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International Commission for the Northwest Atlantic Fisheries

Serial No. 3573
(D.c. 9)

ICNAF Res.Doc. 75/93

ANNUAL MEETING - JUNE 1975

Direct observations of herring (*Clupea harengus harengus* L.) egg beds on Jeffreys Ledge, Gulf of Maine in 1974

by

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Introduction

The Northeast Fisheries Center's Manned Undersea Research and Technology (MURT) Dive Team continued its study of the spawning and early life history of the North Atlantic herring (*Clupea harengus harengus* L.) during September and October 1974. This report presents data and direct observations on two deep-water spawning beds discovered on Jeffreys Ledge, Gulf of Maine. The information is expected to 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.

Boyar, Cooper and Clifford (1973) hypothesized that herring spawning on Jeffreys Ledge results in a major source of recruitment to the fishery of coastal Maine. A major gap in our understanding of the potential of the herring spawning on 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 1974 was directed towards (1) locating spawning sites, (2) defining the spatial distribution of the beds, (3) describing the egg bed-substrate relationship, (4) defining the density of eggs and larvae by depth and substrate type, (5) determining the kinds and numbers of predators, (6) observing the hatching and immediate fate of the yolk sac larvae, (7) defining the timing and associated bottom water temperatures during spawning and hatching and (8) determining the relative success of hatching. These objectives were addressed through shipboard and SCUBA diver operations.

Methods and materials

Diving operations

SCUBA operations totaled 25-man dives at Stations A, B, C and D (Figure 1), all sites of herring spawning. Divers were not able to work beyond a depth of 42 meters (23 fms), due to NOAA diving regulations re SCUBA. The collection of samples at greater depths was accomplished with a Smith-McIntyre grab. Initial indications of spawning came from the presence of adult herring and herring eggs in the stomachs of cod, bluefish and pollock that were caught commercially at Stations A-D with bottom placed gill nets. Commercial gill nets are set at these locations each fall (September-November) in anticipation of the immigrating predators.

Diver tasks encompassed (1) photographic documentation of the substrate and attached organisms prior to and after spawning and larval hatching, (2) direct sampling of the substrate with attached eggs, (3) observing predation on the eggs and (4) setting larval herring nets over the eggs to capture hatching larvae and assess success of hatching relative to substrate type, depth, and thickness of egg cover.

Macro and micro photographs were taken of the substrate and attached flora and fauna, including herring eggs and larvae, with a handheld Nikonos 35 mm camera with a MK-150 Sub Sea Strobe. Ektachrome X film (ASA 64) was used at 1/60-second shutter speed with a strobe setting of 100 and 150-watt seconds.

Samples of the rock and boulder substrate were placed in thick plastic bags by the divers and returned to the surface vessel for processing. At the surface the rocks were placed in a rinsing tray and all attached organisms were removed and preserved in ethyl alcohol. Next, a length and width measurement in centimeters was made of the dorsal surface of the rock from which the encrusting organisms and attached eggs and larvae had been removed. Egg and larval counts were later made and related to the surface area of ocean bottom from which they had come and the associated flora and fauna.

All SCUBA dives were made between 0900 and 1800 hours. Underwater visibility varied from 8 to 20 meters, permitting divers to observe the behavior of daytime predator activity. Photographic documentation of predation was not possible while maintaining a reasonable distance from the predators.

Larval herring nets were positioned at three locations on the egg bed at Station A. A one-meter wide and 0.5-meter high aluminum frame, cylindrical in shape, with 1 mm nylon meshed netting affixed to the inside wall of the frame was positioned over specific rocks and boulders with attached eggs. These nets were placed on October 7, two days prior to the beginning of hatching. Plankton sampling nets of 1 mm mesh were affixed to the upper rim of the aluminum frames with the cod end oriented downstream to capture hatching larvae.

Surface sampling operations

One hundred and fifty Smith-McIntyre grab samples were made at Stations A through D during October to define the spatial distribution of two (Station A and C-D) of the three egg beds. On approximately 15 percent of the grabs a sufficient substrate sample was not obtained because of a rock wedged between the blades of the grab. Repeat grabs were made at such stations until a decision on egg presence or absence could be made. A quantitative assessment of substrate type and egg abundance on a hard substrate was not possible with this type of grab.

Plankton tows

Ten surface plankton tows with a one-meter net were made at Station A, the egg bed location permitting the most detailed *in situ* study by the divers, to define the time of larval hatching and dispersal. All tows were made between 1200 and 1800 hours for 15-minute durations.

B.T. casts

Eighteen B.T. casts were made at Stations A through D to define temperature distribution from surface to bottom. All B.T. casts were made between 1200 and 1800 hours.

Results

General characteristics of spawning and egg bed

Table 1 presents the pertinent information describing the herring spawning phenomenon and egg bed characteristics at three locations. Spawning at Stations A and B, from discussions with commercial fishermen (gill netters), occurred from September 29 through October 3, when bottom water temperature was 9.6° C. (B.T. cast on October 2). Bottom grab samples (October 6-12) indicated the egg bed at Station A was elliptical in shape covering approximately 0.23 nm^2. Substrate type was boulders, rocks and gravel from the crest of a submarine rise at 35 meters to a depth of 50 meters. The shape of the egg bed at Station B, which appeared to be discontinuous with the egg bed at Station A, was not determined. Depth profiles at both stations are similar. Primary substrate at Station B was boulders and rock up to 1.5 meters maximum diameters.

Approximately 70 percent of the substrate at Station A was covered with clumps of the red alga, *Ptilota serrata*. This alga was not observed on the substrate at Station B. The remainder of the substrate was encrusted with bryozoans, sponges, colonial hydrozoans and coralline algae. Small rocks and gravel were relatively free of encrustaceans. No evidence of siltation was observed at either station. Observed bottom currents ranged from 0 to 1.0 knots.

Spawning at Stations C and D occurred between October 23 and 25 when bottom water temperature was 9.5° C. Egg deposition occurred from a depth of 40 meters, near the 37-meter crest of s seamount shaped elevation, and down the 20 to 40-degree slopes to the talus material at the base (53 meters) and beyond to 55 meters. Substrate type ranged from bedrock with attached red alga, *Ptilota serrata*, hydrozoans and brachiopods with encrusting sponge at 37 to 43 meters, boulders and rocks from 43 to 49 meters, rocks and gravel from 49 to 53 meters and fine gravel-coarse sand-broken shell with attached polychaete worm tubes from 53 to 55 meters. Beyond 55 meters depth the substrate was fine sand with no evidence of herring eggs.

Maximum concentrations of eggs at Stations C and D, as evidence from the grab samples, were found on the rock-gravel substrate. Although our grab samples represent a minimum estimate of egg abundance, the rock-gravel substrate appeared to contain 90 percent or more of the eggs. The gravel-shell-coarse sand substrate ranked second in egg abundance; the lowest concentrations of eggs occurred on the bedrock-boulder and coarse sand substrates.

Larval hatching at Station A began on October 6 and was completed by October 11. Direct observations and sampling by the dive team documented the presence of newly hatched larvae on the substrate on October 6 and the absence of all eggs, excluding the opaque dead eggs, by October 11. Hatching time is assumed to have been the same at Station B. Grab samples of the substrate at Station B on October 12 were free of eggs. Hatching time at Stations C and D is not known.

Egg bed-substrate relationship

The following discussion of egg-substrate relationship is based on the direct observations and sampling conducted by divers within the 35 to 40 m depth interval at Station A between October 6 and 12. A relatively uniform thickness of eggs occurred from 35 to 40 meters with discontinuous clusters associated with clumps of red algae, *Ptilota serrata*, which covered about 70 percent of the ocean floor. Between 80 and 90 percent of the eggs were adhering to the red algae. Algal clumps were attached to the dorsal surface of all rocks 6 cm in diameter and larger up to boulders 1.5 meters in diameter. On a given algal branch eggs were from one to three layers (egg layers) thick. The larger algal clumps, rising as much as 20 cm from the substrate, had the greater concentrations of eggs. Depositions on non-algal covered surfaces of the boulders and rocks was discontinuous and one egg layer thick. The remaining 30 percent of the ocean bottom was characterized by small (<5 cm) barren rocks, gravel and an occasional patch of coarse sand with a relatively sparse occurrence of eggs. Substrate surfaces that were vertically oriented, or overhangs, had very few attached eggs. It is not known whether the herring spawned selectively over the algal clumps or whether the algae functioned as an egg trap for the spawn that was settling to and drifting over the bottom with the tidal current.

Relatively large numbers of yolk sac larvae were discovered amongst the algal clumps during examination of the diver-collected substrate samples. These larvae were not visible to the divers during *in situ* examination of the substrate prior to sample collection.

Density of eggs and larvae

Table 2 presents data on egg and larval density, egg maturity stage (Colton *et al.*, 1962), length (mm) of larvae and their condition re absorption of the yolk sac, presence of aborted (hatched prematurely) larvae,and area of substrate from which the eggs and larvae were sampled by the dive team at Station A. Diver collected samples from the other stations were not made. All samples were taken from a depth of 35 to 40 meters. Differences in egg and larval densities were not apparent over this depth range. These samples, because of the method of collection discussed above, are considered to quantitatively and qualitatively represent actual egg and larval conditions on the spawning grounds. Unfortunately, the limited "bottom time" available to the divers at 35 to 40 meters and limiting weather conditions did not permit a greater number of substrate samples to be collected.

Visual examination of the rock surfaces and algal clumps suggested that the major hatching began on October 7 and 8 at Station A (Table 2). It appears that newly hatched larvae are retained for one to several days among the algal branches during which time the yolk sac is partially absorbed. Three to five days after peak hatching the algal clusters were free of larvae and viable eggs. Egg and larval densities varied from 1.4 - 16.3 eggs per cm^2 and 0.9 - 19.5 larvae per cm^2 regardless of depth. Variability in density estimates is partly a function of date of sampling and size of rock or boulder obtained in the sample. The largest boulder had the largest clumps of algae and thus the greatest density of eggs and larvae. Density of eggs and larvae combined ranged from 3.7 - 22.3 per cm^2.

Predators

The fish predator most abundant on the egg bed at Stations A, C and D during daytime was the cunner, *Tautogolabrus adspersus*. Cunners were observed on several dives (October 6, 8 and 10) feeding upon clusters of eggs among the branches of algae.

The stomachs from approximately 1,000 cod, *Gadus callarias*, bluefish, *Pomatomus saltatrix* and pollock, *Pollachius virens*, were examined by NMFS biologists and commercial gill netters. These fish were taken at Stations A, B, C and D in gill nets that fished overnight (September 28-October 10). Adult spawning herring (ripe and running) were found in the stomachs of approximately 90 percent of the bluefish and pollock; eggs were found in 70 percent of the cod. Predators ranged from 30 to 65 cm (12 to 26 inches) in total length. Bluefish had up to 8 adult herring in their stomachs. Cod fed primarly on the eggs; their stomachs were enlarged with clusters of red algae and attached eggs.

Schools of cod and pollock were observed swimming over the egg bed during daytime but were not observed feeding. The high catches of predators during nighttime with relatively undecomposed adult herring and eggs in their stomachs suggests that predation on the eggs, and probably on the adults, occurs primarily at night.

Hatching success

Rock samples taken on October 11 and 13 with 1,344 cm^2 of surface had 18 eggs (all dead) that hadn't hatched (Table 2). Assuming an average density of 5.5 eggs/cm^2 (October 6 observation-Table 2), that 1,344 cm^2 would have contained about 7,392 attached eggs. Therefore, hatching success would be greater than 99 percent. Hatching success, defined herein, is the percentage of eggs that were deposited on the ocean bottom during spawning that hatched. Since mortality, due to predation (cod, cunner etc.) is not known the above estimate of 99 percent is an overestimate of hatching success. If the definition of hatching success excludes the effects of predation the estimate of 99 percent is probably valid. Direct observations by divers indicated that less than one percent of the eggs observed on the substrate on October 6 and 8 (hatching period) were dead, as evidenced by an opaque appearance.

Future considerations

An international Man-In-The-Sea Program is planned for the fall of 1975, Jeffreys Ledge, Gulf of Maine. An underwater laboratory will be placed on the ocean bottom (37 meters) at Station A in early September. Five four-man teams of aquanaut scientists will live in this laboratory and conduct *in situ* studies of the ecological factors that affect survival of herring eggs and larvae during their benthic and planktonic phases. This saturation diving facility will permit diver scientists to spend up to 15-man hours a day, regardless of surface weather conditions, and to conduct experiments on egg maturation, predation, hatching, and dispersal.

Literature cited

Colton, J. B., Jr. and R. R. Marak. 1962. Use of the HARDY CONTINUOUS PLANKTON RECORDER in a fishery research program. Bull. Mar. Biol., 5(49): 231-246.

Boyar, H. C., R. A. Cooper and R. A. Clifford. 1973. A study of the spawning and early life history of herring (*Clupea harengus harengus* L.) on Jeffreys Ledge in 1972. ICNAF Res. Doc. 73/96, 27 pp.

Table 1. General characteristics of herring spawning and egg beds at three locations.

Spawning Location (Fig. 1)	Dates of Spawning	Bottom Water Temp. (°C) at Spawning	Substrate Type (Algal Cover)	Depth Range of Eggs (Meters)	Area of Egg Bed (nm^2) & Shape	Dates of Hatching	Egg Density No/m^2	Predators (Finfish)
STA. A	Sept. 29 to Oct. 3	9.6° C	Boulder Rock Gravel 70-80% Algal Cover (*Ptilota serrata*)	35-50 m	0.23nm^2 Elliptical	Oct. 6-10	161,000	Cunners Pollock Bluefish Cod Haddock Hake
STA. B	Sept. 29 to Oct. 3	------	Boulder Rock Gravel No *P. serrata*	------	------	Oct. 6-10 (assumed)	-------	---------
STA. C-D	Oct. 23 to Oct. 25	9.5° C	Bedrock Boulder Rock Gravel Shell 10% Algal Cover	40-55 m	0.41nm^2 Irregular	Nov. 1-3 (probable)	-------	Cunners Pollock Cod Haddock

Table 2. Density and general condition of eggs and larvae sampled by divers from known areas of ocean bottom at Station A. Egg maturity stage was judged as 1 through 6 (fully mature--stage 6).

Sampling Date	Substrate Area (cm^2)	Number Eggs	Egg Density (No/cm^2)	Egg Stage	Number Larvae	Larval Density (No/cm^2)	Yolk sac Presence	Length of Larvae(mm)	Total Eggs and Larvae	Density of Total Egg & Larvae (No/cm^2)
Oct. 6	145.1	900	6.2	Late 6	177	1.2	complete	4-5	1,077	7.4
Oct. 6	38.7	111	2.9	Late 6	33	0.9	complete	4-5	144	3.7
Oct. 8	580.5	9483	16.3	Late 6	3491 (few aborted)	6.0	complete to partially absorbed	5-6	12,974	22.3
Oct. 8	206.4	300	1.4	Late 6	4031	19.5	complete to partially absorbed	5-6	4,331	21.0
Oct. 8	464.4	987	2.2	Late 6	3674	7.9	complete to partially absorbed	5-6	4,661	10.0
Oct. 10	522.5	1838	3.6	Late 6	163	0.3	partially absorbed	6-7	2,001	3.8
Oct. 11	484.0	10	0.1	4-6 (all dead)	9 (few aborted)	0.02	50 percent absorbed latest stage larvae found on substrate	6-7	19	0.04
Oct. 13	860.0	8	0.00	5-6 (all dead)	0	0.0	---------	---	8	0.00

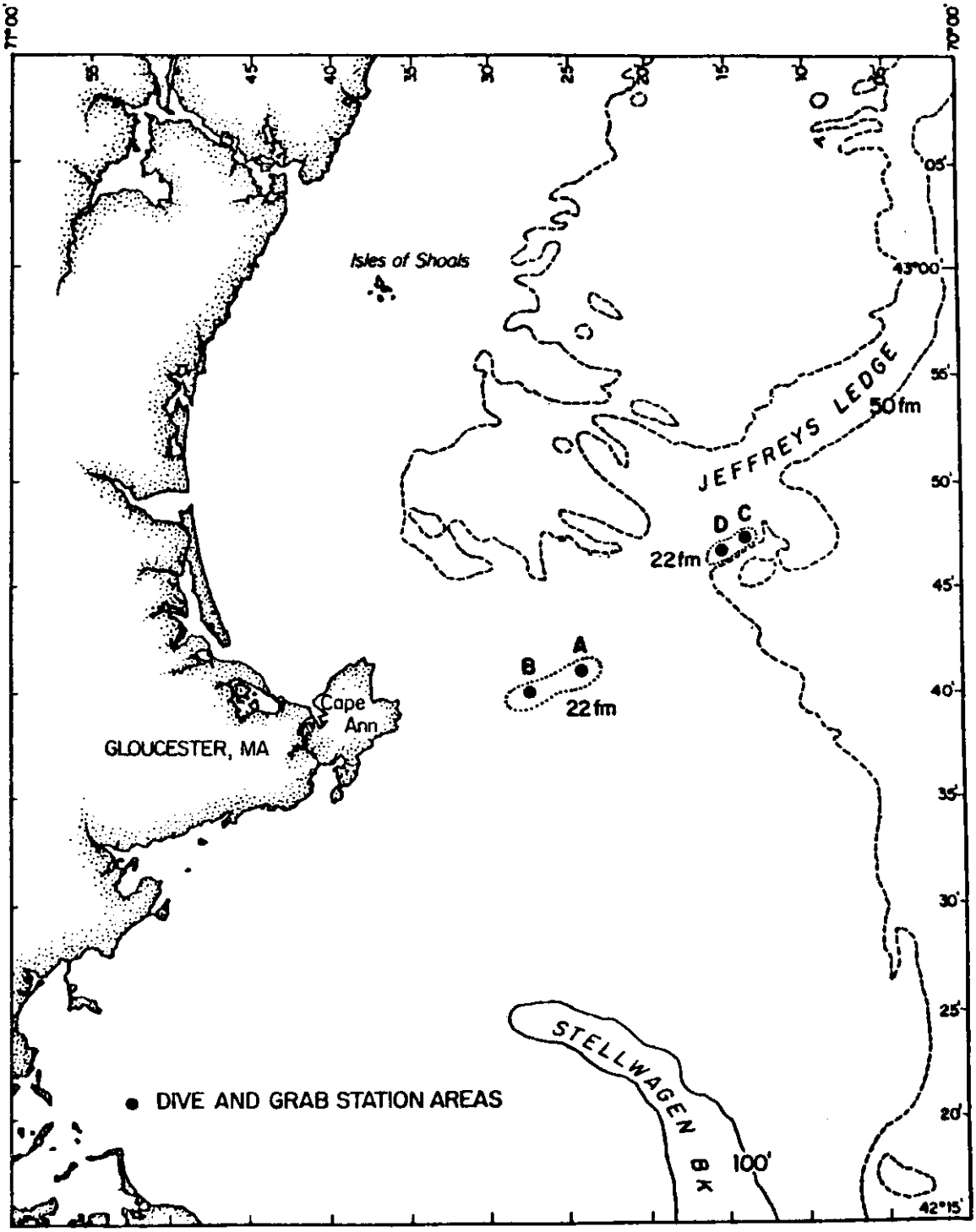

Figure 1. Sampling stations on Jeffreys Ledge where evidence of herring spawning was found.