Herring Spawning Bed Survey in Miramichi Bay, NB in Spring 1984

by

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Abstract

Herring spawning beds in the Escuminac area of Miramichi Bay, NB were surveyed by SCUBA divers in May, 1984. Three spawning beds were found near Escuminac wharf in the previously known spring spawning area. The developmental stage of herring eggs indicated that spawning had occurred within 1-2 days from their discovery. A fourth spawning bed was located just south of Pt. Escuminac on May 31. Its developmental stage showed that it has been produced 2 weeks after the other spawning beds, indicating its relationship with another spawning population.

Size of the spawning beds ranged from 34,297 eggs/m^2 at Bed II to 166,869 eggs/m^2 at Bed IV. Incubation period was 17-19 days. Mean bottom temperature during the incubation period was 5.9°C. Natural egg mortalities ranged from 5.9% to 9.4%. Winter flounder (Pseudopleuronectes americanus) were the major predators on herring eggs. Predation by fish on herring eggs was estimated at 45% to 69% over the incubation period.

The herring spawning biomass estimate was 2,237 $\pm$ 358 tons. Herring catch from the Escuminac spring fishery in 1984 resulted in exploitation rates of 47.9% - 59.3%. These rates are lower than those of the 1983 (83.7 - 96.9%) but still much higher than the level (20%) recommended by CAFSAC and ICES for herring fisheries.

Résumé

En mai 1984, on a eu recours à la plongée sous-marine autonome pour réaliser un relevé des aires de frai du hareng dans la région d'Escuminac, dans la baie Miramichi, N.-B. Trois aires de ponte ont été décelées près du débarcadère d'Escuminac, dans la zone de frai de printemps déjà connue. Le stade de développement des oeufs de hareng indiquait que le frai avait eu lieu un ou deux jours avant l'arrivée des plongeurs. Une 4^e aire de frai a été localisée juste au sud de Pointe Escuminac le 31 mai. Le stade de développement des oeufs indiquait que le frai avait eu lieu deux semaines plus tard que dans les autres aires de frai, ce qui laisse supposer qu'il s'agissait d'une autre population de géniteurs.

Le nombre d'oeufs dans les aires de ponte variait de 34 297 oeufs/m^2 dans l'aire II à 166 869 oeufs/m^2 dans l'aire IV. La période d'incubation était de 17-19 jours. La température moyenne du fond de l'eau pendant la période d'incubation était de 5,9°C. La mortalité naturelle des oeufs variait de 5,9 % à 9,4 %. La plie rouge (Pseudopleuronectes americanus) était le principal prédateur des oeufs de hareng. La prédation par les poissons au cours de la période d'incubation a varié entre 45 et 69 %.

La valeur estimée de la biomasse de hareng en frai est de 2 237 $\pm$ 358 tonnes. Les prises de harengs découlant de la pêche du printemps dans la région d'Escuminac en 1984 correspondent à des taux d'exploitation de 47,9 % à 59,3 %. Ces taux sont plus faibles qu'en 1983 de 83,7 à 96,9 %, mais ils demeurent encore très élevés par rapport au taux (20 %) recommandé le CSCPCA et le CIEM pour la pêche au hareng.

Introduction

In May 1979 evaluation of herring spawning bed surveys as a data source for enhancing herring stock assessment began in Miramichi Bay, N.B. The spring herring fishery at Escuminac, Miramichi Bay, has been the largest in the southern Gulf of St. Lawrence for several years (Messieh and Moore 1981). The 1979 survey was only exploratory and was not designed to provide quantitative estimates of spawn. Nevertheless, it provided useful information on the spawning site off Huckleberry Island and between Preston Beach and Escuminac (Figues 1). Aerial photographs of gill net distribution revealed that fishing effort was most intense near Escuminac, but encompassed the entire area between Fox Island and Point Escuminac.

In 1980 it was decided that the herring spawning bed surveys should be carried out on a quantitative basis to monitor the spawning stock biomass and to estimate exploitation rates. Three surveys were carried out in the spring of 1980, 1981 and 1983. No surveys occured in 1982 due to lack of funds for the divers contract. Results of the previous surveys were reported by Pottle et al (1980) Messieh et al (1981), and Messieh et al (1983).

In the present report, results of the 1984 survey are presented. As in previous years, the purpose of the survey was to collect data on spawning areas, size of spawning beds, size of spawning biomass, and to try to determine egg mortality, both natural and by predation.

Materials and Methods

Search Area and Procedure

The search area for herring spawning beds was restricted to the south shore of Miramichi Bay between the junction of the Fox and Huckleberry Islands and Pt. Escuminac (Figure 1). Searches for herring spawn were confined to this area as previous studies have indicated that the area has suitable substrate with abundant macrophytes was required for spawning (Tibbo et al, 1963; Pottle et al, 1980). A search grid with 200 m squares was plotted on a hydrographic field sheet of the study area. LORAN C bearings were determined for each transect line parallel to shore and for each position of the search grid. LORAN C accuracy is approximately ± 20 m. Surface and bottom temperatures were recorded regularly throughout the survey.

Between May 11 and June 1 the entire area known to have been herring spawning beds plus Herring Cove and Pt. Escuminac, were checked for spawn deposition by SCUBA divers. On May 11 fishermen reported that the herring schools had arrived and an area with spawn deposition was located west of Escuminac wharf the following day. On May 14 a second spawning bed was located to the east of the wharf. On May 25 a third spawning bed was discovered further to the east of the second bed. On May 31 a fourth and younger bed was found off Pt. Escuminac (Figure 1).

Divers located and mapped the perimeters of each spawning bed with buoys in the manner described by Pottle et al (1980). Buoy positions were determined with the LORAN C and plotted on the hydrographic field sheet.

Quadrat Sample Collection

A 100 m interval sampling grid was plotted on the first of four spawning beds located with 40 stations within the bed, and 20 outside of the diver estimated perimeter, as a check on the accuracy of boundary determination. A 200 m sampling grid was used on the second, third and fourth beds with 16, 18 and 7 stations inside of the perimeters and 22, 13 and 12 stations outside of the perimeters, respectively. Each station was sampled in the method described by Messieh et al (1983). The first bed was sampled from May 24 to May 25, the second from May 26 to May 27, the third from May 27 to May 29 and the fourth on June 1.

Quadrat Sample Analysis

Quadrat samples were examined and analyzed in the manner described in the 1983 survey report (Messieh et al 1983). Each 0.25 m^2 quadrat sample was partitioned into major macrophyte species, loose herring eggs, and sand, rocks and other debris. A plankton splitter was used to enumerate the loose fraction of eggs which could not be manually separated from the debris. Egg number was determined by either direct count or, with large samples, by volumetric measurement referred to a calibrated standard number of eggs per milliliter. Quadrat data were converted to equivalent values per square meter, and used to estimate the total number of eggs deposited.

Predatation on Herring Eggs by Benthic Fish

Counts of benthic fish were made along 200 m transect lines randomly positioned within the first and third spawning beds. Fish, primarily winter flounder (Pseudopleuronectes americanus) and various sculpins (Cottidae), were collected by hand spear, and their stomach contents were checked for herring eggs. The number of herring eggs/fish stomach was determined volumetrically after separation from other gut contents.

To follow the expected decline in egg abundance prior to hatching, five sites within the first spawning bed and one site within the third spawning bed located near the Escuminac wharf were selected for repeated sampling (Figure 2). At each site divers obtained 0.25 m^2 quadrat samples within 5.0 m. of a marker fixed to the bottom.

These samples were collected from May 12-29 on the first spawning bed,and from May 15-29 on the third bed.

Results

The first spawning bed (Bed I) near Escuminac was discovered on May 12. This spawning bed was located 100 m west of the Escuminac wharf over a depth range of 1.4 - 4.3 m near low water (Figure 2). The second spawning bed (Bed II) was located 400 m east of the wharf on May 14, in an area which had been checked with negative results by divers on the previous day. Eggs at this site had been deposited primarily on bare rock substrate over a depth range of 2.6 - 4.4 m. mean low water (MLW).

A third spawning bed (Bed III) was found further east on May 25 (Figure 2). This was approximately the same distance from the wharf as the spawning bed surveyed in 1983 but further from shore. Eggs at this site were found at depths of 1.2 - 2.9 m MLW. The developmental stage of herring eggs at this site indicated that spawning had occurred in the same 1-2 day period as at the first two spawning beds located. A fourth spawning bed (Bed IV) located just south of Pt. Escuminac on May 31 appeared to have been produced at least two weeks after the others, on approximately May 27-28. Eggs at this site were distributed over a depth range of 1.7 - 2.6 m MLW. The approximate areas of the four spawning beds ranged from 445,000 - 1,100,000 m^2 (Table 1).

The predominant substrate was sandstone rubble with patches of sand and considerable variation in algal cover over short distances. Irish moss (Chondrus crispus) was the dominant macrophyte at all surveyed spawning locations (Table 2) Macrophyte biomass on the spawning beds and in the immediately adjacent areas is presented in Table 3. Macrophytes were present in six of 38 quadrat samples collected at Bed II. Significant correlations between macrophyte biomass (wet wt.) and herring egg abundance were obtained at Beds I and III only ($P < .05$ and $< .01$ respectively; Table 4).

As noted in previous reports, a large percentage of eggs collected in quadrat samples were not attached to a substrate, but may have been dislodged during collection or subsequent handling. At Beds I and IV more than 55% of the eggs were attached to macrophytes, the corresponding figures at Beds II and III being 0.8% and 29.7% respectively (Table 5).

Herring Egg Abundance

Mean herring egg abundance ranged from 34,297 eggs/m^2 at Bed II to 166,869 eggs/m^2 at Bed IV, and egg deposition within each bed varied considerably from station to station, as indicated by the large standard errors (Table 1). In this Table, the total numbers of herring eggs estimated on each spawning bed during quadrat sampling are also presented.

Developmental Stages

Egg samples were collected for identifying their developmental stages according to Baxter's (1971) classification at Beds I and II, from May 12-29. Results are presented in Table 6 and Figure 3. Initial staging of samples from Bed III indicated that spawning bed had occurred approximately 1-2 days after spawning at Bed I. Eggs collected at Bed IV on May 31 to June 1 were in stage 2.

Developmental stage data from eggs in winter flounder stomachs are presented in Figure 3. The temporal pattern of egg development plotted with this data lags about one day behind that from quadrat data. A sharp dip in the plot on May 24 reflects the capture of two fish, one of which had eaten stage 1 eggs and the other a mixture of stage 2-4 eggs. These fish were collected in the area near Escuminac wharf, the one containing stage 1 eggs being captured outside of the surveyed spawning beds.

Large numbers of empty egg cases were first noted on May 31 on spawning beds I and III and were taken to indicate hatching during the preceding night. Approximate duration of the incubation period at Beds I - III was 17-19 days.

Water temperatures ranged between 6.1 - 11.7°C and 3.1 - 10.0°C for surface and bottom temperatures respectively (Table 7). Mean bottom temperature during the incubation period was 5.9°C. Natural herring egg mortality estimates are presented by spawning bed and by substrate type in Table 8.

Predation by Benthic Fish

Predation data are available for winter flounder (Pseudopleuronectes americanus) and sculpins (Myoxocephalus scorpius, M. octodecemspinosus). No cod (Gadus morhua) were caught by fishermen in the spawning area this year.

Only flounder captured after May 11 had eaten herring eggs. All fish were collected along the southern shore of Miramichi Bay in the historical spawning area, the majority on spawning beds I, II and III. Eighty-one of eighty-three winter flounders collected between May 12 and June 1 had eaten herring eggs ($\bar{X}$ = 6,478 eggs/stomach, n = 83, S.E. = 670, range = 0-24,211 eggs/stomach). A plot of mean number of eggs/stomach against date of collection (Figure 4) shows no clear temporal pattern of predation during the incubation period, although the largest peak appears around the approximate midpoint of the period.

Sculpins (Myoxocephalus sp.) were also collected along with the flounder, but in lower numbers. Two of the seven collected had consumed herring eggs. ($\bar{X}$ = 561 eggs/stomach, n = 7).

Predator Abundance

Predator counts along bottom transect lines were made on Bed I from May 14-24 and on Bed III from May 27-30 (Table 9). During this period gales and near zero visibility due to turbidity prevented counts on eight days. Mean sculpin abundance was < 0.006 fish/m^2. These fish do not appear to be important predators of herring eggs, given their low numbers and relatively low consumption of eggs per fish.

Mean winter flounder abundance was 0.87 fish/m^2 on Bed I and 0.79 fish/m^2 on Bed III, with a combined mean abundance of 0.83 fish/m^2. The mean total length and wet weight of captured flounders were 29.2 cm (N = 83; S.E. = .58 cm) and 327 g (N = 83; S.E. = 20.8 g) respectively.

Mortality Due to Winter Flounder Predation

Estimates of egg loss due to flounder predation in the period between spawning and quadrat sampling was calculated on the assumption that winter flounder feed once per day, based on stomach clearance rate (MacDonald and et al, 1982), and on diurnal feeding periodicity (Frank and Leggett, 1984). The one day lag between plots of egg development based on quadrat and stomach content data (Figure 3) supports the stomach clearance rate of 50% clearance of soft-tissued prey in 23-24 hr as suggested by MacDonald et al (1982).

All flounders were collected in daylight hours and the mean number of herring eggs per stomach was considered to be representative of the daily mean egg consumption, given that winter flounders appear to be visually oriented predators (Pearcy, 1962; Olla et al , 1969).

Estimated losses of herring eggs due to predation on the spawning beds prior to quadrat sample collection were:

Bed I	45% in 13 days
Bed II	69% in 14 days
Bed III	47% in 16 days
Bed IV	No data on predator abundance.

Estimates of Spawning Herring Population Numbers and Biomass

Numbers of spawning herring were estimated from egg abundance on the spawning beds and female fecundities. A sex ratio of 1:1 based on field observations (Pottle et.al. 1980) was assumed. Mean fecundity was estimated for mean size of herring spawners on the spawning beds based on linear regression fit of fecundity on size. For a mean size of 225g, fecundity was 67,500 ± 1,840 (Messieh, unpublished data).

Spawning biomass (expressed as wet weight of fish in metric tons) was estimated from the quadrat samples taken during incubation period (Table 10). The estimates of spawning biomass corresponding to egg losses to predators (Table 11) and the estimates from quadrat samples were combined to yield a total spawning biomass. Estimated total spawning biomass was as follows:

Spawning Bed	Estimate ± S.E.
I	580.5 ± 86.9 mt
II	319.5 ± 63.4 mt
III	1,336.5 ± 341.2 mt
IV	600.7 ± 331.7 mt (Does not include herring consumed by predators)

Exploitation Rates

In 1984 the spring herring fishery was restricted to catching fish for bait purposes only. Hence, there were neither herring landings for sale, nor purchase slips for recording the catch. However, the Resource Allocation Division (personal communication) monitored the fishing activities and estimated the catch. A total catch of 4,070 mt in May, of which 80% (3,256 mt) was estimated to have been taken in Escuminac near the spawning beds.

Exploitation rate based on this catch, and taking into account total biomass of the four spawning beds, was estimated at 47.9%. However, by excluding Bed IV which was spawned about 2 weeks later, and most likely comprised a different spawning group, the exploitation rate of the Escuminac herring spawning component was estimated to be 59.3%.

DISCUSSION

This was the first year since the Escuminac herring spawning bed surveys began in which more than one large spawning bed has been found. In this survey, three of the four spawning beds were found near the Escuminac Wharf, not far from the spawning bed found in 1983. The fourth bed was located southeast of Pt. Escuminac, about 7 km east of the other beds. Based on the developmental stages of eggs it was estimated that spawning on this bed

occurred approximately 17 days after the Escuminac spawning. It is believed that this bed resulted from a different herring spawning group moving southwards to Pt. Sapin, as indicated from its different age structure and spawning time.

The 1984 survey showed an increase in egg abundance on the spawning beds compared to the 1983 survey. Mean number of eggs/m^2 ranged between 34.3 X 10^3 to 166.9 X 10^3. In 1983 mean number of eggs/m^2 was 24.7 X 10^3 for the entire bed, and 155.4 X 10^3 for a small site within the bed.

The estimated incubation periods at Beds I-III were 17-19 days. Incubation was approximately 2-4 days longer than in 1983 but mean water temperature on the bottom during the 1984 incubation period was 1.4°C lower than in 1983.

Natural mortality was markedly higher than previously recorded, except at Bed IV where the strongest correlation between macrophyte biomass and egg abundance was obtained. The highest mortality (9.39%) was on Bed II (Table 8) where algae were present at only 6 of 38 quadrat sample sites. The highest mortality was among loose eggs not attached to the substrate (9.54%). Lowest mortalities (1.20%) were for eggs attached to kelp (Laminaria sp.) and eelgrass (phyllophora sp.). Interestingly, eggs attached to bare rock did not have a high natural mortality (4.70%). The high mortality on Bed II may be due to the high percentage of loose eggs present, which may in turn be due to the lack of algae.

Loss of eggs due to wave action and winds was substantial. Field personnel noted algae and eggs washed ashore after strong onshore winds. The bulk of these eggs (mostly loose) and algae as well as dead herring were found on the eastern side of the Escuminac Wharf.

Estimates of herring egg mortality due to predation on Beds I and III were 45% over 13 days and 47% over 16 days respectively. Mortality estimate for Bed II was markedly higher at 69% over 14 days. This difference would reflect the greater vulnerability of eggs laid in the absence of algae cover which provides physical protection. Eggs on bare substrate are probably subject to higher predation than those which are scattered throughout clumps of algae. These require greater effort to locate and detach by divers.

Biomass estimates showed that the Escuminac spring spawning herring population increased in 1984 over those in 1983. Excluding Bed IV which most likely represent a different spawning group, the spawning biomass was 2,236.5 ± 357.8 mt.

In 1983, estimates of the spawning biomass in Escuminac ranged between 151.3 ± 46.8 mt to 936.2 ± 510.6 mt. Herring catches in 1984 resulted in an exploitation rate of 59.3%. With the inclusion of Bed IV, the exploitation rate was estimated at 47.9%. The 1984 exploitation rates were much lower than those of the 1983 (83.7 - 96.9%). However, these levels of exploitation are much higher than the level (20%) recommended by CAFSAC and ICES for herring fisheries.

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Table 1: Details of herring egg deposition on the four surveyed spawning beds. Mean number of eggs/m^2 ($\bar{x}$), number of samples (N) and standard error of mean (S.E.) are shown.

Spawning Bed	Area (m^2)	$\bar{X}$	S.E.	N	Total No.	S.E.
I	560,000	85,924	19,977	40	48.1×10^9	11.2×10^9
II	445,000	34,297	9,482	16	15.3×10^9	4.2×10^9
III	1,100,000	95,833	56,502	18	105.5×10^9	62.2×10^9
IV	540,000	166,869	84,795	7	90.1×10^9	45.8×10^9

Table 2: Percentage of macrophyte species (wet weight) in algae as estimated from quadrat sample.

Spawning Bed	Chondrus	Fucus	Phyllophora	Laminaria	Epiphytes Filamentous
I	96.2	0.0	3.3	0.3	0.2
II	96.3	0.0	3.7	0.0	0.0
III	93.1	6.6	0.0	0.0	0.3
IV	87.3	3.8	3.7	0.8	4.5

Table 3: Macrophyte biomass in three spawning beds (g/m^2 wet weight).

		On Spawning Bed	Outside Perimeter
Bed I	$\bar{X}$	360.40	23.30
	S.E.	46.42	20.99
	N	40	11
Bed II	$\bar{X}$	76.3	0
	S.E.	37.3	0
	N	16	22
Bed III	$\bar{X}$	409.70	10.40
	S.E.	101.89	10.37
	N	18	11
Bed IV	$\bar{X}$	459.30	Quadrat samples
	S.E.	173.50	not collected.
	N	7	

Table 4: Results of linear regressions of herring egg deposition ($eggs/m^2$) on wet weight of algae ($algae/m^2$).

	r	df	p		r	df	p
I	.33	38	.05		.35	38	.05
II	.06	15	N.S.		.29	16	N.S.
III	.01	4	N.S.		.49	3	N.S.
IV	.84	5	.01		.75	5	.02

Table 5: Percentage distribution of herring egg deposition by substrate type.

SPAWNING BED	% EGGS ON ALGAE	% EGGS ON BARE SUBSTRATE	% EGGS UNATTACHED
I	55.2	1.7	43.2
II	0.8	47.5	51.7
III	29.7	0.04	70.3
IV	60.9	0.4	38.7

Table 6: Developmental stages of herring eggs examined from 'Predator Site' quadrat samples. Classification according to Baxter (1971).

DATE	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6
May 15		2	2		2	1,2
16			2	2	2	2
17	3		3	3	3	2
21	4		4	3	4	4
24	4		4	5	4	5
25	4,5		3,5	5		
27	5		5	5	5	5
28				5		5

Table 7: Mean daily water temperatures (°C) during the spawning bed survey. Depths varied from 1.8 to 6.0 m with mean 4.0 m.

DATE	SURFACE	BOTTOM
11/05/1984	7.4	3.5
12/05	6.6	3.1
13/05	6.1	4.1
14/05	8.2	6.2
15/05	7.0	5.1
16/05	8.1	6.3
17/05	9.5	6.0
18/05	8.1	5.4
20/05	8.8	6.0
21/05	9.2	5.2
23/05	8.3	4.9
24/05	6.2	5.0
25/05	10.7	8.1
26/05	9.3	6.6
27/05	11.7	9.5
28/05	9.8	5.4
29/05	11.5	10.0
30/05	6.4	5.7
31/05	8.4	6.9
01/06	10.3	9.8

Table 8: Natural herring egg mortality by spawning bed and substrate. Standard error (S.E.) and number of samples (N) are shown.

CATEGORY	MEAN PERCENTAGE NONVIABLE	S.E.	N
Spawning Bed			
I	7.06	2.47	18
II	9.39	2.11	7
III	8.49	3.00	8
IV	5.97	2.39	8
Substrate			
Filamentous	6.10	3.92	5
Chondrus	7.65	3.16	6
Fucus	3.70	--	1
Laminaria	1.20	--	1
Phyllophora	1.20	0.12	3
Loose	9.54	2.18	21
Bare	4.70	1.87	3

Table 9: Predator counts on two herring spawning beds.

BED	DATE	LINE LENGTH	TRANSECT WIDTH	AREA SURVEYED	FLOUNDERS/ m^2	SCULPINS/ m^2
I	14/05	200 m.	2.0 m.	400 m.	0.25	0.01
	16/05	200	2.0	400	0.57	0.00
	17/05	200	2.0	400	0.66	0.01
	21/05	200	0.4	80	2.66	0.00
	24/05	100	2.0	200	0.19	0.01
III	27/05	200	2.0	400	0.17	0.00
	28/05	200	2.0	400	0.09	0.02
	29/05	200	1.0	200	2.26	0.00
	30/05	200	1.5	300	0.63	0.00

Table 10: Estimates (± standard error) of numbers and biomass of spawning herring in Miramichi Bay, based on quadrat survey data.

SPAWNING BED	ESTIMATED NUMBER OF HERRING (MALES & FEMALES)	ESTIMATED BIOMASS OF HERRING (mt)
I	$14.2 \times 10^5 \pm 2.3 \times 10^5$	319.5 ± 51.8
II	$4.4 \times 10^5 \pm .8 \times 10^5$	99.0 ± 18.0
III	$31.2 \times 10^5 \pm 13.0 \times 10^5$	702.0 ± 292.0
IV	$26.7 \times 10^5 \pm 13.8 \times 10^5$	600.7 ± 331.7

Table 11: Estimates (± standard error) of numbers and biomass of herring consumed by predators on the spawning beds.

SPAWNING BED	ESTIMATED NUMBER OF HERRING (MALES & FEMALES)	ESTIMATED BIOMASS OF HERRING (mt)
I	$11.6 \times 10^5 \pm 3.1 \times 10^5$	261.0 ± 69.8
II	$9.8 \times 10^5 \pm 2.7 \times 10^5$	220.5 ± 60.8
III	$28.2 \times 10^5 \pm 7.8 \times 10^5$	634.5 ± 175.6
IV	—	—

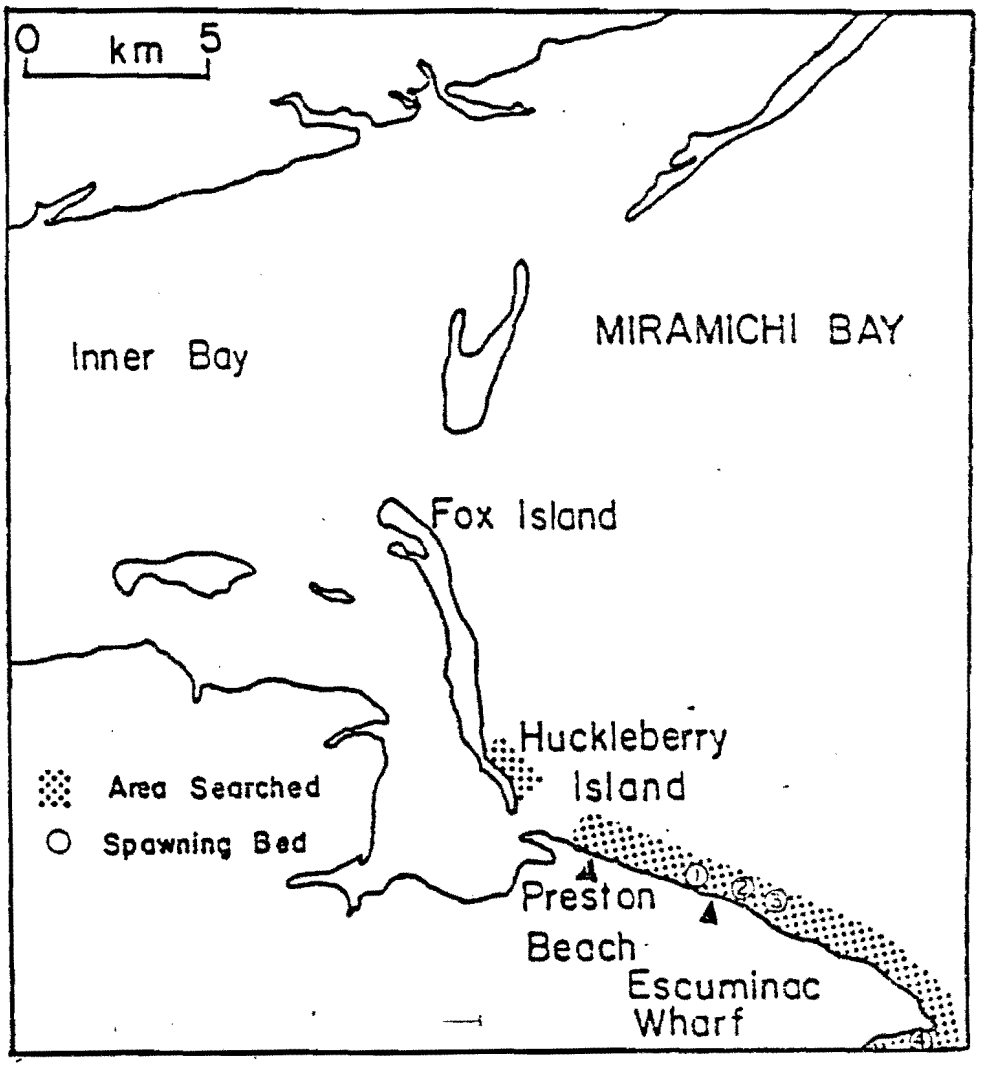

Figure 1: Map of the 1984 search area in Miramichi Bay, NB, and locations of herring egg deposition.

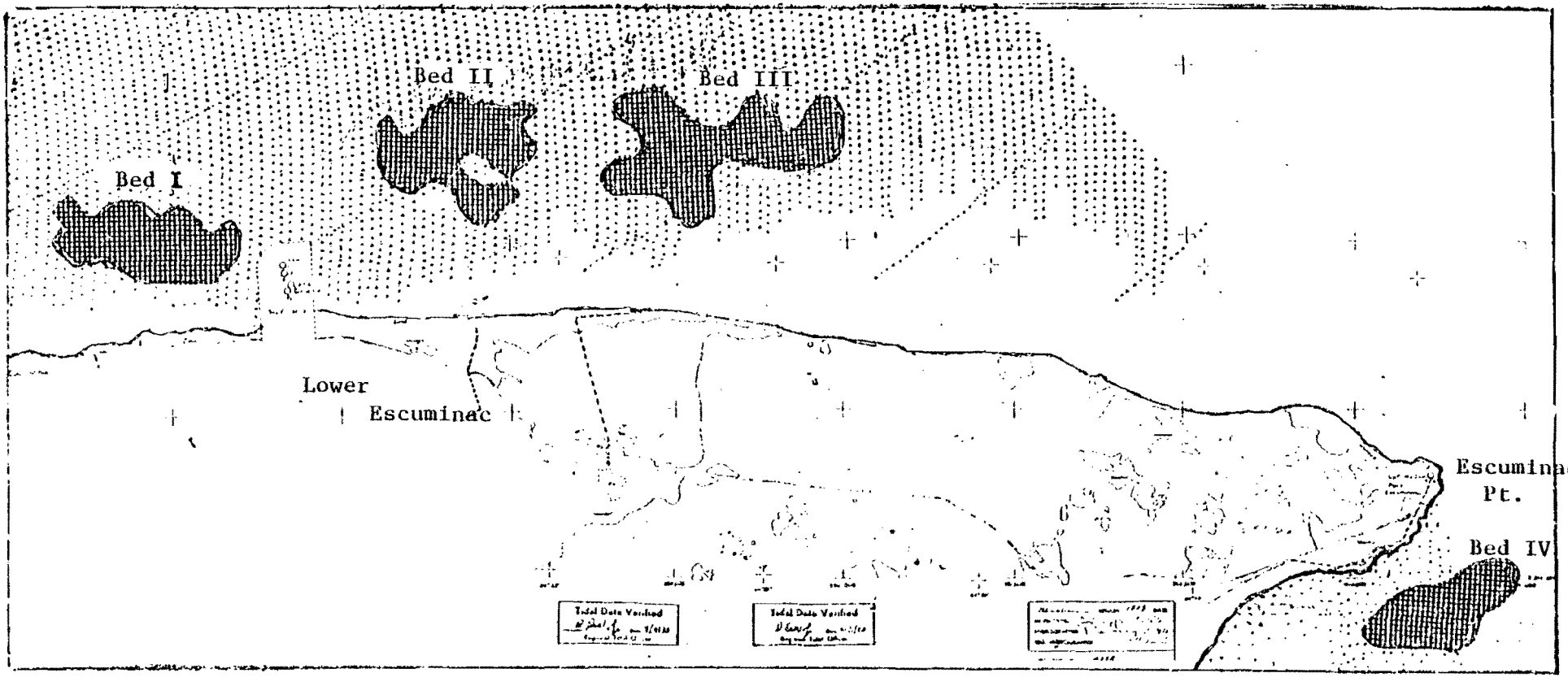

Figure 2 . Herring spawning beds surveyed by scuba divers in spring 1984. Three spawning beds near Escuminac wharf in Miramichi Bay, and one spawning bed outside the bay east of Pt. Escuminac were found.

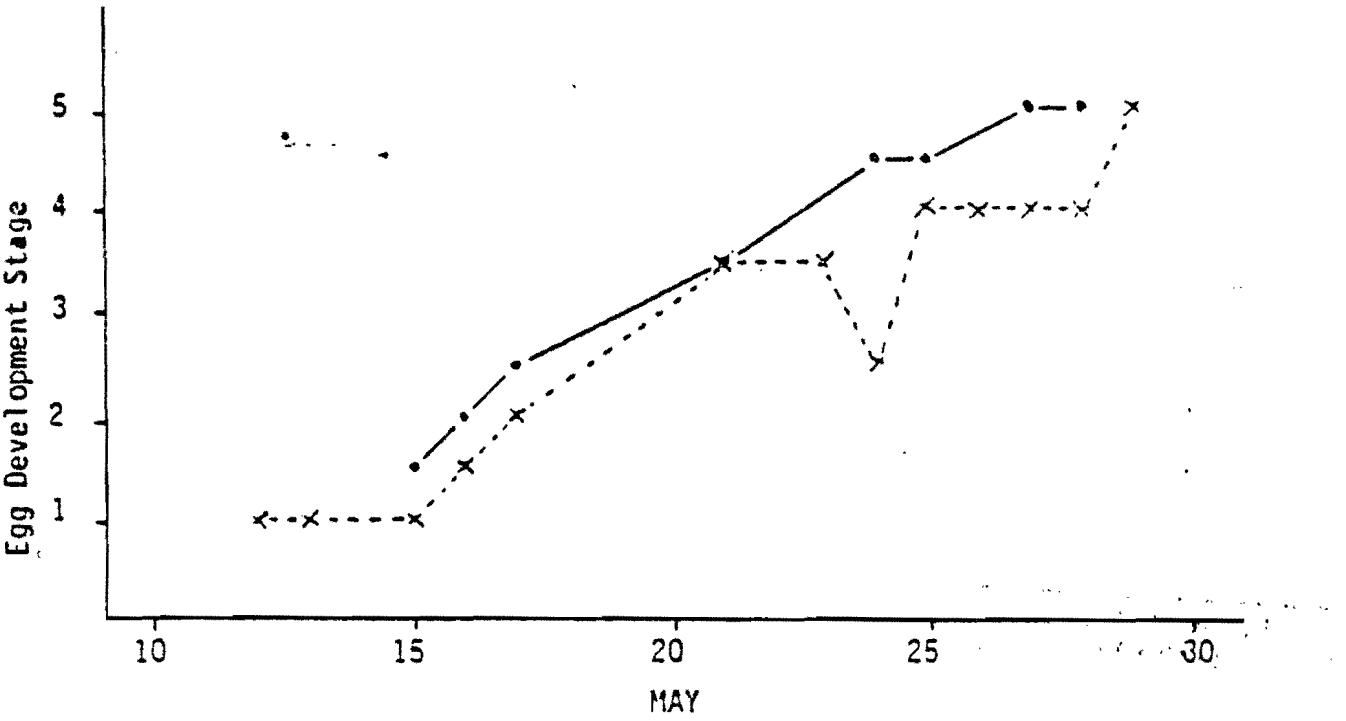

Figure 3: Herring egg developmental stages as shown from the predation sites on the spawning beds (——) and from flounder stomach examination(--).

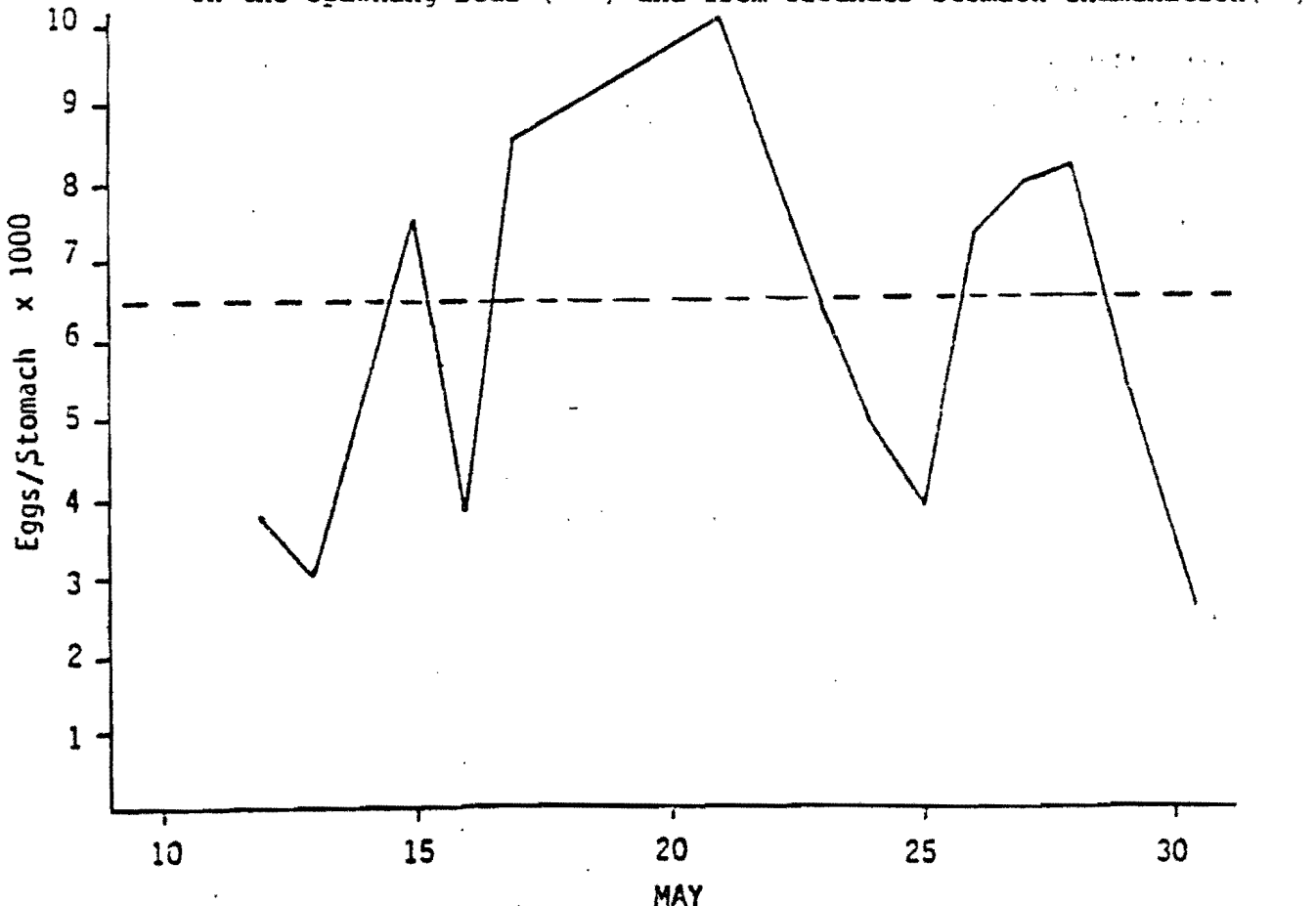

Figure 4: Consumption of herring eggs by winter flounder (Mean number/stomach/day).