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The distribution and abundance, growth and mortality of Georges Bank-Nantucket Shoals herring larvae during the 1975-76 winter period[1]

by

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Introduction

USA R/V *Albatross IV* conducted two plankton-hydrography cruises during December and February in the Georges Bank-Nantucket Shoals area as part of the 1975 ICNAF cooperative surveys to monitor larval herring production, growth, mortality, and dispersal (Cruise 75-14, 5-17 December 1975; Cruise 76-01, 9-25 February 1976). Five larval herring cruises were conducted this past fall prior to the December and February surveys: *Challenge* (USA) 75-01, 4-9 September 1975; *Delaware II* (USA) 75-15, 23 September-20 October 1975; *Belogorsk* (USSR) 75-02, 25 September-8 October 1975; *Belogorsk* (USSR) 75-03, 17-30 October 1975; *Anton Dohrn* (FRG) 75-01, 1-18 November 1975. The larval herring surveys were initiated in 1971 to gain a better understanding of the various physical and biological factors affecting larval survival and relative strength of recruitment. Herring typically spawn in the northeast part of Georges Bank and Nantucket Shoals. The bulk of the larvae hatch in late September-October dispersing in a southwesterly direction at the rate of 1-5 miles per day (Boyar et al., 1973; Bumpus, 1975). Maximum dispersion of the larvae occurs by December when they are usually found covering the entire Georges Bank-Nantucket Shoals area within the 100 m contour. Larvae grow about 5 mm per month from initial hatching at 6 mm length in September to post-larvae of 50-55 mm by June. One of the leading hypotheses being investigated is that the number of recruits available in the spring is dependent upon survival through the winter period when planktonic food organisms are sparse. Results of the 1975-76 winter surveys are presented in this paper and compared with the two previous winters (Lough and Grosslein, 1975).

Methods

Plankton gear consisted of the standard 61 cm bongo sampler (.505 mm and .333 mm mesh nets) mounted below a 20 cm bongo sampler (.253 mm and .165 mm mesh nets). A V-fin depressor and time-depth recorder were attached to the towing wire. A standard oblique plankton tow was made at each station to a maximum depth of 100 m or to within 5 m of the bottom in shallower areas. The sampling gear was set to maximum depth at 50 m/min. and retrieved at 10 m/min. while the ship was underway at 3.5 knots. A 10 mm surface neuston trawl was made simultaneously at all stations employing a 1x½ m aluminum frame fitted with a .505 mm net. Extra stations were sampled between standard stations where greater than 100 larvae per sample were collected in December and where any larvae were collected in February.

An XBT drop, surface salinity sample, wind-sea state, and cloud cover observations were taken routinely at each occupied station. An environmental profiling system measuring salinity, temperature, and depth (STD) was used at each standard station for hydrographic sampling at depth. Nutrients, chlorophyll, and primary productivity measurements also were taken routinely.

[1]Data presented at Environmental Working Group meeting, Szczecin, Poland, April 1976.

MARMAP optically-scanable forms were used at sea to record station information (Master Station Record) and plankton tow data (Zooplankton Sample Log) for easy computer entry and quality control. In the laboratory, information on a sorted sample of larvae, such as aliquot size, number of specimens, and length-frequency, were recorded on another opt-scan MARMAP form (Ichthyoplankton Data Record--Larvae). Various examples of computer outputs available are provided in this paper (Tables 1-3). Further development of the MARMAP system is in progress in regard to quality control audits and more specialized analyses and listings.

Herring larvae were sorted from the 61 cm bongo, .505 mm mesh samples, counted, and measured to the nearest mm (standard length). Plots of the number of herring larvae per 10 m^2 at each station were produced for length-frequency groupings of <10 mm, 10-15 mm, and >15 mm. Length-frequency tables and graphs were made for Nantucket Shoals (stations 1-30, 31-33, 35) and Georges Bank (stations 50-64, 70-85, 88-99).

The abundance of larvae in the Georges Bank and Nantucket Shoals areas was found by summing the number per 10 m^2 for the total length frequency. Each standard station of the grid represents approximately an area of 1.16×10^9 m^2.

Instantaneous mortality rate, Z, and percent mortality per day was calculated for the December-February Georges Bank larval totals by the methods described in Lough and Grosslein (1975) and Ricker (1958):

$$Zt = -\ln \frac{N_1}{N_0} \quad (1)$$

where N_1 is the abundance of larvae in February, N_0 is the abundance of larvae in December, and t is the period of time between the midpoints of the cruise surveys, 70 days for the 1975-76 winter period. Only catches of larvae for standard stations were used in the mortality rate analysis.

Larval growth during the winter period was calculated by two methods. Specific growth rate, based on successive mean lengths, was calculated from the relationship:

$$G = \frac{\ln L_1 - \ln L_0}{t} \times 100 \quad (2)$$

where G is the percent growth per day, L_1 is the mean larval length in February, L_0 is the mean larval length in December, t is the time in days between the midpoints of the cruises. The second method calculated an instantaneous growth rate based on dry weight (W) of larvae at mean length. The relationship between larval length and weight was calculated from Chenoweth's (1970) data, Table 2, p. 1877, from samples collected along the Boothbay area of the Maine coast:

$$\log W = 4.66 (\log L) - 5.73 \quad (3)$$

The derived weight values were substituted for length in equation 2 for instantaneous growth estimates.

Temperatures at surface, 30, and 100 m depth were contoured for both cruises. The mean ($\bar{X}$), variance (s^2), and standard deviation (s) were calculated for December 1975 and February 1976 temperature observations at 0, 10, 30, 50, and 0-50 m levels for comparison with the previous two years.

Results

Station positions occupied during the surveys and cruise tracks for *Albatross IV*, Cruise 75-14 and 76-01, are shown in Figures 1, 2 and 11, 12. Sampling on Georges Bank-Nantucket Shoals proceeded from east to west for both cruises. The December plots of herring larvae per 10 m^2 (Figures 3-6) show most catches of herring larvae within the 100 m contour area but distributed more on the central-northern edge of Georges Bank and Nantucket Shoals. The westernmost distribution of larvae was not delimited by this cruise. Densities of larvae typically were 10-100 per 10 m^2 (Figure 6). Highest densities occurred along the northern part of Georges Bank and the northern Nantucket Shoals area. Some recently hatched larvae (less than 10 mm) were observed on a few stations in northeast Georges Bank and Great South Channel area (Figure 3). Smaller size larvae of 10-15 mm (Figure 4) were distributed more in the Nantucket Shoals area than on Georges Bank.

Larval catches by February (Figure 13) appeared to be consolidated into three main areas within the 100 m contour: 1) northeast central part of Georges Bank, 2) southwest central Georges Bank-Great Southwest Channel, and 3) a small pocket south of Martha's Vineyard. Few larvae appeared outside the 100 m contour. The western distribution of larvae was clearly defined by the February survey. Densities of larvae generally were lower than catches in December; however, two stations in the northeast part of Georges Bank had 203 and 507 larvae per 10 m^2.

The December and February larval length-frequency distributions for Nantucket Shoals and Georges Bank are shown in Tables 4 and 5 and Figures 7 and 14. Two length modes appeared during December in the Nantucket Shoals area, *ca.* 9-15 mm and 16-22 mm, whereas the Georges Bank population had one dominant length mode of 13-24 mm. Mean lengths for the Nantucket Shoals and Georges Bank larval populations were 16.2 mm and 17.4 mm respectively. By February the larval length means had increased to 30.5 mm for the Nantucket Shoals population and to 31.1 mm for the Georges Bank population. A single broad modal length was observed for the larval population in each area. The three subpopulations of larvae observed during February were analyzed further for differences among their length-frequency distributions. Length frequencies for the three areas of high concentration of larvae were tallied for those stations where greater than 10 larvae per 10 m^2 were observed, and are summarized in Table 6. The small numbers of larvae in the Nantucket Shoals population had a mean length of 1-2 mm greater than the populations in southwest Georges Bank-Great South Channel and northeast Georges Bank. The Kolmogorov-Smirnov nonparametric two-sample test, sensitive to differences in population shape and distribution (Tate and Clelland, 1959, p. 93), indicated no significant difference between the length-frequency populations for northeast Georges Bank and southwest Georges Bank-Great South Channel. A significant difference at the 10% probability level was calculated between the northeast Georges Bank and the Nantucket Shoals population length frequencies, and a significant difference at the 1% level was found between southwest Georges Bank-Great South Channel and Nantucket Shoals length frequencies. The small number of large larvae just south of Martha's Vineyard may indicate a shoreward migration of older larvae in the Nantucket Shoals area.

Larval abundance, mortality, and growth estimates for Georges Bank and Nantucket Shoals areas during December-February 1975-76 and the two previous winters are given in Table 7. Georges Bank larval abundance in December 1975 was considerably lower (1,120) than for the previous two years (7,410 and 5,076 in 1974 and 1973 respectively); however, the February abundance estimates were similar for all three years (range 406-506). A corresponding change was observed for estimates of mortality, growth, and mean length. Mortality rate decreased from 3.93 to 1.27% per day for the period 1973-74 to 1975-76. Larval mean length was greater for each successive December with a considerable increase in mean length by February each year. The same trends in larval mortality and growth rates were shown for the Georges Bank and Nantucket Shoals total; when mortality was low, growth was high, and the converse. The Nantucket Shoals area mortality and growth estimates were somewhat more inconsistent, reflective of the fewer numbers of larvae collected. For instance, the December-February 1973-74 mortality and growth rates are at variance with the same estimates from the Georges Bank and combined areas. Very few larvae were collected in the Nantucket Shoals area during February 1974.

Water temperatures of 9-11°C predominated over the Georges Bank-Nantucket Shoals area during December 1975 (Figures 8-10) and 5-6°C during February 1976 (Figures 15-17). Mean temperatures and other statistics at various levels on Georges Bank and Nantucket Shoals during December and February 1975-76 are given in Table 8. Temperatures generally increase with depth and seaward of the 100 m depth contour along the southern part of the bank in the area of the warm slope water front. Georges Bank mean temperatures (0-50 m) during December and February 1975-76 were the same as the previous year, 1974-75; however, temperatures during the same months in 1973-74 were about 0.5°C warmer (Table 7). Nantucket Shoals mean temperatures (0-50 m) were similar to those of Georges Bank except that they were about 1°C warmer during December. Schlitz (1976) compared the February 1976 temperature data with the 1940-1959 mean temperatures (Colton and Stoddard, 1972) and observed no significant changes in the upper water column on eastern Georges Bank and southern New England continental shelf. Also, no significant trends were apparent in the mean temperatures from September through December of 1975 compared with the previous year, 1974. On the other hand, Davis (1976) found mean October bottom temperatures on Georges Bank to be similarly high for 1973 and 1974 ($\overline{X}$ = 13.4 and 13.2°C, respectively), but more than a degree lower ($\overline{X}$ = 12.1) for 1975. It is interesting to note from Davis' study that the eastern part of Georges Bank is always several degrees colder during the fall than the central and western parts even though the yearly temperature trends are similar for all three parts.

Discussion

The distribution of larvae on Georges Bank and Nantucket Shoals was very similar during December 1973 and 1974 (*cf.* Lough and Grosslein, 1975). Uniformly high catches of larvae were observed within the 100 m bottom contour. Larval abundance also was similar for both years. During December 1975, however, the distribution of larvae was markedly different; the population was centered in the northern part of the Great South Channel and along the northern half of Georges Bank. Also, abundance of larvae was reduced compared to the previous two Decembers. No larvae were found beyond the southern 100 m contour in December 1975 as were observed during 1973 and 1974. Larvae observed along the southern boundary would indicate some offshore dispersal of larvae into slope waters.

Larval abundance and distribution during February was broadly similar for all three years, 1974-76; the bulk of the larval populations usually is located in a more restricted area in the central part of southwest Georges Bank extending across the Great South Channel into Nantucket Shoals. However, the February 1976 distribution was unusual in that three separate concentrations of larvae were observed; high densities of larvae were collected in the northeast part of Georges Bank in addition to the central part. It appears that the center of the larval population in December 1975 moved to a more southerly position by February 1976. The limited hydrographic data on temperature for these two surveys does not show any evidence for a southerly current transport. Bumpus and Lauzier (1965) have summarized the available evidence on surface drift on Georges Bank. A southerly flow of surface waters is suggested for the Georges Bank area during the winter months with a westerly component across the Great South Channel. Surface drift during the fall and winter months is different from the clockwise circulation observed for the other seasons and may respond more to short-term wind effects. Results from past ICNAF Larval Herring Surveys show that advection of larvae is principally southwest and that the larvae are retained in the Georges Bank-Nantucket Shoals area (*cf.* Bumpus, 1975). Recent observations of interest this past season are the occurrence in Georges Bank-Nantucket Shoals of large numbers of the colonial siphonophore, *Nanomia cara*, a cold-water form found in the Gulf of Maine rarely below Cape Cod (Rogers, 1976). Their southerly occurrence on Georges Bank during fall 1975 corresponds with the more southerly movement of herring larvae. These changes in the distribution of animal populations suggest changes in circulation patterns in the study area that may result in potentially different prey-predator interactions. Their impact on the larval herring population still needs to be assessed.

The three-year range in winter mortality rates (1-4% per day) for Georges Bank-Nantucket Shoals herring larvae is similar to that observed by Graham and Davis (1971) for larvae along the coastal Gulf of Maine during four winter periods. Low condition factors of winter larvae from the Maine coast were associated with relatively high mortalities suggesting that the winter period was a time of stress (Chenoweth, 1970). Incidence of feeding for larval herring also was low during the winter when plankton volumes were low (Sherman and Honey, 1971), indicating that the level of suitable food organisms may be closely linked to larval condition factors.

Size and growth rates of the Georges Bank-Nantucket Shoals herring larvae are indicators of the population's physiological condition and are closely linked to mortality rates. According to recent theoretical models by Jones (1972), Cushing (1973, 1974, 1975), and Ware (1975), mortality and growth during larval life are believed to be a density-dependent process regulated by the availability of food. If food is abundant, larvae are able to grow rapidly through a succession of decreasing predatory fields, thereby reducing their mortality. The three winters of Georges Bank-Nantucket Shoals larval herring data presented in this paper also suggest that density-dependent growth and mortality have occurred. A decrease in larval abundance was associated with an increase in growth rate and a decrease in mortality rate. According to Ware's (1975) theoretical model based on larval studies of plaice, haddock, and mackerel, larval growth exceeds mortality (M = 0.7G) under average conditions. Only the 1975-76 winter growth rate exceeded the mortality rate for Georges Bank-Nantucket Shoals herring larvae. More refined estimates of growth and mortality will be made in the future, but the following considerations must be taken into account when one attempts to relate field estimates of population parameters with theoretical models:

a. Winter growth and mortality rates for Georges Bank-Nantucket Shoals herring larvae are estimated for a relatively short period and may well vary at other periods or from the average condition for the entire larval life. Growth was assumed to be an exponential curve but it may not be necessarily true during the winter period. Also, the length to weight regression was based on samples combined over four years; this relationship varies from year to year depending on condition of the larvae. Growth and mortality rates will be estimated for the entire larval period in the near future.

b. The low mortality estimate (1.27% per day) for Georges Bank larvae during the 1975-76 winter compared to the previous two winters (*ca.* 3.9% per day) might have been due to a greater westward dispersal of the Georges Bank larval population into the Nantucket Shoals area. That is, dispersal may have been responsible for a high loss rate and not mortality per se. The separation of the Georges Bank and Nantucket Shoals area was originally based on relatively isolated spawning grounds but it is somewhat arbitrary for older larvae without attempting to delineate separate subpopulations. Based on the separate and combined estimates of mortality and growth for both areas, it appears that dispersal of larvae from Georges Bank into Nantucket Shoals is small at this time in their life and does not significantly alter the dominant trends in mortality and growth. Future estimates will attempt to separate and combine cohesive larval subpopulations.

c. Growth rate of late larvae may be underestimated due to avoidance of the sampling gear, particularly if larvae are of greater size in the same time period from one year to the next. Perhaps growth rates of late larvae should be estimated from larvae collected during night tows only.

d. The increased size of Georges Bank larvae in December with the concomitantly greater growth through the winter during the three years in both areas may have been influenced to a great extent initially by conditions during the early larval period in the fall. Considerable variability was observed during the past three years in the time of initial hatching of larvae, total production, and the duration of the spawning-hatching season as indicated by length-frequency modes (Schnack, 1975; unpublished observations, 1976). Production of larvae was high in 1973 and 1974, but considerably lower for the 1975 season as suggested by the December and November surveys (*cf.* Joakimsson, 1976). Recently hatched larvae were observed on Georges Bank in late September 1973, early October 1974, and late October 1976. Despite the increasing lateness of the hatching season from 1973 to 1975, larvae were successively larger by December. There is some evidence to suggest that bottom water temperatures were cooler during October 1975 than the previous two years at a time when most of the larval hatching occurs. While temperature conditions in the spawning beds may control the maturation of eggs and hatching times from year to year, it would not appear to have a direct effect on growth and mortality of the larvae. Significant differences in temperature trends during December and February were not observed over the three years. The growth and mortality processes are more likely a function of the available food supply and predators. Analyses of the zooplankton community and larval gut contents are in progress and may elucidate some of the causal mechanisms in the larval-plankton-environment matrix.

It would be well at this time to examine possible relations among early and late larval abundance and the size of the recruited year-class for sea herring. Studies off coastal Maine by Graham et al. (1972), Graham and Davis (1971) indicated that the initial abundance of larvae in the fall was reduced to a common level by early winter each year. Although mortality was higher in the fall than the winter, the winter period was considered critical in that years of low winter mortality were subsequently related to a greater percentage of that year-class as two-year-old fish in the fishery. A comparison is made in Table 9 of the available data on initial larval production (larvae <10 mm standard length), December larval abundance (>15 mm), and catch per tow of three-year-old herring in the Georges Bank-Nantucket Shoals area. The larval abundance estimates were made by Schnack (1975) and myself from the ICNAF Larval Herring Surveys, 1971-76, and the three-year-old survey indices are stratified numbers of herring caught per 30-minute tow on the Young Herring Surveys by the research vessels of the Federal Republic of Germany (*Walther Herwig* and *Anton Dohrn*) and the German Democratic Republic (*Ernst Haeckel*) in 1973-76 (ICNAF, 1976, p. 40). No estimate could be made for the 1975 initial abundance of larvae as all the data are not available yet. The time series of data is still too short to permit firm conclusions but several points seem to corroborate past thinking. The initial production of larvae does not appear to be directly related to the size of the subsequent recruited year-class, and in fact, there may be an inverse relationship at the extremes of abundance--a density-dependent function. Also, the relative abundance of larvae as late as December still appears to be proportional to the initial production of larvae in the fall. However, differential winter mortality occurs between December and February, and by February (Table 7) it does appear that the size of the recruited year-class may be set. We believe, therefore, for herring in the Georges Bank-Nantucket Shoals area, that the winter period is critical in the sense that the year-class is established in most years as hypothesized by Graham. We still need to study the entire larval period to understand the processes which may influence survival through the winter period and more unusual events that occur in early larval life.

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Table 1. Sample Sheet.

MARMAP INFORMATION SYSTEM - STATION ACTIVITIES SUMMARY

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE

TIME IS EXPRESSED IN GMT AND DEPTH IN METERS.
S MEANS SURFACE AND C MEANS CONTINUOUS.
ZOOPLANKTON NET SIZES ARE EXPRESSED AS MOUTH DIMENSIONS IN CM (BONGO DIAMETER) OR METERS (NEUSTON HEIGHT X WIDTH)/MESH IN MICRONS.
BONGO DEPTHS FROM TDR (A INDICATES DEPTH CALCULATED FROM WIRE ANGLES).
ASTERISKS INDICATE DATA NOT AVAILABLE.
E INDICATES AN ESTIMATE.

ALBATROSS: CRUISE 75-14
5 DECEMBER 1975 - 17 DECEMBER 1975

STATION	DATE	POSITION LAT.	POSITION LONG.	OBSERVATIONS TYPE	BT	HAUL	START TIME	DURATION (MIN:SEC)	FREQUENCY/ MAX. DEPTH
1	17 12 75	41 11 N	071 00 W	BONGO 61/505		1	1835	4:19	1/19
				BONGO 61/333		1	1835	4:19	1/19
				BONGO 20/253		1	1835	4:19	1/19
				BONGO 20/165		1	1835	4:19	1/19
				NEUSTON 0.5X1.0/505		1	1835	10:03	1/S
				XBT					
4	17 12 75	41 00 N	071 00 W	BONGO 61/505		1	1724	9:06	1/39
				BONGO 61/333		1	1724	9:06	1/39
				BONGO 20/253		1	1724	9:06	1/39
				BONGO 20/165		1	1724	9:06	1/39
				NEUSTON 0.5X1.0/505		1	1725	10:00	1/S
				XBT					
5	17 12 75	41 00 N	071 25 W	BONGO 61/505		1	1541	10:00	1/40
				BONGO 61/333		1	1541	10:00	1/40
				BONGO 20/253		1	1541	10:00	1/40
				BONGO 20/165		1	1541	10:00	1/40
				NEUSTON 0.5X1.0/505		1	1542	10:08	1/S
				XBT					
6	17 12 75	40 44 N	071 00 W	BONGO 61/505		1	1132	10:02	1/35
				BONGO 61/333		1	1132	10:02	1/35
				BONGO 20/253		1	1132	10:02	1/35
				BONGO 20/165		1	1132	10:02	1/35
				NEUSTON 0.5X1.0/505		1	1133	10:05	1/S
				XBT					
				STD					
				ROSETTE SAMPLER					
				NUTRIENTS					
				OXYGEN					
				PLANT PIGMENT					

Table 2. Sample Sheet.

MARMAP INFORMATION SYSTEM - NET TOW DATA

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE

REFER TO LAST PAGE FOR DEFINITIONS OF SYMBOLS, COLUMN HEADINGS, AND COLUMN CONTENTS.

ALBATROSS: CRUISE 75-14
5 DECEMBER 1975 - 17 DECEMBER 1975

STATION	HAUL	NET TYPE	NET SPEED FROM FLOWMETER M/SEC	VOLUME FILTERED (M3)	DEPTH (M)	WATER COLUMN STANDARD HAUL FACTORS #/10 M2	WATER COLUMN STANDARD HAUL FACTORS #/1000 M3	SURFACE STANDARD HAUL FACTOR #/1000 M2
1	1	BONGO 61/505	1.84	139.44	19	1.36	7.17	
		BONGO 61/333	1.79	135.74		1.39	7.36	
		BONGO 20/253	1.80	14.67		12.95	68.18	
		BONGO 20/165	1.50	12.17		15.61	82.16	
	1	NEUSTON 0.5X1.0/505	1.80 E	271.41 E	S			0.92 E
4	1	BONGO 61/505	1.59	254.28	39	1.53	3.93	
		BONGO 61/333	1.56	249.41		1.56	4.02	
		BONGO 20/253	1.61	27.43		14.11	36.18	
		BONGO 20/165	1.33	22.77		17.12	43.91	
	1	NEUSTON 0.5X1.0/505	1.80 E	270.06 E	S			0.92 E
5	1	BONGO 61/505	1.81	316.56	40	1.26	3.15	
		BONGO 61/333	1.76	308.12		1.29	3.24	
		BONGO 20/253	0.78	14.73		27.16	67.90	
		BONGO 20/165	0.63	11.96		33.43	83.58	
	1	NEUSTON 0.5X1.0/505	1.80 E	273.66 E	S			0.91 E
6	1	BONGO 61/505	2.22	391.22	35	0.89	2.55	
		BONGO 61/333	2.11	370.81		0.94	2.69	
		BONGO 20/253	1.17	22.21		15.76	45.02	
		BONGO 20/165	1.09	20.49		17.08	48.80	
	1	NEUSTON 0.5X1.0/505	1.90 E	272.31 E	S			0.91 E
7	1	BONGO 61/505	1.77	467.81	65	1.38	2.13	
		BONGO 61/333	1.73	456.08		1.42	2.19	
		BONGO 20/253	1.91	51.28		12.67	19.49	
		BONGO 20/165	1.50	42.53		15.28	23.51	
	1	NEUSTON 0.5X1.0/505	1.30 E	275.46 E	S			0.90 E
8	1	BONGO 61/505	1.73	575.63	83	1.43	1.73	
		BONGO 61/333	1.68	558.46		1.48	1.79	
		BONGO 20/253	1.77	63.25		13.12	15.80	
		BONGO 20/165	1.50	53.69		15.45	18.62	
	1	NEUSTON 0.5X1.0/505	1.80 E	270.96 E	S			0.92 E
9	1	BONGO 61/505	1.35	553.16	100	1.80	1.80	
		BONGO 61/333	1.31	537.89		1.85	1.85	
		BONGO 20/253	1.29	56.97		17.55	17.55	
		BONGO 20/165	1.14	50.21		19.91	19.91	
	1	NEUSTON 0.5X1.0/505	1.80 E	272.31 E	S			0.91 E

Table 3. Sample Sheet. MARMAP Information System - Density of *Clupea harengus* Larvae by 1mm Intervals.

ALBATROSS 75-14
5 DEC 75 - 17 DEC 75
BONGO 61/505
HARENGUS
(CONTINUED)

STA	DEP	VOL	15.00-16.00 MM #	#/ 1000M3	#/ 10M2	16.00-17.00 MM #	#/ 1000M3	#/ 10M2	17.00-18.00 MM #	#/ 1000M3	#/ 10M2	18.00-19.00 MM #	#/ 1000M3	#/ 10M2	19.00-20.00 MM #	#/ 1000M3	#/ 10M2
5	40	316.6															
6	35	391.3				1.0	2.6	0.9									
8	83	576.7							1.0	1.7	1.4				1.0	1.7	1.4
12	88	588.6													1.0	1.7	1.5
17	60	355.1							1.0	2.8	1.7	1.0	2.8	1.7			
19	65	373.7															
20	44	227.5	1.0	4.4	1.9							2.0	8.8	3.9			
21	37	237.3	1.0	4.2	1.6							1.0	4.2	1.6	1.0	4.2	1.6
22	30	148.6	2.0	10.6	3.2	1.0	5.3	1.6	2.0	10.6	3.2	1.0	5.3	1.6	4.0	21.2	6.4
23	35	214.2	1.0	4.7	1.6	1.0	4.7	1.6	1.0	4.7	1.6	3.0	14.0	4.9	2.0	9.3	3.3
24	65	435.7				2.0	4.5	3.0	2.0	4.5	3.0	5.0	11.4	7.4	4.0	9.1	5.9
25	82	480.0	1.0	2.0	1.7	3.0	6.1	5.0	1.0	2.0	1.7	1.0	2.0	1.7			
26	50	296.5							1.0	3.4	1.7	2.0	6.7	3.4	1.0	3.4	1.7
27	46	224.4	3.0	13.4	6.1	1.0	4.5	2.0	6.0	26.7	12.3	3.0	13.4	6.1	3.0	13.4	6.1
28	100	647.6				2.0	3.1	3.1	8.0	12.4	12.4	9.0	13.9	13.9	9.0	13.9	13.9
29	105	700.7	2.0	2.9	3.0	5.0	7.1	7.5	7.0	10.0	10.5	5.0	7.1	7.5	6.0	8.6	9.0
30	46	323.9	4.0	12.3	5.7				2.0	6.2	2.8	2.0	6.2	2.8	4.0	12.3	5.7
31	95	634.7	5.0	7.3	6.9	5.0	7.3	6.9	4.0	5.8	5.5	8.0	11.7	11.1	5.0	7.3	6.9
32	100	805.9	2.0	2.5	2.5	2.0	2.5	2.5	5.0	6.2	6.2	5.0	6.2	6.2	6.0	7.4	7.4
33	102	678.9	11.0	16.2	16.5	9.0	13.3	13.5	14.0	20.6	21.0	15.0	22.1	22.5	6.0	8.8	9.0
34	101	801.4	1.0	1.2	1.3				10.0	12.5	12.6	9.0	11.2	11.3	5.0	6.2	6.3
35	82	623.2	6.0	9.6	7.9	6.0	9.6	7.9	8.0	12.8	10.5	2.0	3.2	2.6	1.0	1.6	1.3
36	102	723.9				4.0	5.5	5.6				3.0	4.1	4.2	1.0	1.4	1.4
46	102	679.0	1.0	1.5	1.5	2.0	2.9	3.0	1.0	1.5	1.5	7.0	10.3	10.5			
47	102	759.2	4.0	5.3	5.4	7.0	9.2	9.4	10.0	13.2	13.4	13.0	17.1	17.5	2.0	2.6	2.7
48	103	676.2	1.0	1.5	1.5	2.0	3.0	3.0	1.0	1.5	1.5	2.0	3.0	3.0	1.0	1.5	1.5
49	102	736.6				2.0	2.7	2.8	2.0	2.7	2.8	4.0	5.4	5.5	2.0	2.7	2.8
50	94	769.0	10.0	13.0	12.2	11.0	14.3	13.4	16.0	20.8	19.6	29.0	37.7	35.4	13.0	16.9	15.9
51	95	543.9	3.0	5.5	5.2	13.0	23.9	22.7	21.0	38.6	36.7	15.0	27.6	26.2	13.0	23.9	22.7
52	53	301.2				2.0	6.6	3.5	6.0	19.9	10.6	8.0	26.6	14.1	2.0	6.6	3.5
53	37	214.7							1.0	4.7	1.7	1.0	4.7	1.7			
60	35	242.5										2.0	8.2	2.9	1.0	4.1	1.4
61	33	154.0										3.0	19.5	6.4	1.0	6.5	2.1
62	40	208.9													1.0	4.8	1.9
63	50	347.2	2.0	5.8	2.9	5.0	14.4	7.2	1.0	2.9	1.4	2.0	5.8	2.9	4.0	11.5	5.8
64	102	738.7	8.0	10.8	11.0	17.0	23.0	23.5	7.0	9.5	9.7	9.0	12.2	12.4	2.0	2.7	2.8
65	104	751.0							1.0	1.3	1.4						
66	93	728.3										2.0	2.7	2.6			
71	26	193.1	3.0	15.5	4.0	3.0	15.5	4.0	3.0	15.5	4.0				1.0	5.2	1.3
72	35	241.0	1.0	4.1	1.5	1.0	4.1	1.5	4.0	16.6	5.8	2.0	8.3	2.9	3.0	12.4	4.4
73	27	159.8										1.0	6.3	1.7	2.0	12.5	3.4
74	46	252.5				2.0	7.9	3.6									
75	66	369.7													1.0	2.7	1.8
80	70	438.9													1.0	2.3	1.6
81	????	637.8										1.0	1.6	1.1			
82	60	316.1	3.0	9.5	5.7	1.0	3.2	1.9	1.0	3.2	1.9	2.0	6.3	3.8	2.0	6.3	3.8
83	55	418.1				2.0	4.8	2.6	3.0	7.2	3.9	6.0	14.4	7.9			
84	94	338.9	3.0	8.9	8.3	3.0	8.9	8.3	2.0	5.9	5.5	6.0	17.7	16.6	5.0	14.8	13.9

Table 4. Length frequency summary for Nantucket Shoals (stations 1-30, 31-33, 35) herring larvae.

Standard length (mm)	December, 1975		February, 1976	
	Number	Percent	Number	Percent
4				
5	1	0.2		
6				
7	1	0.2		
8				
9	3	0.7		
10	19	4.3		
11	19	4.3		
12	17	3.9		
13	23	5.3		
14	30	6.9		
15	40	9.2		
16	38	8.7		
17	63	14.4		
18	66	15.1		
19	54	12.4		
20	37	8.5	1	0.6
21	11	2.5		
22	5	1.1		
23	4	0.9		
24	1	0.2	2	1.3
25	2	0.5	7	4.5
26	2	0.5	3	1.9
27			13	8.3
28			13	8.3
29			15	9.6
30	1	0.2	24	15.3
31			21	13.4
32			19	12.1
33			17	10.8
34			8	5.1
35			7	4.5
36			3	1.9
37			2	1.3
38			2	1.3
39				
40				
Total	437	100.0	157	100.2
$\bar{x}$	16.44		30.48	
s	3.30		3.03	

Table 5. Length frequency summary for Georges Bank (stations 50-64, 70-85, 88-99) herring larvae.

Standard length (mm)	December, 1975		February, 1976	
	Number	Percent	Number	Percent
4				
5				
6	2	0.3		
7	12	1.5		
8	23	2.9		
9	5	0.6		
10	2	0.3		
11	5	0.6		
12	9	1.1		
13	20	2.5		
14	38	4.8		
15	57	7.2		
16	89	11.3		
17	104	13.2		
18	136	17.3		
19	97	12.3		
20	77	9.8		
21	45	5.7		
22	27	3.4	1	0.2
23	10	1.3	1	0.2
24	12	1.5	3	0.6
25	5	0.6	7	1.3
26	4	0.5	18	3.4
27	4	0.5	32	6.0
28	3	0.4	39	7.3
29	1	0.0	45	8.4
30			84	15.7
31			68	12.7
32			66	12.4
33			63	11.8
34			38	7.1
35			30	5.6
36			25	4.7
37			7	1.3
38			6	1.1
39			1	1.2
40				
Total	787	100.0	534	100.0
$\bar{x}$	17.83		31.10	
s	3.58		2.90	

Table 6. Length frequency summary for Georges Bank-Nantucket Shoals subpopulations during the February, 1976 survey.

Standard length (mm)	Nantucket Shoals		S.W. Georges Bank-Great South Channel		N.E. Georges Bank	
	Number	Percent	Number	Percent	Number	Percent
20			1	0.5		
21						
22					1	0.2
23					1	0.2
24			3	1.5	2	0.5
25			9	4.4	4	1.0
26			7	3.4	12	2.9
27	3	11.5	8	3.9	24	5.7
28	1	3.8	10	4.9	34	8.1
29	2	7.7	23	11.3	32	7.6
30	2	7.7	32	15.7	67	15.9
31	1	3.8	34	16.7	49	11.6
32	2	7.7	30	14.7	50	11.9
33	3	11.5	23	11.3	60	14.3
34	4	15.4	10	4.9	30	7.1
35	4	15.4	7	3.4	26	6.2
36			5	2.5	19	4.5
37	2	7.7	2	1.0	5	1.2
38	2	7.7			4	1.0
39					1	0.2
Total	26	100.0	204	100.0	421	100.0
$\bar{x}$	32.58		30.56		31.19	
s	3.38		2.80		2.86	

Table 7. Mortality and growth estimates for Georges Bank-Nantucket Shoals herring larvae and mean water temperature during three winter periods. See text for details.

Sampling period midpoint	Larval abundance ($n \times 10^{-8}$)	Instantaneous mortality rate (-Z)	Instantaneous mortality rate (% per day)	Mean length (mm)	Specific growth (L) rate (% per day)	Instantaneous growth (wt) rate (% per day)	Mean temperature(°C) (0-50 m)
				GEORGES BANK			
Dec. 13, 1973	5076			15.1			10.4
Feb. 14, 1974	406	0.040	3.93	22.9	0.661	3.08	6.3
Dec. 13, 1974	7410			16.5			9.9
Feb. 14, 1975	506	0.040	3.87	26.7	0.708	3.30	5.7
Dec. 9, 1975	1120			17.4			9.9
Feb. 16, 1976	457	0.013	1.27	31.1	0.830	3.87	5.7
				NANTUCKET SHOALS			
Dec. 13, 1973	2801			15.5			11.6
Feb. 14, 1974	57	0.062	6.00	27.6	0.916	4.27	6.1
Dec. 13, 1974	2944			14.2			11.0
Feb. 14, 1975	103	0.049	4.81	27.1	0.950	4.43	5.9
Dec. 9, 1975	647			16.4			11.6
Feb. 16, 1976	149	0.021	2.08	30.5	0.886	4.13	5.9
				GEORGES BANK & NANTUCKET SHOALS TOTAL			
Dec. 13, 1973	7877			16.7			11.0
Feb. 14, 1974	463	0.044	4.40	23.5	0.542	2.53	6.2
Dec. 13, 1974	10354			15.8			10.5
Feb. 14, 1975	609	0.042	4.08	26.7	0.772	3.60	5.8
Dec. 9, 1975	1767			17.1			10.8
Feb. 16, 1976	606	0.015	1.52	31.0	0.850	3.96	5.8

Table 8. Temperature statistics for Georges Bank and Nantucket Shoals during December, 1975 and February, 1976.

Statistic	0 m	10 m	30 m	50 m	0-50 m
			GEORGES BANK		
			December 2-17, 1975		
$\bar{x}$	9.7	9.8	9.9	10.0	9.9
s^2	1.2	1.0	1.2	2.3	1.4
s	1.1	1.0	1.1	1.5	1.2
n	43	43	43	37	166
			February 10-25, 1976		
$\bar{x}$	5.5	5.6	5.8	6.0	5.7
s^2	3.6	4.0	4.8	6.3	4.7
s	1.9	2.0	2.2	2.5	2.2
n	51	51	51	46	199
			NANTUCKET SHOALS		
			December 2-17, 1975		
$\bar{x}$	11.0	11.0	11.6	12.6	11.6
s^2	6.8	6.8	7.8	9.0	7.8
s	2.6	2.6	2.8	3.0	2.8
n	33	33	33	26	125
			February 10-25, 1976		
$\bar{x}$	5.3	5.3	5.5	7.3	5.9
s^2	1.4	1.2	1.4	4.4	2.0
s	1.2	1.1	1.2	2.1	1.4
n	46	45	45	33	169

Table 9. A comparison of production of early herring larvae (<10 mm standard length), abundance of December larvae (>15 mm), and an index of abundance at age 3 from the juvenile herring surveys in the Georges Bank-Nantucket Shoals area.

Year-Class	Initial Larval Production <10 mm length ($n \times 10^{-11}$)	December Larval Production >15 mm length ($n \times 10^{-9}$)	Index of Abundance (age 3) (no. per 30 min. tow)
		GEORGES BANK	
1971	150	180	924
1972	49	47	42
1973	1200	550	10
1974	1300	650	-
1975	-	89	-
		NANTUCKET SHOALS	
1971	13	50	608
1972	180	36	5
1973	850	180	33
1974	230	130	-
1975	-	42	-
		GEORGES BANK & NANTUCKET SHOALS TOTAL	
1971	160	230	1532
1972	230	80	47
1973	2100	730	43
1974	1600	780	-
1975		131	-

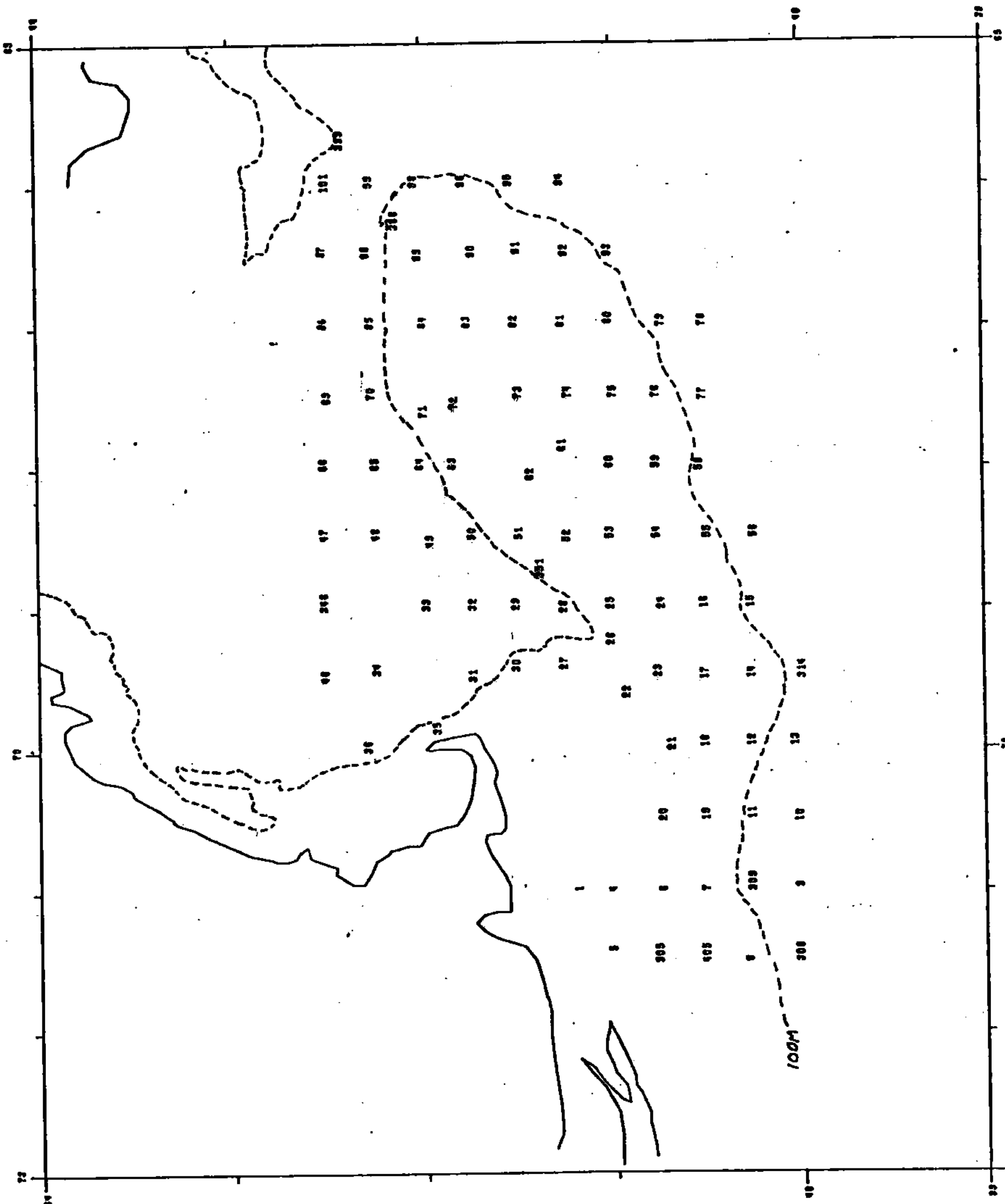

Figure 1. Station Positions: Albatross IV Cruise 75-14, 5-17 Dec 1975.

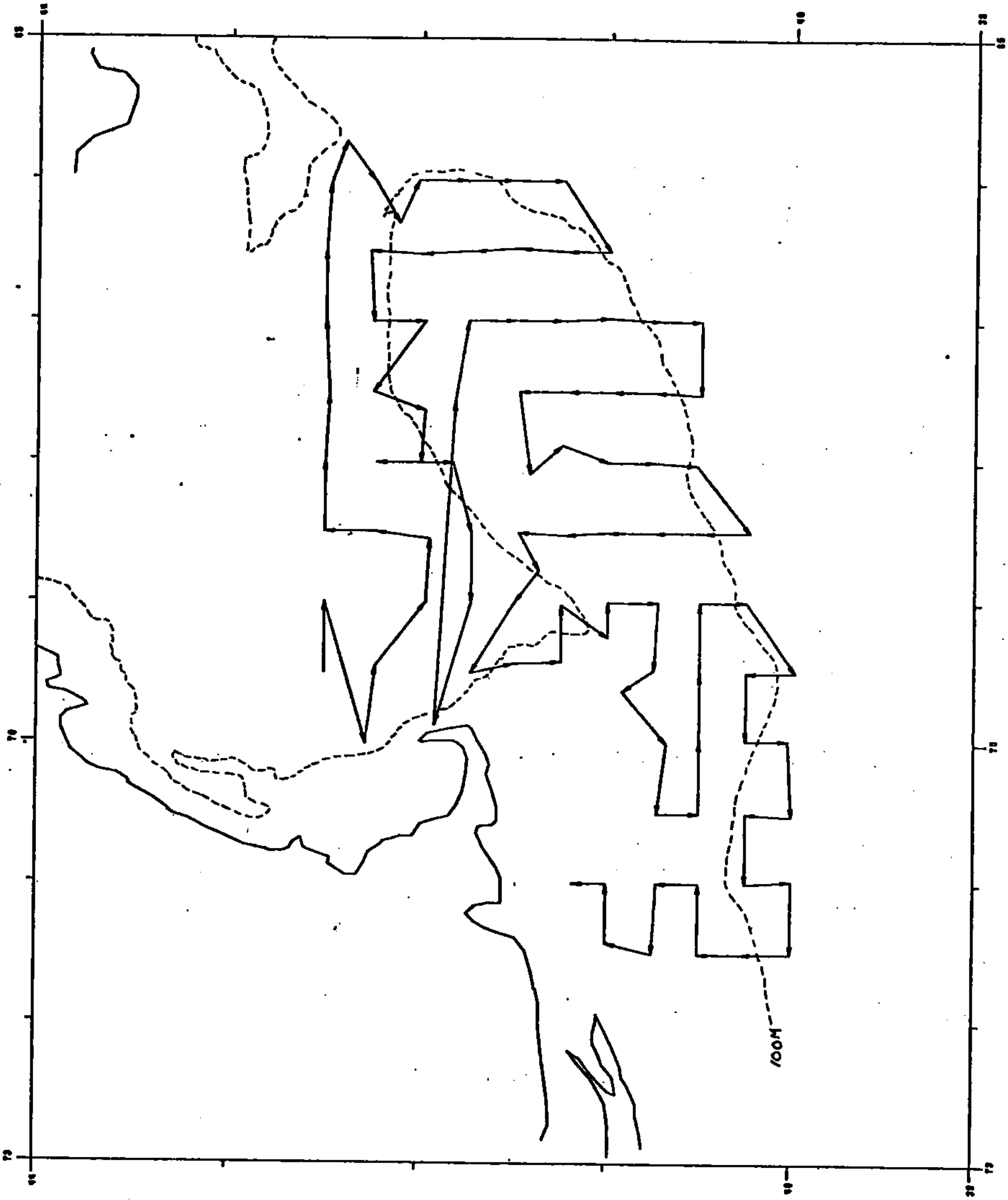

Figure 2. Cruise Track: Albatross IV Cruise 75-14, 5-17 Dec 1975.

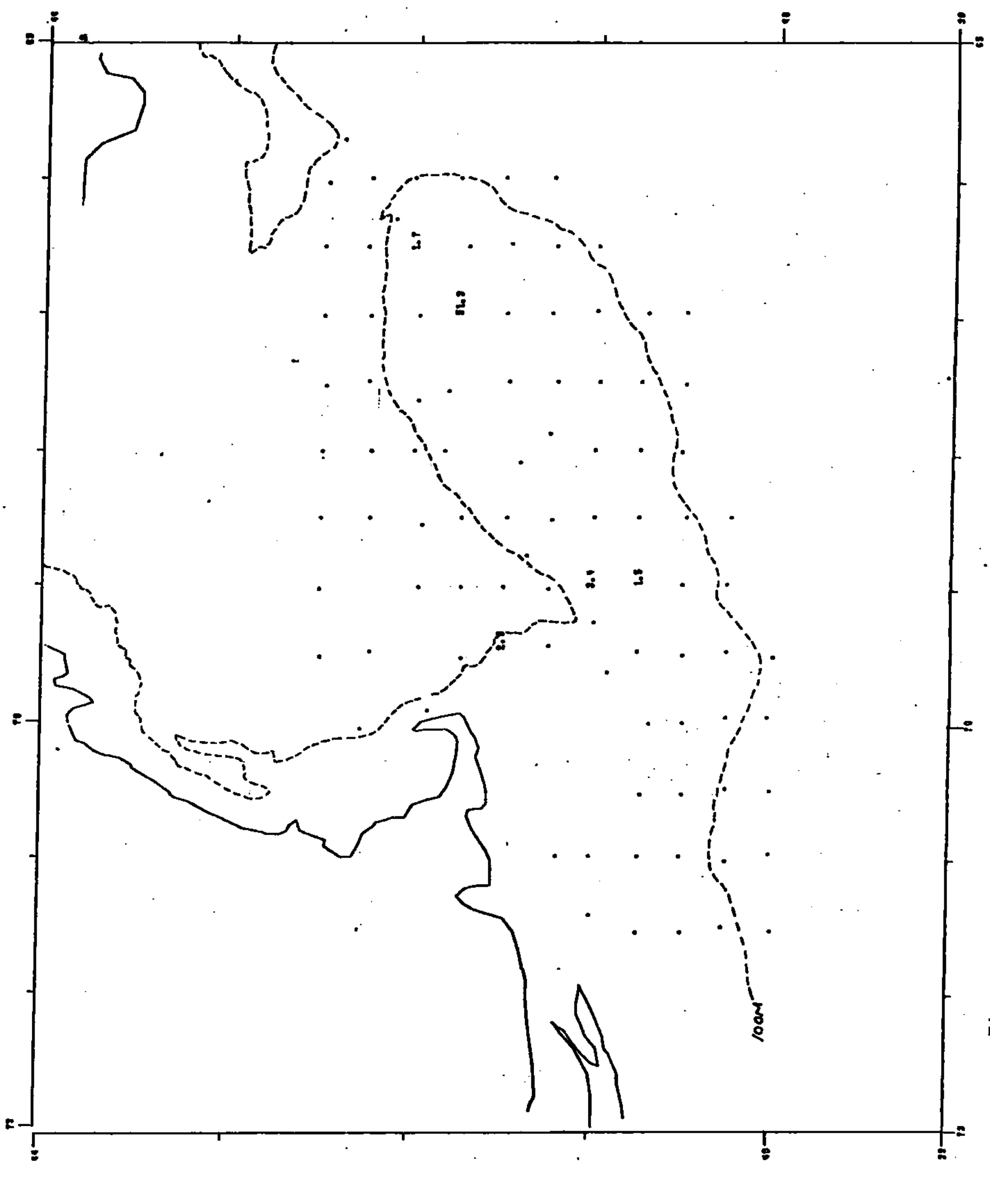

Figure 3. Larval Fish Distribution (Bongo 505), Herring lengths < 10 mm: Albatross IV Cruise 75-14, 5-17 Dec 1975.

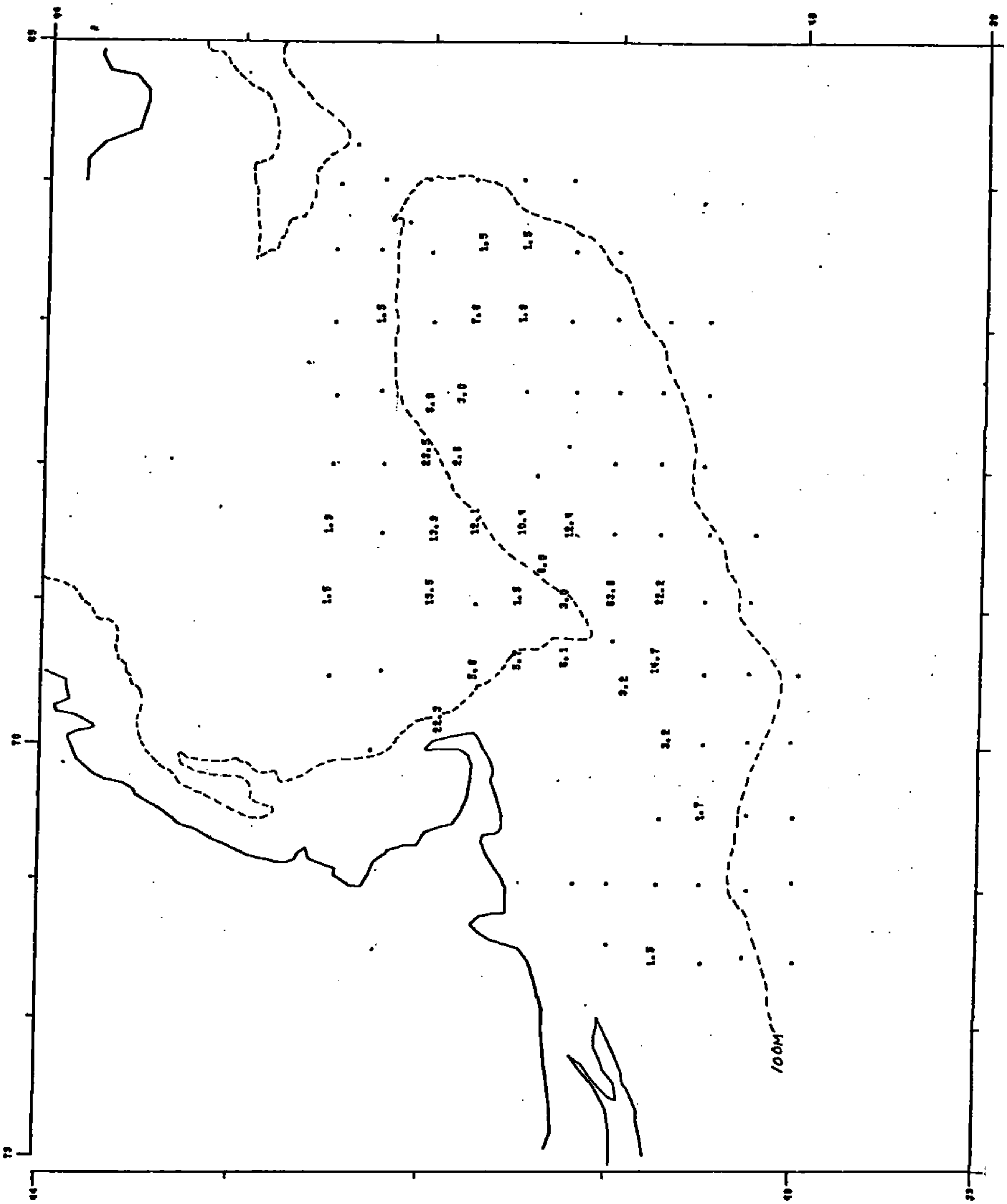

Figure 4. Larval Fish Distribution (Bongo 505), Herring lengths 10 - 15 mm: Albatross IV Cruise 75-14, 5-17 Dec 1975.

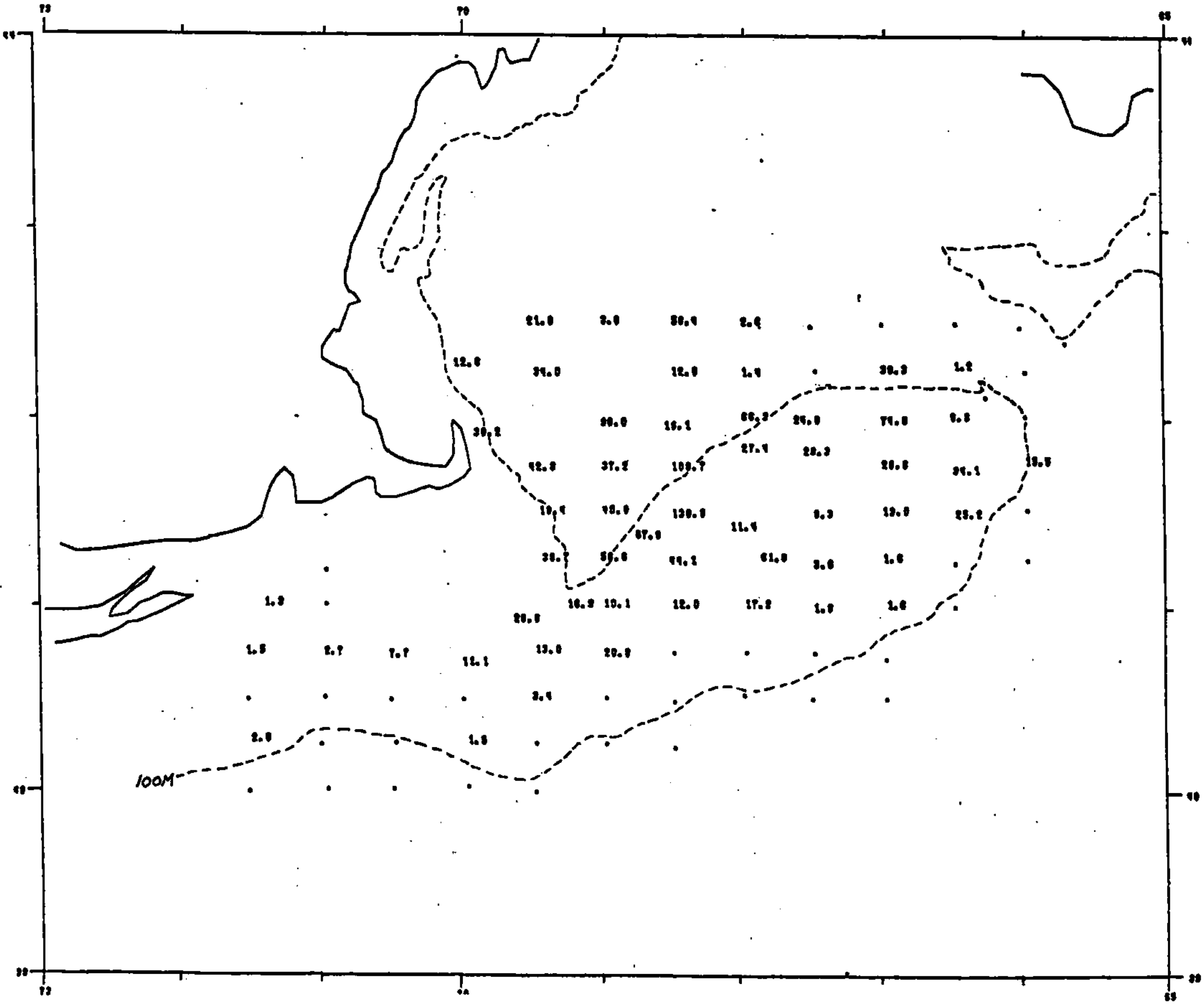

Figure 5. Larval Fish Distribution (Bongo 505), Herring lengths > 15 mm: Albatross IV Cruise 75-14, 5-17 Dec 1975.

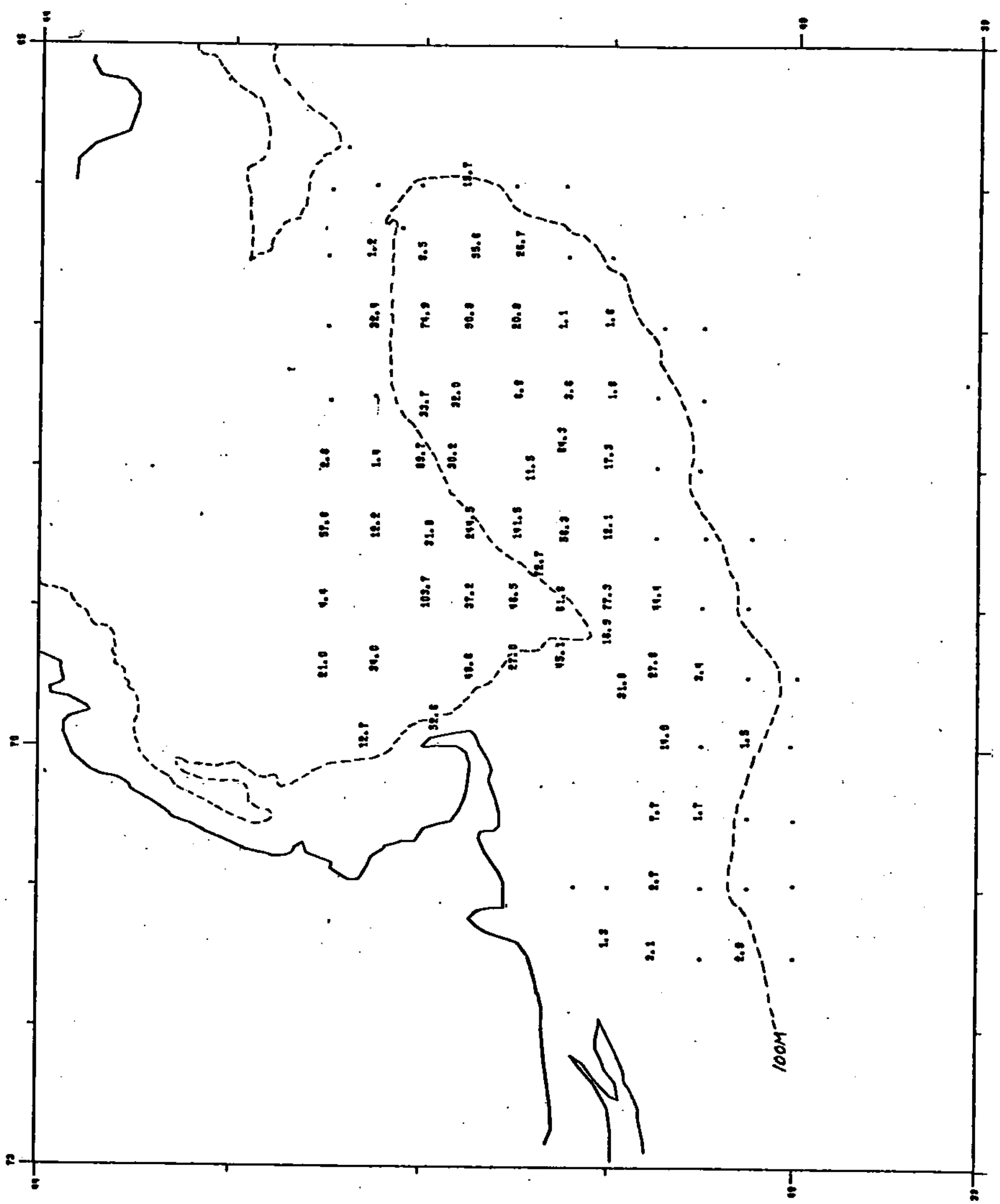

Figure 6. Larval Fish Distribution (Bongo 505), Herring: Albatross IV Cruise 75-14, 5-17 Dec 1975.

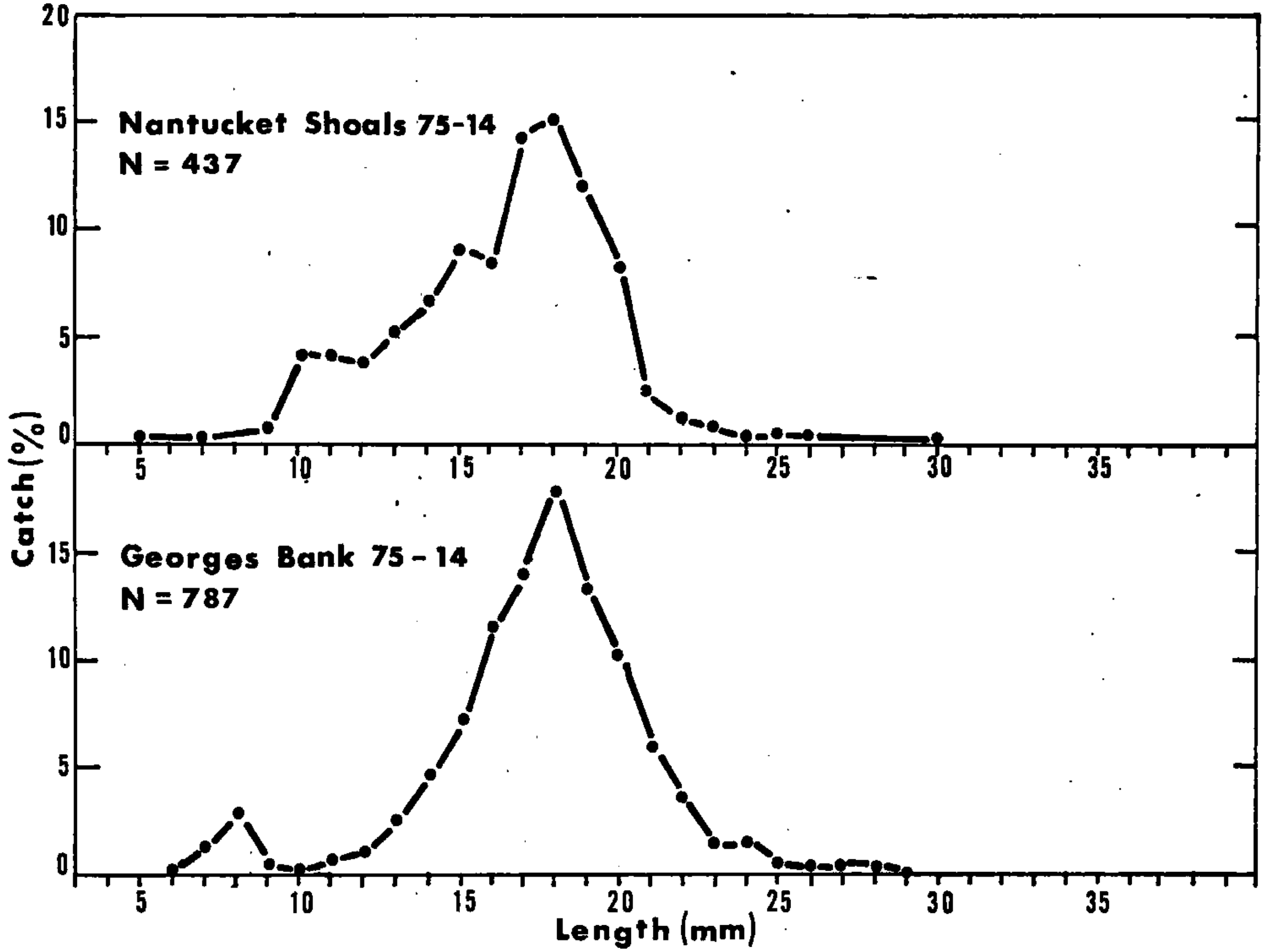

Figure 7. Percentage length frequency for Nantucket Shoals and Georges Bank herring larvae collected December 5-17, 1975, by ALBATROSS IV, cruise 75-14.

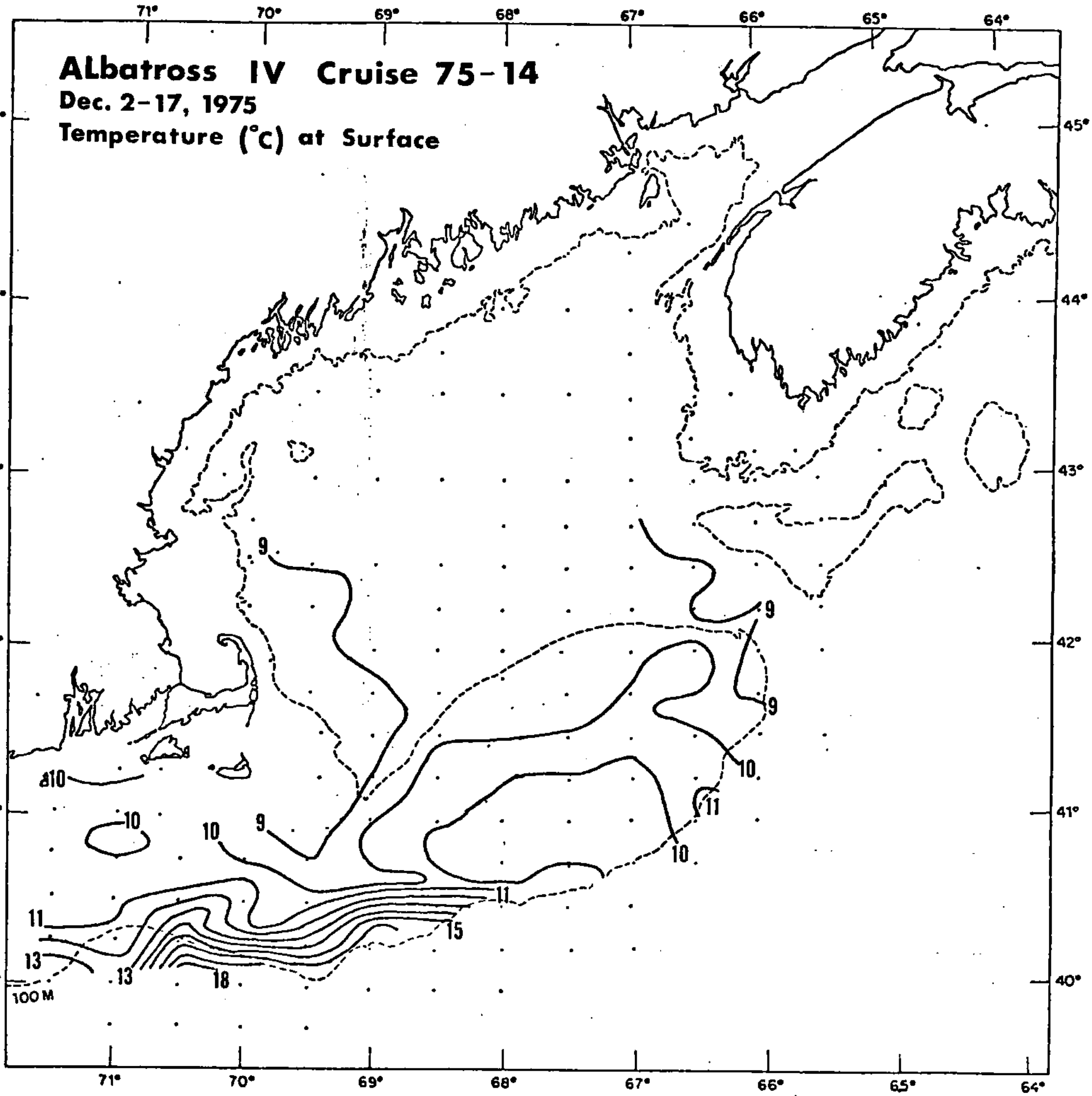

Figure 8. Temperature (°C) at Surface: Albatross IV Cruise 75-14, 2-17 Dec 1975.

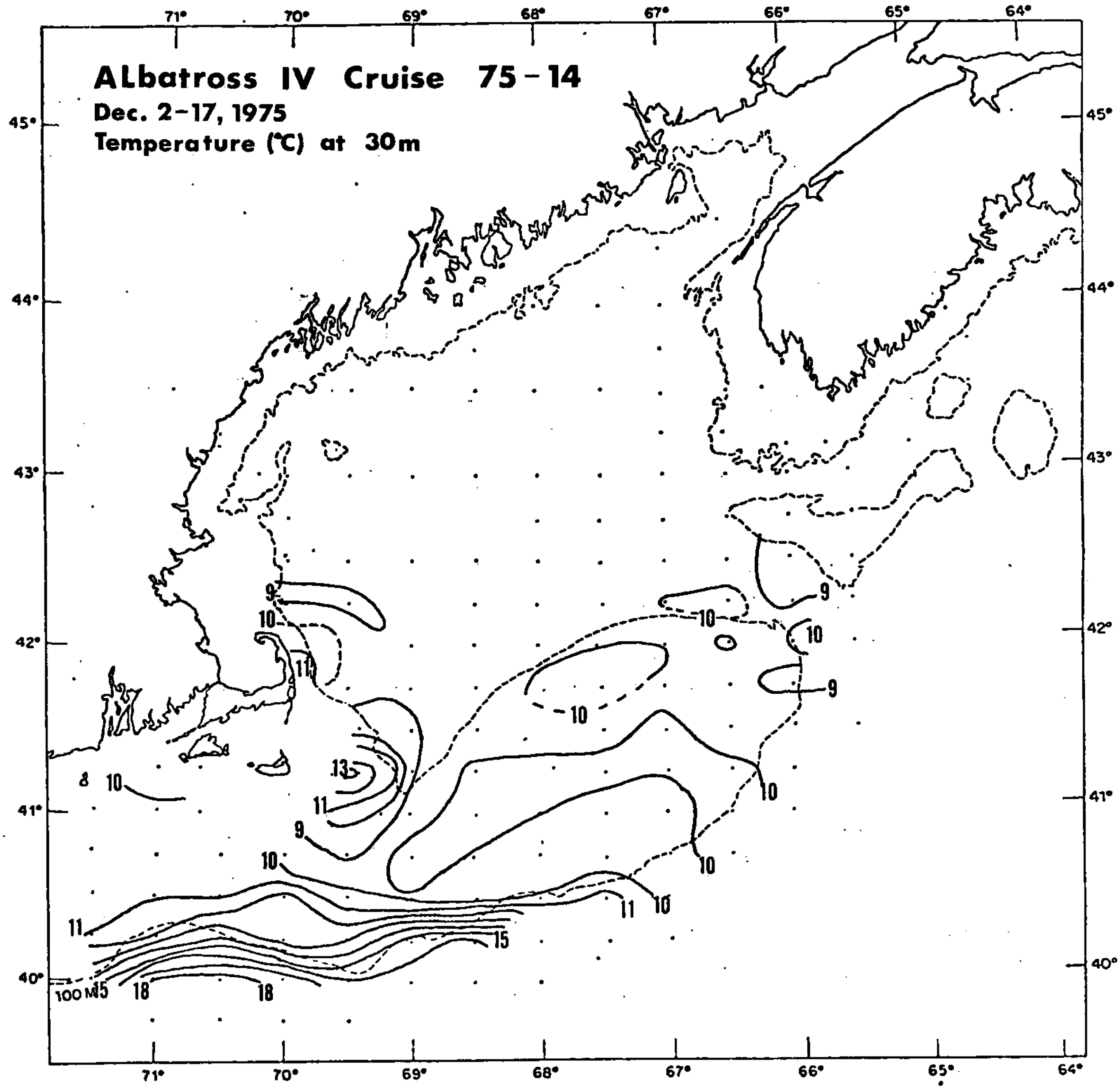

Figure 9. Temperature (°C) at 30 m: Albatross IV Cruise 75-14, 2-17 Dec 1975.

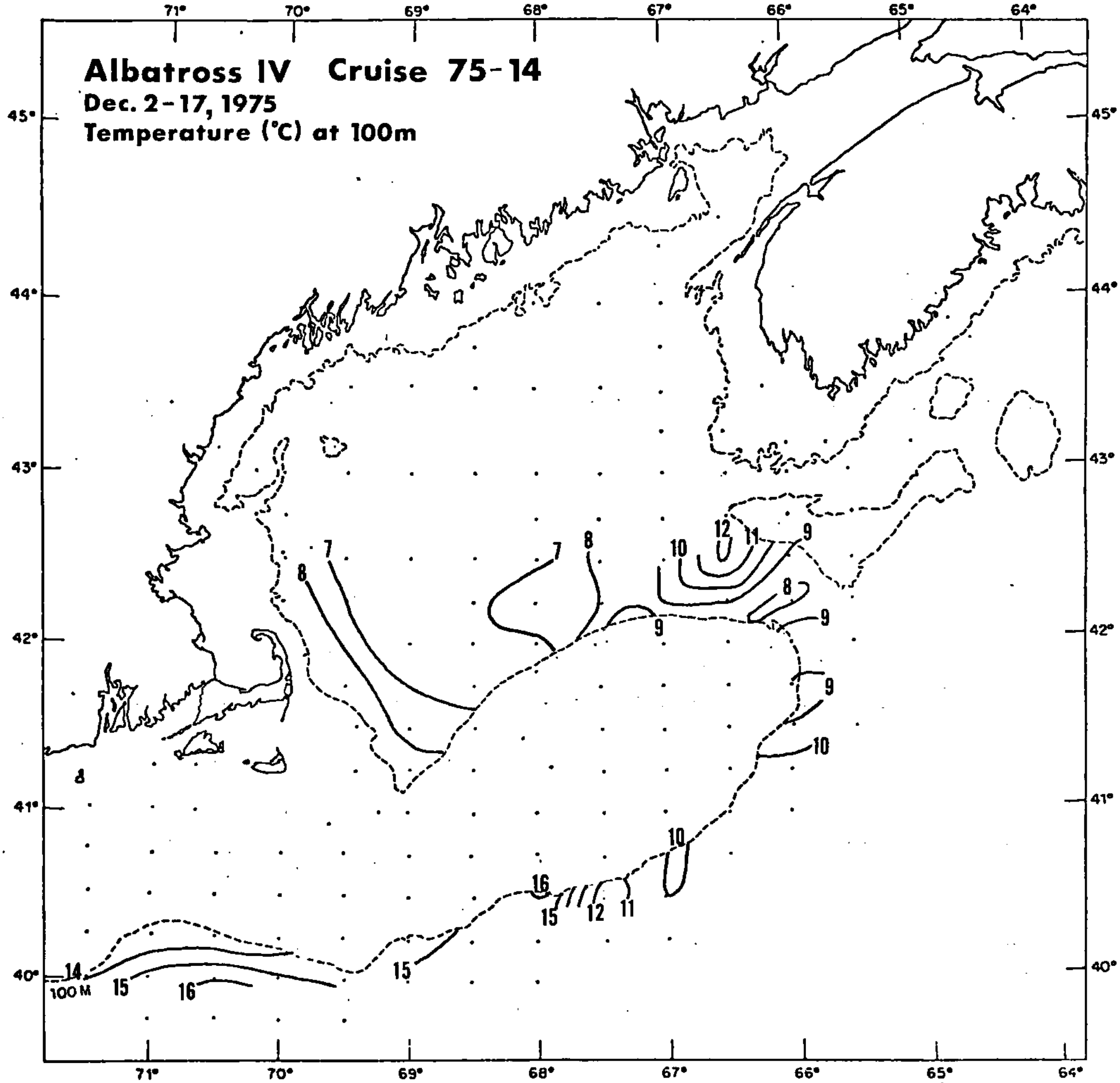

Figure 10. Temperature (°C) at 100 m: Albatross IV Cruise 75-14, 2-17 Dec 1975.

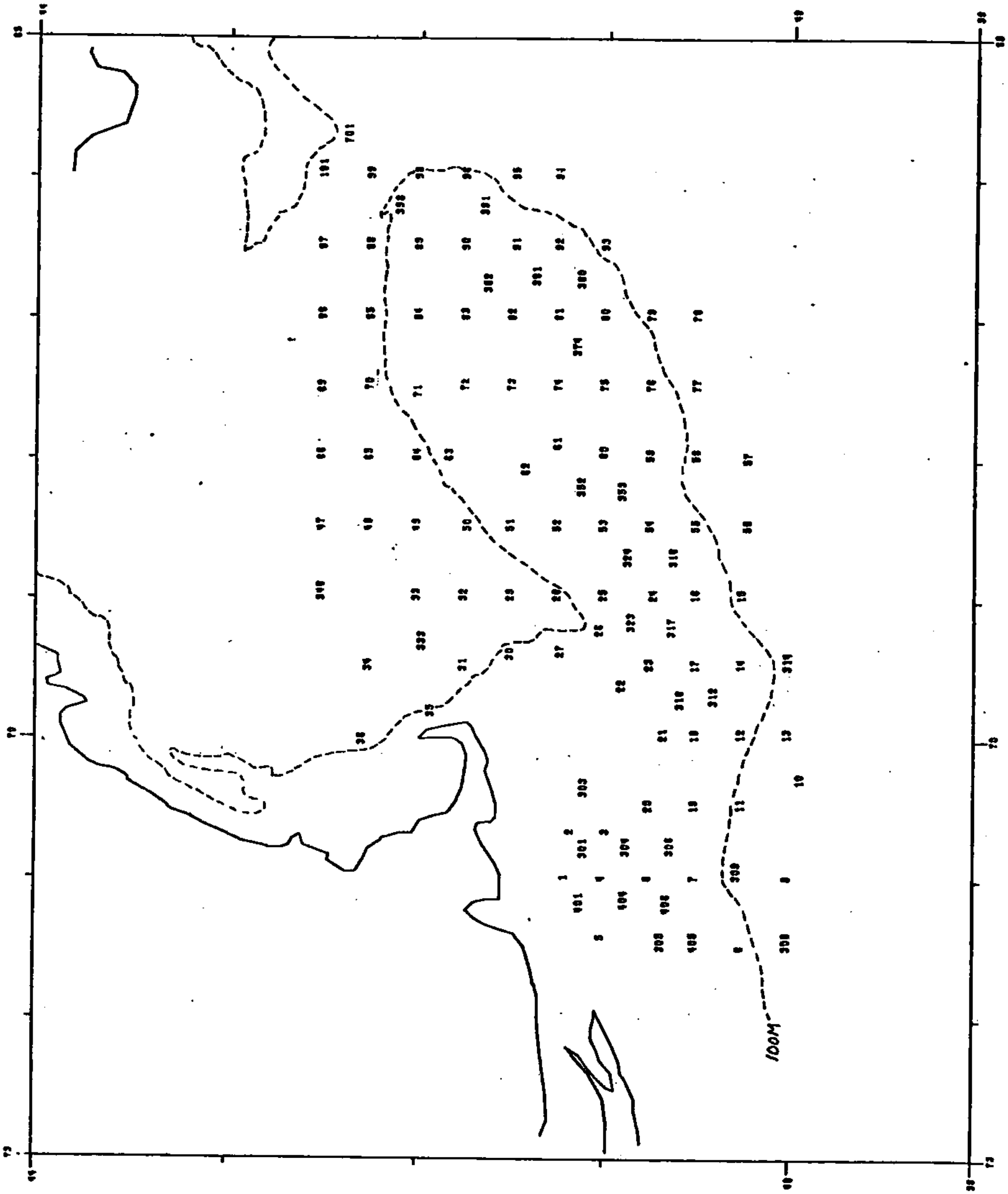

Figure 11. Station Positions: Albatross IV Cruise 76-01, 10-25 Feb 1976.

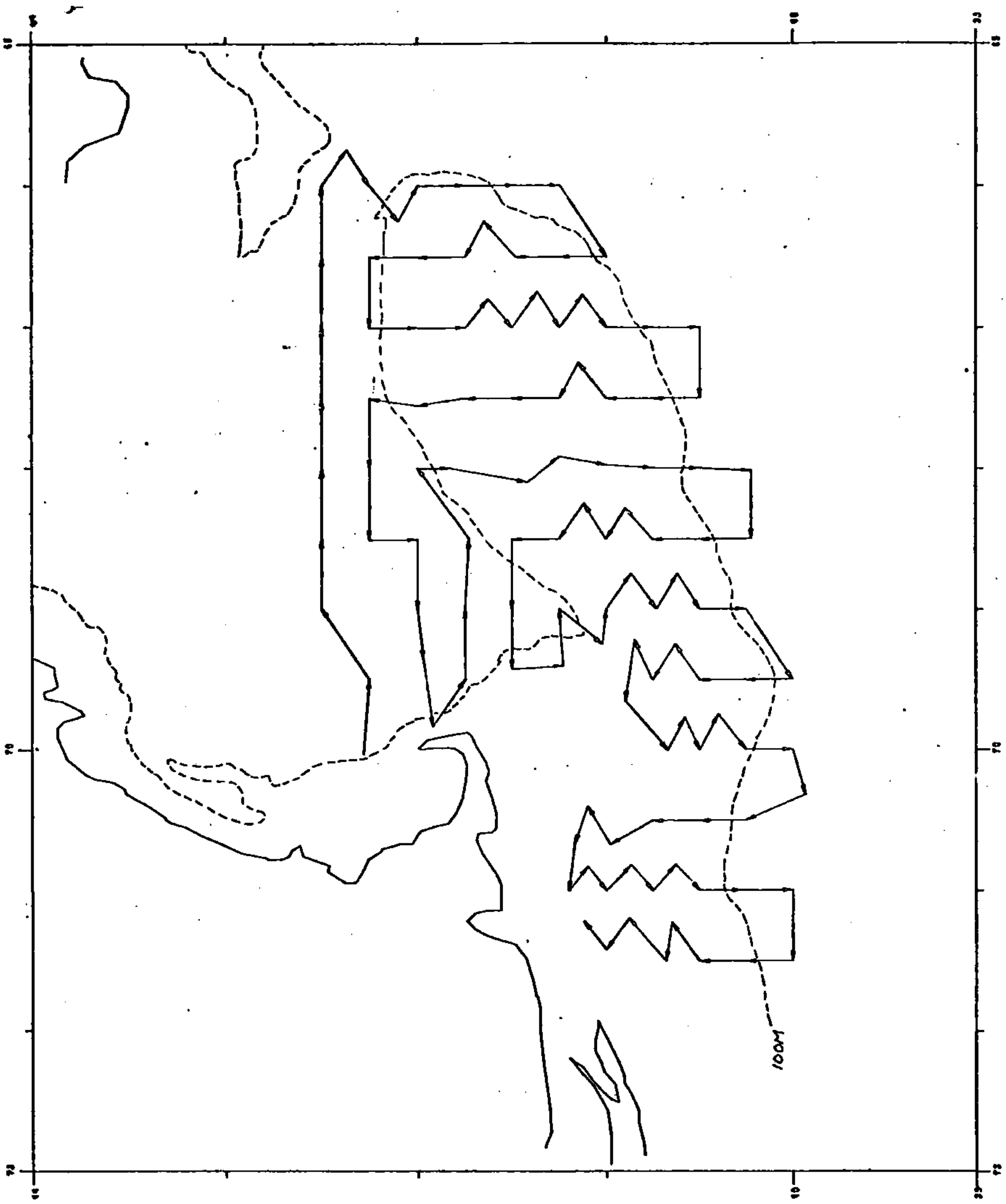

Figure 12. Cruise Track: Albatross IV Cruise 76-01, 10-25 Feb 1976.

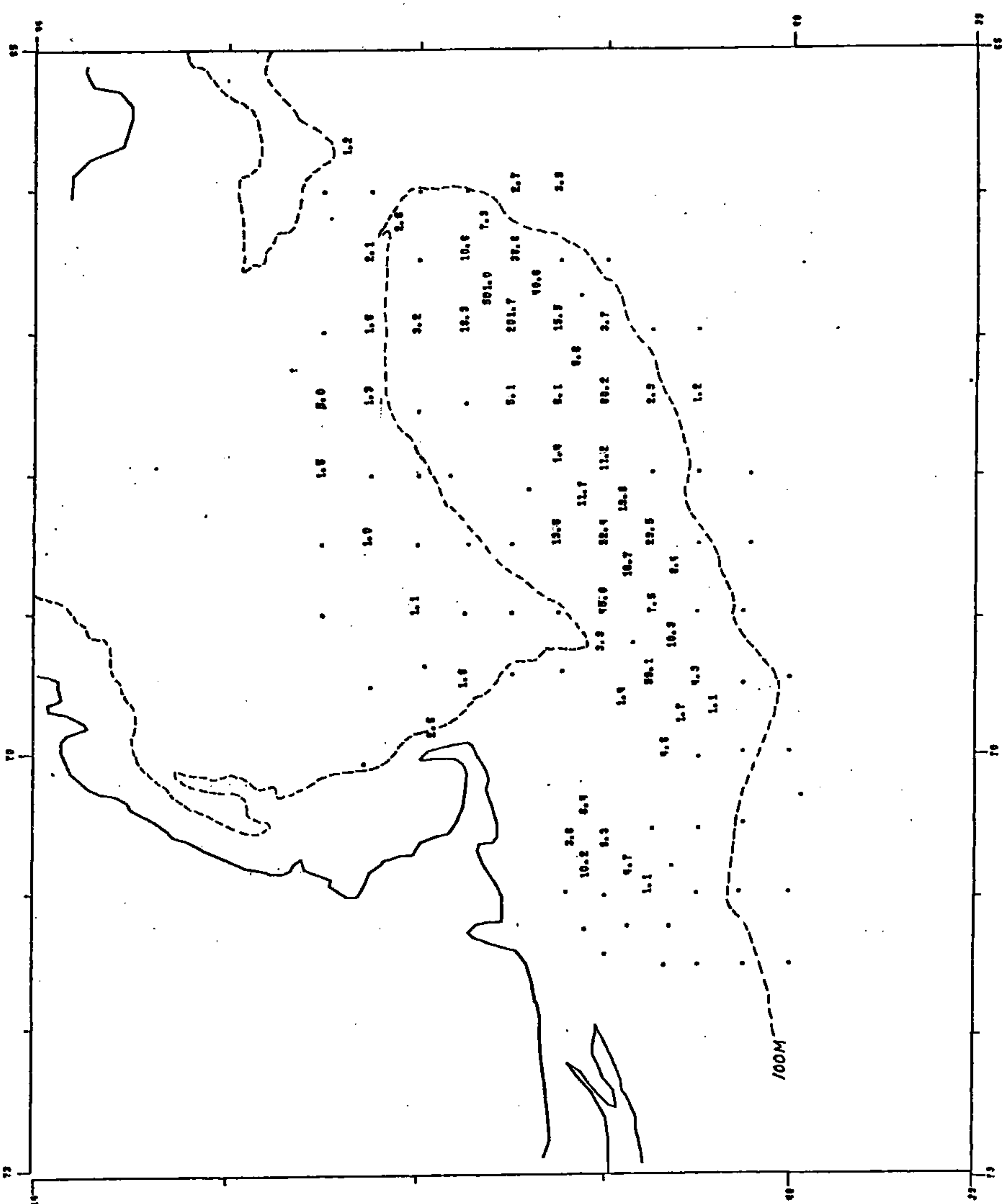

Figure 13. Larval Fish Distribution (Bongo 505), Herring lengths > 15 mm: Albatross IV Cruise 76-01, 9-25 Feb 1976.

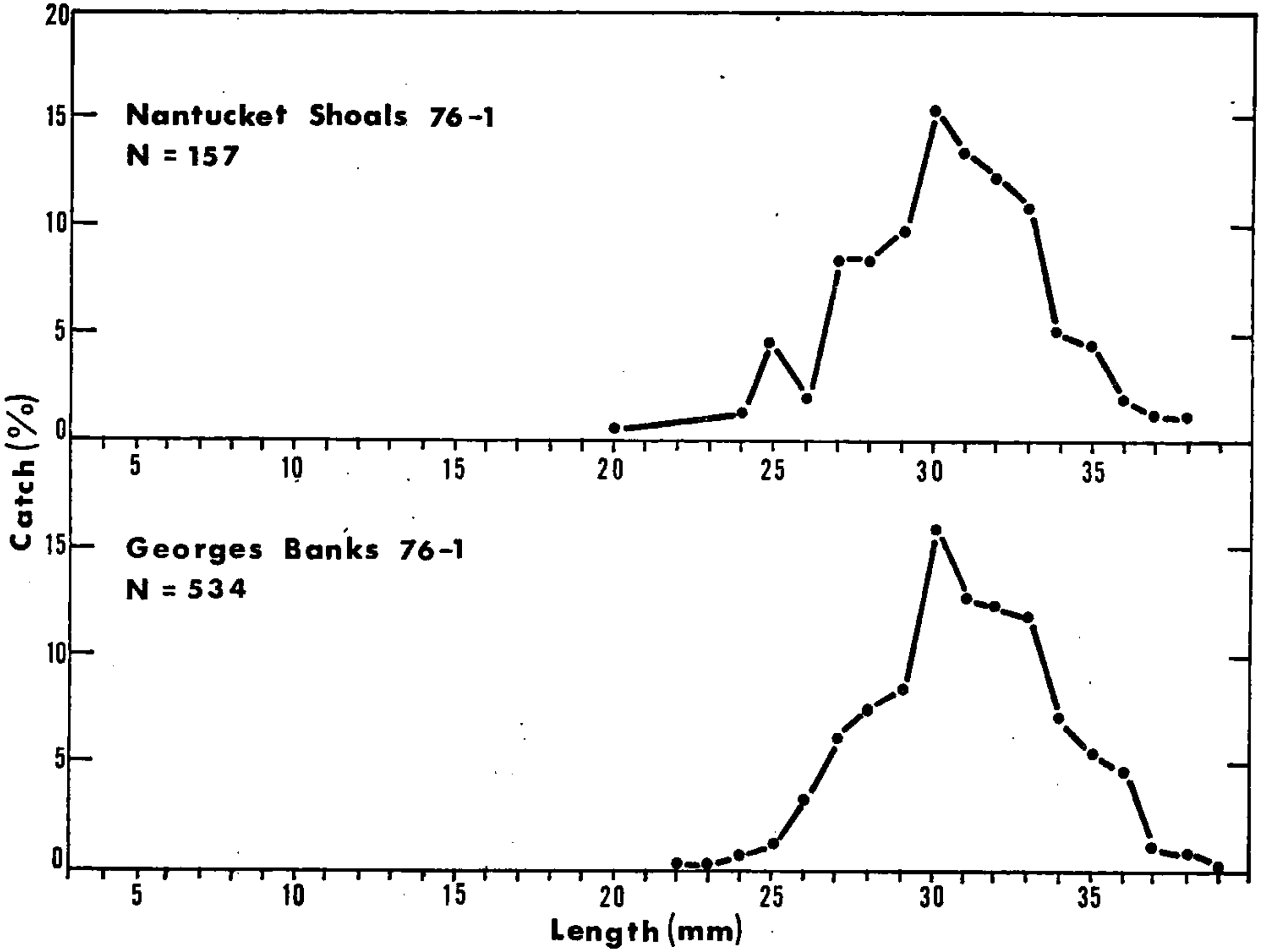

Figure 14. Percentage length frequency for Nantucket Shoals and Georges Bank herring larvae collected February 10-25, 1976, by ALBATROSS IV, cruise 76-01.

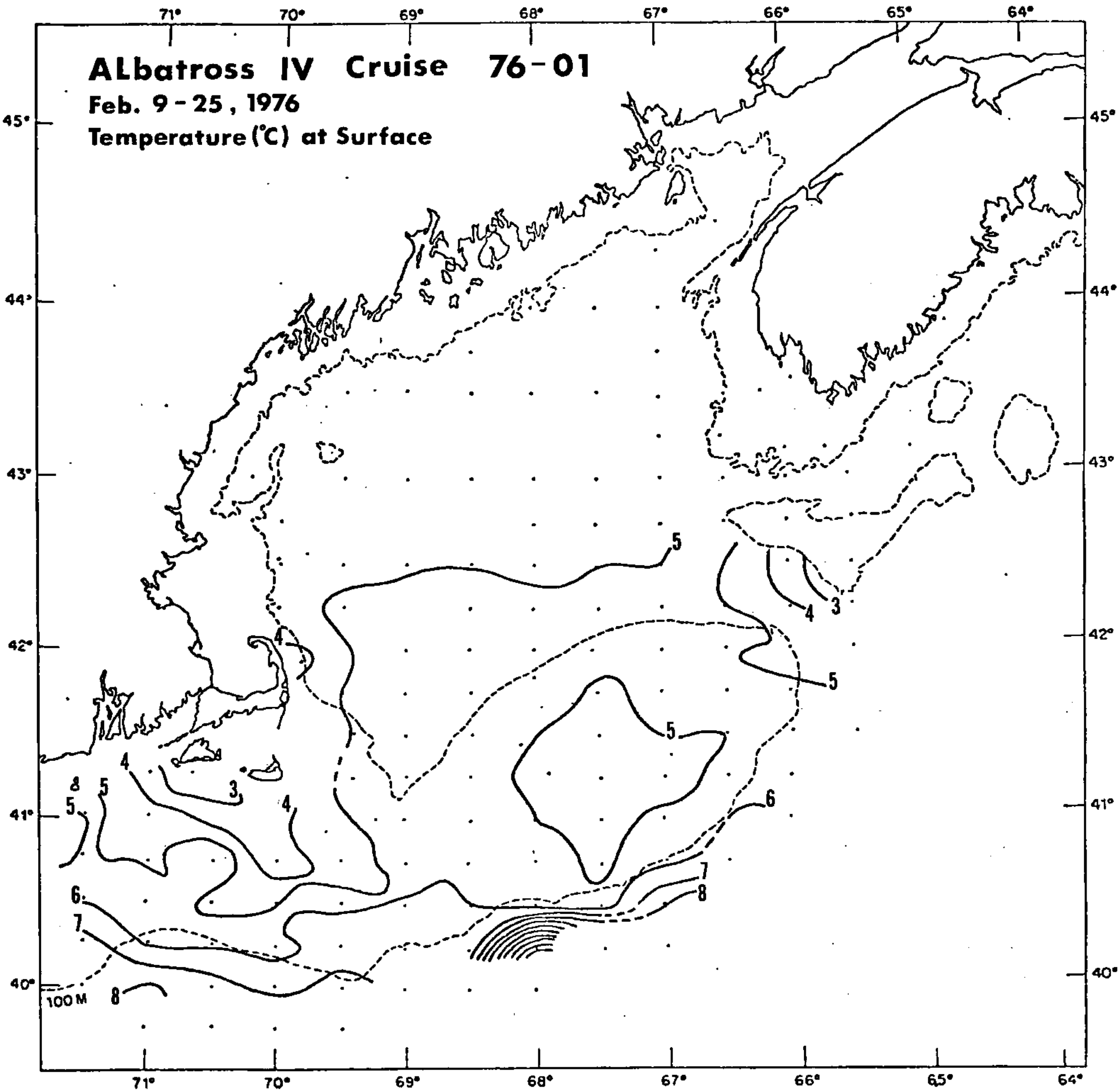

Figure 15. Temperature (°C) at Surface: Albatross IV Cruise 76-01, 9-25 Feb 1976.

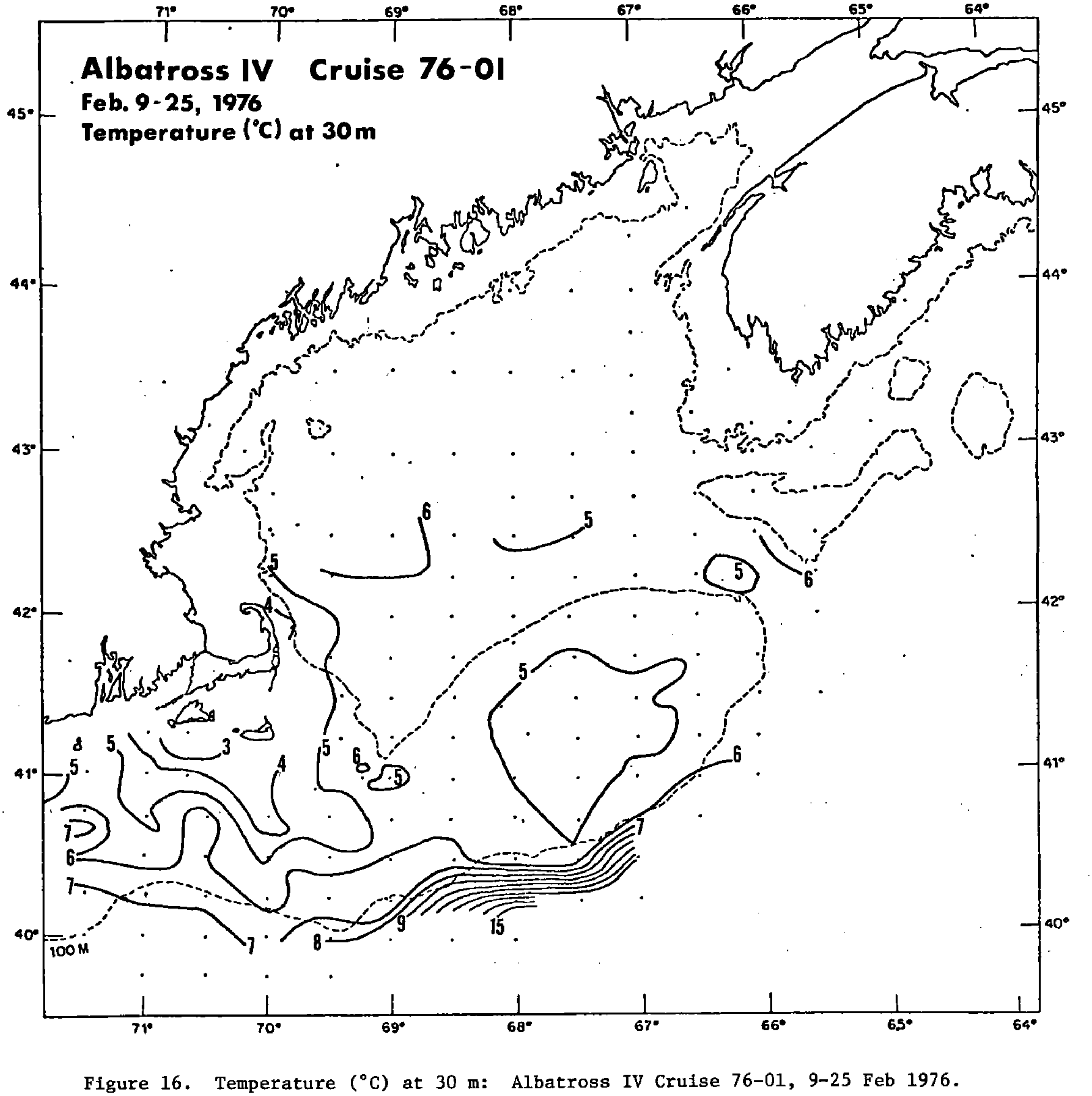

Figure 16. Temperature (°C) at 30 m: Albatross IV Cruise 76-01, 9-25 Feb 1976.

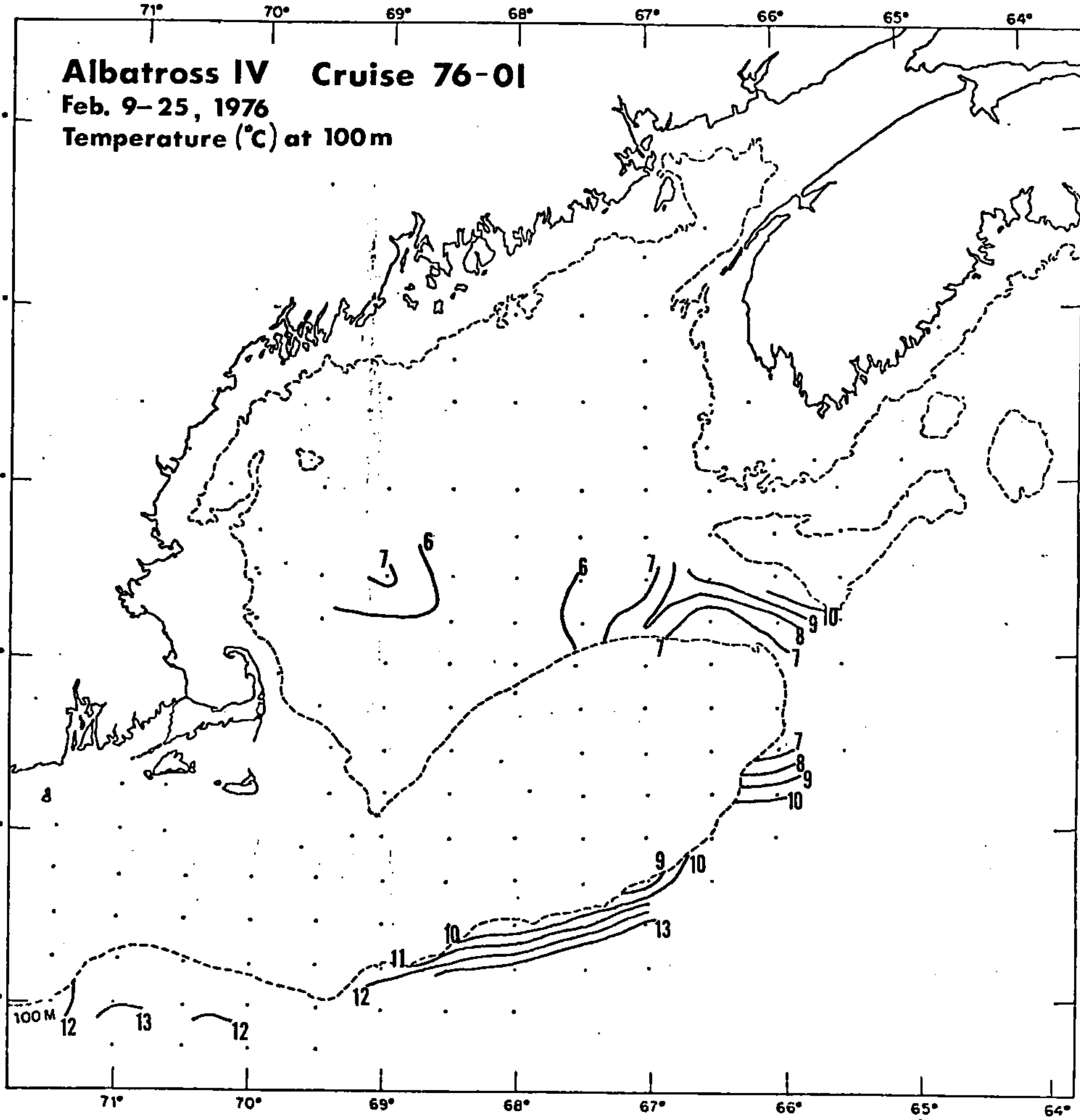

Figure 17. Temperature (°C) at 100 m: Albatross IV Cruise 76-01, 9-25 Feb 1976.