Herring Spawning Bed Survey in Fisherman's Bank, P.E.I. in fall 1985

by

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ABSTRACT

Herring spawning beds in Fisherman's Bank, P.E.I., were surveyed by SCUBA divers in fall 1985. Five spawning beds were found in depths between 15 to 25 meters. The spawning beds covered an area of 1,820,300 m^2. Intensity of egg deposition ranged from 4,714 eggs/m^2 to 7.9 X 10^6 eggs/m^2. Mass mortalities of herring eggs in areas of heavy egg deposition (up to 30 layers of eggs) were observed. Fish preying on herring eggs included winter flounder, Atlantic cod, Atlantic mackerel, pollock and cunners. The herring spawning biomass in Fisherman's Bank was estimated as 28,530 mt. Based on herring catch of 4,500 mt taken from the Fisherman's Bank fishery during the spawning season, the exploitation rate is estimated as 13.6%.

RESUME

Les frayères de harengs du banc Fisherman (Ile-du-Prince-Edouard) ont été examinées par des plongeurs autonomes en automne 1985. On a trouvé cinq frayères à des profondeurs variant de 15 à 25 m. Elles couvrent une superficie de 1 820 300 m^2. Les dépôts d'oeufs varient en intensité de 4 714 oeufs/m^2 à 7,9 x 10^6 oeufs/m^2. On a pu observer une mortalité en masse du frai de hareng dans des lieux de dépôt à forte concentration (jusqu'à 30 couches d'oeufs). Les poissons prédateurs comprenaient la plie rouge, la morue, le maquereau bleu, la goberge et le tanche-toutogue. La biomasse du frai de hareng du banc Fisherman a été estimée à 28 530 mt. En se fondant sur des prises de hareng de 4 500 mt capturées par les entreprises pêchant sur ce banc, au cours de la saison de frai, on estime que le taux d'exploitation s'établit à 13,6 %.

INTRODUCTION

The herring spawning bed survey in Fisherman's Bank, PEI was initated in fall 1985. The choice of Fisherman's Bank as a site for the fall-spawning herring survey was made for three reasons: (1) no information on spawning of fall-spawning herring population in the Gulf of St. Lawrence is available; (2) the Fisherman's Bank herring population has gained an increasing importance in the last few years as a major stock in the Gulf; (3) following the problems raised by local fishermen in Escuminac in spring 1985, the spawning bed survey in Miramichi Bay was discontinued.

Herring spawning bed surveys in the Gulf were conducted since 1981 to study the spawning conditions of herring and to provide independent estimates of the spawning biomass and exploitation rates. These surveys achieved their objectives insofar as the provision of estimates of egg intensity, egg mortalities and predation, stock biomass, and exploitation rates. However, the data collection comprised only 3 years of observation (1981, 1983 and 1984) and, therefore, these data are of limited use in monitoring the trends in herring abundance.

In the present report, the results of the Fisherman's Bank herring spawning bed survey are presented. As in the spring spawning surveys, the purpose of this survey was to collect information on spawning conditions, locate the spawning beds, estimate the intensity of egg deposition, and estimate of spawning stock biomass.

MATERIALS AND METHODS

Search Area and Procedure

The search area for herring spawning beds was conducted in Fisherman's Bank (N 46 0100; W 62 1600), southeast Prince Edward Island (Figure 1). Based on information from local fishermen, the herring stock in this area does not spawn outside the Bank. Herring are caught on the Bank by fishermen, mostly from Kings Co., P.E.I. and Pictou, N.S., using drift-nets. About 50 boats were engaged in this fishery in fall 1985. The Fisherman's Bank covers an area approximately 6 km^2 (Figure 2). It is located about 10 km offshore Murray Harbour, southeast PEI. The substrate of Fisherman's Bank is mostly flat ranging from 10 m to 25 m depth, and composed of bedrock with cobble.

Four SCUBA divers were engaged in the spawning bed survey. Search procedure was similar to that of previous surveys (Messieh et al. 1985a). A small 40 ft. fishing boat was chartered for use as a diving platform. Searches for herring by SCUBA divers covered the entire area of the Bank (Figure 1) from end of August until end of September. Special concentration of diving effort was given to the locations of commercial fishing, where herring fishermen have located herring schools by SONAR. A standard search grid with 200 m squares was plotted on a hydrographic field sheet of the study area, and LORAN C bearings were determined for each position of the search grid. Occasionally, a finer search grid (100 m squares) and a coarser search grid (400 m squares) were used. Divers located and mapped the perimeters of each spawning bed with buoys and their positions were determined with LORAN C.

Quadrat Sample Collection and Analysis

A sampling grid was plotted on each spawning bed found, with stations about 200 m apart. Some stations were taken outside the bed as a check on the accuracy of boundary determination. At each station the diver collected a quadrat sample (0.25 m^2) of the herring deposit, using an airlift operated by compressed air from the diver's tank. The airlift propelled loose material and eggs scrapped from the substrate into special bags. In case of heavy egg deposition, the airlift was not used, and the samples were cut out of the egg sheet within the quadrat. Sample bags were labelled and placed in 5% formalin for laboratory examination. Some fresh egg batch samples were incubated in a recirculated sea water system for further observation of their development. Counting of eggs was estimated from dried samples. Eggs were thoroughly cleaned from gravel and then placed in an oven (60°C) to dry for about 16 h to a constant weight. Subsamples of about 1000 eggs were weighed, accurately counted, and estimates of total number of eggs per quadrat were made. Two to three counts were usually taken for validation, and differences in egg counts did not exceed 1%. Egg density deposition was expressed as number of eggs per m^2.

Predation on Herring Eggs

Counts of benthic fish predators within visual range of the diver were made along 300-400 m transect lines randomly positioned on the spawning bed. Samples of demersal fish, e.g. winter flounder (Pseudopleuronectes americanus) and cunner (Tautogolabrus adspersus) were collected by hand spear and saved for stomach analysis. Samples of Atlantic mackerel (Scomber scombrus), Atlantic cod (Gadus morhua), and pollock (Pollachius virens) were caught by hand line. The number of herring eggs per fish stomach was counted after separation from other gut contents.

RESULTS

Two of the spawning beds were found in 10-15 m depth contours. The other 3 spawning beds were found in 20-25 m depth contours. The visibility was good (5-6 m), with currents occasionally swift. Water temperatures ranged between 15.0°C-19.5°C and 15.1°C-17.0°C for surface and bottom waters respectively.

The 1st spawning bed (Bed I; Figure 2) was located at the west shoal of the Fisherman's Bank on September 6. The spawning bed area was 286,000 m^2. The intensity of egg deposition was heavy in most parts of the spawning bed. Egg deposition formed a thick carpet over an area of about 200 x 500 m. This area frequently reached thicknesses of 20-30 layers of eggs (about 4.5 cm thick). Much of the egg mass on this spawning bed was covered with fungi, and some eggs were in deteriorating condition. Microscopic examination of egg samples taken from various layers showed that most of the eggs were fertilized. Incubated egg batch samples showed embryos in various developmental stages.

The 2nd spawning bed (Bed II) was located about 500 m east of the 1st spawning bed on September 9. Eggs were deposited in 10-15 m depth. Intensity of egg deposition was less than the 1st spawning bed (0.24×10^6 eggs/m^2 compared to 2.59×10^6 eggs/m^2) (Table 1). The area of this spawning bed was 488,800 m^2.

The 3rd spawning bed (Bed III) was found about 1 km southeast of the 2nd spawning bed in a depth of about 20 m, on September 13. Spawning was light, with eggs spread sporadically over the spawning bed. Intensity of egg deposition ranged from 1000-10,000 eggs/m^2, with an average of 4,714 eggs/m^2 (Table 1).

The 4th and 5th spawning beds (Bed IV and V) were found on September 18, on both sides of the original sight of the 3rd spawning bed, overlapping part of the old spawning bed. By that time, all eggs from the old spawning bed were hatched. Intensity of egg deposition on spawning bed IV was 7.94×10^6 eggs/m^2, which was highest of all spawning beds. Intensity of egg deposition on spawning bed V was next highest (2.83×10^6 eggs/m^2).

Information on sample location, date and estimates of number of eggs/m^2 at each station are presented in Appendix I.

Predation on Herring Eggs

Examination of stomach contents of fish species collected during this survey, showed that winter flounder and mackeral were the major predators of herring eggs. Mean number of herring eggs per stomach was 7,640 $\pm$ 1,190 and 3,920 $\pm$ 1,230 for the two species respectively.

Mean abundance of winter flounder was 0.10 $\pm$ 0.02 fish/m^2. All flounder were collected in daylight and the mean number of herring eggs per stomach was considered to be representative of the daily mean egg consumption, given that winter flounder appear to be visually oriented predators (Olla et al. 1969). Estimated loss of herring eggs due to predation by winter flounder was 44.63 $\pm$ 6.35 mt. Estimate of herring egg loss due to predation by other predators was not possible.

Estimates of Spawning Herring Population Numbers and Biomass

Biological data relevant to calculation of spawning biomass are presented in Table 2. Length frequency distribution of herring samples during the spawning survey is shown in Figure 3. Spawning biomass expressed as wet weight of fish in metric tons was estimated at 28,530 mt (Table 2). Based on herring catch of 4,500 mt, the exploitation rate was estimated as 13.6%.

DISCUSSION

This was the first time an *in situ* spawning bed survey for fall spawning herring was carried out in Canadian waters. Spawning bed surveys of the spring-spawning herring were previously carried out in Miramichi Bay (Messieh

et al. 1985a) and in Chaleur Bay (Tibbo et al. 1963). The only other in situ fall-spawning herring bed survey in northwest Atlantic was conducted in Georges Bank in September 1970 using a submersible (Caddy and Iles 1973). Observations were made from a 2-man submersible on egg deposition, type of substrate and associated fauna on the spawning ground. However, the observations made from the submersible did not allow determination of the size and extent of spawning area and, therefore, no estimate of spawning biomass was made. McKenzie (1964) surveyed a herring spawning bed in Trinity Ledge, southwest Nova Scotia, and used a grab sampler from aboard a small vessel to collect herring egg samples from one of the spawning beds. He provided a rough estimate of the population size based on that spawning bed, but did not survey other spawning beds in nearby areas.

The Fisherman's Bank spawning bed survey carried out in September 1985, allowed direct observations on fall-spawning herring activities, intensity of egg deposition, and estimation of spawning stock biomass. Figure 4 shows underwater photographs of one of the spawning beds with divers examining herring spawn. Herring spawn was found on substrate, mostly flat surface of bedrock with cobble. A sparse epifauna of sea anemone and bryozoa was observed. Algal cover was negligible and comprised mostly filamentous red algae (Polysiphonia Sp.). This is in contrast to the shallow spawning grounds observed in the spring-spawning herring spawning beds in Miramichi (Messieh et al. 1985a) where Irish moss (Chondrus sp.) and rockweed (Fucus Sp.) dominated the spawning substrate, and in Chaleur Bay (Tibbo et al. 1963) where seaweeds (Laminaria and Phyllophora Sp.) dominated the deeper areas of the spawning bed, and Chondrus Sp. and Fucus Sp. dominated the shallower areas of the spawning bed. Large areas of the Fisherman's Bank spawning grounds surveyed by divers were free of spawn although they appeared to be of substrate type similar to areas where spawning had occurred. This indicates that the availability of suitable spawning substrate may have not been a limiting factor in depositing eggs.

The lack of vegetation on the spawning beds in Fisherman's Bank could expose the herring eggs to a higher predation. Fish predators comprised groundfish such as Atlantic cod, winter flounder and cunner, and pelagic fish such as Atlantic mackerel and pollock. Stomach analysis showed that winter flounder and Atlantic mackerel are the major predators on herring eggs. As in the case of spring spawning, winter flounder were feeding heavily on herring eggs (7,640 eggs/stomach in this survey, compared to 6,480 eggs/stomach in the Miramichi spring spawning survey).

Mackerel stomachs were also full of herring eggs (3,920 eggs/stomach) showing that these pelagic fish were actively feeding on herring eggs deposited on the spawning bed. Divers observed mackerel schools swiftly swimming over the spawning bed, apparently stirring the spawn and loosening eggs from substrate. To our knowledge this is the first time to report predation of a pelagic species such as mackerel on benthos. Winters (1976) reported that mackerel feed on herring larvae in the southern Gulf, but did not consider herring eggs as potential prey for mackerel.

Fisherman's Bank spawning ground resembles that of Georges Bank as described by Caddy and Iles (1973). However, egg deposition was restricted to 10-25 m depth, whereas in Georges Bank spawning occurred in 50 m depth.

Water was well mixed on the Fisherman's Bank. This is in agreement with earlier observations of spawning conditions on Georges Bank. Drapeau (1973) suggested that high energy environments may serve two purposes: (1) the mixing of waters presents the settling of fine sediment on substrate and deposited eggs; and (2) the water circulation over the spawn removes the metabolites and supplies the necessary oxygen.

High egg mortalities observed on the spawning beds of Fisherman's Bank, particularly in the first spawning bed resulted from dense egg deposition (up to 30 layers of eggs) and lack of oxygen. Possible causes for spontaneous mass spawning, leading to heavy egg mortalities were discussed by Messieh and Rosenthal (1986). Egg mortalities in previous surveys in northwest Atlantic did not exceed 10% (Caddy and Iles (1973) for Georges Bank herring; Messieh et al. (1985b) for Escuminac herring). However, high egg mortalities for Atlantic herring are not unusual. Runnstrom (1941) reported egg mortalities as high as 40-80% for herring in the west coast of Germany.

Estimates of number of eggs laid and the spawning stock biomass on Fisherman's Bank showed a relatively large herring populaton in this area compared to Escuminac fishery. Estimated stock biomass (28,530 mt) is more than 10 folds of the Escuminac fishery in 1984 (Messieh et al. 1984). This estimate assumes a predation rate (30%) similar to that of the spring spawning herring in Escuminac. Actual predation rate in Fisherman's Bank was not possible to obtain due to the difficulty in estimating the predator abundance. Based on the reported catch of herring in 1985, the exploitation rate (13.6%) in Fisherman's Bank was less than the rate (20%) recommended by CAFSAC for Atlantic herring.

ACKNOWLEDGEMENTS

The spawning bed survey was conducted under a DSS contract by Murdock, Pottle and Macpherson, Marine Services, Halifax. Clarence Bourque helped in the initial dives and underwater photography.

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Table 1. Estimates of herring egg deposition and spawning biomass (mt) on Fisherman's Bank spawning ground.

Spawning Bed	Area (m^2)	Number of Quadrats	Mean No. of eggs/m^2 ($\pm$ 95% confidence limits)	Total No. of eggs ($\pm$ 95% confidence limits)
I	286,000	7	$2.59 \times 10^6 \pm 1.79 \times 10^6$	$7.42 \times 10^{11} \pm 5.12 \times 10^{11}$
II	488,800	13	$0.24 \times 10^6 \pm 0.25 \times 10^6$	$1.16 \times 10^{11} \pm 1.23 \times 10^{11}$
III	239,000	6	$4,714 \pm 3,473$	$1.13 \times 10^6 \pm 0.83 \times 10^6$
IV	247,000	26	$7.94 \times 10^6 \pm 1.75 \times 10^6$	$1.96 \times 10^{12} \pm 0.43 \times 10^{12}$
V	559,500	6	$2.83 \times 10^6 \pm 3.06 \times 10^6$	$1.58 \times 10^{12} \pm 1.71 \times 10^{12}$

Table 2. Biological data of fall-spawning herring in Fisherman's Bank, relevant to calculation of spawning biomass.

Age (yr)	Catch Composition %	Mean Length (cm)		Mean Weight (g)		Mean Fecundity (000)	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
3	1.8	280	4.6	196	9.2	80	8.2
4	14.3	295	1.3	235	3.4	95	3.5
5	41.5	312	0.9	293	3.5	118	6.1
6	17.1	328	1.4	352	7.3	130	5.2
7	11.1	342	1.1	387	8.4	145	8.5
8	8.3	349	2.8	395	8.9	160	7.1
9	2.8	363	5.8	375	35.0	195	7.2
10	3.2	362	2.7	422	23.2	210	9.1

Estimated total egg deposition	4.40×10^{12}	(A)
Proportion lost by fish predation	.30	(B)
Initial egg deposition	5.72×10^{12}	(C)
Weighted average fecundity	127,780	(D)
Number of spawning females, C/D	4.476×10^{7}	(E)
Total males and females, 2E	8.953×10^{7}	(F)
Weighted average weight	.319 kg	(G)
Estimated spawning biomass F X G/1000	28,530 tons	(H)
Catch of spawning fish	4,500 tons	(I)
Exploitation rate, 100 X I/(H+I)	13.6%	

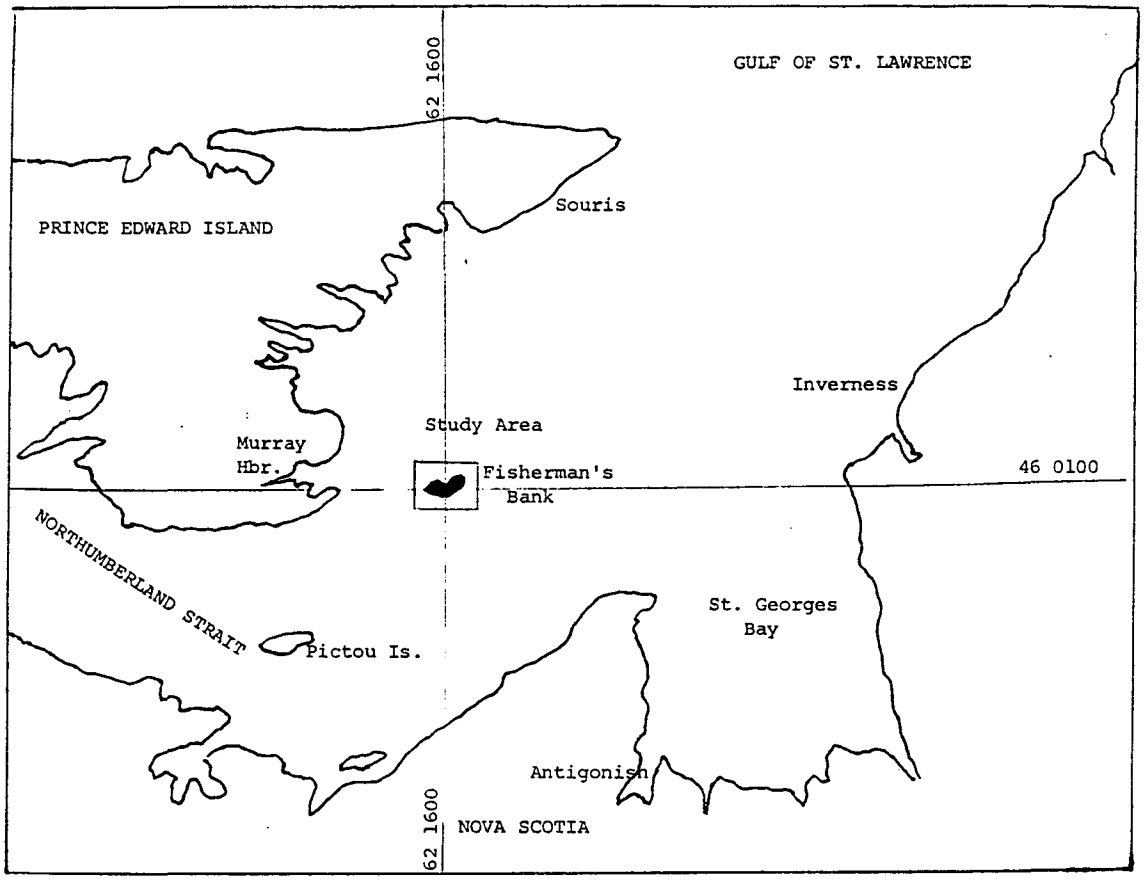

Figure 1. Map of the southern Gulf of St. Lawrence showing the herring spawning bed survey area of Fisherman's Bank

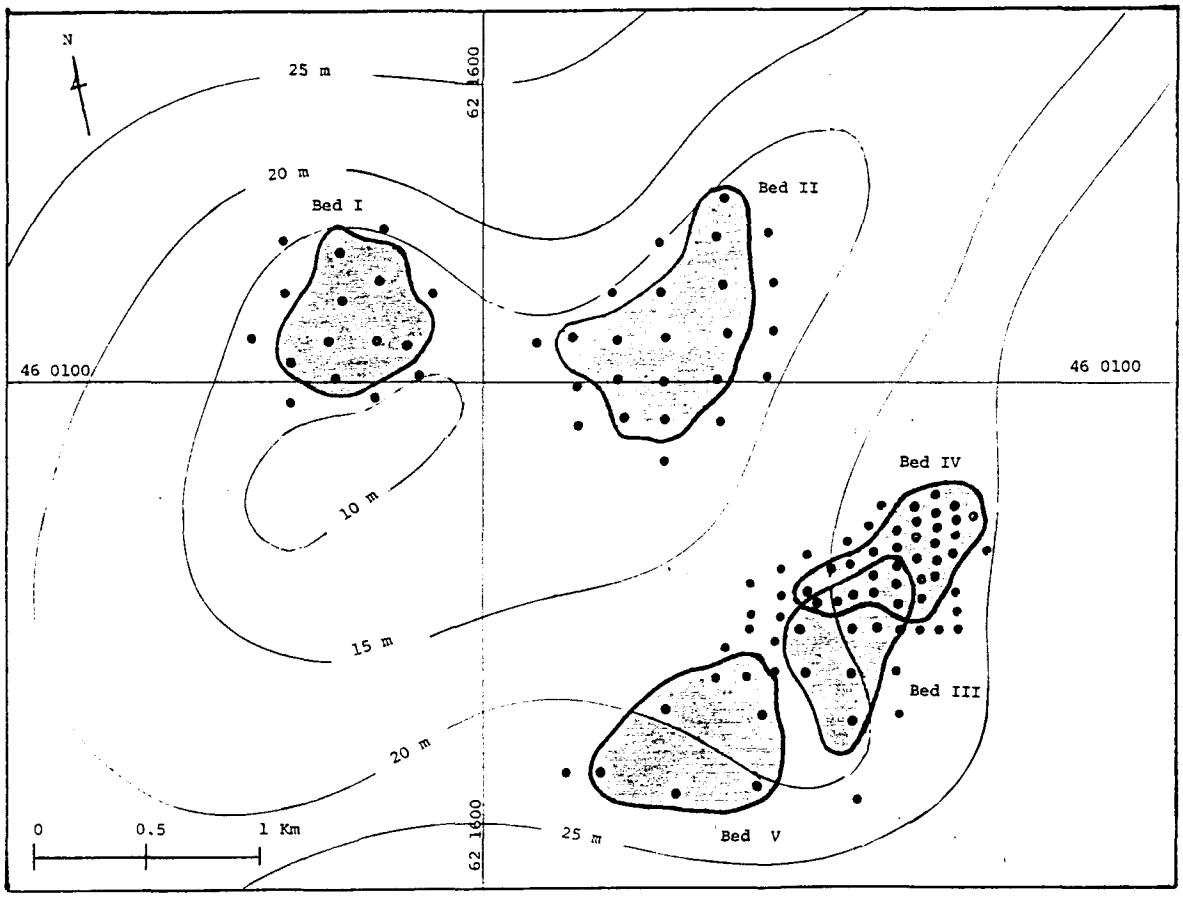

Figure 2. The Fisherman's Bank area showing the herring spawning beds found in the fall, 1985 survey. Depth contours and sampling locations are also shown.

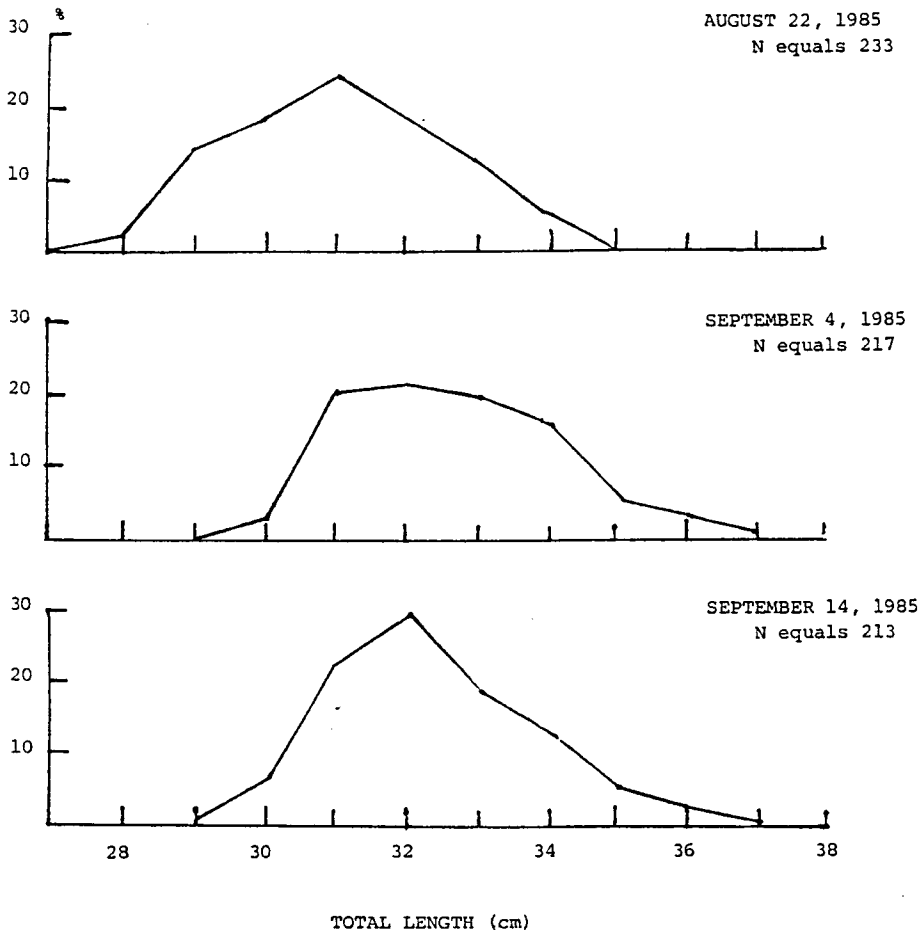

Figure 3. Length frequency distribution of herring samples taken from the Fisherman's Bank during the spawning bed survey, fall 1985.

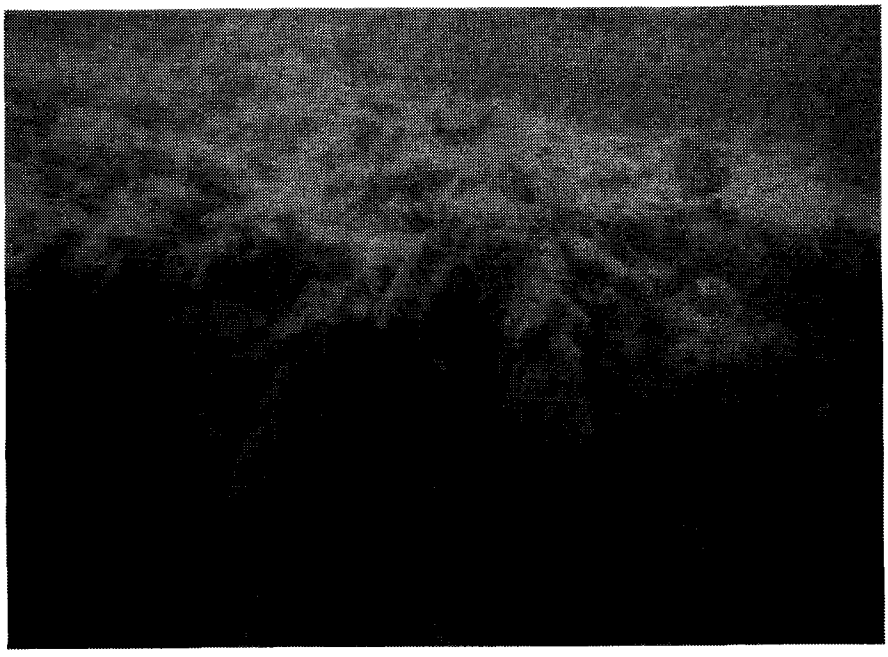

Figure 4. Underwater photographs showing (A) divers collecting herring egg sample using quadrat and airlift, and (B) herring spawn near the edge of Fisherman's Bank.

Appendix I. Sampling date, location and number of eggs/m^2 on the spawning beds.

Date	Location (LORAN C) Lat	Long	No. of eggs/m^2 ($X10^6$)
Bed I			
Sept. 6	46 01 10	62 16 32	5.760
6	46 01 00	62 16 32	3.320
6	46 01 32	62 16 32	0.080
6	46 01 18	62 16 32	0.400
7	46 01 23	62 16 19	3.260
7	46 01 10	62 16 19	5.280
7	46 01 10	62 16 03	0.050
Bed II			
Sept. 9	46 01 10	62 15 30	0.340
9	46 01 22	62 15 28	0.090
9	46 01 22	62 15 10	1.890
9	46 01 11	62 15 08	0.290
9	46 01 32	62 15 10	0.130
9	46 01 42	62 15 09	0
9	46 01 11	62 15 41	0.010
10	46 01 00	62 15 26	0.120
10	46 01 00	62 15 10	0
10	46 01 00	62 15 41	0.130
10	46 00 89	62 15 41	0.010
10	46 00 89	62 15 26	0.010
10	46 01 12	62 15 58	0.070
Bed III			
Sept. 13	46 00 35	62 14 78	0.100
13	46 00 45	62 14 79	0.001
13	46 00 23	62 14 80	0.001
13	46 00 45	62 14 94	0.010
13	46 00 56	62 14 65	0.003
13	46 00 45	62 15 26	0.004

Appendix I. continued

Bed IV

Sept. 23	46 00 53	62 14 86	20.100
23	46 00 49	62 14 86	0.280
23	46 00 54	62 14 94	10.200
23	46 00 51	62 15 02	8.960
23	46 00 43	62 15 05	6.120
23	46 00 58	62 14 94	2.060
24	46 00 53	62 14 79	0.510
24	46 00 53	62 14 72	9.840
24	46 00 53	62 14 62	5.760
24	46 00 53	62 14 55	3.780
24	46 00 59	62 14 55	9.400
24	46 00 48	62 14 55	0.240
24	46 00 48	62 14 62	1.270
24	46 00 64	62 14 55	10.900
24	46 00 69	62 14 55	14.700
24	46 00 74	62 14 55	2.460
24	46 00 69	62 14 65	11.400
24	46 00 69	62 14 48	9.960
25	46 00 74	62 14 48	11.000
25	46 00 69	62 14 41	2.100
25	46 00 64	62 14 65	14.800
25	46 00 59	62 14 72	8.280
25	46 00 59	62 14 79	6.360
25	46 00 59	62 14 69	11.100
25	46 00 59	62 14 62	13.900
25	46 00 64	62 14 48	11.200

Bed V

Sept. 26	46 00 11	62 15 11	1.190
26	46 00 12	62 15 72	1.340
26	46 00 11	62 15 41	1.340
26	46 00 34	62 15 10	1.340
26	46 00 34	62 15 41	1.340
26	46 00 45	62 15 26	10.410