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A PRELIMINARY REPORT ON THE COMBINED U.S.S.R., U.S.A., AND CANADIAN SURFACE SHIP AND SUBMERSIBLE STUDY OF HERRING SPAWNING GROUNDS, GEORGES BANK, 1970

By

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INTRODUCTION

Russian scientists have carried out quantitative surveys of the extent and intensity of spawning on Georges Bank since 1964 (Noskov and Zinkevich, 1967) using bottom grabs to sample deposited spawn. These surveys have shown a progressive contraction in the spawning area and in the total number of eggs laid from which a corresponding reduction in adult stock size was deduced. In first presenting evidence of this kind for a declining stock, Noskov and Zinkevich (1967) drew attention to the desirability of a more direct study of the spawning grounds by *in situ* observation.

The offer of the use of a submersible by Canada and of a mothership by the United States in mid 1970 made it possible to plan and organize a combined survey for the fall involving all three countries with this object in mind. Scientists from the three countries met in Halifax, Nova Scotia, in September to discuss details and final co-ordination of plans took place in Woods Hole, Massachusetts, just prior to the sailing of the mothership, *ALBATROSS IV*, which carried the submersible, *PISCES I*, on its aft deck, together with the auxiliary equipment.

Scientists from each participating country have prepared preliminary reports dealing with those aspects of the project they were most concerned with. These reports are presented below. For the purpose of this document the contributing scientists have been listed at the beginning in alphabetical order.

1. STUDIES ON GEORGES BANK HERRING SPAWNING IN 1970

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INTRODUCTION

One of the main objectives of the third cruise by SRTM-8006 *ALFERAS* from July 12 to December 5, 1970, was to conduct a complex of studies on the intensity of herring spawning on Georges Bank. The program included the following steps:

1. The collection of material on the distribution and biology of prespawning herring in the northern part of Georges Bank.

2. The location of herring spawning grounds.

3. The estimation of the area of the spawning beds and of the number of eggs deposited on the spawning grounds; the study of the character of egg depositions and survival and of the effect of predators.

4. The subsequent distribution of herring larvae on Georges Bank.

METHODS

Material on the distribution, behaviour and biology of herring was collected by means of trawl stations (32.5 m trawl) carried out from the end of August until the end of October. Areas of intensive fishing for herring by the commercial fleet were mapped out and echo-sounding surveys of the whole northern part of Georges Bank conducted.

Biological analysis included length measurements, determination of sex and maturation stage (by the 8-grade table) and of intestinal fat using the Hjort criteria; the feeding intensity was recorded and the Fulton and Clark coefficient of body fat content determined. Otoliths were taken for subsequent age determination.

The search for herring spawning beds, using a 1.2 m drag, was directed towards areas selected as a result of the first stage of the research program. As soon as the drag brought aboard herring eggs with substratum, an OKEAN - 50 grab was substituted. Sampling then continued until the whole area of an egg patch was delimited so that the total number of eggs on one spawning ground could be estimated. The vessel then moved to sample another likely area.

Sampling for herring larvae over the spawning period covered a large triangular area in the northern part of Georges Bank where herring spawning had been observed in recent years. In November, the whole area of Georges Bank and the region west of the Bank up to Hudson Canyon was surveyed as part of the regular ichthyoplankton survey.

Larval sampling was carried out using an IKS - 80 net (ichthyoplankton conical net, with a mouth diameter of 80 cm) towed for 10 minutes in the surface 1-m stratum with the vessel circulating at lowest speed.

RESULTS

In the last ten days of August herring were concentrated on the eastern slopes of Georges Bank at depths of 50-100 m. By that time feeding had virtually ceased and intestinal fat had declined to the "0" stage. Gonads were in stages IV and IV-V. Echo-sounder surveys showed that the largest concentrations of spawning herring occurred during September. From late August to early October the prevailing size range was from 26 cm to 34 cm herring, with a peak at 29 cm and a mean size of 29.5 cm. The sex ratio of prespawning and spawning concentrations was close to 1:1.

Maturation stages for herring sampled in September are given in Table 1, and Fig.1 shows the length distribution.

Table 1. Maturation stages of Georges Bank herring, September 1970.

Date	No. fishes analy-zed	juv.	Sex ♂	Sex ♀	II ♂	II ♀	III ♂	III ♀	IV ♂	IV ♀	IV-V ♂	IV-V ♀	V ♂	V ♀	V-VI ♂	V-VI ♀	VI ♂	VI ♀	VII ♂	VII ♀
9.11.70	100	-	42	58	1			1	5	4	36	52		1						
9.15.70	100	5	51	44					1		16	20	25	7	9	15		2		
9.20.70	100	-	35	65												1		5	35	59
9.26.70	100	1	62	37							1		10	1	29	6	12	29	1	
9.27.70	100	11	47	42						2	18	25	20	9	6	8			1	
9.28.70	100	1	61	38								1	29	2	26	29	5	6	1	

According to data collected by *ALFERAS*, herring spawning in 1970 was prolonged compared with previous years. It began in the first five days of September and continued until the end of October. The spawning grounds were found in the northern part of Georges Bank at approximately the same locations as in previous years. Egg deposition in the centre of spawning beds was not uniform but formed a discontinuous layer. Also, the thickness of the egg layer diminished from the centre to the periphery. The maximum density of eggs recorded was 24.4 kg/m^2 but samples from the outlines were much less dense. Eggs taken from the centre of spawning grounds had apparently been laid in several layers which could be easily separated by washing. Tables 2, 3 and 4 give estimates of egg density for the two spawning beds in the eastern part of the area and for one on the western part. The eggs spawned on the eastern grounds (Fig.2) were developing in homothermal environments at 13-14°C, while on the western spawning ground (Fig.3) the bottom temperature was 11-12°C. Eggs throughout the mass were in the same or similar stage of development and it may thus be suggested that spawning takes place over a short period of 2-3 days.

Egg survival is high. The number of dead eggs in each sample did not exceed 1%.

Dense concentrations of cod which had fed heavily on eggs were found in the area after spawn had been laid. Flatfish, haddock, skates, dogfish and invertebrates (starfish, sea urchins, polychaetae and hermit crabs) were also in abundance on the spawning grounds.

The estimated time of spawning was September 16-17 on the first eastern ground and September 29-30 on the second one, so that the main body of the herring spawned within a period of two weeks. Eggs on the eastern grounds were mainly in the second and third stages of development, while on the western grounds they were in the first and second stages. Assuming an incubation period of about 150 degree days, the larvae from the eggs on the first eastern spawning ground would have been hatched on September 25-26, on the second one on September 27-28, and on the western ground on October 12-13. To confirm the time of hatching on the first eastern ground, a subsequent egg sample was taken (in the fourth stage of development) and incubation was completed in Petri dishes and polyethylene jars. Mass hatching of larvae was observed after one hour in the water at 16.4°C; the mean length of the newly hatched larvae was 4.5 mm and the larvae survived for about one hour.

Table 2. Egg density (kg/m^2) on the eastern spawning ground No. 1

Sta. no.	Latitude	Longitude	Quantity of eggs kg/m^2	Sta. no.	Latitude	Longitude	Quantity of eggs kg/m^2
6	41°53.90'	67°14.60'	0.15	116	41°53.65'	67°14.67'	0.06
7	41°54.10'	67°14.50'	9.10	117	41°53.65'	67°14.80'	0.02
48	41°54.30'	67°15.20'	0.80	118	41°53.87'	67°14.93'	0.27
51	41°54.10'	67°14.55'	0.90	119	41°53.90'	67°15.00'	18.80
57	41°54.28'	67°15.18'	0.10	120	41°53.98'	67°15.08'	8.60
59	41°53.90	67°15.00'	12.20	132	41°54.12'	67°14.35'	0.02
60	41°54.00'	67°14.80'	15.50	137	41°53.60'	67°14.96'	0.20
88	41°54.16'	67°14.92'	7.30	155	41°54.30'	67°15.58'	0.04
99	41°54.26'	67°15.17'	0.12	50	41°54.21'	67°14.97'	0.04
97	41°54.43'	67°15.50'	0.02	49	41°54.26'	67°15.15'	0.03
100	41°54.20'	67°15.10'	24.40				

Table 3. Egg density on the eastern spawning ground No. 2.

Sta. no.	Latitude	Longitude	Quantity of eggs kg/m^2	Sta. no.	Latitude	Longitude	Quantity of eggs kg/m^2
3	41°52.33'	67°15.31'	6.40	15	41°52.40'	67°15.55'	2.90
5	41°52.10'	67°15.25'	0.20	23	41°52.10'	67°15.40'	2.60
9	41°52.53'	67°15.10'	0.75	30	41°52.12'	67°15.36'	0.55
14	41°52.53'	67°15.50'	0.23				

Table 4. Egg density on the western spawning ground.

Sta. no.	Latitude	Longitude	Quantity of eggs kg/m^2	Sta. no.	Latitude	Longitude	Quantity of eggs kg/m^2
4	41°58.90'	67°33.10'	0.70	40	41°58.60'	67°32.60	6.87
39	41°58.60	67°32.50'	2.90	41	41°58.65'	67°32.70'	0.08

Estimates of the herring population which spawned in this area (Figs. 2 & 3) were made from the equation (Noskov and Zinkevich, 1967):

$$N = \frac{q^{AB}}{Cx10^9}$$

in which

N = size of the spawning population (thousand tons)

A = abundance of eggs on the spawning ground (in numbers)

B = mean weight of herring specimens (grams) (equal to 200 gm)

C = 118,000 eggs (mean fecundity)

q = coefficient to account for the number of males (sex ratio 1:1)

A = DSZ, where

D = mean number of eggs in the area, kg/m^2

S = area of spawning ground in m^2

Z = mean number of eggs in 1 kg of deposited spawn - 500,000.

The area of the first eastern spawning ground was 1,099,621 m^2 (1.1 km^2), that of the second one 526,444 m^2, and of the western one 299,163 m^2. It is calculated that 9.282, 1.374, and 1.339 thousand tons of herring had spawned on these grounds respectively. Observations on the distribution of herring larvae began on October 14, by which time larval hatching on the eastern grounds was completed and was coming to the end on the western ground. From October 14 *ALFERAS* began a series of six surveys within a large triangle covering all of the known spawning areas of recent years. Work in this triangle continued to the end of October and besides samples of plankton and ichthyoplankton, water temperatures and water samples for salinity were taken at each station. Larval distribution throughout the period October 14-28 is shown on Fig. 4. The first surveys in this triangle showed that hatching was coming to the end on the western spawning ground and the following surveys revealed the process of larvae drifting into the survey area, presumably from spawning grounds located southwest of those detected. Larval size varied between 6-18 mm.

Table 5 shows the range of surface and bottom water temperature for six surveys in the triangle.

Table 5. Surface and bottom temperatures in the triangular survey area.

Date (October)	Water temp. °C at the surface	Water temp. °C at the bottom	Date (October)	Water temp. °C at the surface	Water temp. °C at the bottom
14-16	14.0-16.0	10.0-15.0	22-23	12.5-13.7	9.0-13.5
16-20	12.0-14.0	10.0-14.0	24-25	13.0-13.5	9.0-13.4
20-22	12.0-13.6	10.0-13.4	26-28	12.2-13.4	8.0-13.4

The pattern of herring larval distribution in the fall for the whole area of Georges Bank, Gulf of Maine, and American shelf as revealed by the ichthyoplankton surveys made during November is given in Fig. 5.

Biggest larval catches were recorded on the north-eastern slopes of Georges Bank. Larval size varied from 6 to 19 mm. The largest larvae of 23.5 mm were caught on the Nantucket Shoals and in the area south of Long Island.

SUMMARY

Preliminary analysis of the results of herring spawning studies on Georges Bank in 1970 shows some differences compared with previous years. One of these is the long duration of spawning which lasted for about 2 months. The cause of this phenomenon will probably become clearer after further and more detailed analysis of all the data.

The area of spawning grounds detected by *ALFERAS* appeared to be half the size of those in 1969. It may be suggested that the three detected spawning grounds are the main ones, since they are located in the same areas as in recent years and also because the main body of commercial fleet fishing for prespawning herring was found only in this area. It is quite possible that, apart from the spawning grounds detected in 1970, there were other smaller ones, but the search for them would have entailed additional expense and time.

Observations on herring larvae in the triangle indicate the existence of herring spawning grounds west and south of those detected and also confirm the fact that herring spawning begins in the eastern part of the Bank and gradually shifts further to the west, covering the area of the north-western slopes and later the Cape Cod area.

LITERATURE CITED

Noskov, A. S. and Zinkevich, V. N. 1967. Abundance and mortality of herring (*Clupea harengus* L.) on the Georges Bank according to the results of eggs counting in spawning areas in 1964-1966. ICNAF Res. Doc. 67/98.

2. OBSERVATIONS ON HERRING SPAWNING BEDS FROM THE SUBMERSIBLE *PISCES I*, 1970

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PROCEDURES AND METHODS

Two herring spawning beds were discovered by grab and dredge from the U.S.S.R. research vessel *ALFERAS* (AtlantNIRO, Kalingrad) between September 20 and 23, 1970, and the position of one of these marked by a radar buoy at Lat. 41°53'N, Long. 67°15'W. This buoy was located by the U.S. research vessel *ALBATROSS IV* on September 24 and grab and dredge operations confirmed the position of the spawning bed relative to the buoy.

The *PISCES I* is an 8-ton, 2- to 3-man submersible of 2,000 feet depth capability and a 72-hour life support endurance with a maximum speed of 3 knots. It was launched and retrieved from the modified after-deck of *ALBATROSS IV* by a 15-ton boom crane (Gallion type). Tether lines attached to a *PISCES* cradle were used to prevent undue pendulum movement during launch and retrieval operations. Even so, the pendulum length of more than 10 feet from the boom of the crane was such as to restrict operation to conditions below sea state 2.

Because of strong tidal currents in the operational area and the rotary tidal regime with no slack-water period, transects of the sea bed were passive, by tidal drift.

A radar buoy attached to *PISCES* by 275 m of light warp served to mark its position and *ALBATROSS* kept within 400 m of this buoy during transects by the submersible. The direction and distance from *ALBATROSS IV* to both the U.S.S.R. marker buoy and the *PISCES* radar buoy was monitored by Azimuth bearing and radar fix at 10-minute intervals and at 5-minute intervals while *PISCES* was on herring spawn. Contact between *PISCES* and *ALBATROSS IV* was maintained by hydrophone and observations on major changes in bottom terrain or egg density relayed to the surface to be logged. Sounder records were kept continuously while *PISCES* operated and these were annotated at the time of radar fixes.

These sources of information were subsequently collated and used to prepare course and distance charts (Fig. 6), supplemented by observations on direction (by gyrocompass) and estimated bottom speed recorded and timed on *PISCES*. The results of the largely improvised system of navigation proved to be consistent within themselves and with information, particularly on bottom type by grab sample, gathered during other parts of the *ALBATROSS IV* operations.

OBSERVATIONAL AND RECORDING TECHNIQUES

Observations through the 15 cm diameter viewport in the front of *PISCES* were recorded on magnetic tape which were subsequently transcribed verbatim and interpolated with minute time checks. Observers and pilots were briefed before each dive on priorities for the type of observation. Tapes were run through after each dive to check on and, if necessary, to modify priorities and to clear up problems of identification of fauna and bottom type. The pilots provided valuable background continuity to the record and relevant comments and observations were relayed by them to the observers for recording.

Photographic records were made in black and white and in colour. A 70-mm camera mounted at the front of *PISCES* was triggered automatically at 15-second intervals. Movie and still photographs were taken through the porthole.

A sample rack containing four rectangular pipe samplers was mounted below and in sight of the port to be manipulated to take spawn and sediment samples and returned to the rack by the hydraulic arm fixed to the front of *PISCES*. This was used only on the relatively few occasions when *PISCES* could remain stationary on the sea bed.

Dives were made mostly in the 35-60 m range at which depths ambient light was too dim for satisfactory viewing. This was facilitated by 2 x 1000 watt floodlamps. Visibility varied from about 3 m to not more than about 8 m and was lower near or on egg patches than on clear bottom because of suspended debris.

RESULTS

Substrate type

Three types of substrate were found:

1. Gravel bottom - made up of rusted brown rounded pebbles 2 to 20 mm diameter, with larger sizes up to 6 cm interspersed. Occasional ice-rafted boulders up to 50 cm or more were embedded in the substrate; in some areas, up to 10% shell gravel was estimated to be present. This was made up of remains of *Ensis*, *Spisula* and *Placopecten* and had accumulated locally in some places to form patches of shell a few square metres in extent.

The most characteristic topographical feature was the level, almost horizontal nature of the sea bed, although minor surface irregularities were noted.

2. Transitional sediment. Fine sand streaks on the gravel surface merged into ripples and then waves of 0.6 m amplitude and about 3.5 m wavelength with coarse gravel in the troughs. They lay in approximately an E.W. direction, sloping gradually up from the north and dropping steeply on the south face at an angle of approximately 33° onto the coarse gravel. Sand was continuously transported across the crests of these waves.

3. Sand dunes. Proceeding southward these sand waves built up in height to form dunes. Maximum dune height was at least 10 m, with a steep drop off on the south face of each dune. The currents in these troughs and in the lee of the dunes were much weaker than near the crests and often deflected at an angle to the prevailing current direction - even almost through 90°. Although it was apparent that these systems of dunes were traversing the gravel substrate, muddy reefs of tubiculous polychaete worms often carpeted the lower face of the larger dunes suggesting that their movement was slow.

On three dives concave gouges 30-60 cm across and about 8 cm deep exposed the gray sand below the gravel surface which was heaped up on either side. These gouges continued in a straight line beyond the limits of visibility and on one dive occurred every 20 m or so for half the dive duration. It was concluded that these were caused by spreader boards of otter trawls.

Sediment preferences of spawning herring

Herring spawn was found during the course of four dives but only on type 1 sediment, i.e., on mineral gravel. It became thin and finally absent on the transitional type of sediment. Although spawn was firmly attached to gravel, rock and epifaunal growths such as hydroids and bryozoa, it was rarely seen on shell, and egg coverage invariably decreased as shell increased in proportion.

Fauna associated with the spawning grounds

All observers reported an increase in fish abundance in spawning areas. The transcribed records were analyzed for faunal occurrences for each substrate type separately, all dives being considered together. Because reference to more than one individual of a species was counted as a single occurrence to eliminate the disproportionate effect of aggregations, this analysis is not considered to give abundance estimates. It does give an estimate of the relative frequencies of each species on the three bottom types, the figures for occurrence being adjusted for distance travelled on each type of terrain using data in Table 6.

Table 6. Estimated distances travelled over three types of terrain during the 12 dives.

Dive No.	Herring spawn on gravel (metres)	Gravel:no herring spawn (metres)	Sand (metres)
1			300
2			700
3	400 +400		400
4		2,200	200
5		800	500
6			1,100
7			900
8	2,400	300	
9		500	1,200
10	700	1,400	100
11		2,400	
12	900	400	
Total distances (m)	4,800	8,000	5,400

The four fish species represented in Table 7 were relatively more abundant on spawn than elsewhere and this proved to be so for the predatory invertebrates, starfish and moon-snail. The substrate preferences of sedentary forms, scallops and sea urchins, were independent of spawn deposition.

Sedimentary preference independent of the presence of spawn was demonstrated by comparisons of occurrence on sand with that on egg-free gravel. Hake, sea urchins and scallops preferred gravel; spiny dogfish, skate, starfish and moon-snails preferred sand to egg-free gravel in contrast to their greater frequency on spawn beds.

Only red hake and moon-snails were seen feeding on spawn, although holes 0.3 m across and dug into the underlying gravel, and narrow swathes cut into the surface obviously represented predatory effects.

The occurrence of one of the most common and abundant species, the hermit crab, was independent of both substrate type and of presence or absence of spawn. This does not preclude a predatory role and it undoubtedly could be an important spawn predator.

Table 7. Estimated frequencies of observation per kilometer of dive transit for 10 common benthic fish and invertebrates over three types of terrain.

Species	Total no. observations	Frequency of observations (no./km)		
		Herring spawn on gravel	Gravel: no herring spawn	Sand
Hake (*Urophycis chuss*)	104	14.4	4.2	0.2
Sculpin (*Myoxocephalus* sp)	153	17.6	6.1	3.7
Spiny dogfish (*Squalus acanthias*)	103	9.0	3.1	6.5
Skate (*Raja* sp)	124	10.7	3.6	8.1
Starfish (*Asterias vulgaris*)	103	8.2	3.9	6.1
Moon-snail (*Polinices heros*)	43	3.4	1.1	3.3
Scallop (*Placopecten magellanicus*)	170	10.5	11.1	5.7
Hermit crab (*Pagurus* sp)	134	7.1	6.2	9.2
Sea urchin (*Strongylocentrotus droebachiensis*)	41	1.9	3.4	0.9
Bar clams (dead shells) (*Spisula solidissima*)	41	1.5	2.9	2.0

Ontogeny of a herring spawning bed

Diving operations over the spawning beds took place over a period of 7 days. A sequence of bed conditions and characteristics was observed which, although not necessarily referring to the same egg patch, appeared to represent successive stages in the ontogeny of a spawn bed.

1. The spawn formed a uniform cohesive layer 1-2 cm thick, appearing dark and with up to 95% coverage. The edges of the bed were discrete. Predators were already present and predation signs evident.

2. Bottom coverage more variable, between 40-50% with opaque white patches suggesting dead and decomposing eggs.

3. Thinly scattered traces of spawn; the decomposing or unhatched residues of a large bed.

4. Decomposing, anoxic residues of a spawning bed. A thin layer of egg shells, dead eggs and flocculent debris covered a black layer on the substrate which, when sampled, proved to smell putrid. Early yolk-sac stages of larvae were found close to the bottom.

5. In the vicinity of a bed observed earlier, no spawn but large amounts of organic debris and a discrete aggregation (estimated at about 45 metres across) of larvae, still with yolk-sacs, being carried along by the current.

DISCUSSION AND PRELIMINARY CONCLUSIONS

A more complete picture awaits further analysis of data and the assimilation and collation of results from other aspects of the project as a whole.

The *PISCES* operation, however, had demonstrated the feasibility of a submersible operation for *in situ* observation even in an area where hydrographic conditions are limiting. Observations were made which would be difficult or impossible to make in any other way and observational experience at the sea bed provided valuable insight, particularly into dynamic processes.

Some of the more obvious and immediately more interesting points to arise are dealt with here. Undoubtedly others will suggest themselves.

The geography and sedimentology of the general spawning area

The flat gravel plain, the preferred spawning substrate, has the appearance of an intertidal sediment suggesting relict beach gravel. There is an analogy here with the Dogger Bank spawning area in the North Sea. The large dunes are thought to move only slowly, possibly only a few metres a year, so that the spawning areas substantially retain their identity from year to year. The continual movement of sand ripples and of smaller sand waves might, however, explain the relatively sparse epifauna which was a feature of the bed area.

Large expanses of gravel were traversed which, although apparently identical to areas where spawn occurred, were spawn-free. It seems highly unlikely that lack of suitable spawning substrate is, or ever has been, a limiting factor in the reproduction of Georges Bank herring.

In view of the highly specific substrate preference it would be advantageous to prepare sedimentary maps of potential spawning areas before a survey, to avoid searching unsuitable areas.

Ontogeny of spawning beds and quantitative sampling

The first successful dive, on a recently laid bed, indicated a firm cohesive uniform egg mat with discrete margins. Patchiness and friability increased at later stages from predation and developmental processes, uneven hatching or death and decomposition of eggs; estimates of original densities of spawn (and thus of size of the spawning community) would thus progressively decline. It seems possible that weighting factors could be derived to correct for the ontogeny of the bed by determining development stages of sampled eggs, though not necessarily from the results of this survey alone. This possibility is being investigated.

The development of an anoxic residue and its apparent persistence after the fertile eggs have all hatched is surprising in view of the strong currents in the area. It does suggest that a period of recuperation is necessary before spawning can recur in the same locality.

Spawn density

The level nature of the substrate and the uniform thickness of recently laid spawn estimated at more than 1 and less than 2 cm allows reasonable estimates of spawn density of from 13 to 20 kg/m^2. This is close to the highest individual estimates from *ALFERAS* grab samples and tends to confirm opinions (and the argument above) that conventional grab techniques would lead to underestimates of spawning stock sizes.

Spawning behaviour

The uniform deposition of eggs over considerable areas in a region swept by currents suggests highly co-ordinated spawning behaviour involving very large numbers of individuals - very likely aggregated as a single unit in a single spawning occasion. The surprising uniformity of coverage suggests that eggs are laid some little distance from the bottom by a uniformly layered school to sink down to the substrate.

That eggs are invariably associated with a level gravel substrate, in an area where several substrate types exist in close proximity, raises the question as to the mechanisms that could lead to this result.

The use of submersibles for survey work

The 1970 experience with *PISCES* reinforces impressions from earlier studies (e.g. Caddy and Watson, 1969) that submersibles can play a valuable role (a) in confirming earlier hypothesis, (b) in generating new lines of approach, and (c) as a calibrating tool.

Provided that problems are clearly defined and areas of operation accurately located, the versatility of submersibles is as great as the variety of equipment that can be installed and their continuing use in fisheries can be expected to expand in scope and value.

REFERENCE

Caddy, J. F., and J. Watson. 1969. Submersibles for fisheries research. Hydrospace 2(1): 12-16.

3. DISTRIBUTION OF HERRING LARVAE IN THE *PISCES I* SURVEY AREA

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INTRODUCTION

The first objective of the American research was to place the Canadian submersible over the egg beds previously located by the scientists of the U.S.S.R. and to participate in the dives as an observer. The second objective was to obtain information concerning the condition of the egg beds by conventional sampling and the third, to follow the progression of hatching from the beds through the occurrence and distribution of the larvae. This is a preliminary report of these aspects of the co-operative cruise (U.S., Canada, and U.S.S.R.) to survey the distribution of herring, *Clupea harengus harengus* Linnaeus, eggs on Georges Bank (Sept. 24-Oct. 6, 1970).

MATERIALS AND METHODS

Samples of eggs were obtained from the bottom with a Naturalist dredge and a Smith-McIntyre grab sampler. The grab sampled an area of 0.5 m^2. The dredge was fished in waters approximately 26 fathoms for 5 minutes by permitting the drift of the vessel to drag the dredge over the bottom. When eggs were obtained in the dredge, the grab was lowered over the side and the bottom sampled further. The dredge was towed 21 times and the grab was lowered 9 times. The quantity of eggs in the sample was expressed relatively as light, medium and heavy. A light catch referred to eggs scattered within the gravel or cobble; a medium catch contained small clumps (about 1 cm^2 or less); and a heavy catch contained larger clumps. Eggs were preserved in 3% buffered formalin for examination in the laboratory.

Two pairs of Bongo sampling nets (Posgay et al., 1968) were used to capture larval herring. A large pair of Bongo samplers were mounted on the towing wire above a depressor and a smaller pair were mounted 28 inches (71 cm) below it. The nets of the small Bongos had a mouth diameter of 8 inches (20 cm) and those of the larger Bongos had a mouth diameter of 24 inches (61 cm). The smaller pair had mesh openings of .253 mm and .366 mm in diameter and the larger pair had mesh openings of .333 mm and .505 mm in diameter. A single meter was installed in one net to determine the distance towed in meters and the volume of water strained was calculated by multiplying this distance by the cross-sectional area of the mouth of a given net to obtain cubic meters of water strained during a tow. The catch was expressed as the number of larvae captured per 100 cubic meters of water strained during a given tow. The gear was towed at 5 knots for 15 minutes in a staggered oblique sequence with 5 minutes each at depths of 30, 20 meters and the surface. These depths were changed to 20, 10 meters and the surface when the scientist on watch believed the nets might contact the bottom. Towing stations varied from 17 to 144 fathoms in depth. Seventy plankton stations were occupied, most during darkness. To facilitate counting, 10 samples were split in half, 5 into fourths and on into an eighth; the total number of larvae in a given sample was estimated from the split portions. For the purposes of this report, only larvae from catches with the small-mouthed net and the .366 mm mesh have been examined.

A bathythermograph cast was made at the plankton stations and a surface bucket temperature was taken. In addition, surface water was collected at each station for salinity determination and a Nansen bottle cast was made at 10 stations.

RESULTS

Although the samples obtained with the dredge and grab sampler were sufficient to place the submersible on egg beds, the number of samples collected containing eggs were few. Two samples contained light amounts of eggs, one medium and two others, heavy amounts. The largest clump of eggs was 15 cm^2 and 5.2 cm thick. The eggs were viable throughout this clump and began to hatch when transferred to sea water in the wet laboratory of the *ALBATROSS IV*.

During the cruise, 52,333 larval herring were captured. These were split into two size groups: equal to or less than 9 mm in length, 49,996 fish; and larger than 9 mm, 2,737 fish. The average catch rate of the smaller larvae was 131 per 100 m^3 of water strained per tow and 42 for the larger larvae. Catch rates varied from 0 to 1,167 for the smaller larvae and from 0 to 96 for the larger larvae. The distribution of the two size groups was similar in that the larvae were very abundant near the location of the egg beds and extended southerly from them (Fig. 7). They differed because the distribution of the larger larvae was directed more to the southeast and the location of two catches (>1) to the northwest suggested a discontinuity in their distribution. Larvae bearing yolk-sacs were obtained in the vicinity of the egg beds.

Apparently the presence of the *ALBATROSS* over the egg beds coincided with a period of hatching. No yolk-sac larvae were obtained over the egg beds on September 25, the day the *ALBATROSS* arrived. But on September 28, large numbers of larvae bearing yolk-sacs were captured; this was the day after eggs were dredged from the bottom and hatched on board in sea water. Larvae with yolk-sacs were not captured near the end of the cruise, possibly concurrent with the final deterioration of the egg beds observed from the submarine *PISCES*. Either hatching had ceased in sufficient time for the larvae to absorb their yolk-sacs or, since larvae were observed from the submersible near the bottom, perhaps our plankton tows were not deep enough to sample the entire population of larvae. These two possibilities will receive further consideration.

Sea surface temperature and salinity plots indicate an intrusion of colder (14°C) and more saline (32.15‰) water into the vicinity of the egg beds. This will be investigated further when data from the hydrographic casts are processed.

REFERENCE

Posgay, J. A., R. R. Marak and R. C. Hennemuth. 1968. Development and test of new zooplankton samplers. ICNAF Res. Doc. 68-34, 7 p.

GENERAL SUMMARY AND REMARKS

To have been able to locate, traverse and observe spawning beds at such a distance from the shore is itself to be considered an achievement in which all the contributing member countries played essential roles. This preliminary report is not intended to deal with all aspects of the operation as a whole and more detailed studies are being prepared for publication.

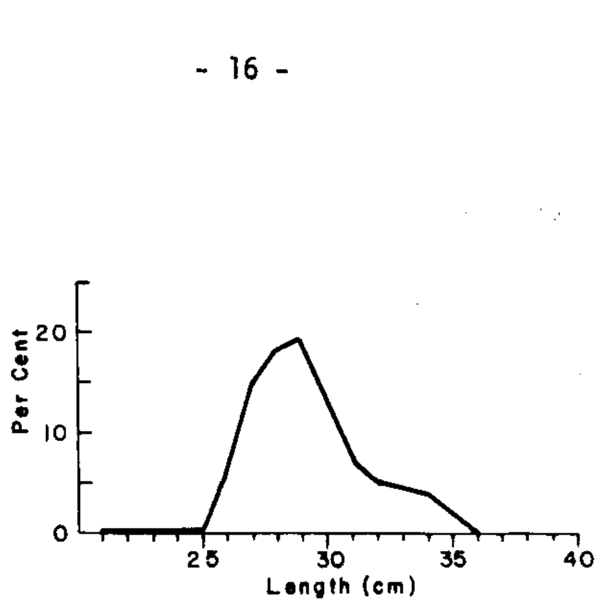

Fig. 1. Length-frequency distribution of Georges Bank herring, 1970.

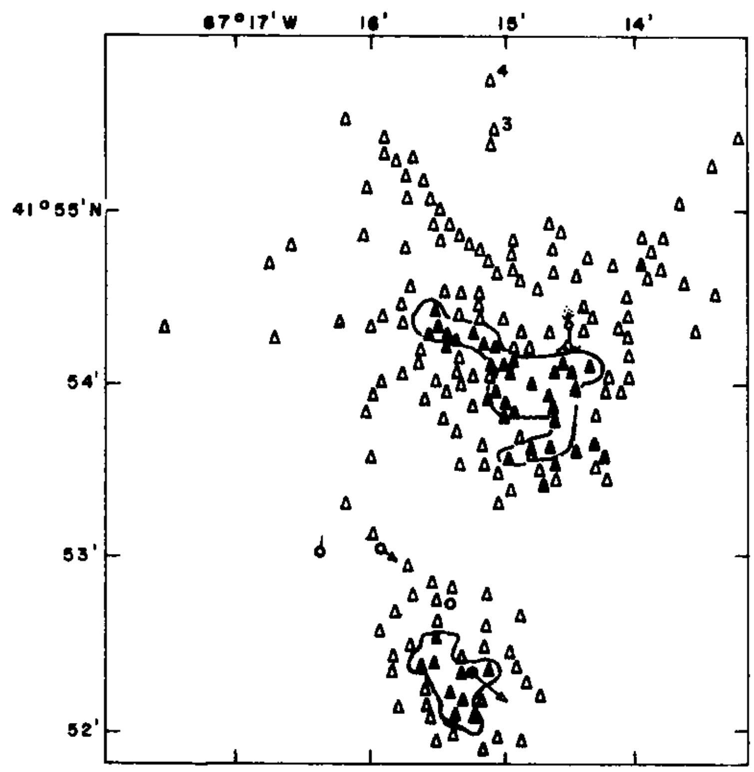

Fig. 2. The Eastern spawning grounds.

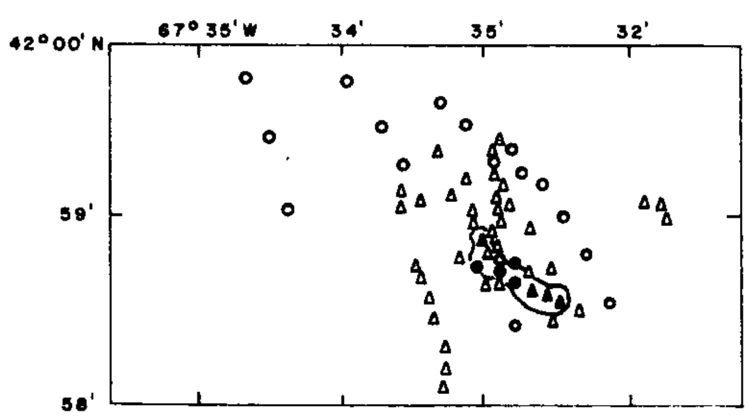

Fig. 3. The Western spawning grounds.

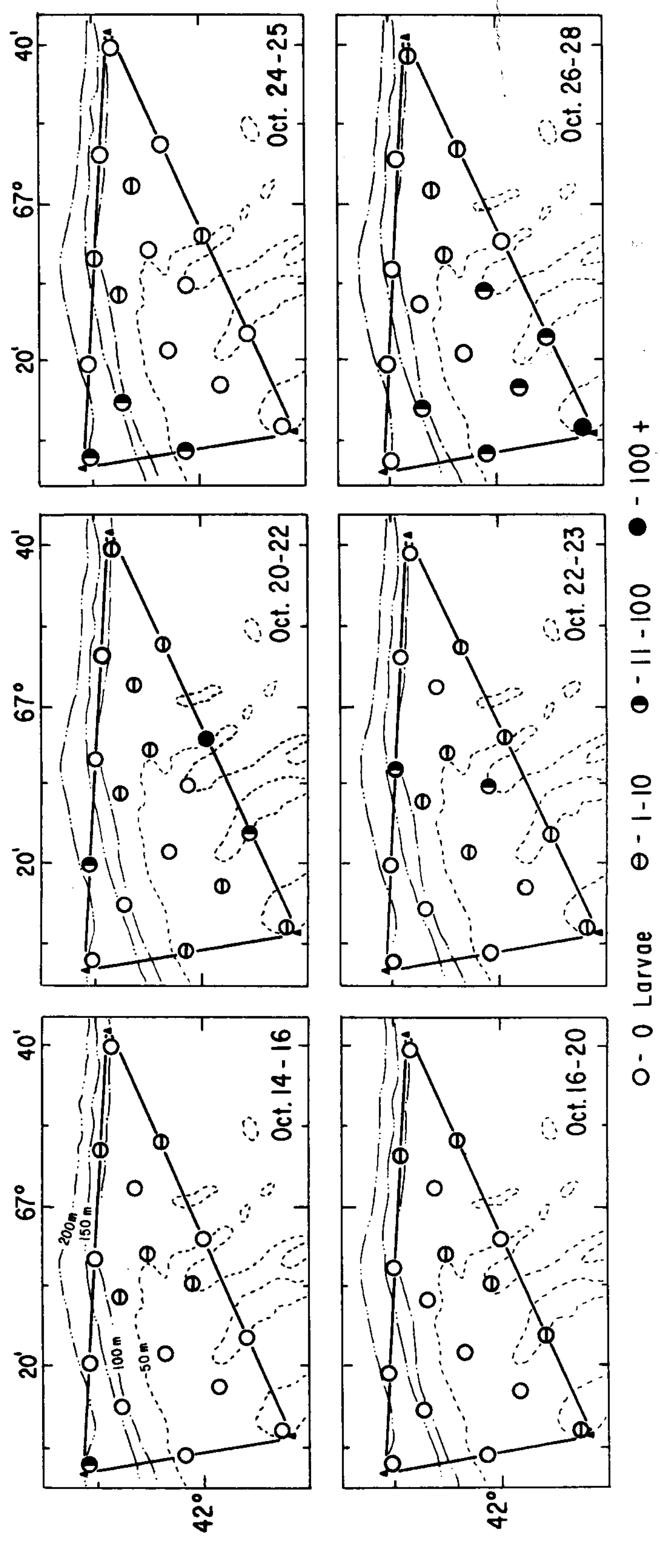

Fig. 4. Distribution of herring larvae over the triangular survey area, October 14-28, 1970.

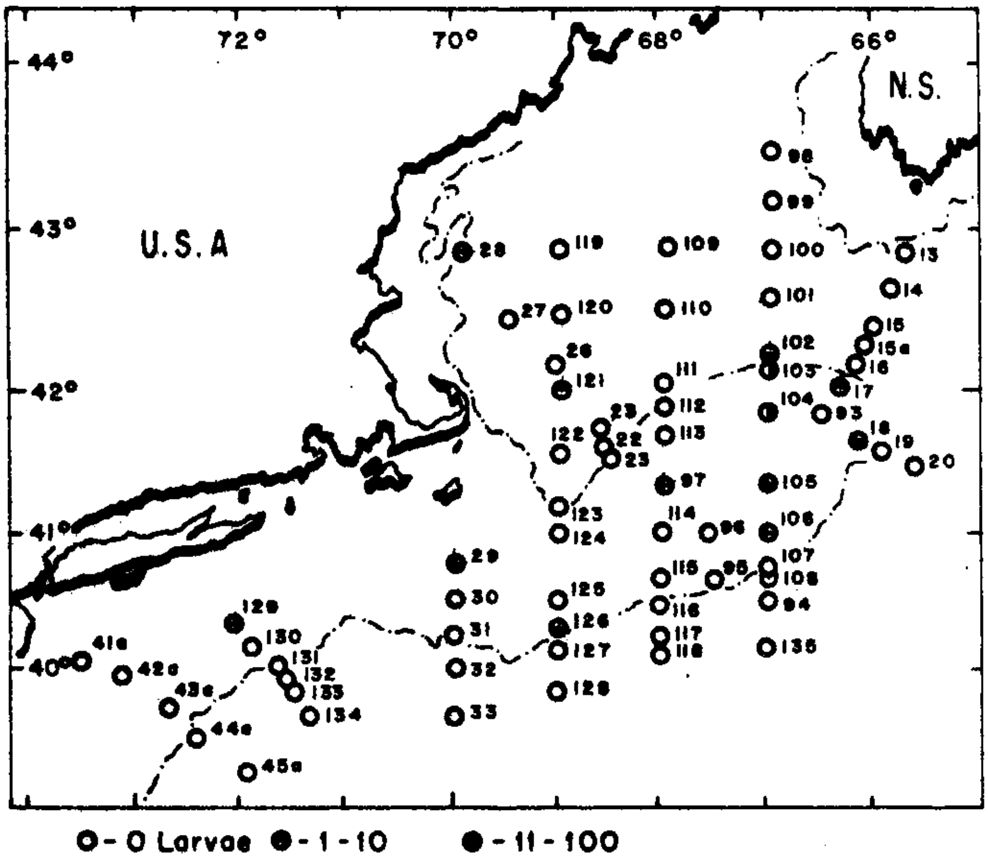

Fig. 5. Herring larval distribution, November 1970.

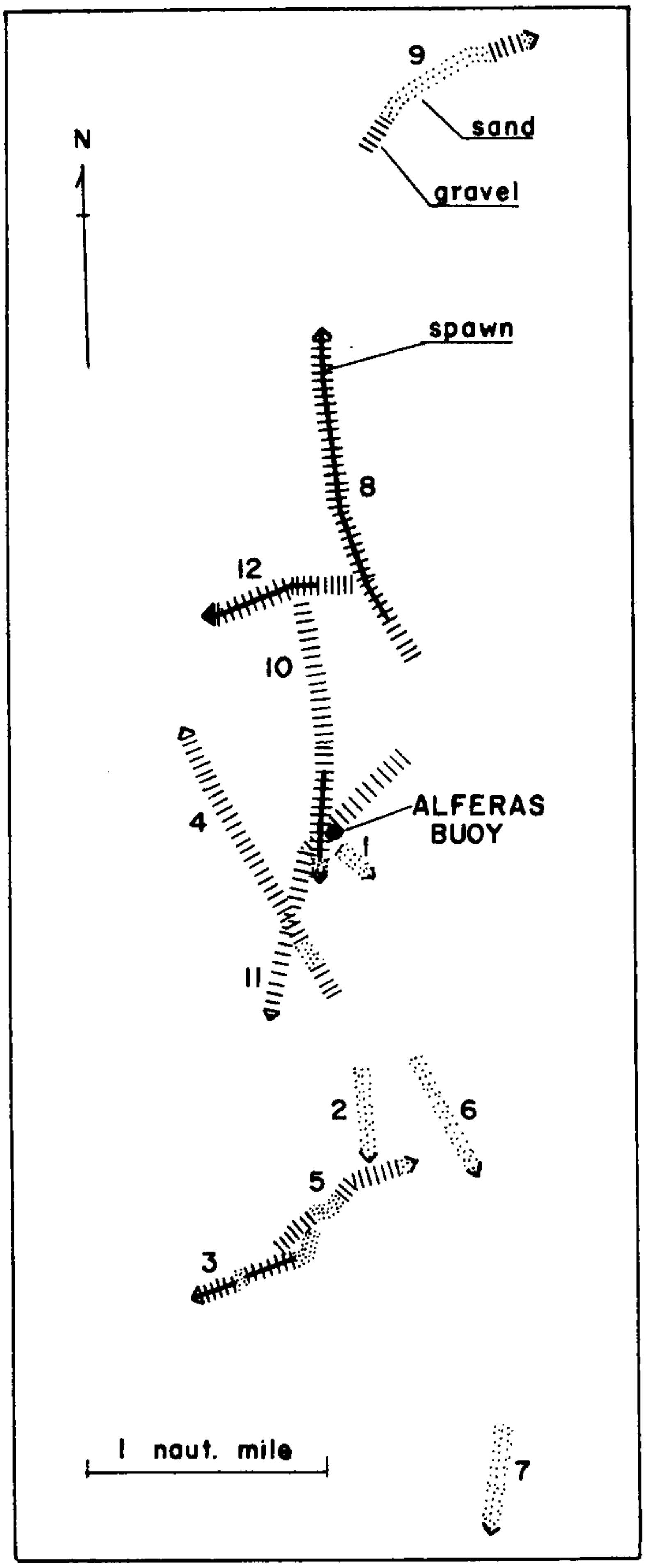

Figure 6

Estimated positions and distances travelled during PISCES Dives 1-12 in relation to Alferas radar buoy

(Observed positions of areas of herring spawn are shown in relation to predominant sediment type)

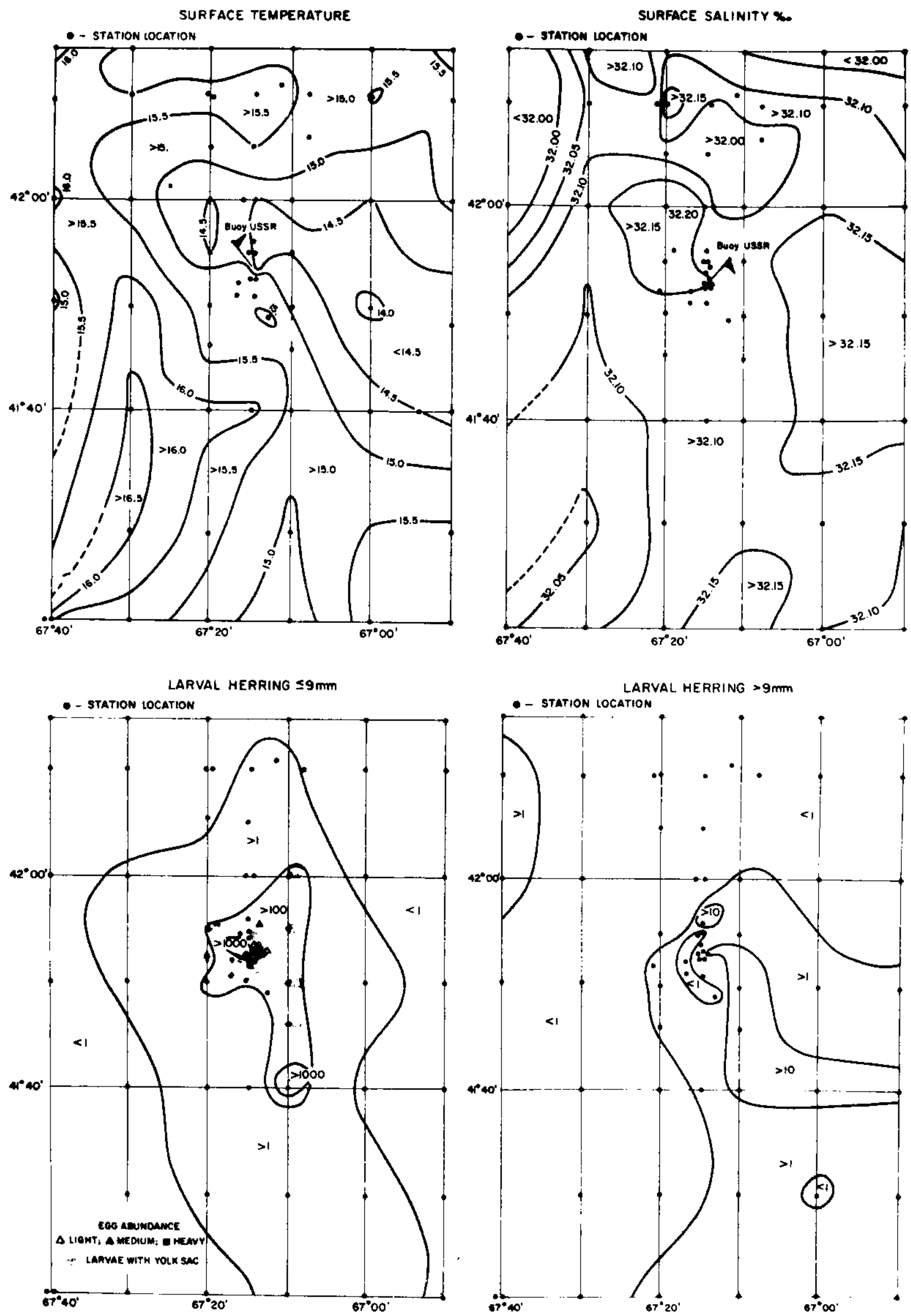

Fig. 7. Surface temperatures and salinities and herring larval distributions in the PISCES I survey area.