--	40	60	--	--		
3/10	105	6	--	50	33	--	--	17	
3/10	142	27	--	37	52	7	4	--	
4/10	63	4	--	25	50	25	--	--	
18/10	26	120	50	36	5	7	2	--	
18/10	133	63	40	55	5	--	--	--	
18/10	13	385	64	24	8	3	1	--	
18/10	138	192	47	40	5	6	2	--	
18/10	7	129	86	11	1	1	1	--	
18/10	8	72	46	41	11	1	1	--	
18/10	137	56	23	64	9	--	4	--	
18/10	12	159	37	54	2	4	3	--	
18/10	10	62	23	58	5	3	11	--	
18/10	9	65	28	63	5	3	1	--	
21/10	63	44	82	16	2	--	--	--	
21/10	57	108	86	12	--	--	--	2	
21/10	56	161	89	9	1	1	--		
21/10	55	16	88	6	--	6	--		
21/10	68	2	50	--	--	--	50		
21/10	67	26	96	--	--	--	4		
21/10	64	153	90	8	--	1	1		
21/10	142	6	66	--	17				17

Table 10. Percentage occurrence of lengths (4 mm groupings) of larval herring from Jeffreys Ledge, October 22, 25, 26, 27 and 29, 1972. (C.P. equals Center Point)

Date	Station Number	Total no. of larvae	Percentage of length groups 5-8	9-12	13-16	17-20	21-24	25-28
22/10	A1	61		30	55	12	3	
22/10	A2	43	12	53	35	--	--	
22/10	A3	15	13	54	13	--	20	
22/10	A4	46	78	15	7	--	--	
22/10	A5	10	100	--	--	--	--	
22/10	C.P.	51	88	10	2	--	--	
22/10	B3	12	92	8	--	--	--	
22/10	B2	24	75	21	--	4	--	
22/10	B1	20	55	35	10	--	--	
25/10	C.P.	73	85	12	3	--	--	
25/10	C6	29	52	31	17	--	--	
25/10	C5	42	79	14	7	--	--	
25/10	D3	1	--	--	--	100	--	
25/10	D4	2	--	--	--	50	50	
25/10	D5	1	--	--	--	--	100	
26/10	C.P.	60	82	8	5	5	--	
26/10	H5	35	46	40	11	3	--	
26/10	H4	41	24	32	32	12	--	
26/10	H3	39	43	28	26	3	--	
26/10	H2	17	53	6	35	6	--	
26/10	H1	58	41	36	14	7	2	
27/10	C.P.	170	83	9	6	2	--	
27/10	G5	474	88	7	2	1	1	1
27/10	G4	99	66	23	10	--	--	1
27/10	G3	16	--	38	44	12	6	
27/10	G2	27	4	41	44	11	--	
27/10	G1	13	16	38	38	--	8	
27/10	F1	4	--	--	--	75	25	
27/10	F3	4	--	50	50	--	--	
27/10	F4	209	94	4	2	--	--	
27/10	C.P.	177	78	15	4	1	2	
27/10	D5	6	100	--	--	--	--	
29/10	C.P.	97	11	48	30	9	2	
29/10	E6	486	94	5	1	--	--	
29/10	E5	6	66	17	17	--	--	
29/10	E4	5		20	--	20	60	
29/10	E3	1		--	--	100	--	
29/10	E2	1		--	--		100	
29/10	E1	2		50	50			

DISCUSSION

In recent years, the fishing industry of the United States has intensified its efforts to harvest the Atlantic sea herring. At the same time, other nations of the world have come to the waters of the Northwest Atlantic with the same goal in mind. The herring is important commercially as food for humans and lower animals, lobster bait, fish meal, pearl essence and oil extract. The average total tonnage (mostly adults) landed from Georges Bank for 1968 through 1971 was 257,000 metric tons. In the Gulf of Maine the average tonnage landed (adults) was 42,000 metric tons.

Fishermen from the United States have been concerned with increasing their catches of juvenile herring and fishermen from other nations with increasing their catches of adult herring. Within the last five years there has been a concerted effort by a segment of the U.S. fishermen to also harvest adult herring. An area which they have fished extensively is Jeffreys Ledge. Vessels from other nations are now also fishing this area.

In 1972 approximately 9,026 metric tons of herring (primarily adults) were obtained by U.S. fishermen from Jeffreys Ledge and contiguous waters. The tonnage obtained by other vessels from this area is not yet documented for 1972. The results of our studies as well as those of Graham, Chenoweth and Davis (1972) and the "Working group on joint survey of larval herring in the Georges Bank-Gulf of Maine area (ICNAF Subareas 4X, 5Y and 5Z)" (1972) indicate that the stock of herring from Jeffreys Ledge makes a substantial contribution to the fishery for herring in the inshore waters of parts of the Gulf of Maine. Additional proof is that although there is no documentation of a large juvenile fishery on Jeffreys, herring spawn in these waters.

The fall, 1972 investigation on Jeffreys Ledge was a preliminary study of the spawning and early life history of the herring. The spawning area including substrate type and physical characteristics of the water mass, time of spawning and dispersal of the larvae was documented. In-situ observations on spawning, predation on the eggs, and hatching were not possible because of the depth limitations on the SCUBA team.

Mortality processes acting on this early life history stage, as investigated by Noskov and Zinkevich on Georges Bank (1967), may effect recruitment levels through (1) over-thickness (layer depth) of eggs on a specific bed with suffocation of the bottom layer of eggs (2) predation of the eggs, (3) unsuitable substrate for egg adhesion (4) unfavorable physical and chemical conditions of the water mass, (5) disturbance of the egg bed through fishing operations (i.e. - trawling) and (6) low number of viable eggs due to insufficient sperm cover. Direct measurements on these factors via diver/scientists is planned for the fall of 1973, using a diver lock-out vehicle.

Trawl collections of pre-spawning, spawning and post-spawning herring indicated that the 1967, 1968 and 1969 year classes were dominant in the samples. Of these, the majority of fish from the 1969 year class would not spawn until 1973. Fish of age-groups IV to VIII+ spawned at least at two sites on Jeffreys. The site where the majority of the fish congregated was at approximately 42°46.0'; 70°11.0'. The second spawning site was at approximately 42°40.0'; 72°25.0'. Although it has been proposed that herring school according to size, our catches indicated that

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herring of varying sizes of an age-group and several age-groups were mixed. There was no indication that older fish or the large fish of an age-group spawn first, move off the spawning ground, and are replaced by the smaller fish of the age-groups as reported by Boyar (1968) for Georges Bank.

Larval catches indicate that the onset of spawning on Jeffreys, occurred in early September. The peak of spawning occurred during the first three weeks of October; the majority of the fish had dropped their eggs by October 20. Newly hatched larvae, 6-8 mm long, were relatively abundant on October 18, suggesting that spawning had occurred one to two weeks earlier. Our results are similar to those of Graham and Chenoweth (1973) who reported that on Georges Bank the bulk of spawning is completed in approximately ten days.

The herring on Jeffreys spawned in waters of 53-59 meters. The temperature of the bottom during spawning ranged between 7° C to 8.5° C. In the ten dredge-sets in which eggs were obtained the bottom was primarily a gravel-rock-boulder substrate. Eggs were, however, found on a few sand-rock and clay-rock substrates. The fact that we did not obtain eggs at many stations does not imply that they were not there. We may have actually dredged a short distance from a bed. In addition, we question the efficiency of the Naturalist Dredge to adequately sample egg beds. Martin (1962) used SCUBA techniques in a survey of herring spawning in the Bay of Chaleur and found eggs attached to seaweeds and fishing gear, but not on bare sand, gravel or rock. Graham and Chenoweth (1973) obtained eggs from gravel- rock-boulder substrate on Georges Bank in the autumn of 1970. Tibbo, Scarratt and McMullon (1963) used SCUBA techniques to survey a herring spawning bed near Blanchard Point, Chaleur Bay, New Brunswick, Canada. They reported that the substrate where eggs were deposited consisted of small stones and gravel with large masses of redstone. In addition the area had a dense cover of vegetation. In contrast, McKenzie (1964) sampled a spawning bed off southwest Nova Scotia (district of Black Point) and found that the substrate was primarily sand with some gravel and was completely devoid of vegetation. Bowers (1969) studied the spawning beds of Manx autumn herring and reported that the substrate was gravel-rock. It appears that herring in different parts of the Atlantic Ocean spawn over various types of substrate, but in most cases a gravel-rock bottom is preferred.

The presence of yolk-sac larvae in close proximity to the center of fishing activity (purse seiners) and close to the area where eggs were obtained from the stomachs of codfish taken by commercial fishermen add credence to the conclusion that there were at least two spawning sites on Jeffreys. The length frequencies and mean lengths of larvae obtained prior to October 10 further indicate that the onset of spawning occurred in September. The large larvae (20-28 mm) obtained on Jeffreys prior to the peak of spawning may have come from waters other than Jeffreys. These larvae could have drifted down from either St. Mary's Bay, Nova Scotia where spring spawning occurs (Tibbo, 1968) or from eastern Gulf of Maine where the onset of spawning occurs earlier than in the western Gulf of Maine (Graham, Chenoweth and Davis, 1972).

Immediately after the peak of spawning, we began sampling the larval herring sampling stations described above. The mean lengths of larvae on each transect increased with increasing distance from the spawning bed. Only on transects A and H did the number of larvae increase with increasing distance from the egg bed. There is a definite indication that the majority of the larvae are transported inshore by the current.

We hypothesize that Jeffreys Ledge is a major source of herring larvae for the coastal waters of the western Gulf of Maine. These larvae probably are a major contributor to the larvae found during the spring in the western sector of the coast of Maine. The larvae would appear to move with the currents that are directed shoreward in the spring in compensation for river outflows.

In general, it appears that the progeny of the herring that spawn on Jeffreys Ledge contribute to the population of larvae found along the coastal waters of the western Gulf of Maine. These larvae eventually grow to become juvenile herring exploited by coastal fishermen. The relative importance of spawning on Jeffreys to their progeny of juvenile herring in the coastal waters is still unknown, as well as the contribution of these juveniles to the future adult fishery.

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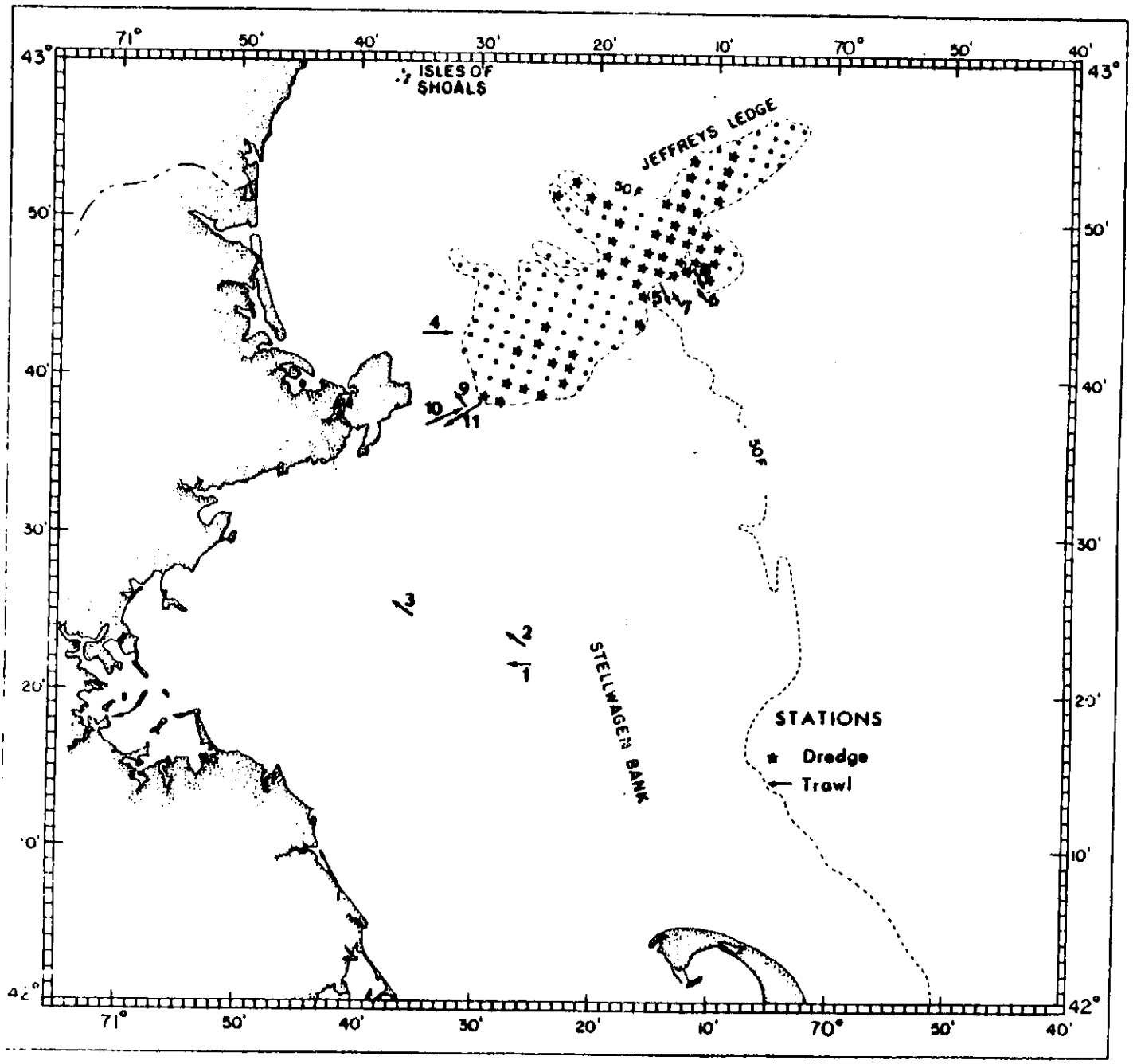

Figure 1. Sampling grid and actual dredge and trawl stations for Jeffreys Ledge and Stellwagen Bank, autumn, 1972.

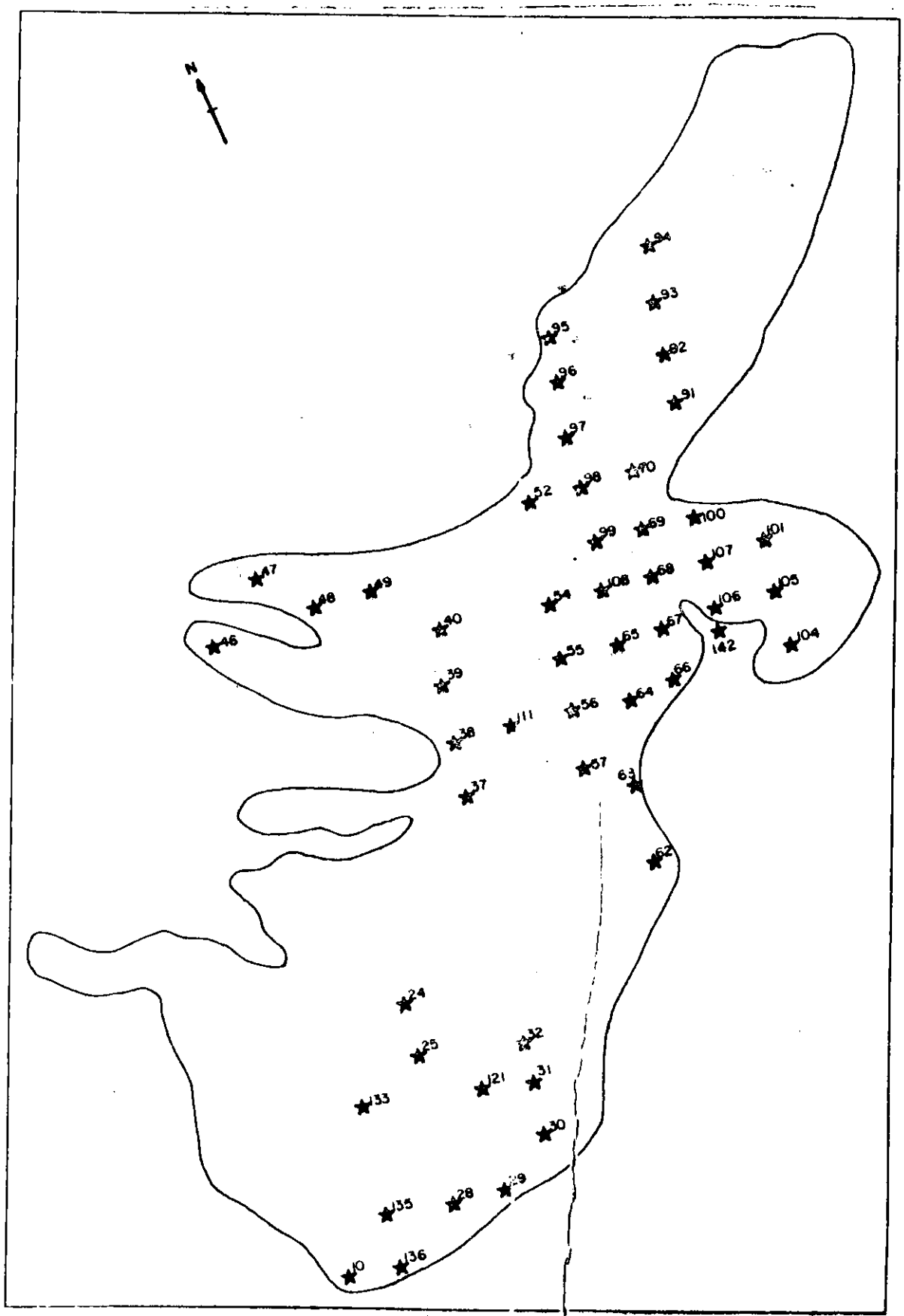

Figure 2. Location of dredge stations on Jeffreys Ledge, autumn, 1972.

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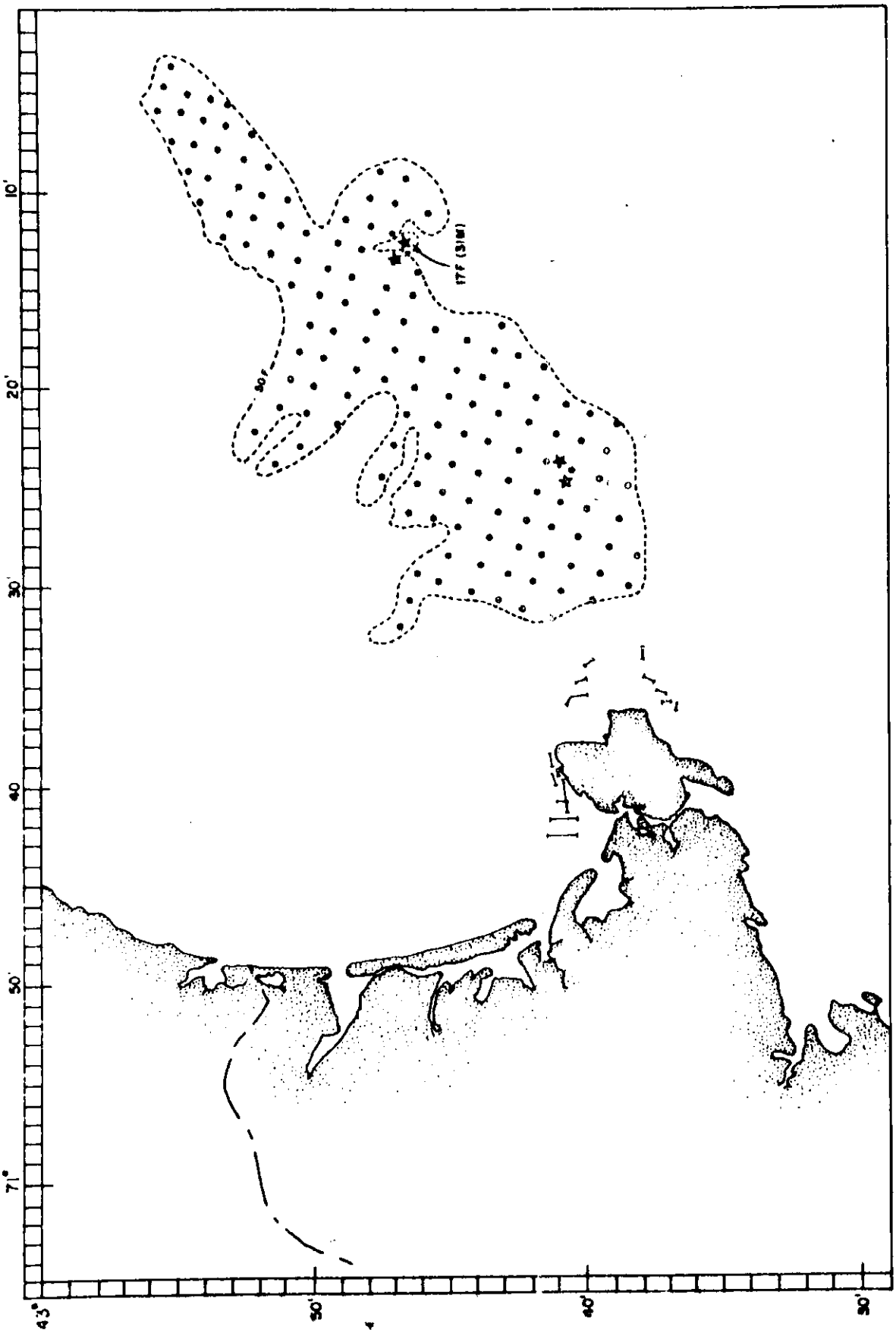

Figure 3. Location of dive sites by SCUBA, autumn, 1972.

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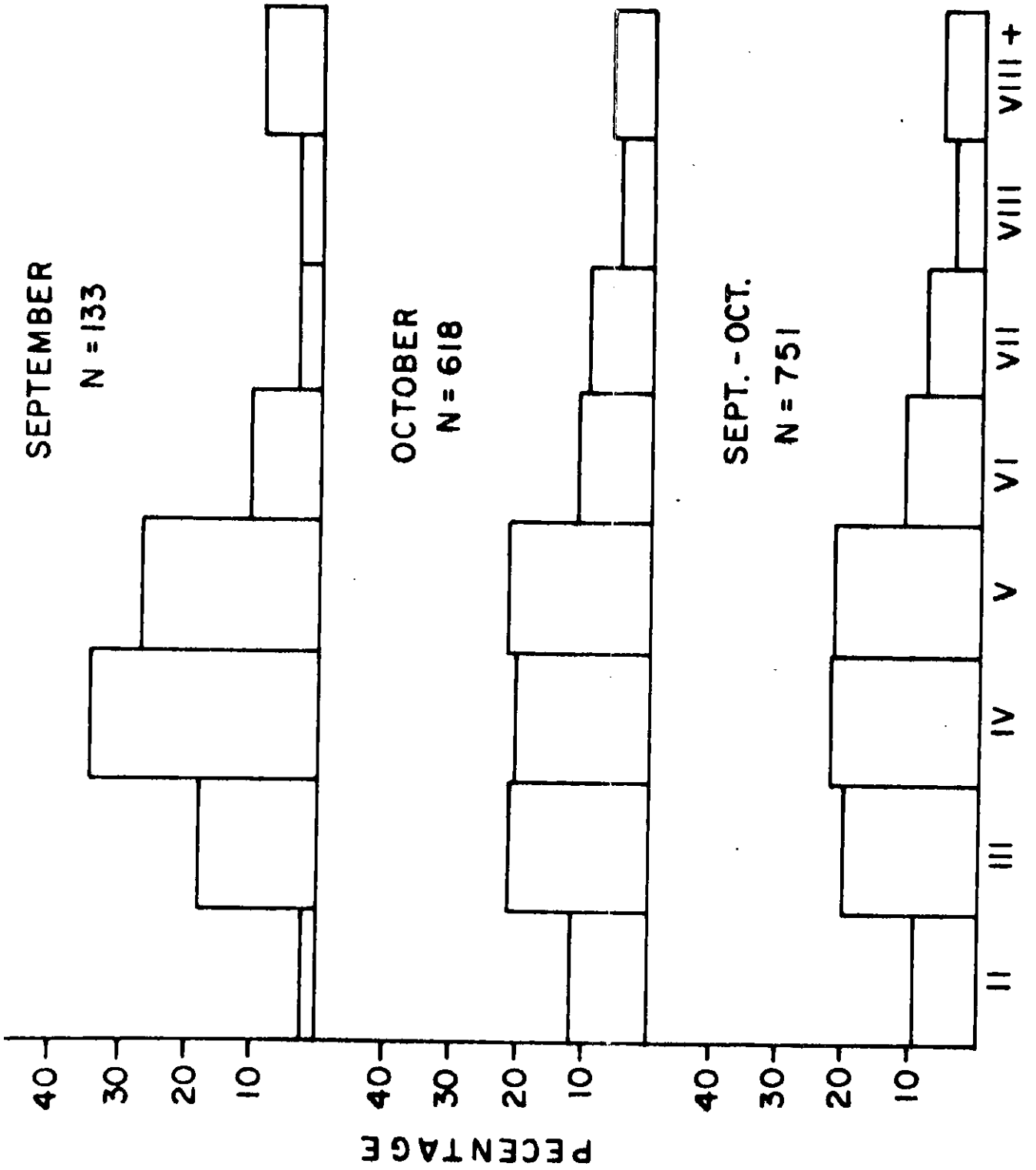

Figure 4. Age composition of herring from Jeffreys Ledge, September and October, 1972. N equals total number of fish sampled.

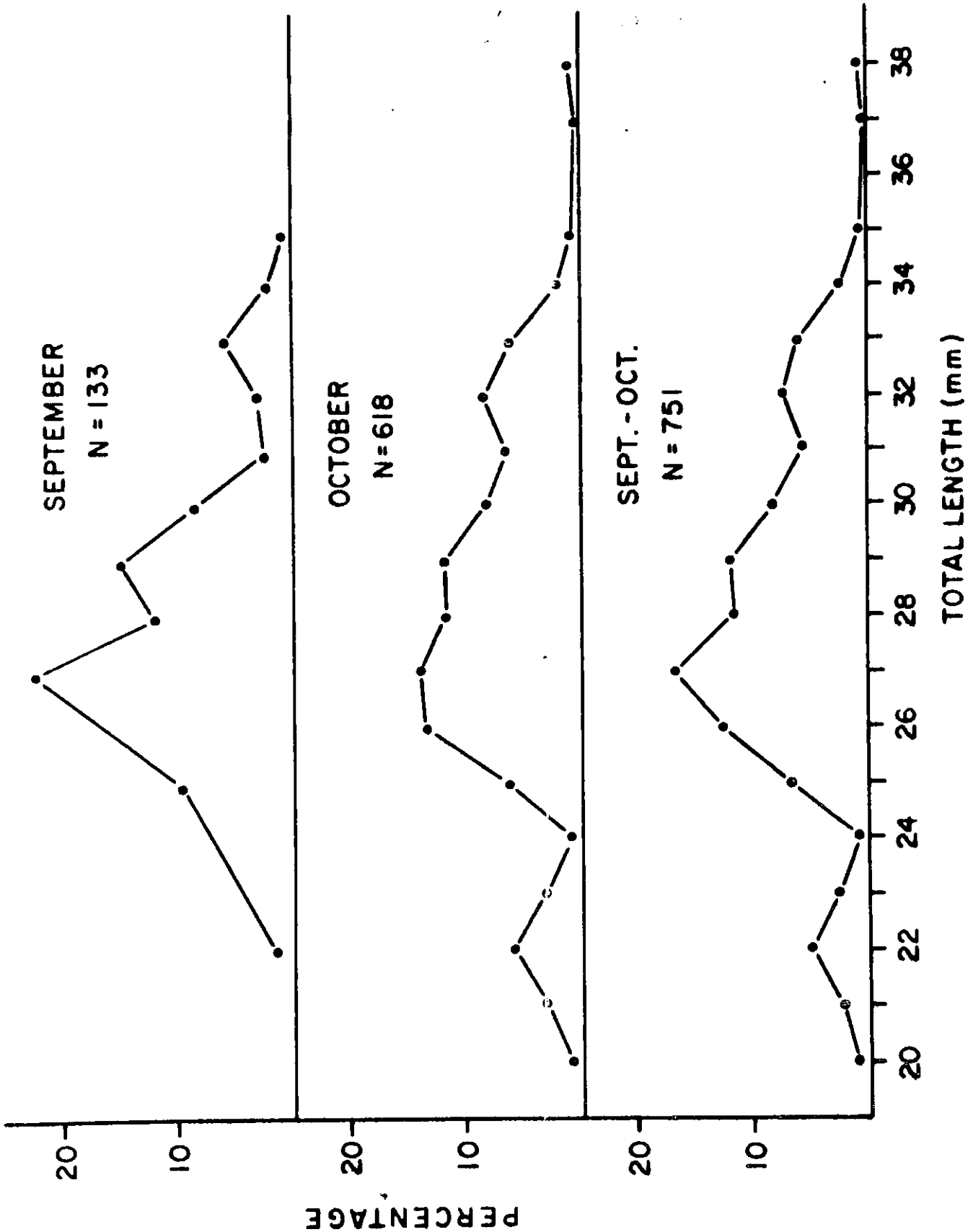

Figure 5. Length frequency and distribution of herring from Jeffreys Ledge, September and October, 1972. N equals number of fish sampled.

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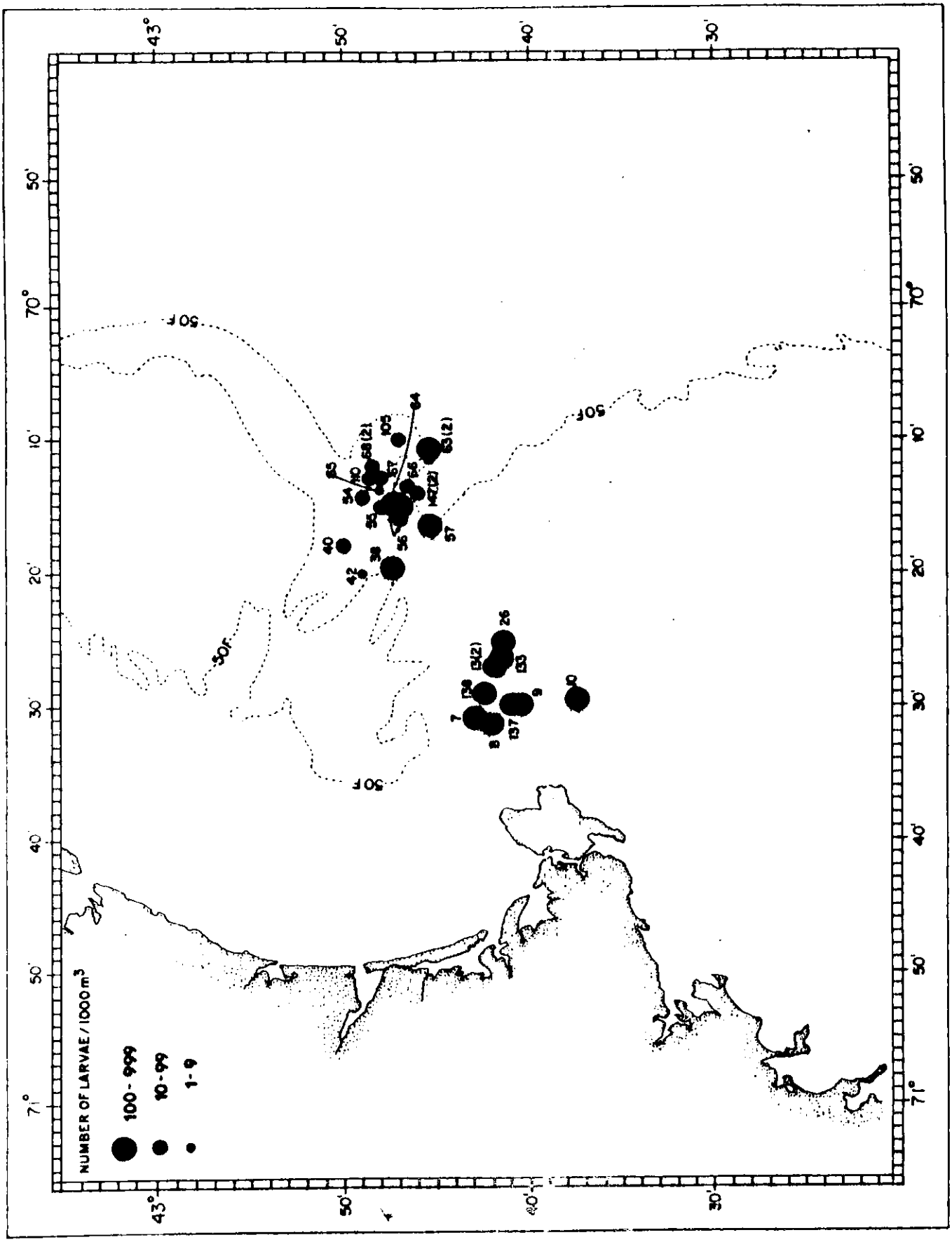

Figure 6. Distribution and abundance of larval herring from Jeffreys Ledge, September 27 to October 3-21, 1972.

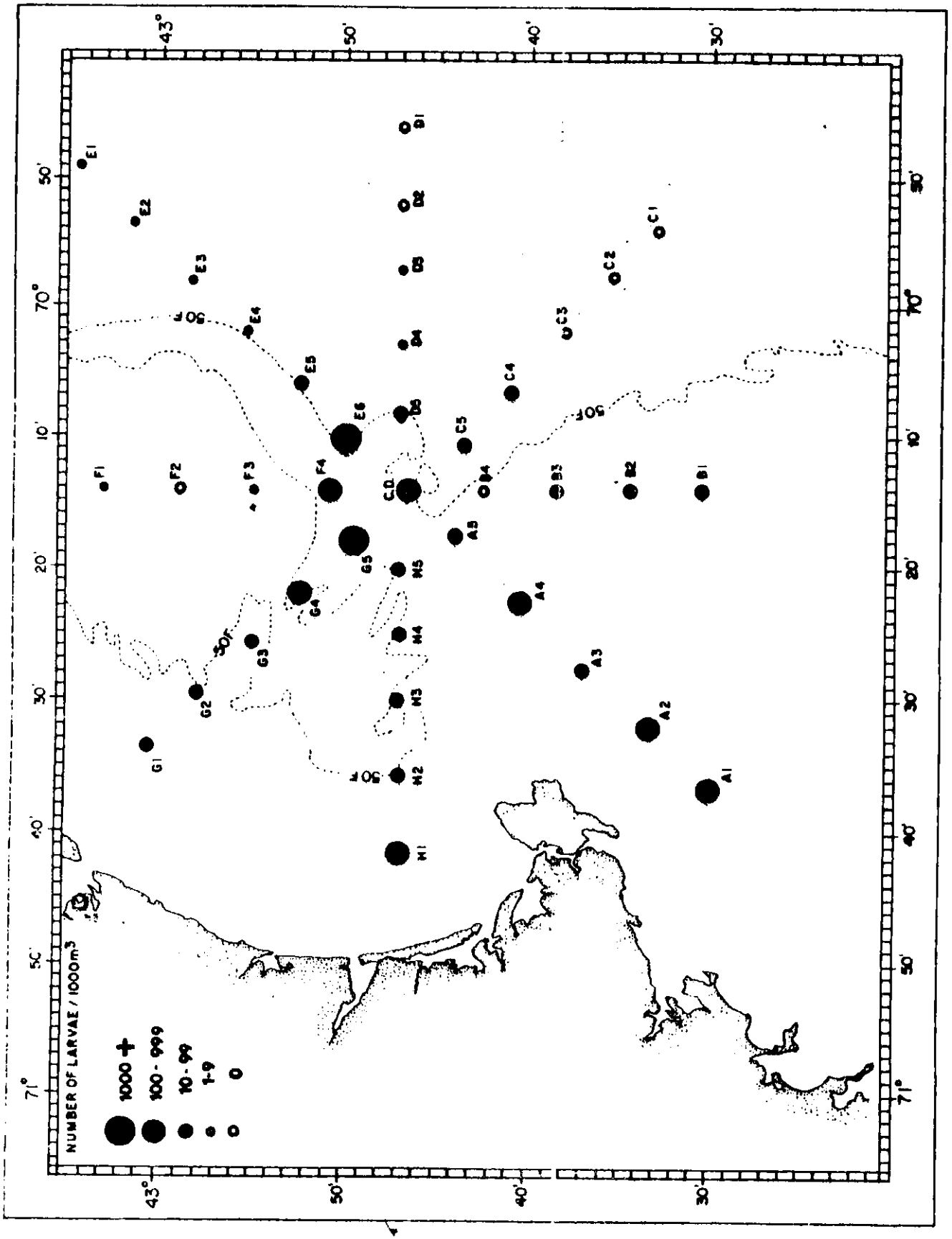

Figure 7. Distribution and abundance of larval herring from Jeffreys Ledge and adjacent waters, October, 1972.