HERRING EGG BED RESEARCH AND MANAGEMENT IN EASTERN MAINE

Final Report

to

The Maine State Planning Office

[redacted]

David K. Stevenson

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INTRODUCTION

Investigations of various aspects of the early life history of the Atlantic herring (Clupea harengus) on the eastern Maine spawning ground (Fig. 1) by the Maine Department of Marine Resources (DMR) began with larval surveys in 1982 and 1983. Work in 1982 was carried out in collaboration with the Canadian Department of Fisheries & Oceans aboard the R/V J.L. Hart. In 1983, operations were conducted aboard the R/V Lee, a research vessel belonging to the University of Maine. Additional work carried out in 1983 included the collection of hydrographic data and information on the abundance and distribution of larval food organisms in eastern Maine. This work was conducted jointly by DMR and the Bigelow Laboratory for Ocean Sciences. Results of the first two years of work (Townsend et al. 1983; Graham et al. 1983) revealed that larvae hatch nearshore in the vicinity of Cutler and the entrance to Machias Bay (Fig. 2) and are transported westward in a tongue of cold water that moves along the coast and that the abundance of food is very low on the spawning ground and increases downstream in the vicinity of Mt. Desert Island. Subsequent hydrographic work along the coast (Townsend et al. 1986) has provided more details concerning primary production and its relation to the physical oceanography of eastern Maine coastal waters and the production of zooplankton, the principal food resource for the larvae. Additional larval studies were carried out on the eastern Maine spawning ground in 1984 with support from the University of Maine Sea Grant program. This work showed that recently-hatched larvae are more abundant near the surface at night and in deeper water during the day and are preyed upon by a copepod (Morrissey MS).

Beginning in 1983, interviews with herring and lobster fishermen in Cutler and Bucks Harbor provided historical and current information on the location of individual spawning sites (egg beds) where herring deposit their eggs on the bottom and the timing of individual spawning episodes in 1983. These interviews were continued in 1984 and 1985. Egg bed surveys were initiated in 1985 with a small, remotely-operated underwater vehicle (ROV) which was used to confirm sightings reported by lobster fishermen who hauled traps with herring eggs adhering to them and to provide information on the physical characteristics of the egg beds and the habitat where they are found. Additional ROV survey work was conducted in 1985. Support for egg bed survey operations in both years was provided by NOAA through its National Undersea Research Program at the University of Connecticut at Avery Point (NURP/UCAP); additional funds were provided in 1985 by the U. Maine Sea Grant program. Results of 1983-85 egg bed studies (Stevenson 1984; 1986a,b) have revealed that herring spawn in a 30 mile stretch of coastline between West Quoddy Head and the Libby Islands in

depths of 50 to 150 ft in an area characterized by strong tidal currents and coarse bottom sediments between mid-August and late September.

With the termination of Sea Grant funding in 1986 and in anticipation of renewed support from NURP/UCAP for ROV surveys, a proposal for supplementary funding was submitted to the Maine State Planning Office/Maine Coastal Program. A total of $10,000 was approved for the period July 1 1986 to June 30 1987. The primary objectives of this project were to provide information on: 1) the duration of the 1986 spawning season; 2) the location of spawning sites where herring spawned in 1986; 3) the spawning times at each spawning site; and 4) the timing of maximum egg and larval production on the spawning ground. This report summarizes the principal results of the 1986 NURP/SPO egg bed survey work in eastern Maine, to date, and presents a summary of current management regulations for herring in this area along with some recommendations for changes in management policy.

RESULTS

Operations

Field work in 1986 was conducted continuously, except for three days lost to bad weather, during the period September 8 to October 3. The base of operations was Cutler. Information collected during the 26 day survey period consisted of: 1) interviews with local fishermen to determine spawning locations and times; 2) video observations with the ROV of egg beds and egg bed habitats where herring spawned in previous years to identify the physical characteristics of individual spawning sites and locate suitable locations for sampling; 3) samples of eggs and bottom sediments obtained with a grab sampler deployed from the ROV support vessel and by SCUBA divers; and 4) bathymetric data obtained from an echosounder aboard the support vessel. NURP funds were used to finance all ROV and boat operations; this service was provided by Eastern Oceanics of W. Redding, CT. SPO funds were used to pay for a portion of the food and lodging costs in Cutler, to provide some supplies, and to pay 20 weeks of salary for a conservation aid who assisted with the field work and with some of the subsequent laboratory analyses of the bathymetric data and the egg and sediment samples.

A total of 43 ROV dives were made at four sites in 1986 (Table 1; Figs. 2 & 3). Two of these sites (1 and 4) were egg bed locations where herring spawned during the survey period; the other two (6 and 7) were sites where herring had spawned earlier during the spawning season, i.e., before Sept. 8. Most of the ROV dives were made at the two sites where eggs were observed on the bottom during the course of the survey.

Benthic grab samples were collected at five locations (Table 2; Figs. 2 & 3). Of the 107 samples obtained, 85 were from the same two spawning sites where eggs were observed during the survey period and 22 came from three of the other locations where spawning occurred prior to Sept. 8. These samples were used for laboratory analysis of sediment sample type and also for determining the relative degree of egg density at various locations at the two primary egg bed sites (1 and 4) aboard the boat at the time the samples were collected. Observations of egg density made with the video camera and from bottom grab samples were used in combination with bathymetric data to map the area of spawning at site B. Additional samples of eggs and bottom sediments were made at site B on Sept. 20 and 21 by two SCUBA divers.

Laboratory work began following the termination of the field work and consisted of several tasks: 1) the transfer of all field notes which were originally recorded on casette tape to paper; 2) a review of all ROV dive observations recorded on video tape; 3) the construction of accurate, small-scale bathymetric maps of the two primary spawning sites; 4) the estimation of egg densities at various site B locations; 5) determinations of egg mortality and comparisons of egg development rates at different positions in the egg mass; and 6) analysis of sediment samples to test for differences in substrate type inside and outside of egg beds A and B. This work was performed by Robert Knowles, the conservation aid employed for this project with SPO funds, in consultation with the principal investigator.

Scientific

Fishermen who were interviewed in Cutler reported that eggs were observed on lobster traps between the Old Man and the Black Ledges (site 4 in Fig. 2) on July 29. Additional herring spawn was observed on traps off Great Head (site 5) on August 5. Schools of herring were observed in this area at about the same time. In the four years that information on spawning times and locations has been compiled for this spawning ground, spawning has never been reported this early. A large quantity of eggs were spawned at site 4 again on the night of Sept. 22-23; this was the last reported spawning in 1986. Thus, the spawning season lasted from late July to late September and covered a period of approximately two months. During the previous three years, spawning lasted from four to six weeks (Table 3).

Herring spawned at seven distinct locations in 1986 (Figs. 2 & 3). Four of these sites (1,4,6 and 7) corresponded to locations where herring spawned at least once during the previous three years (sites G,C,L and M in Figs. 4 & 5). As in previous years, all egg bed sites were located within three miles of the shoreline or an island and in depths of

50-150 ft. The two sites where video observations, bathymetric data, and bottom grab samples were obtained were located east of the Libby Islands and in the entrance to Little Machias Bay (see Fig. 6).

Eggs were observed with the ROV at site 1 on the morning of Sept. 9 in 150 ft. Additional observations were made the following day (Table 1). Seven bottom grab samples were obtained in this area on the same two days (Table 2). Because of the exposed nature of this site and the extreme depth, no attempt was made to use SCUBA divers. Three days of high winds interrupted operations at this site. Upon resumption of operations on Sept. 14, only a few sparse patches of eggs were observed. Because the date of spawning at this site was not known with any certainty, it was not clear whether the eggs underwent their normal incubation period (10 days at the bottom temperature typical of this area and time of year) or were dislodged from the bottom by the storm. Given the depth at this location, the latter possibility seems unlikely. Additional information on egg distribution at this site was provided by lobster fishermen (Fig. 7). This information suggested that the extent of egg cover east of Libby Island in early September may have been considerable; unfortunately, there was not enough time to determine whether or not the egg bed was continuous between points where traps with eggs on them were hauled.

Information collected at the Little Machias Bay site (site 4) during the period Sept. 23-Oct. 3 was much more complete. A large school of herring was repeatedly observed at night in the area for about a week prior to spawning. Spawning took place on the night of Sept. 22 and eggs were first seen on lobster traps and with the video camera the next morning. The adults left the area as soon as they finished spawning. Eggs incubated for 10 days and began hatching on Oct. 2; they were still hatching on Oct. 3, the day that field work was terminated. Eggs were laid in depths of 60-100 ft (20-35 m) at this site.

The Little Machias Bay egg bed site was mapped using information obtained from video observations with the ROV, bathymetric data, and samples of eggs and bottom sediments collected by SCUBA divers and the grab sampler. SCUBA operations were limited to the shallower, nearshore portion of the egg bed. Additional information on egg cover was obtained from the fishermen. All of the information collected in the field (Fig. 8) was combined to show the distribution and extent of egg cover at this spawning site (Fig. 9). Eggs were deposited over an area approximately 1 km^2 in size. The egg bed extended along the shoreline within 500 ft from shore east of Deer Island, behind three near- shore rocky ledges, in depths of 60-80 ft (20-25 m) and in deeper water (100-110 ft or 25-35 m) further offshore be- tween the Black Ledges and the Old Man. Egg cover

dimin- ished west of Cape Wash Island and the Old Man, offshore in depths greater than 110 ft (35 m) inside the entrance to Little Machias Bay, and east along the shoreline. It was uncertain whether the inshore, eastern edge of the bed was clearly defined; some fishermen reported finding more eggs on traps nearer to Great Head. Where egg cover was heavy, a continuous "carpet" of eggs about 1 inch (1-3 cm) thick was laid on the bottom. Near the edges of the bed, egg cover diminished in density and eggs were either found in more isolated, discrete clumps or scattered loosely on top of the bottom sediments.

The bottom substrate at sites 1 and 4, as well as at other egg bed sites that have been surveyed on this spawning ground, is composed of a mixture of shell fragments, gravel, and sand. Tidal currents along this part of the coast are strong, reaching 2 knots at the surface and 1.5 knots at the bottom at one location east of Cross Island (Townsend et al. 1985). Consequently, bottom sediments are extremely coarse and the amount of clay and silt in surficial sediments is negligible. The absence of fine sediments along this section of coastline accounts for the excellent visibility encountered during the ROV dives. Other herring spawning grounds that have been studied in the Gulf of Maine are also characterized by vertical turbulence, strong bottom currents and coarse bottom sediments (Drapeau 1973; Boyar et al. 1973; Cooper et al. 1975).

Preliminary laboratory analysis of sediment samples obtained at site 4 (Table 4) indicate that the substrate is extremely variable. Samples collected within short distances of each other differ considerably in the percent composition (by weight) of shell material, gravel, and sand. It seems unlikely, given this degree of variability, that there would be a characteristic bottom type that distinguishes egg bed substrate. Final conclusions concerning substrate differences inside and outside of egg beds on the eastern Maine coast will require further analysis of bottom sediments.

Examination of intact pieces of egg mat recovered in the grab sampler or by SCUBA divers failed to reveal any significant number of dead eggs; most estimates of the percentage of dead eggs were 1% or less. Daytime video observations of the egg bed did not show any signs of egg predation at sites 1 or 4, although cod have often been caught at other spawning sites by local fishermen with their stomachs completely filled with herring eggs. Egg bed samples from site B also failed to show any difference in the stages of embryonic development inside the eggs that could be attributed to the position of the eggs in the egg mass, i.e., eggs deposited at the bottom of the egg mass remained viable and developed at the same rate as eggs at the top of the egg mass. Other investigators have reported 60-70% egg mortality rates at the bottom of thick egg mats

(Cooper at el. 1975). The eastern Maine coast appears to provide optimum conditions for egg deposition and survival. Key factors are probably the amount of bottom current and the presence of coarse bottom sediments, both of which allow sufficient quantities of oxygen to reach eggs at the bottom of the egg mat.

Preliminary estimates of egg density and abundance at site 4 (Tables 5 and 6) indicate that egg cover was heavier in the deeper portion of the egg bed. Maximum egg cover (average values at individual sample locations) reached almost five million eggs/m^2 in deeper water and three million/m^2 in shallower water. Using an overall, conservative, estimate of two million eggs/m^2 for the entire egg bed and the known egg production of a 30 cm long female herring (100,000 eggs), it was estimated that approximately 20 million females spawned at this location in late September, or 40 million adults, assuming a 1:1 ratio of males to females. If each adult weighed 0.2 kg, the total biomass of adult herring which spawned at this site was 8000 metric tons. This is clearly a rough estimate, but it suggests that this was a large spawning episode. Estimates of the total adult biomass for the entire coastal herring stock (including Jeffreys Ledge) during the period 1975-1982 varied between 50,000 and 100,000 tons (Fogarty and Clark 1983).

MANAGEMENT

The herring stock along the Maine coast is managed according to objectives outlined in the Interstate Sea Herring Management Plan of Maine, New Hampshire, Massachusetts, and Rhode Island which went into effect in late 1983 following the withdrawal of the federal herring management plan in late 1982. The federal plan was more restrictive than the current state regulations ;it was designed to achieve stock recovery by means of quotas on the capture of adult (age 3+) herring. Maine adopted complementary quota regulations to limit the catch of adults in state waters in 1978 which remained in effect through 1982. Spawning closures were also instituted by the Maine Department of Marine Resources in 1978 and have remained in effect ever since. Aside from a state law that prohibits the catch of juveniles smaller than 4.5 inches, spawning closures are the principal means of herring management currently in effect in Maine.

The rationale for basing management of Maine's herring resource primarily on spawning closures is outlined in the Interstate Herring Management Plan and in a document prepared by DMR in 1981 which outlines management policies for a number of marine resources harvested in the state. Spawning closures prevent the capture of herring containing spawn (roe or milt) during a pre-determined period of time during the spawning season when the adults are congregated

on the spawning grounds and are particularly vulnerable to the purse seiners. It is believed that fishing just prior to and during spawning can disrupt herring behavioral patterns associated with and necessary for successful spawning, in addition to causing excessive fishing mortality.

Since 1983, spawning closures in eastern Maine (east of Schoodic Point to the Canadian border) have been based on the reproductive condition of female herring in the area. As such, there is no fixed date at which the fishery is closed. The fishery is automatically closed to the capture of adults containing spawn on August 15 and remains closed for a period of four weeks unless females 28 cm or longer in length in maturity stages III,IV and V (i.e., with developing ovaries) have not yet reached an average gonad-somatic index (GSI) of 17% by August 15 or if 24-27 cm females have not yet reached a GSI of 10% by the same date. The regulation is delayed for consecutive seven day periods until there is evidence that the females have reached the designated GSI values. These GSI values were selected in order to provide about two weeks of protection to the adult fish before they spawn; the maximum mean GSI reached by large females at full maturity is, for example, 25%. Any spawning closure, regardless of the date when it goes into effect, lasts for four weeks. During that time, catches that contain no more than 25% adults with spawn are allowed. Fixed gear catches east of Cutler are exempted from the spawning closure. Between Schoodic Pt. and Cutler, fixed gear is subject to the same restrictions as mobile gear. Similar closures are in effect in the central and western sections of the Maine coast except that the automatic starting date is September 1 instead of August 15. South of Portland, there is a fixed spawning closure extending from October 1 to 21.

CONCLUSIONS

The following results of research on the eastern Maine spawning ground during 1983-86 directly relate to the four objectives identified in the SPO project.

1) Spawning may begin as early as late July or as late as the end of August and last until mid to late September. Adult herring begin congregating along the coast prior to spawning, i.e. beginning in July. Thus, the spawning season (the period of time during which eggs are actually deposited on the bottom) may last anywhere from four to eight weeks whereas schools of adult fish may persist in the area for three months or so. There is some evidence from larval studies (Graham & Sherman 1984) that in some years spawning may continue into October.

2) Spawning generally occurs within three miles of the coast or islands in depths of 50-150 ft (20-50 m) in locations characterized by considerable vertical turbulence and current action where bottom sediments are coarse and composed of a mixture of sand, gravel, and shell fragments.

3) Approximately half-a-dozen individual spawning sites are utilized each year. Some of these are "popular" locations where adults return frequently; others are visited only once in a while.

4) Most sites are small (less than 1 km^2 in size) although the intensity of spawning varies considerably from site to site depending on how many fish lay their eggs in any one location at any single time.

5) Since each year is different in terms of the timing and intensity of spawning at each individual site as well as the date at which spawning begins and the duration of the spawning season, it is not possible to predict when, during any particular year, maximum egg and larval production will occur. A four week spawning closure clearly does not provide maximum protection for adult herring in eastern Maine; it is understood to be a compromise between a fully effective stock conservation practice and the need to permit some harvest of adults by the purse seine fleet. As long as the spawning closure remains a compromise solution, existing management regulations provide the most feasible means for determining when the fishery should be closed.

6) Coastal development and the dragging of mussels, scallops, quahogs, and groundfish are a potential threat to the survival of herring eggs on the eastern Maine spawning ground since egg beds are located on fairly flat, shallow areas of bottom close to shore. Discharge of domestic sewage, either treated or untreated, could also have a direct effect on egg survival or larval development and could disperse adults which are highly sensitive to low concentrations of pollutants such as chlorine. This issue has already come up in Cutler (see attached). The passage of legislation in the spring of 1987 prohibits the overboard discharge of chlorinated waste along the entire Maine coast and should provide some protection for herring spawning sites. Dragging is currently not a problem in eastern Maine since there is no groundfishery and scallops, mussels, and quahogs are being harvested at other times of year or in other locations. However, steps should be taken to insure that nearshore areas between Jonesport and West Quoddy Head are protected from dragging between August 1 and October 1.

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Table 1

1986 EASTERN MAINE HERRING EGG BED
RESEARCH PROJECT

ROV DIVES

	Location			
Date	1	4	6	7
09/09	1			
09/10	3			
09/14	3			1
09/15		1		
09/17	2	1		
09/18	3	2		
09/19				1
09/20		3		
09/22		1	4	
09/27		6		
09/28		2		
09/29		2		
10/01		3		
10/02		2		
10/03		2		
Totals	12	25	4	2

Table 2

1986 EASTERN MAINE HERRING EGG BED
RESEARCH PROJECT

BENTHIC GRAB SAMPLES

	Location				
Date	1	4	5	6	7
09/09	2				
09/10	5				
09/14	1				1
09/17	5				
09/18	1	1			
09/19					13
09/20			5		
09/22				3	
09/23		4			
09/25		8			
09/26		11			
09/27		17			
09/28		5			
09/29		9			
10/01		6			
10/02		7			
10/03		3			
Totals	14	71	5	3	14

Table 3: Summary of herring egg bed locations and estimated spawning times in eastern Maine coastal waters during 1983, 1984 and 1985.

Site	Location	Spawning Times 1983	1984	1985
A	Long Point	no spawning	Sept. 27-28	no spawning
B	Little River Is.	no spawning	no spawning	Sept. 10-11
C	Great Head/Old Man	Aug. 23-24	Aug. 18	Aug. 15
D	Double Head Shot Is.	Sept. 8	Aug. 22-25	no spawning
E	Seal Cove	Sept. 14	no spawning	no spawning
F	Libby Islands	date unknown	Sept. 7	Aug. 28
G	Libby Islands	no spawning	Sept. 17	no spawning
H	Scabby Islands	early Sept.	no spawning	no spawning
I	Libby Islands	no spawning	no spawning	Aug. 28
J	Libby Islands	no spawning	no spawning	Sept. 16-17
K	Smith Reef	no spawning	no spawning	Sept. 19
L	Holme's Cove	no spawning	no spawning	Aug. 29
M	Jim's Head/Boot Head	no spawning	no spawning	Sept. 6

TABLE 4

1987 EASTERN MAINE HERRING EGG BED STUDY

SEDIMENT SAMPLE ANALYSIS

Sample	Depth (m)	%Shell	%Gravel	%Sand
Inside Egg Bed				
B74	22	97	0	3
B56	25	18	28	54
B68	27	32	36	32
B63	32	40	28	32
B77	32	33	15	52
Outside Egg Bed				
B51	20	15	41	54
B70	22	67	1	32

Table 5: Herring egg density and abundance in shallow water (22-25 m), Little Machias Bay, Sept.1986.

Sample	Thickness (mm)	N	Density (#/cc) Avg.	Density (#/cc) Range	Abundance (#/m^2x10^6) Avg.	Abundance (#/m^2x10^6) Range
B62	8-25	3	248	154-296	3.2	2.9-3.6
B74	10-20	6	159	94-212	2.2	1.7-2.9
B95	10	4	213	180-242	2.1	1.8-2.4
S7P	15	3	225	182-263	2.2	1.8-2.6
S15P	10	3	312	277-332	3.1	2.8-3.3
S8T	20	1	269	---	2.7	---
S10T	10-20	3	192	125-251	2.3	2.0-2.5
S12T	10-15	3	200	124-242	2.4	1.2-3.6
	8-25	26	216±26	94-332	2.5±.25	1.2-3.6

Table 6: Herring egg density and abundance in deep water (31-34 m), Little Machias Bay, Sept. 1986.

Sample	Thickness (mm)	N	Density (#/cc) Avg.	Density (#/cc) Range	Abundance (#/m^2x10^6) Avg.	Abundance (#/m^2x10^6) Range
B63	7.5-30	6	338	299-454	4.9	3.2-7.2
B77	10-26	6	263	185-314	4.5	2.6-7.0
	7.5-30	12	301±41	185-454	4.7±1	2.6-7.2

FIGURE 1

Herring Spawning Grounds in the Gulf of Maine
(Eastern Maine-Grand Manan Spawning Ground in Box)

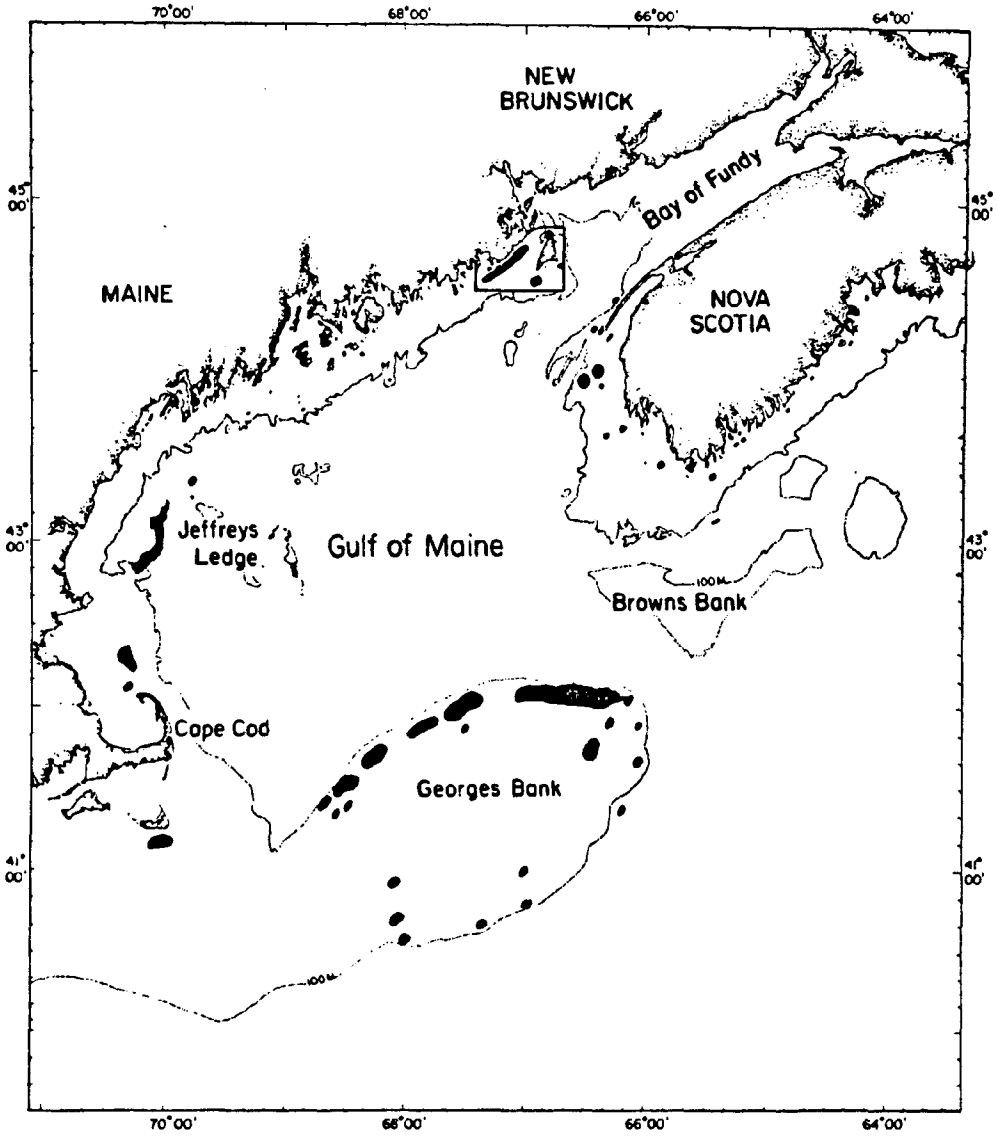


FIGURE 2

1986 Herring Spawning Sites in Eastern Maine

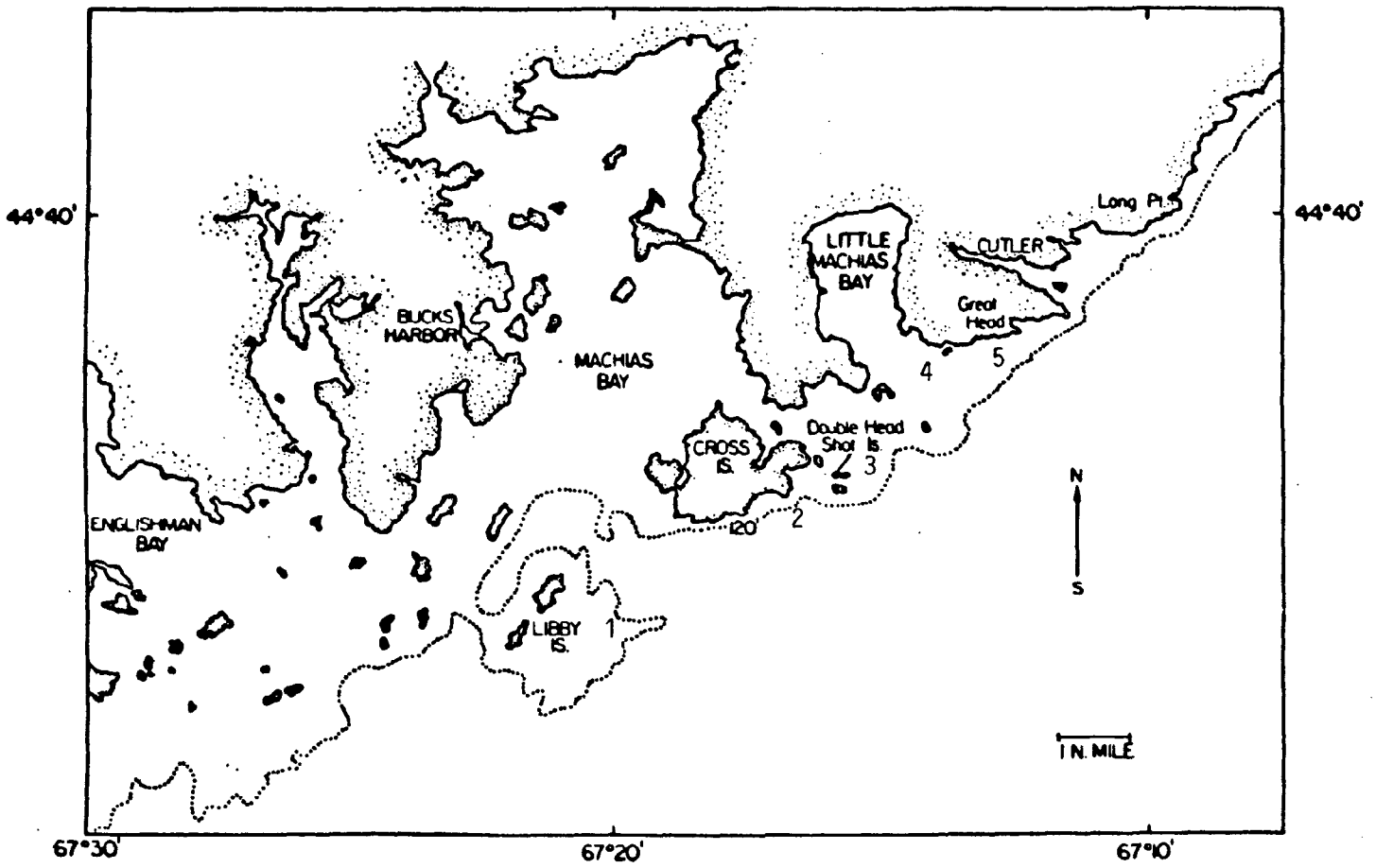


FIGURE 3

1986 Herring Spawning Sites in Eastern Maine

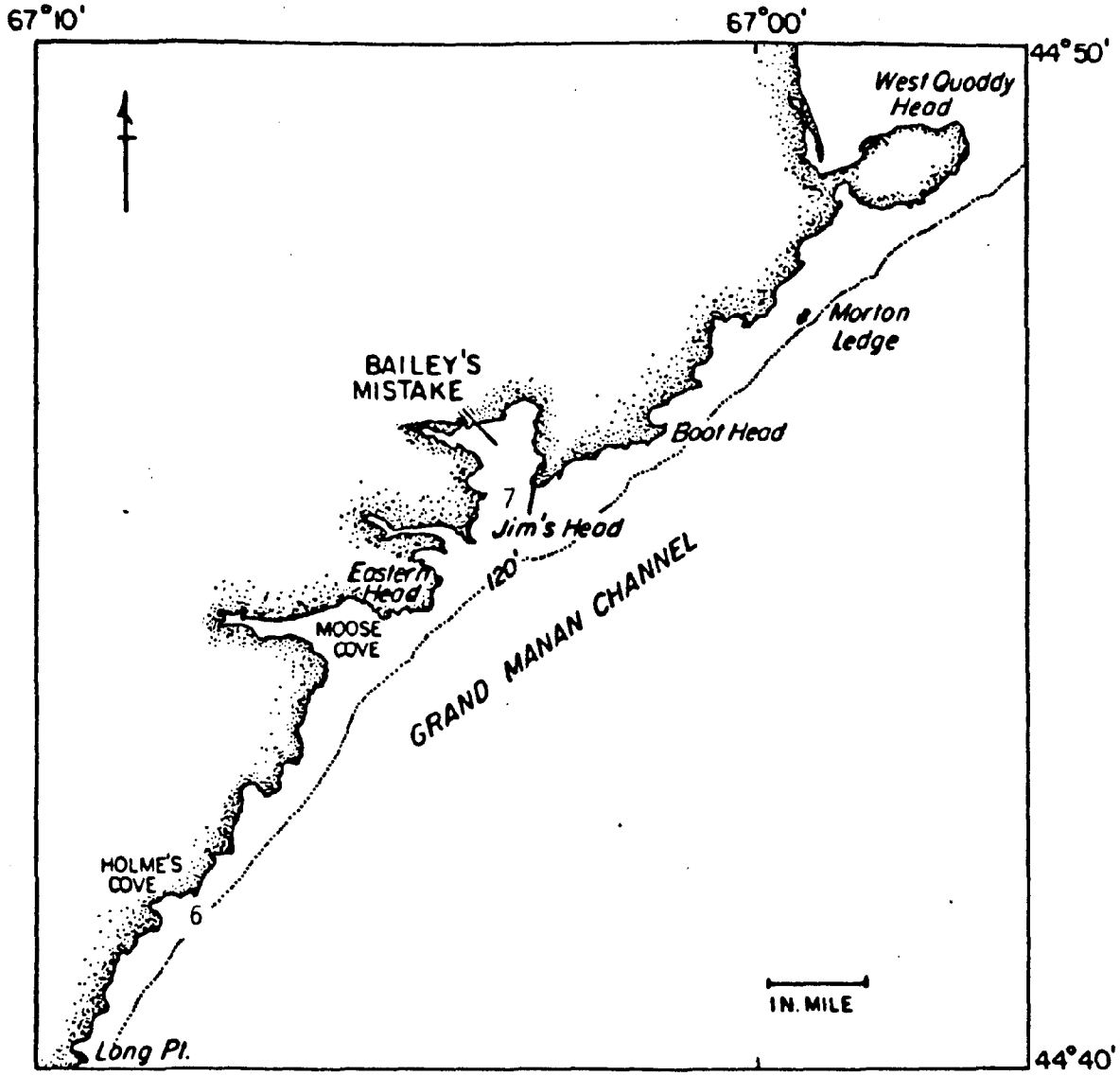


FIGURE 4

1983-85 Herring Spawning Sites in Eastern Maine

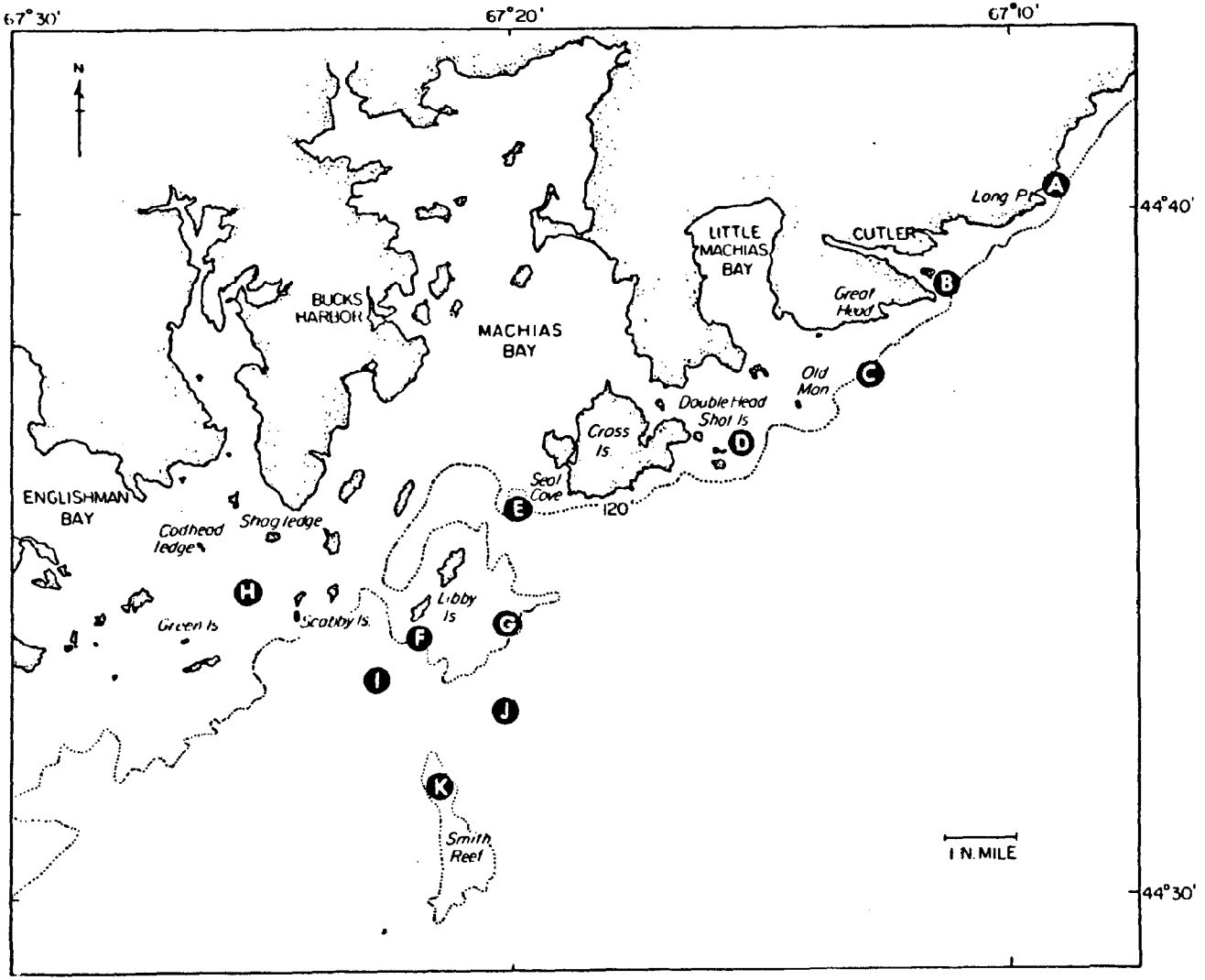


FIGURE 5
1983-85 Herring Spawning Sites in Eastern Maine

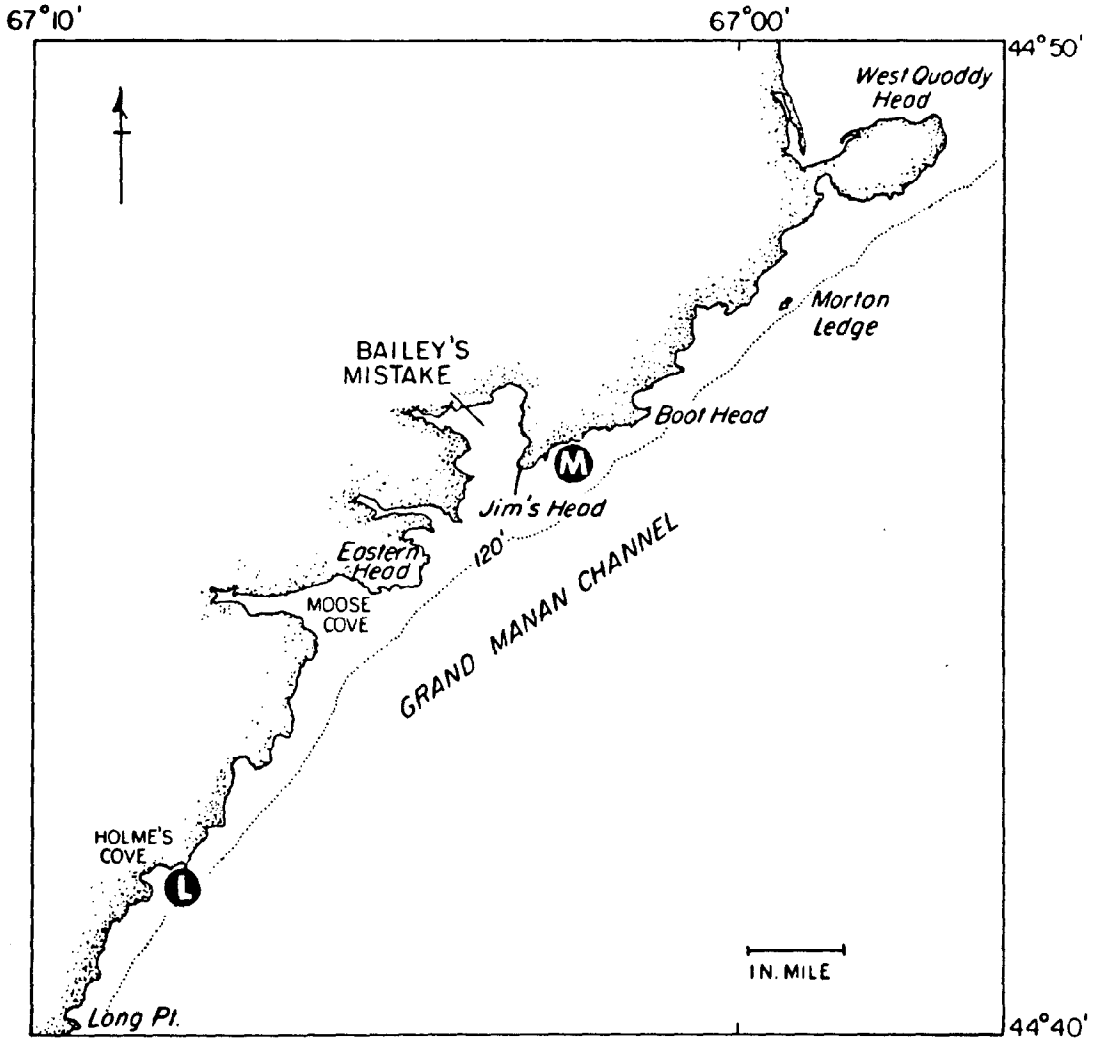


FIGURE 6

1986 Herring Egg Bed Survey Sites

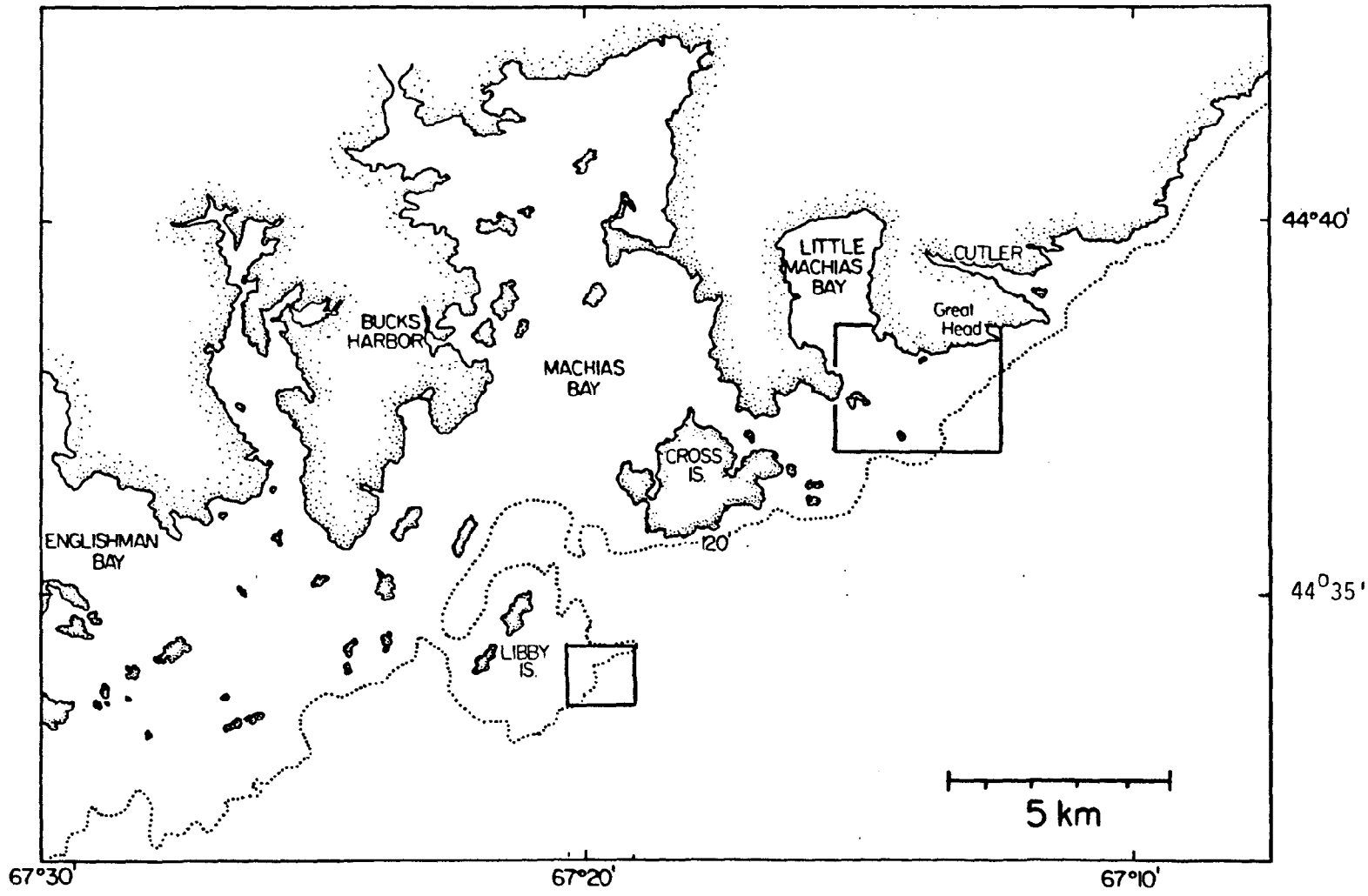


FIGURE 7

Small-scale map of the Libby Island egg bed showing depths (m) and locations of ROV dives, bottom grab samples, and lobster traps where egg were either present or absent (see Fig. 8 for legend).

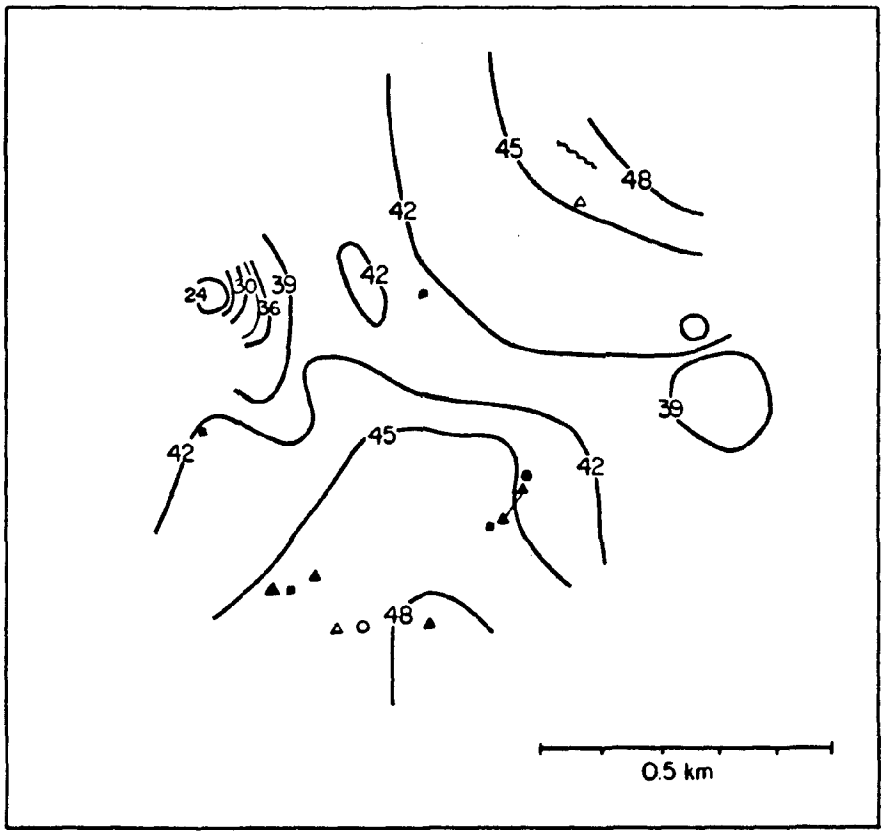


FIGURE 8

Small-scale map of the Little Machias Bay egg bed showing the mainland, islands, and nearshore ledges at high and low water, depth contours (in 5 m increments), ROV dives, bottom grab samples, and lobster traps where eggs were either present or absent. Numbers indicate locations of egg mat samples (see Tables 5 and 6). Legend: ▲,△ = ROV dives with and without eggs; ▲—▲ =ROV transect, ○ ,⊗ ,◍ ,● = grab samples without eggs, with very few eggs, a moderate number of eggs, and heavy egg cover (egg mat); ■ , □ = lobster traps with and without eggs.

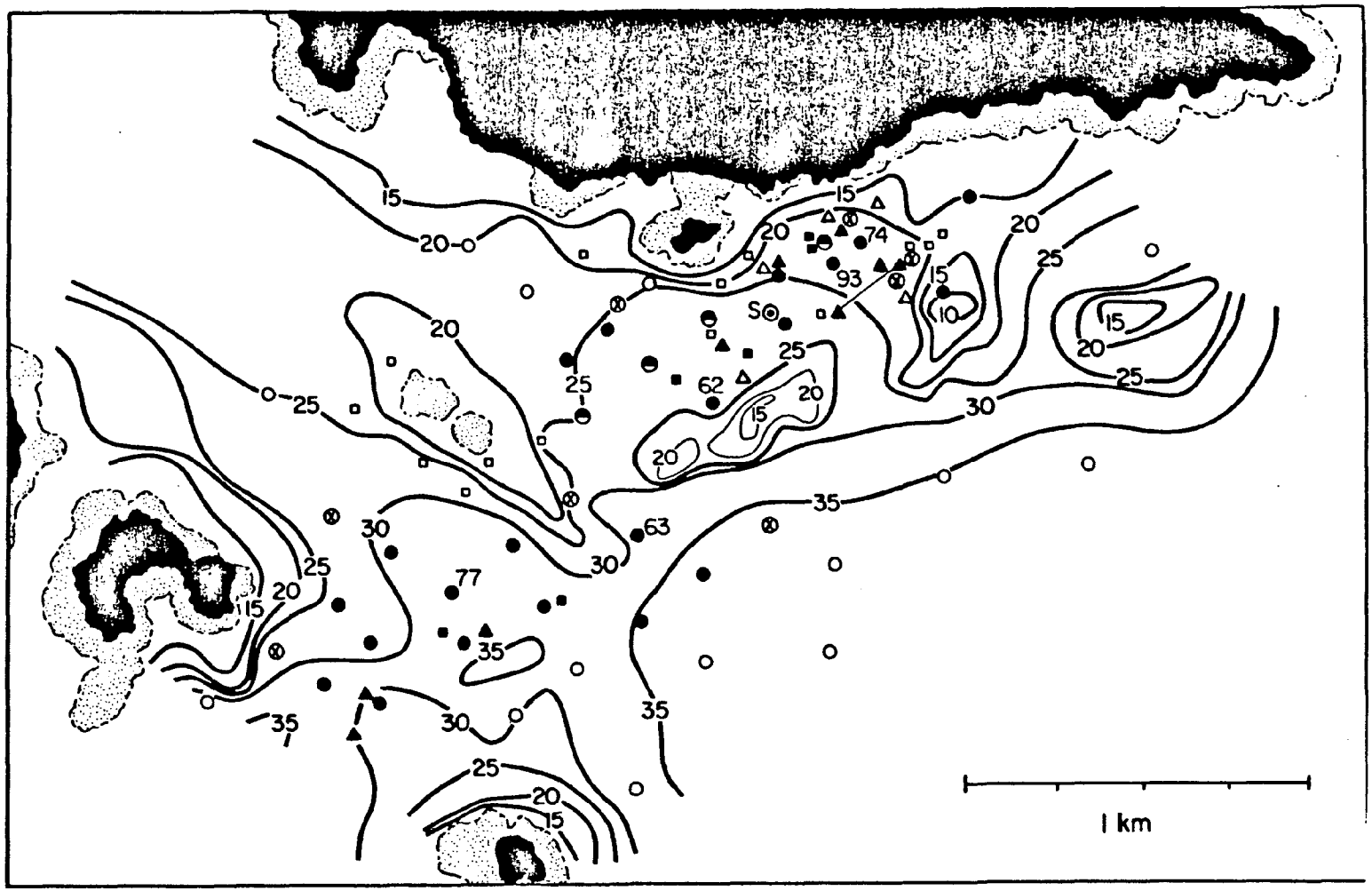
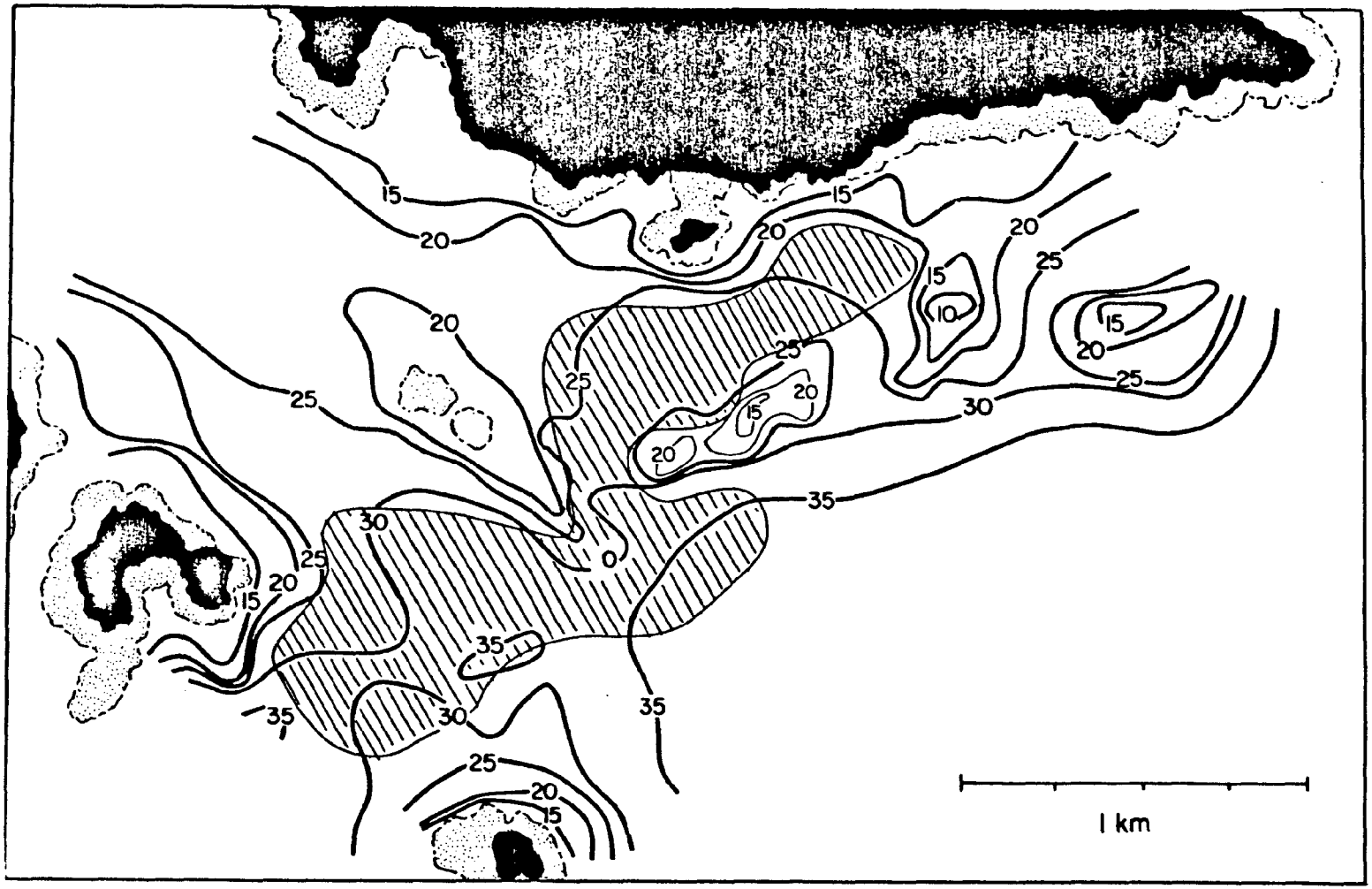


FIGURE 9

Approximate outline of the Little Machias Bay egg bed based on data in Figure 8.



State of Maine
DEPARTMENT OF MARINE RESOURCES

MEMORANDUM

Date June 16 1987

To Walter Foster

From Dave Stevenson

Subject Possible effects of chlorinated discharges on herring in Cutler area

In reviewing the small quantity of information that is in the literature on this subject and what I know about spawning activity in the Cutler area, I offer the following items for consideration in any judgement re overboard discharges at the two proposed sites at House Cove and on the inner side of Western Head in the outer harbor.

1) Herring eggs are deposited at a number of nearshore sites in depths of 50-150 ft sometimes within 100 yards of the shoreline along the coast between West Quoddy Head and Libby Islands during August, September, and October; adults begin congregating over the spawning ground in July and disperse after spawning; larvae remain in coastal waters throughout the fall, but are most abundant in September in the vicinity of the egg beds; larval transport is westward in the prevailing non-tidal coastal current, although larvae move back and forth along the coast with the tides.

2) Older fish (adults and juveniles) are probably highly sensitive to "smells" produced by chemical contaminants in the water (e.g. chlorine) at very low concentrations such that adults that are congregating in preparation for spawning might avoid an area that was near, or downstream from, a discharge point; these fish presumably would spawn somewhere else.

3) Eggs incubate on the bottom for about 10 days before hatching. During this time they would be completely vulnerable to any chlorinated discharge that might cause egg mortality or result in abnormal larval development. LC50 values for eggs of other species (including blueback herring) reported in the literature are 0.2-0.4 ppm (mg/l) total residual chlorine. Recently-hatched larave, which are incapable of any sustained swimming, would also be vulnerable. Sub-lethal effects on larval development have been reported for blueback herring at chlorine concentrations above 0.3 ppm.

4) Both proposed outfall points are located at, or very near to, herring spawning sites which I have located during surveys in the area in 1985 and 1986. Eggs were deposited close to shore on the northern side of Western Head in September of 1985 in about 100 ft of water. A major spawning took place over a 1 km^2 area in the mouth of Little Machias Bay, extending westward along the shore from Great Head to the Black Ledges and offshore to the Old Man, in September of 1986 in depths of 50-100 ft. This spawning was estimated to consist of 2×10^{12} eggs (a rough estimate) and was produced by approx. 40 million fish that remained in the immediate vicinity of the site for a week before spawning. This site has been identified by local fishermen as "the hot spot" for herring spawning in the area; our work confirms that it has been used every year for the last four years and twice in 1986; it would be directly in the path of any discharge from the House Cove outfall moving down the coast on an ebb tide. The distance is about 1 km.