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Winter mortality of Georges Bank herring larvae

by

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Introduction

Larval herring studies along the west coast of the Gulf of Maine have indicated that larval abundance was reduced to a common level by early winter each year regardless of the initial production of larvae hatched in the autumn (Graham, *et al.*, 1972). The abundance of larvae in the spring and subsequent two-year-old juveniles in the fishery generally correlated with winter mortality estimates by Graham and Davis (1972). Low condition factors were usually correlated with high winter mortality, suggesting unfavorable environmental conditions at this time. Monthly condition factors of herring larvae decreased dramatically in December to a low value in February, rising again in the spring (Chenoweth, 1970). Suitable kinds and/or concentrations of food organisms are thought to be the major determinant controlling winter mortality. Sherman and Honey (1971) report a decrease in the incidence of feeding for larval herring in the winter when plankton volumes were lowest. Sea surface temperatures usually reach a low point in February and may be an important mediating factor.

Since inception of the ICNAF Larval Herring Survey in 1971, four ichthyoplankton cruises have been conducted by R/V *Albatross IV* bracketing the winter period in the Georges Bank area (Cruise 73-3, 4-20 December 1973; Cruise 74-2, 11-22 February 1974; Cruise 74-13, 4-19 December 1974; Cruise 75-2, 12-28 February 1975). These cruises provide an initial opportunity to see if survival through the winter for the Georges Bank population is similar to that observed along the western coastal Gulf of Maine.

The objectives of this paper were to: (1) provide first approximations of over-winter mortality of Georges Bank herring larvae for two winter seasons, and relate to hydrographic conditions, (2) propose hypotheses of mortality regulating mechanisms during this period, and (3) set forth recommendations for future work.

Methods

An oblique plankton tow was made to within 5 m of the bottom to a maximum depth of 100 m at each standard ICNAF station covered on the four *Albatross IV* cruises. Gear consisted of a 61 cm bongo sampler (.505 mm and .333 mm mesh nets) with flowmeters mounted in both openings. A V-fin depressor was used to maintain a 2:1 wire angle. A time-depth recorder was attached to the towing wire just beneath the bongo sampler. 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.

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 for hydrographic sampling at depth. STD casts were made on selected stations to within 10 m of the bottom to a maximum depth of 500 m.

All fish larvae were removed from the .505 mm mesh samples of the 61 cm bongo sampler, counted, and measured to the nearest mm (standard length). Plots of the number of herring larvae per 10 m^2 were made at each station for the total catch and various length frequency groupings. The specified study area included most plankton stations on Georges Bank within the 200 m isobath (stations: 50-56, 58-64, 70-77, 79-85, 88-93, 95, 96, 98). This set of stations encompassed the whole of Georges Bank spawning and most of the documented dispersal of these larvae through the fall and winter, and provided a nearly complete station data set for the four cruises. Also, contamination of the Georges Bank population by larvae originating from the Nantucket Shoals area appeared to be minimized by the station grid selected.

Percentage length frequency summaries of herring larvae by 1 mm intervals and the corresponding number per 10 m^2 were made for each December and February cruise period covering the designated Georges Bank stations. The predominant length modes in December of both years appear to separate into two distinct larval age groups about one month apart using Boyar's (1973) average growth rate of 5 mm per month (range 4.1-7.4 mm). These modes appear again in February slightly closer together and have been assumed to separate the same age groups of larvae seen in December. The relative total abundance of larvae for each age group was estimated by arbitrarily selecting the length intervals shown in Table 3 and then adding the number of larvae per 10 m^2 within each interval. Since 38 stations were included, total abundance within each length group represents the number of larvae per 380 m^2. The few stations not sampled during one of the surveys were on the perimeter of the larval distribution and could be justifiably treated as zero hauls.

The instantaneous mortality rate or coefficient of loss per day, Z, was calculated for the December-February larval totals of both winters. Z is derived from the following relationships by Ricker (1958):

$$N_1 = N_o e^{-zt}$$

$$Zt = -\ln \frac{N_1}{N_o}$$

where, N_1 is the abundance of larvae in February, N_o is the abundance of larvae in December, and t is the period of time between the midpoint of the cruise survey covering Georges Bank, 63 and 68 days for December-February, 1973-74, and 1974-75, respectively. The percent larval mortality per day was calculated from the following relationship:

$$e^{-z} = \text{survival/day}$$

$$1-e^{-z} = \text{mortality/day}$$

No estimation of sampling error has been made on these surveys to place confidence levels around abundance estimates. Saville's (1964) half or double limits for larval fish abundance provides a conservative estimation of sampling error. Confidence limits were calculated for the Z and percent mortality per day values by halving abundance estimates for one mode and doubling the other for a high limit, and reversing the operation between the two modes for a low limit.

Temperatures at surface, 10, 30, and 100 m, and surface salinities were plotted and contoured for all cruises. Temperature observations at 1, 10, 30, 50, and 1-50 m levels were compared for December 1973-74 and February 1974-75 by computing their means ($\bar{X}$), variance (s^2), standard deviation (s) and testing for significant differences of the means by t-tests (Snedecor and Cochran, 1967).

Results

Cruise tracks and the total number of herring larvae per 10 m^2 at each station are given in Figures 1-12 for *Albatross IV*, Cruise 73-9, 74-2, 74-13, and 75-2. The general distribution pattern and abundance of larvae is similar for both years, December and February. In December, larvae occurred on most stations within the 100 m isobath with densities typically ranging from 11-1000 per 10 m^2. By February, the distribution of larvae still occurred within the 100 m contour, however, their numbers were greatly reduced with the greatest concentration of larvae, *i.e.*, highest densities, occurring in the central, southern part of Georges Bank.

The length frequency distribution of the larvae for each of the four cruises is given in Table 1 and Figures 13 and 14. Two predominant length modes (A, B) were identified for each period. It is of particular interest to note the difference in timing of the length modes and the relative difference in apparent larval growth between the two winter periods. In December, 1974, the major modes A and B were smaller in length than in the previous December, 1973. However, by February the A and B modes occurred at a much higher length frequency in 1975 than 1974. A station by station appraisal of the length frequencies showed that larger larvae were prevalent on all stations in February, 1975, *i.e.*, the difference in length frequency was not due to one or two stations of high densities of larger larvae.

The abundance of larvae within each modal group, or a combination of the two groups, was found by summing the number per 10 m^2 for the desired length frequency from Table 2 and is shown in Table 3. Logarithmic plots of the abundance of larvae from the A and B modes are given in Figure 15. Mortality rates (Z), percent mortality per day, and confidence limits between successive December-February modes for the two winters also are given in Table 3. Although the sampling error associated with these estimates is extremely wide, some trends are suggested. Larval abundance on Georges Bank was slightly higher in all cases in December, 1974, and February, 1975, than in December and February, 1973-74, respectively. Instantaneous mortality, Z values, and percent mortality per day rates were slightly higher between December-February, 1973-74 than December-February, 1974-75. An average loss rate per day during this period lies somewhere near 3-4%.

Temperatures at 30 m and surface, and surface salinities in the study area are shown in Figures 16-27. Water of 9°-10° C predominated over most of Georges Bank in December for both years, 1973 and 1974. Generally, cooler 8° C water was observed on the northeast part and warmer 10°-11° C water was observed on the southwest part. Surface salinities on Georges Bank ranged from *ca.* 33.0-33.5 ppt. However, a gradient of rapidly increasing temperatures and salinities occurred along the 100 m contour marking the slope front along the southern part of the Bank. In February, water temperatures were considerably colder, and 5°-6° C water prevailed over most of Georges Bank. Water temperatures appeared to be cooler in December-February, 1974-75 than the previous winter, and temperature statistics tend to support these observations (Tables 4 and 5). The December 1973 and 1974 temperature means of total observations 1-50 m are 10.35° and 9.86° C, respectively. Only the means of the total temperature observations were found to be significantly different by t-tests, and not the means at other intermediate depth levels. The February 1974 and 1975 temperature means at 1-50 m are 6.25° and 5.68° C, respectively. The mean temperatures at all depth levels, except at 50 m, were found to be significantly cooler during February, 1975, than 1974.

Discussion

Most evidence seems to indicate that a prime cause of larval mortality is due to starvation, or predation secondarily on starved larvae (*vide* May, 1974; Jones and Hall, 1974). Larval herring studies along the western coastal Gulf of Maine have indicated that a high winter mortality was associated with poor larval condition and reduced incidence of feeding, which in turn was related to seasonally low plankton volumes (see references in Introduction). The winter season in the Gulf of Maine - Georges Bank area may be a "critical period" for herring larvae as described by Marr (1956). Lough *et al.* (1975) noted that the December abundance of herring larvae appeared to be related to sea water temperature during the 1971-74 ICNAF Larval Herring Surveys. It could be hypothesized that high sea water temperatures are associated with high densities of suitable food organisms resulting in greater larval survival. Since the winter of 1973-74 was slightly warmer (*ca.* 1° C) than 1974-75, one might expect greater survival the former winter, however, a reverse trend was observed. The small difference in larval abundance and the lack of a clear separation of mortality rates observed on Georges Bank between these two successive winters does not allow one to adequately define or explore any of the possible underlying mechanisms controlling survival. An average mortality rate of three to four percent per day during the winter for Georges Bank herring larvae is similar to recalculated mortality values (1.56-3.61 percent per day) along the coastal Gulf of Maine during a four year period (Graham and Davis, 1971). This is considerably lower than the apparent mortality of 34.2% per day which I recalculated for recently hatched herring larvae based on a 1970 experiment on Georges Bank (Graham and Chenoweth, 1971). The mortality curve during the entire larval period declines sharply in an exponential manner (see Cushing, 1974, p. 107, Figure 3, for a fitted curve of Graham's *et al.*, 1972, original larval herring data).

Larval growth generally is directly related to temperature, assuming a non-food limiting environment, so that one might expect growth to be greater during the warmer winter, 1973-74, but just the reverse was observed in this study. Larval growth during the cooler winter, 1974-75, appeared markedly greater than the previous year. The difference in apparent growth may be ultimately related to differences in the available food supply between the two years. On the other hand this apparent anomaly may be related more to egg maturation and spawning events than conditions during the winter larval period. Five successive length frequency modes of recently hatched larvae were observed on Georges Bank starting in late September and extending through December, 1973 (*cf.* Schnack, 1973). In contrast to the early, but protracted season of 1973, the appearance of recently hatched larvae during fall 1974 was delayed until early October and only two modes predominated in the length frequency summaries: the second mode followed closely behind the first in late October (Paulmier and Briand, 1975; *Wieczno* ICNAF 1975 Basic Data Summary, Balkovoy, *et al.*, 1975; Schnack and Joakimsson, 1975; Lough, *et al.*, 1975). Larvae produced in the fall, 1974, may have been intrinsically able to grow faster and larger than those produced in 1973. Blaxter and Hempel (1963) have studied the size of eggs from various spawning stocks of North Sea herring and found that larvae from larger eggs contained more yolk reserves and were larger and grew faster as a consequence. Conceivably a similar situation could exist for Georges Bank herring. Egg size, nutritive content, and size-maturity of recently hatched larvae could be monitored on a yearly basis from collections made by divers over egg beds. Laboratory studies of relative yolk utilization of recently hatched larvae perhaps should be investigated also.

Much of the success in determining comparative mortality estimates depends on the ability to separate the polymodal length frequencies into meaningful length groups and to assess the associated sampling error. This aspect has not been dealt with in a rigorous manner in this paper. The existing data are ambiguous, partly because of the difficulty to encompass and follow clearly the dispersal of larvae from discrete spawning beds. Even with the relatively isolated Georges Bank herring population, one notes that there are a number of spawning aggregations scattered around the bank, with hatching at various times. A finer grid of stations and more frequent surveys would enhance separation of these aggregations and thereby improve analyses

of growth and mortality. However, it is difficult to judge the possible benefits of such an expanded effort in relation to the cost. There are undoubtedly a complex play of factors underlying mortality processes, and the information available in the current larval herring survey data base very likely is insufficient to document all of them. Nevertheless, it seems to us that the present program is certainly adequate to document major changes in larval production (*e.g.*, 1972 *vs.* 1973 spawning seasons) and to monitor major changes in over-winter mortality. These two aspects alone may provide insight into possible mortality mechanisms given a sufficient time series within which large variations in production or mortality occur. Of course, additional information such as food availability, growth and condition must be examined as we proceed and these data can be obtained with survey operations comparable to the ones presently in use. Other avenues of study such as egg size, predation, etc. should be explored according to their promise and the available resources. However, even the present level of the ICNAF larval herring program is adequate in our view to justify continuation of the current surveys, at least for several more years. Some thoughts as to possible improvements in sampling strategy are presented in the next section.

Recommendations for future work

1. A minimum of three surveys concentrated in the Georges Bank-Nantucket Shoals area should be conducted between September and December to attain the program objectives of monitoring hatching, production, growth, and dispersal of early larvae. At least one cruise should be made in February and another in March or April to monitor over-winter survival. We already have a time series of 3 years of larval sampling by Federal Republic of Germany in conjunction with the spring bottom trawl surveys; these should be incorporated in the over-winter mortality analysis, and they should be continued if at all possible. In our view this minimum monitoring should be maintained at least for three more years.

2. If additional areal coverage is possible in the autumn, the western Gulf of Maine should be given next priority because larvae originating along the coastal Gulf of Maine tend to drift in a southwesterly direction and may mix with the Nantucket Shoals-Georges Bank larval populations.

3. Efforts should be intensified toward a more comprehensive analysis of the available ICNAF larval herring data base in order to generate hypotheses and refine our sampling scheme. To facilitate this we propose that the current backlog of standard larval herring samples (at least the .333 mm samples) and the future samples be processed at the newly established Polish Sorting Center. This processing would include sorting of invertebrates as well as ichthyoplankton, and would insure uniform sorting methods and quality control.

4. Fine mesh samples are now available for the fall-winter, 1974-75 seasons, and we recommend that these samples be examined to answer questions of food availability. Also, the processing of the invertebrate component for the .333 mm samples during fall of 1972 and 1973 should be examined to evaluate food quantity-quality differences between these two contrasting years of larval abundance. Small bongo (20 cm dia.) sampling with fine mesh (.165 and .053 mm) should be continued on all surveys from September through December to collect small food organisms utilized by young herring larvae.

5. Specialized field and laboratory studies should be considered to investigate certain other aspects of larval ecology. The work should be partitioned among the ICNAF scientists with such areas as feeding of larvae, potential predators, egg size, etc. The vertical distribution of larvae is a particularly important problem in relation to sampling, dispersal, and feeding, and should receive priority. Sampling gear with opening-closing devices should be employed. Nauston sampling, used extensively in the 1974-1975 surveys, indicates diurnal migration of especially the older larvae and should supplement future survey work.

6. New ways should be explored for monitoring abundance of phytoplankton and zooplankton with Continuous Plankton Recorders (CPR). Regular CPR sampling from ships of opportunity would provide a valuable supplement to the larval herring surveys by description of major anomalies in primary and secondary production cycles.

7. Circulation studies in the Georges Bank-Gulf of Maine area should be expanded to improve the basis for predicting and evaluating dispersal. Perhaps more efficient use could be made of available ships by assigning one or two for hydrographic sampling exclusively and using the remainder for more extensive larval sampling.

8. Some investigation of the sources and magnitude of sampling errors is desirable. Knowledge of small vs. large scale variations may lead to improved sampling design and will contribute to more accurate evaluation of assumptions underlying mortality estimates.

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Table 1. Length frequency summary for Georges Bank herring larvae.

Standard length (mm)	December, 1973 %	February, 1974 %	December, 1974 %	February, 1975 %
4	0.01			
5	2.4	0.4		
6	3.8	0.4		
7	1.3			
8	0.5		0.1	
9	0.2		0.9	
10	0.6	0.4	1.6	
11	0.6		4.2	
12	0.9		8.2	
13	1.8	0.4	9.1	
14	3.4		10.4	
15	7.7	0.4	11.9	
16	14.0	2.0	8.1	0.6
17	11.9	4.9	7.8	0.6
18	10.3	2.8	9.5	
19	8.4	4.9	9.1	0.6
20	12.6	7.0	6.4	
21	8.0	8.2	4.9	1.8
22	5.8	11.9	3.8	4.2
23	2.5	6.1	2.1	5.7
24	1.3	14.8	1.6	10.9
25	0.2	10.3	0.9	9.1
26	0.1	7.8	0.4	14.5
27	0.2	4.9	0.5	9.4
28	0.1	4.1	0.1	12.4
29	0.2	3.3	0.2	10.6
30	0.04	2.1	0.1	8.5
31				4.9
32		0.8		1.2
33		1.2		0.6
34				1.5
35				1.2

Table 2. Abundance of Georges Bank herring larvae per 1 mm length interval.

Standard length (mm)	December, 1973 Number per 10 m^2	February, 1974 Number per 10 m^2	December, 1974 Number per 10 m^2	February, 1975 Number per 10 m^2
4	2			
5	123	2		
6	194	2		
7	70			
8	23		3	
9	15		63	
10	32	2	120	
11	35		307	
12	47		608	
13	95	2	675	
14	174		768	
15	393	2	771	
16	712	8	595	3
17	608	20	574	3
18	527	12	705	
19	427	20	675	3
20	643	29	477	
21	407	34	361	9
22	297	49	279	22
23	131	25	157	29
24	67	60	118	55
25	11	42	63	46
26	10	32	27	74
27	15	20	36	48
28	8	17	5	63
29	12	13	13	54
30	2	8	8	43
31				25
32		3		6
33		5		3
34				8
35				3
Total	5076	406	7410	506

Table 3. Mortality estimates (Z) for Georges Bank herring larvae between December and February 1973-74 and 1974-75, respectively. Z is the instantaneous loss rate per day. The range for Z and percent mortality per day are based on the half or double sampling error associated with each larval total. See text for further details.

Sampling Period	Length Group (mm)	Mode	Larval Abundance	-Z	% Mortality per Day	-Z Range	% Mortality per Day Range
December 13, 1973	15-18	B	2240	0.042	4.13	0.020-0.064	1.20-6.22
February 14, 1974	19-23	B	157				
December 13, 1973	19-22	A	1773	0.039	3.80	0.017-0.061	1.66-5.90
February 14, 1974	24-27	A	154				
December 13, 1973	15-22	B + A	4013	0.041	3.98	0.019-0.063	1.84-6.07
February 14, 1974	19-27	B + A	311				
December 13, 1973	4-30	Total	5076	0.040	3.93	0.018-0.062	1.79-6.02
February 14, 1974	5-33	Total	406				
December 13, 1974	12-16	B	3417	0.042	4.06	0.021-0.062	2.08-6.00
February 19, 1975	23-26	B	204				
December 13, 1974	17-21	A	2793	0.037	3.59	0.016-0.057	1.60-5.53
February 14, 1975	27-31	A	233				
December 13, 1974	12-21	B + A	6210	0.039	3.83	0.019-0.059	1.85-5.77
February 14, 1975	23-31	B + A	437				
December 13, 1974	8-30	Total	7410	0.040	3.87	0.019-0.060	1.89-5.81
February 14, 1975	16-35	Total	506				

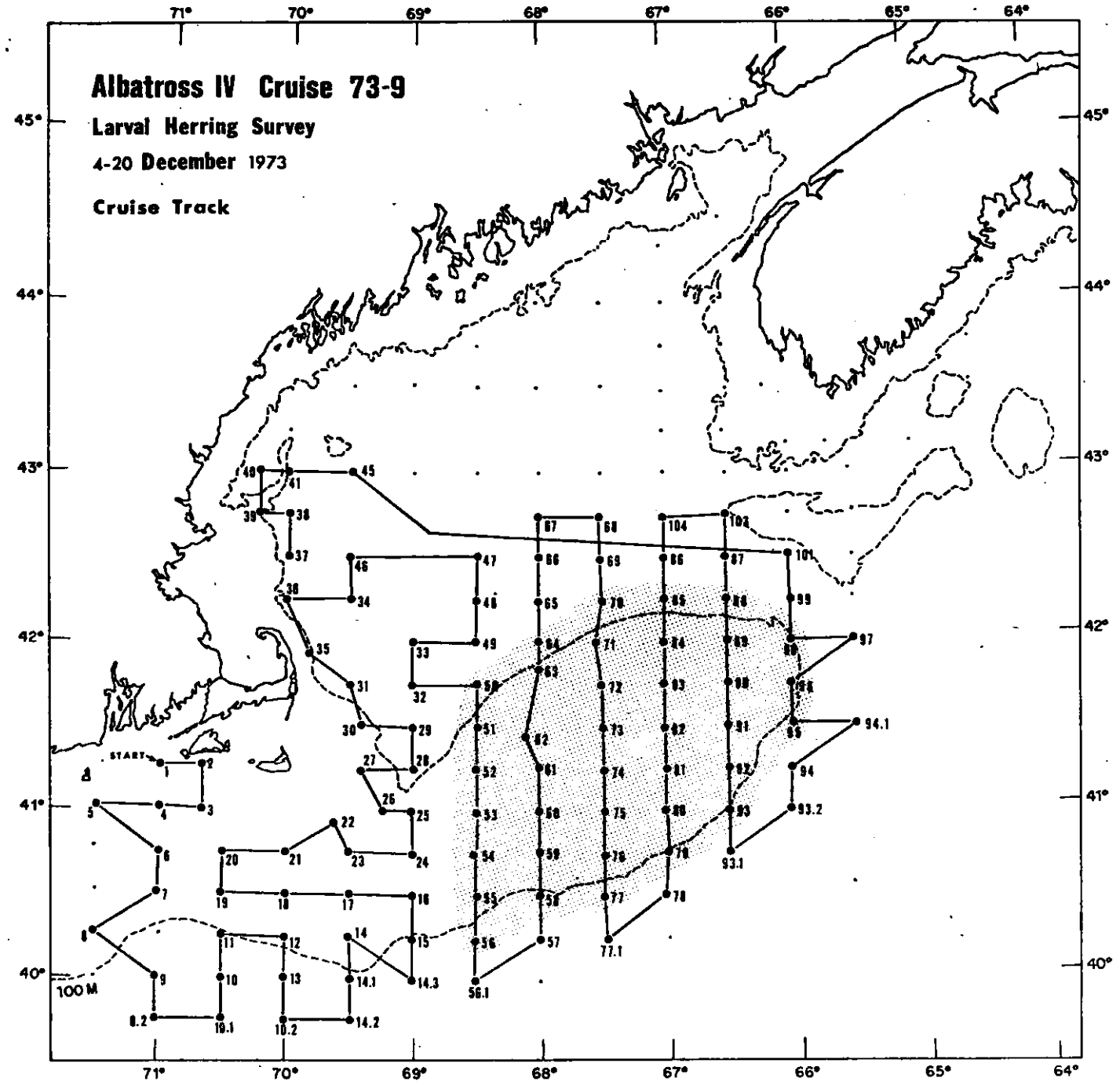
Table 4. Temperature statistics for Georges Bank during December, 1973-74 and February 1974-75.

Statistic	1 m	10 m	30 m	50 m	1-50 m
			December 11-16, 1973		
$\bar{X}$	10.04	10.07	10.58	10.82	10.35
s^2	3.46	3.49	4.73	5.39	4.24
s	1.86	1.87	2.18	2.32	2.06
n	38	38	38	32	146
			February 13-16, 1974		
$\bar{X}$	5.72	5.97	6.45	6.83	6.25
s^2	0.59	0.46	0.73	1.90	0.92
s	0.77	0.68	0.85	1.38	0.93
n	38	38	38	30	144
			December 10-17, 1974		
$\bar{X}$	9.45	9.63	9.92	10.43	9.86
s^2	1.16	1.20	1.55	3.09	1.75
s	1.08	1.10	1.24	1.76	1.30
n	37	36	36	33	142
			February 16-24, 1975		
$\bar{X}$	5.19	5.43	5.81	6.27	5.68
s^2	0.90	0.93	1.02	1.60	1.11
s	0.95	0.96	1.01	1.27	1.05
n	38	37	37	30	142

Table 5. A comparison of mean temperatures at various depth levels by t-tests for Georges Bank between December 1973 and 1974, February 1974 and 1975.

Depth (m)	December 1973-74			February 1974-75		
	t-test	Degrees of freedom	Significance level	t-test	Degrees of freedom	Significance level
1	1.65	73	N.S.	2.64	74	1%
10	1.21	72	N.S.	2.78	73	1%
30	1.57	72	N.S.	2.93	73	1%
50	0.75	63	N.S.	1.61	58	N.S.
1-50	2.56	286	5%	4.87	289	1%

Figure 1.



Georges Bank study area (stippled).

Figure 2.

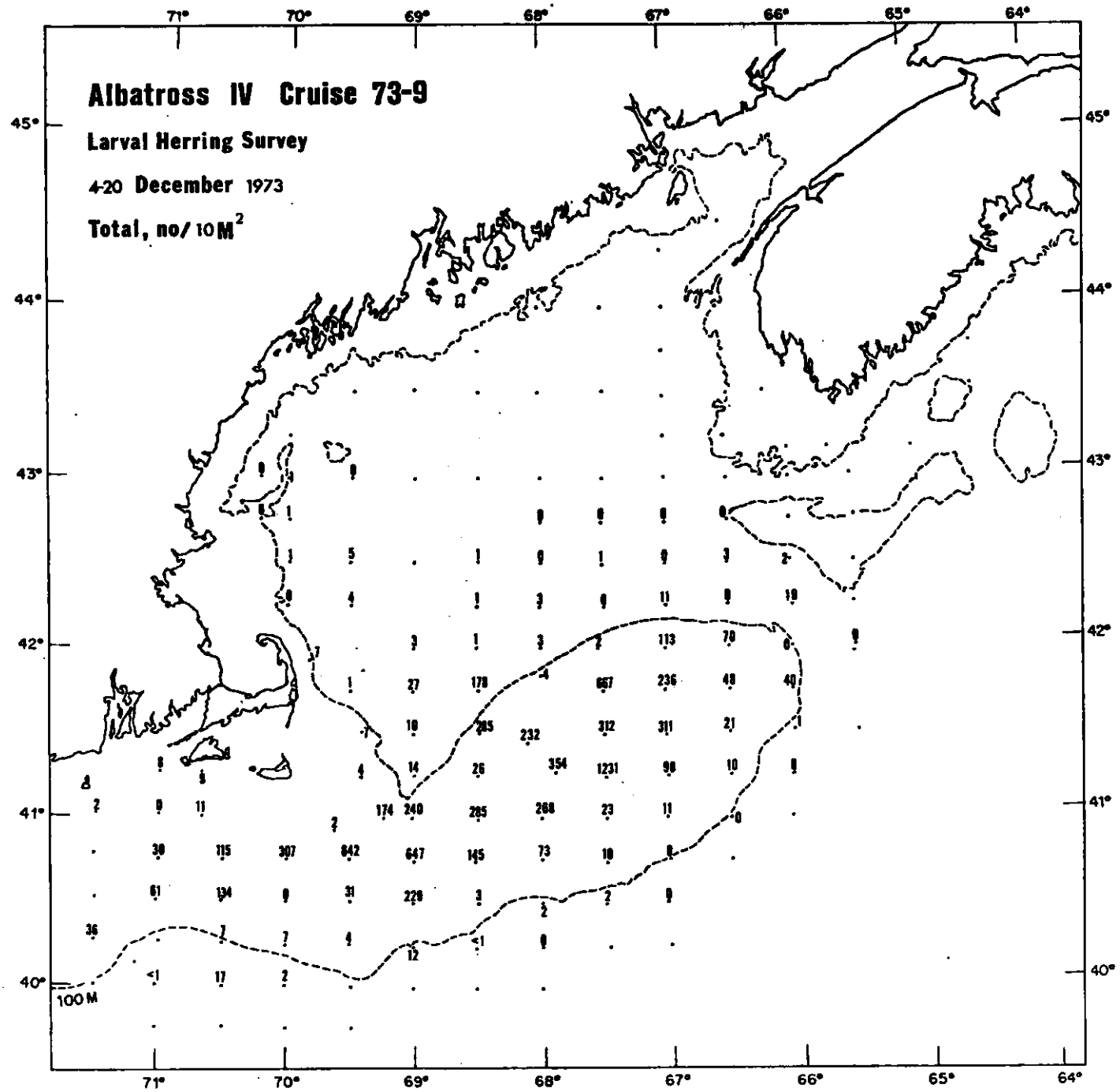

Albatross IV Cruise 73-9
Larval Herring Survey
4-20 December 1973
Total, no/ 10M²
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
100 M

Figure 3.

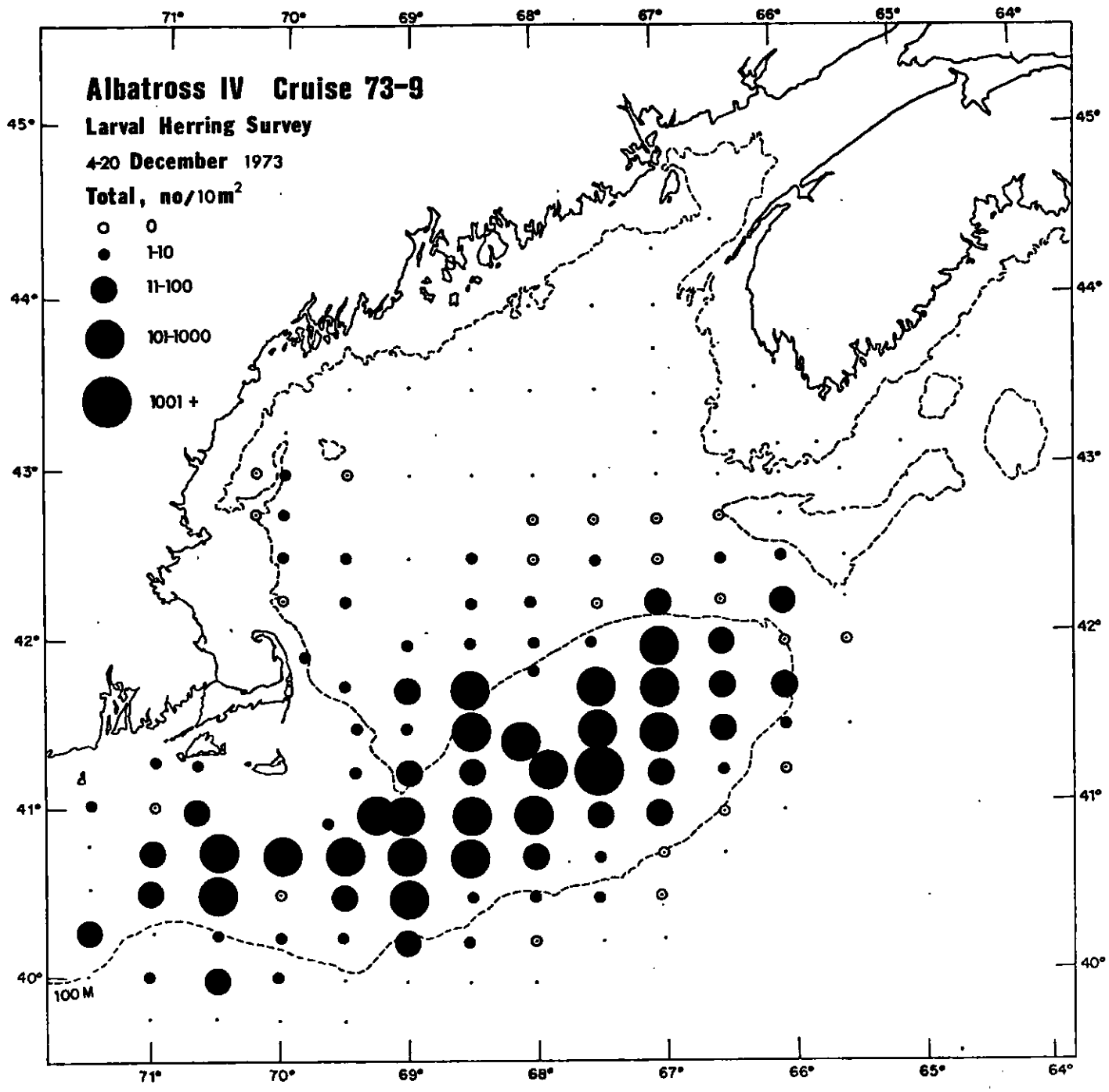

Albatross IV Cruise 73-9
Larval Herring Survey
4-20 December 1973
Total, no/10m²
0
1-10
11-100
101-1000
1001 +
100 M
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°

Figure 4.

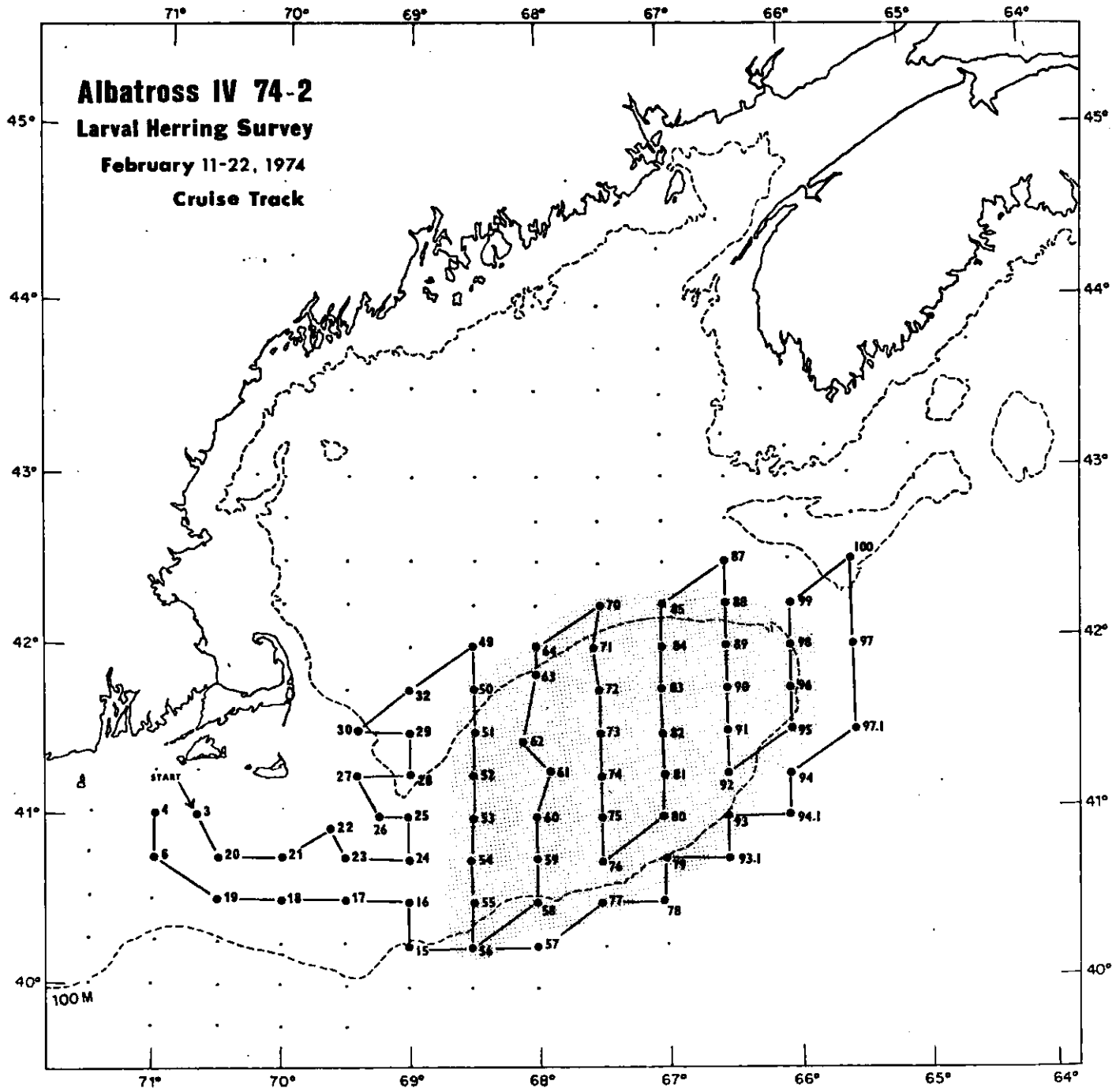

Albatross IV 74-2
Larval Herring Survey
February 11-22, 1974
Cruise Track
START
100 M
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°

Figure 5.

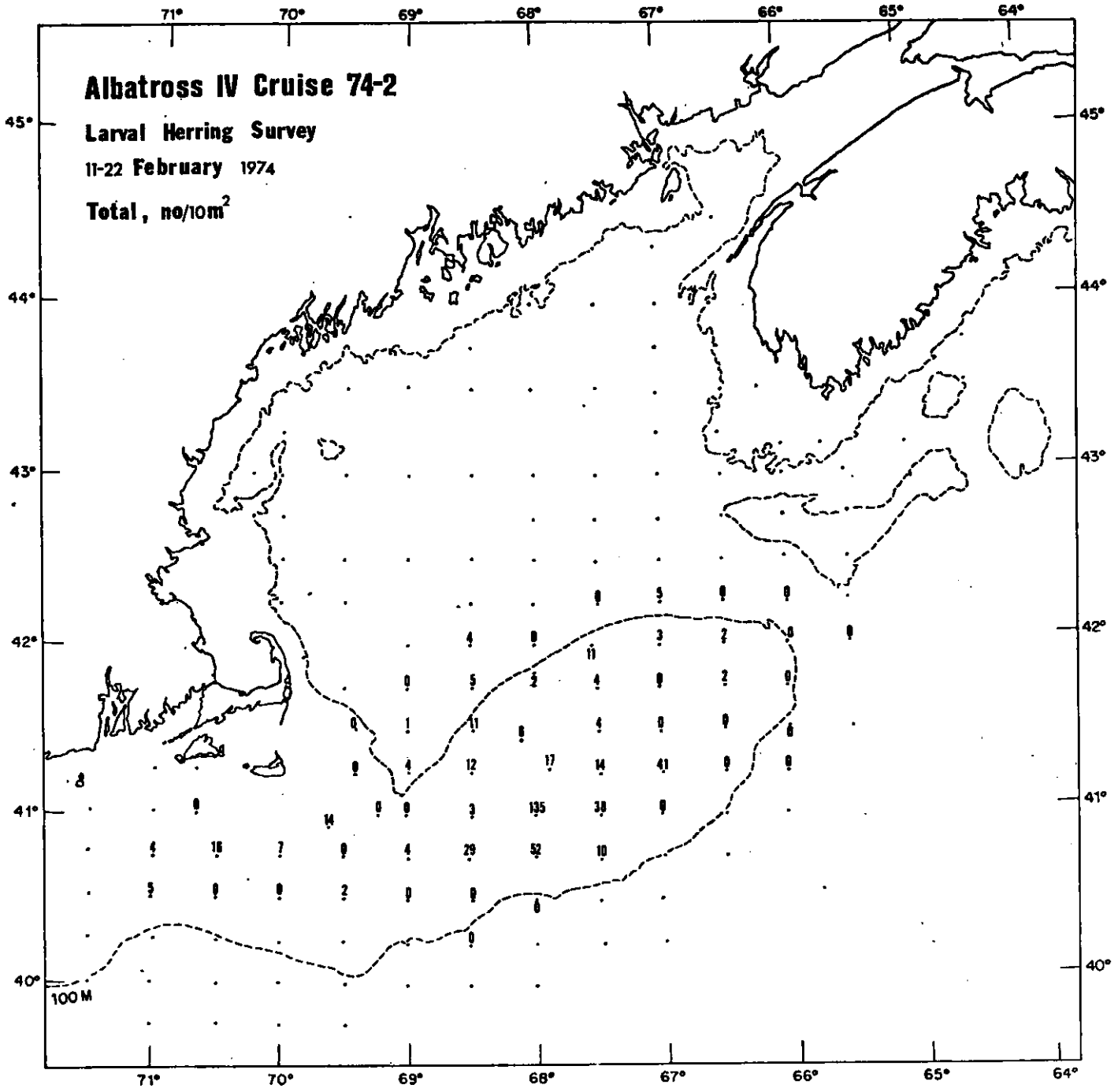

Albatross IV Cruise 74-2
Larval Herring Survey
11-22 February 1974
Total, no/10m²
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
100 M

Figure 6.

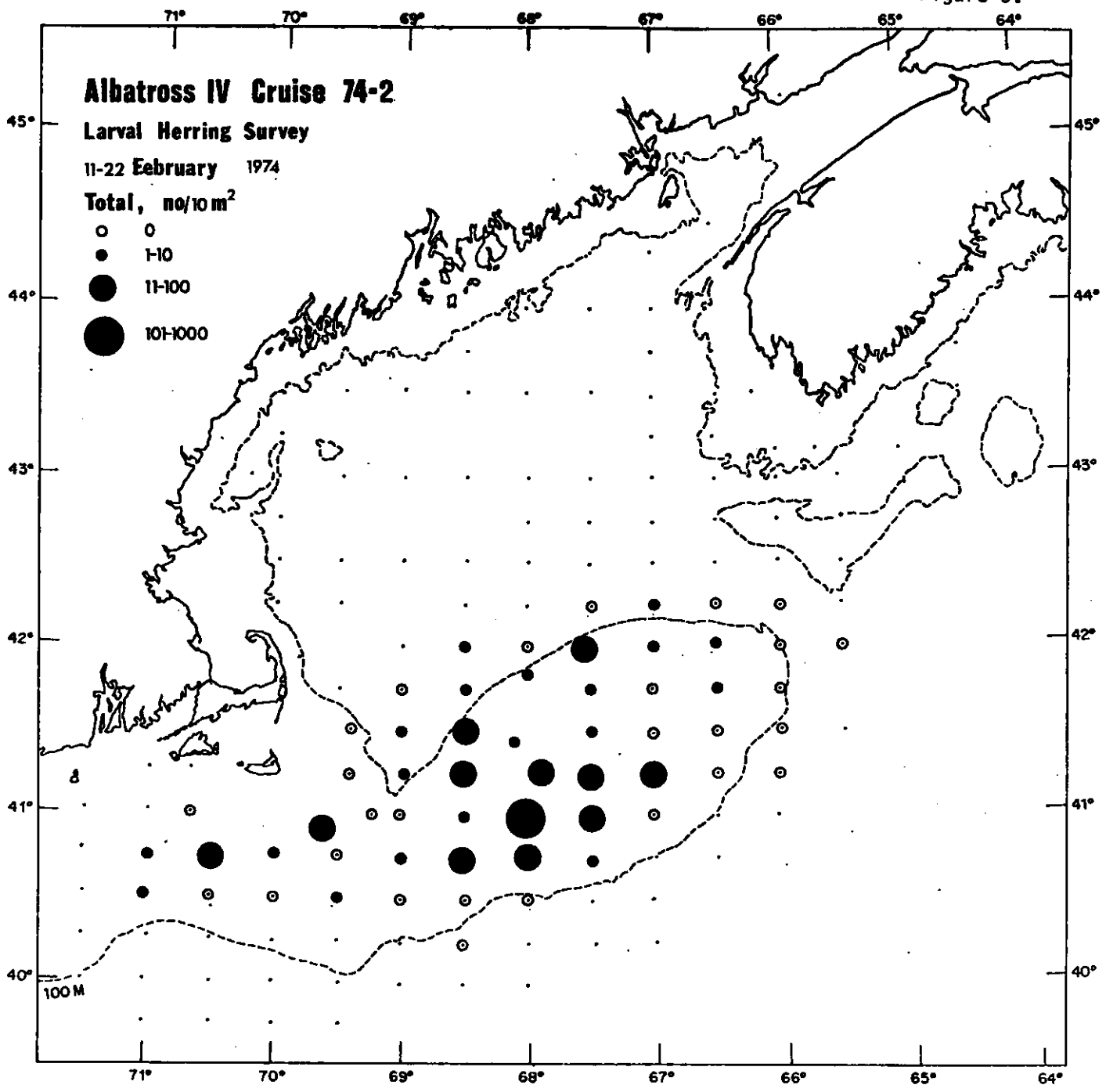

Albatross IV Cruise 74-2
Larval Herring Survey
11-22 Eebruary 1974
Total, no/10 m²
0
1-10
11-100
101-1000
100 M
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°

Figure 7.

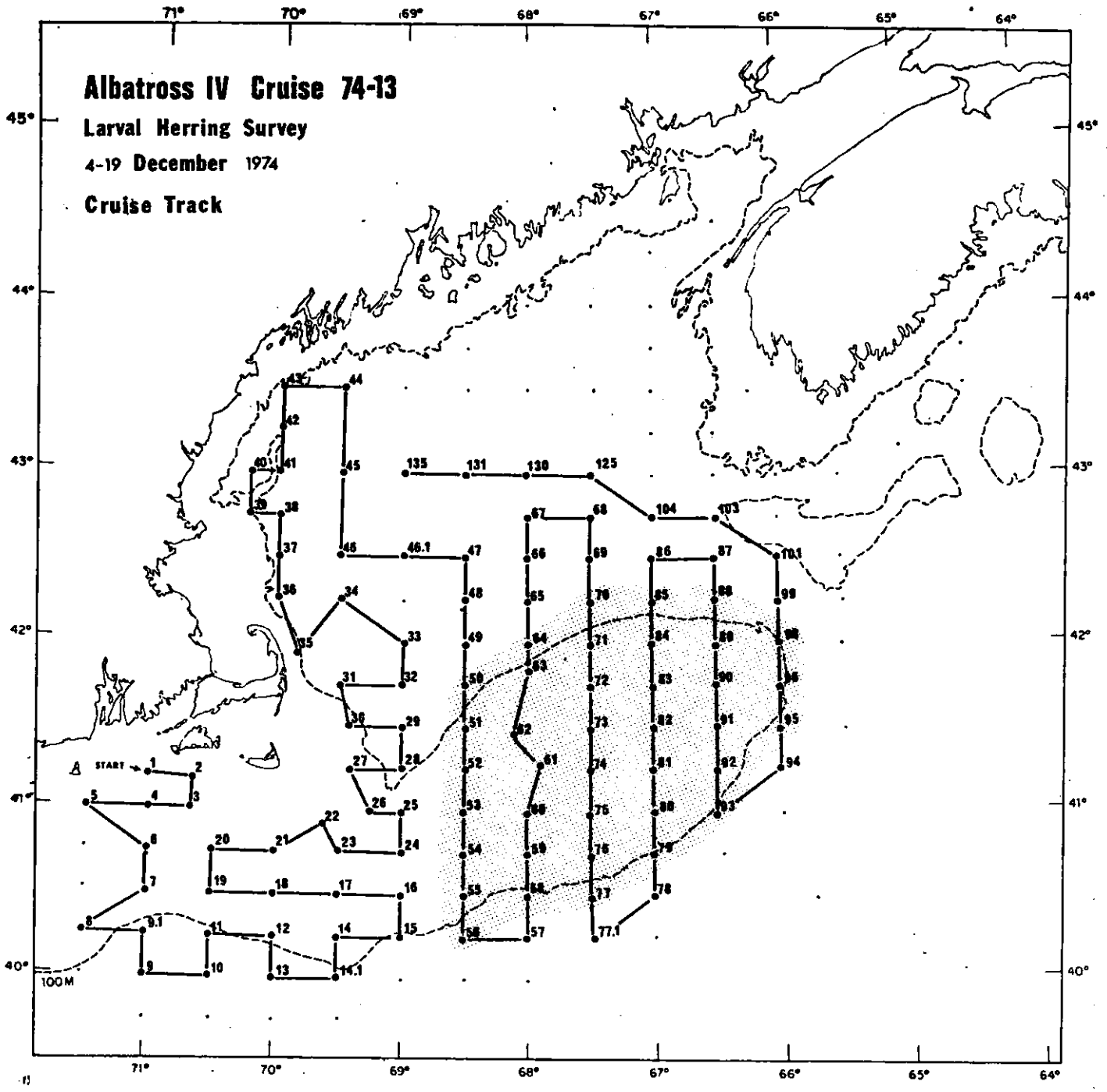

Albatross IV Cruise 74-13
Larval Herring Survey
4-19 December 1974
Cruise Track
START
100 M
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°

Figure 8.

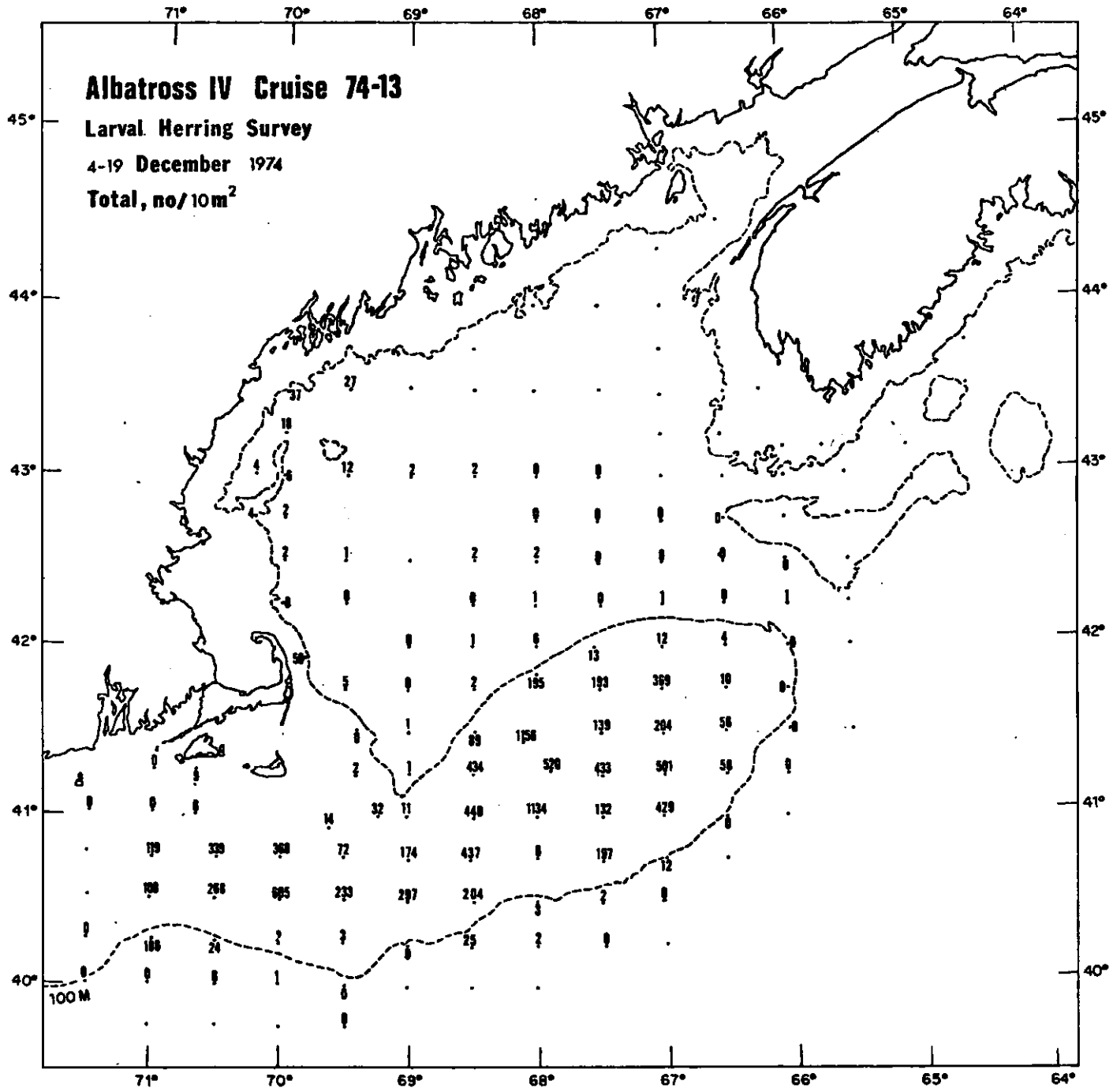

Albatross IV Cruise 74-13
Larval Herring Survey
4-19 December 1974
Total, no/10m²
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
100 M

Figure 9.

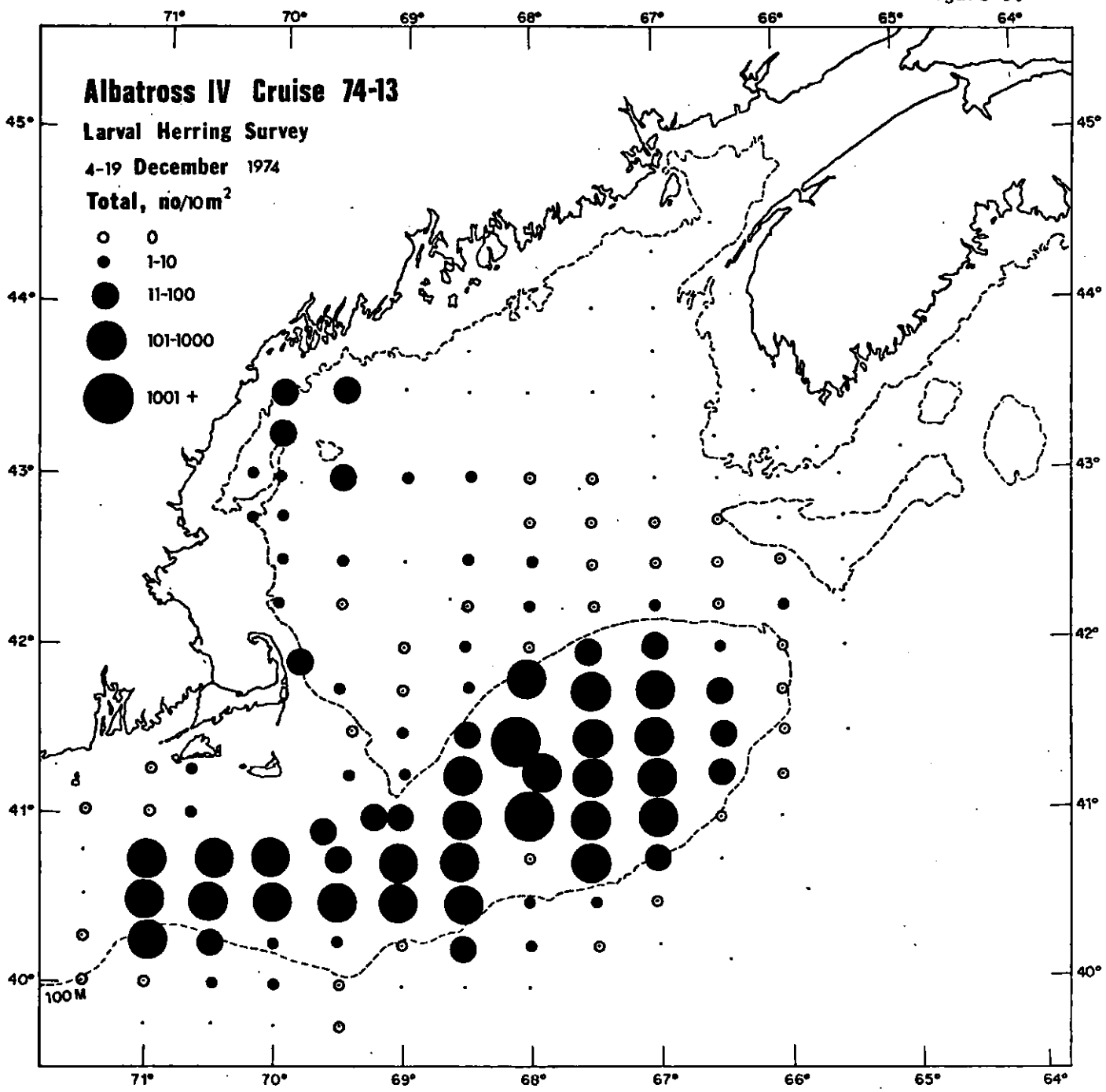

Albatross IV Cruise 74-13
Larval Herring Survey
4-19 December 1974
Total, no/10m²
0
1-10
11-100
101-1000
1001 +
100 M
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°

Figure 10.

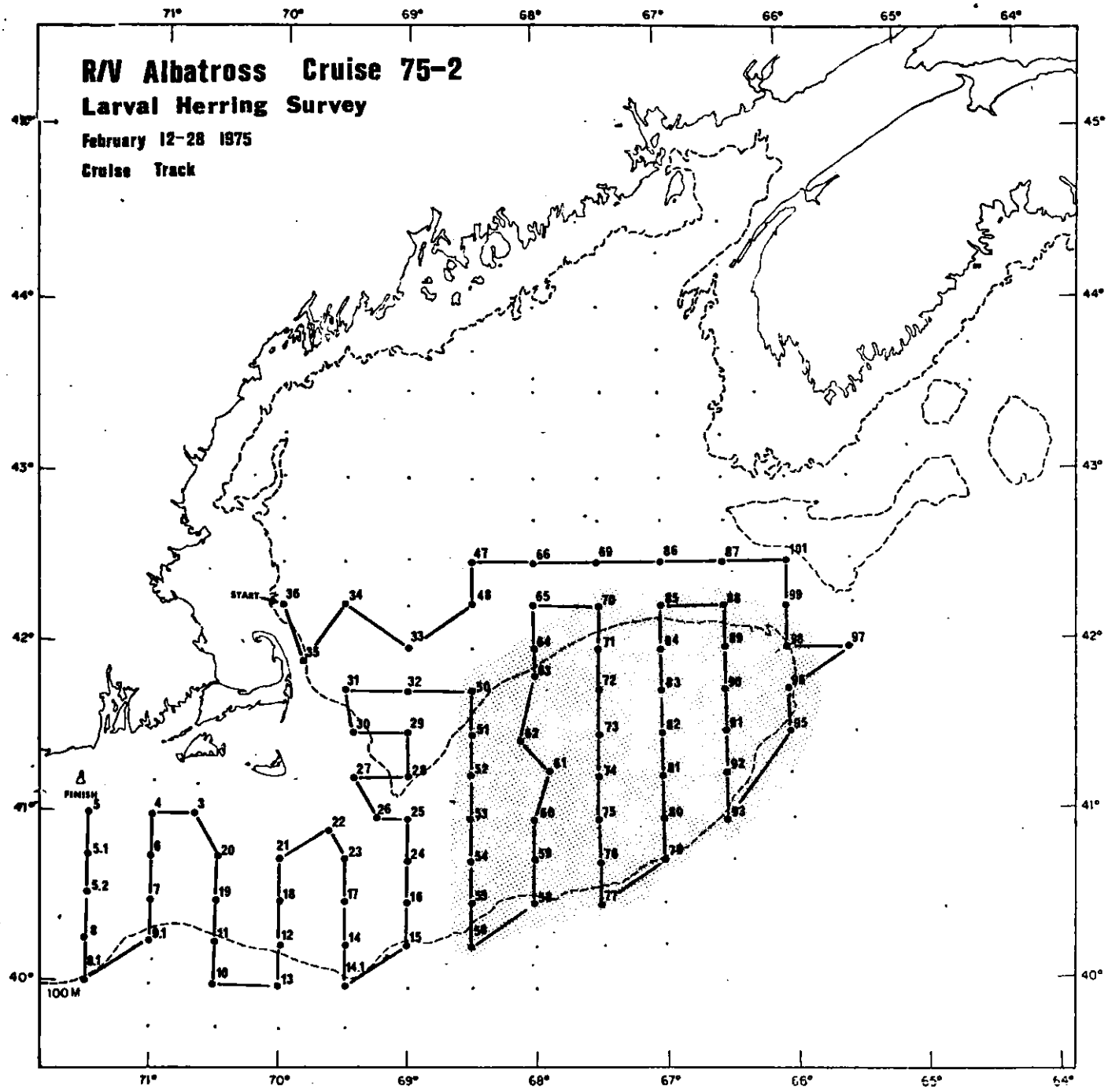

R/V Albatross Cruise 75-2
Larval Herring Survey
February 12-28 1975
Cruise Track
START
FINISH
100 M
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°

Figure 11.

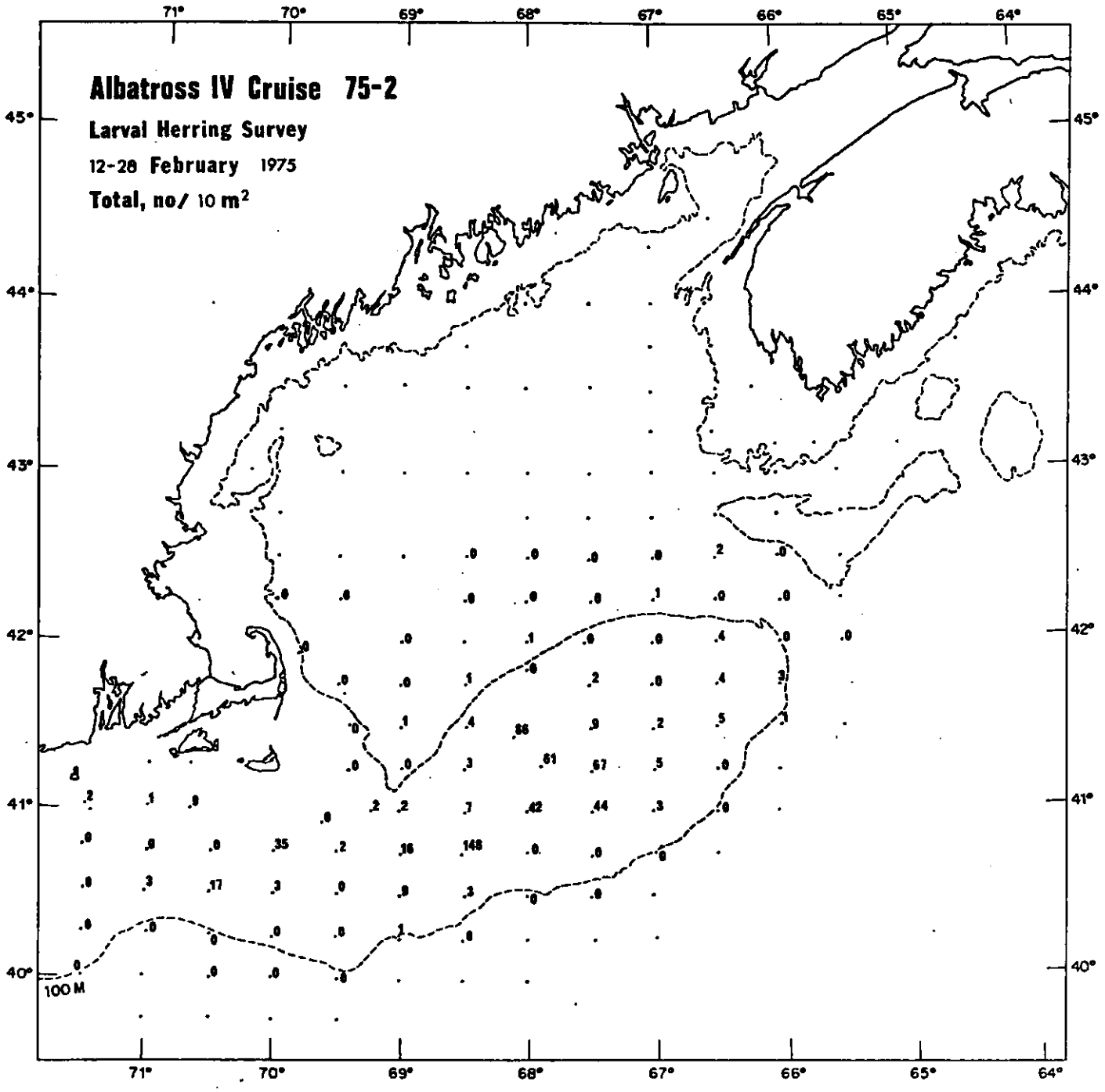
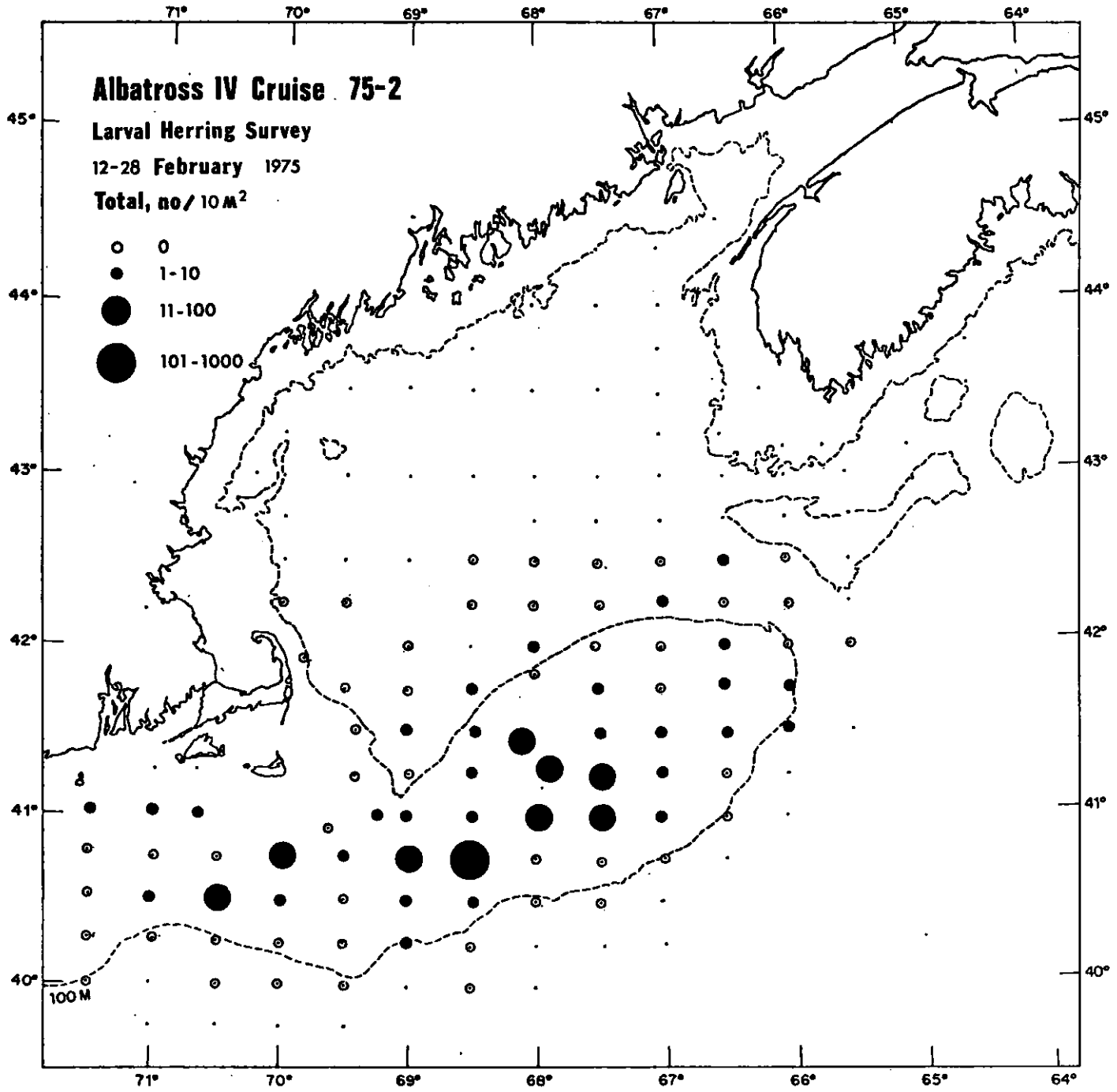

Albatross IV Cruise 75-2
Larval Herring Survey
12-28 February 1975
Total, no/ 10 m²
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
100 M

Figure 12.


Albatross IV Cruise 75-2
Larval Herring Survey
12-28 February 1975
Total, no/10M²
0
1-10
11-100
101-1000
100 M
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°

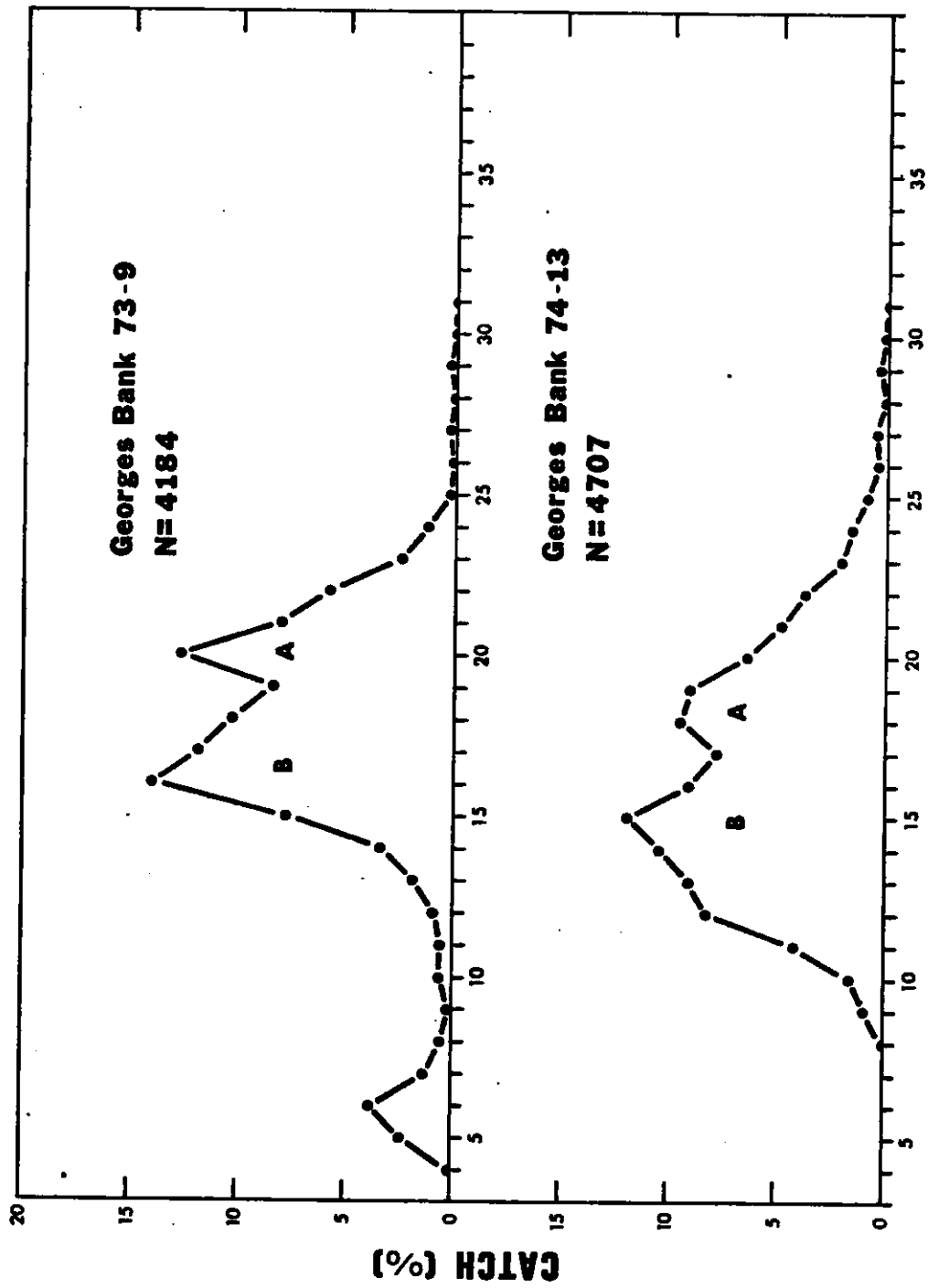


Figure 13. Percentage length frequency for Georges Bank herring larvae collected December 4-20, 1973 (*Albatross IV*, Cruise 73-9) and December 4-19, 1974 (*Albatross IV*, Cruise 74-13). Dominant length modes are designated by the letters A and B.

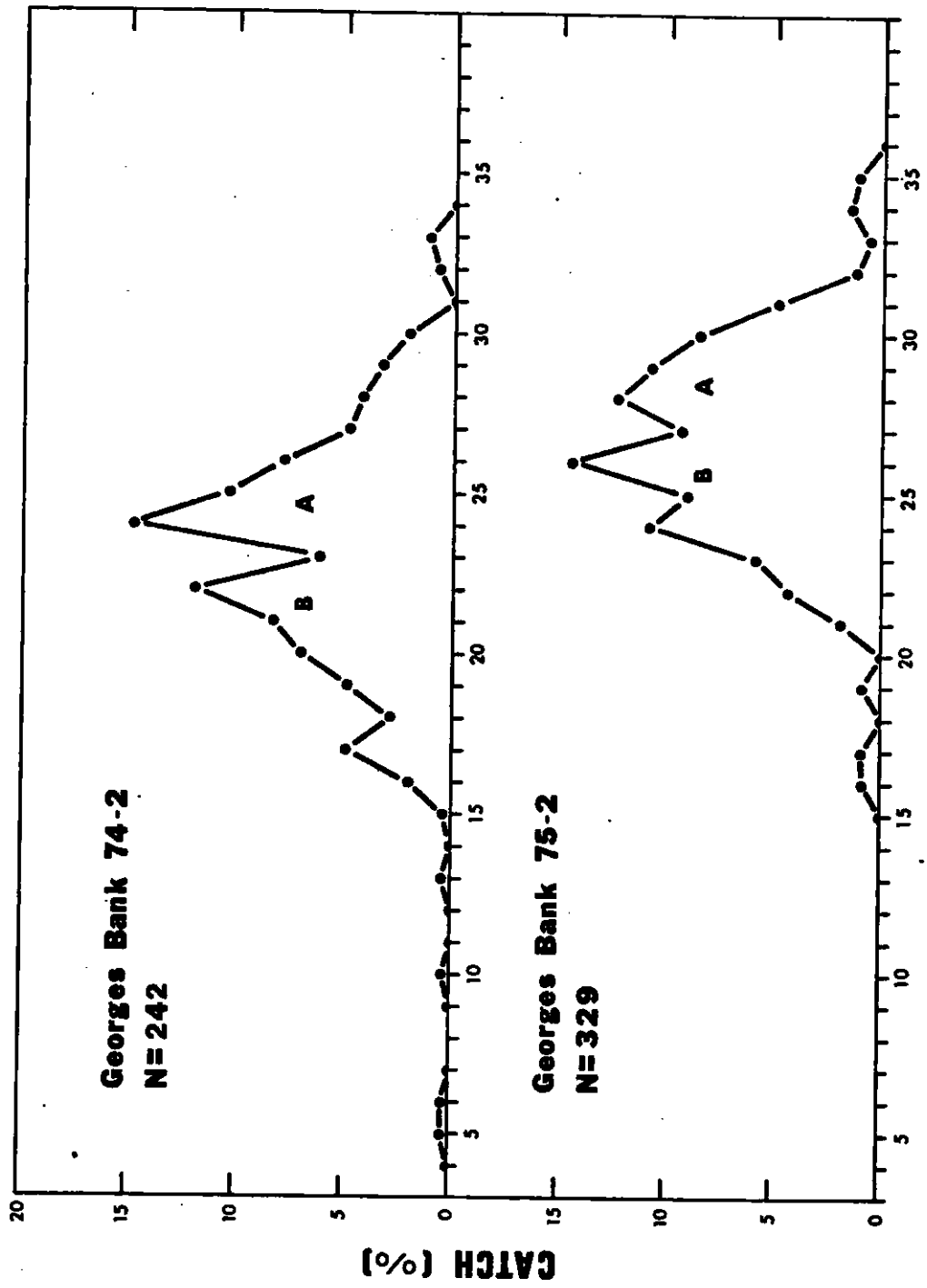


Figure 14. Percentage length frequency for Georges Bank herring larvae collected February 11-22, 1974 (*Albatross IV*, Cruise 74-2) and February 12-28, 1975, (*Albatross IV*, Cruise 75-2). Dominant length modes are designated by the letters A and B.

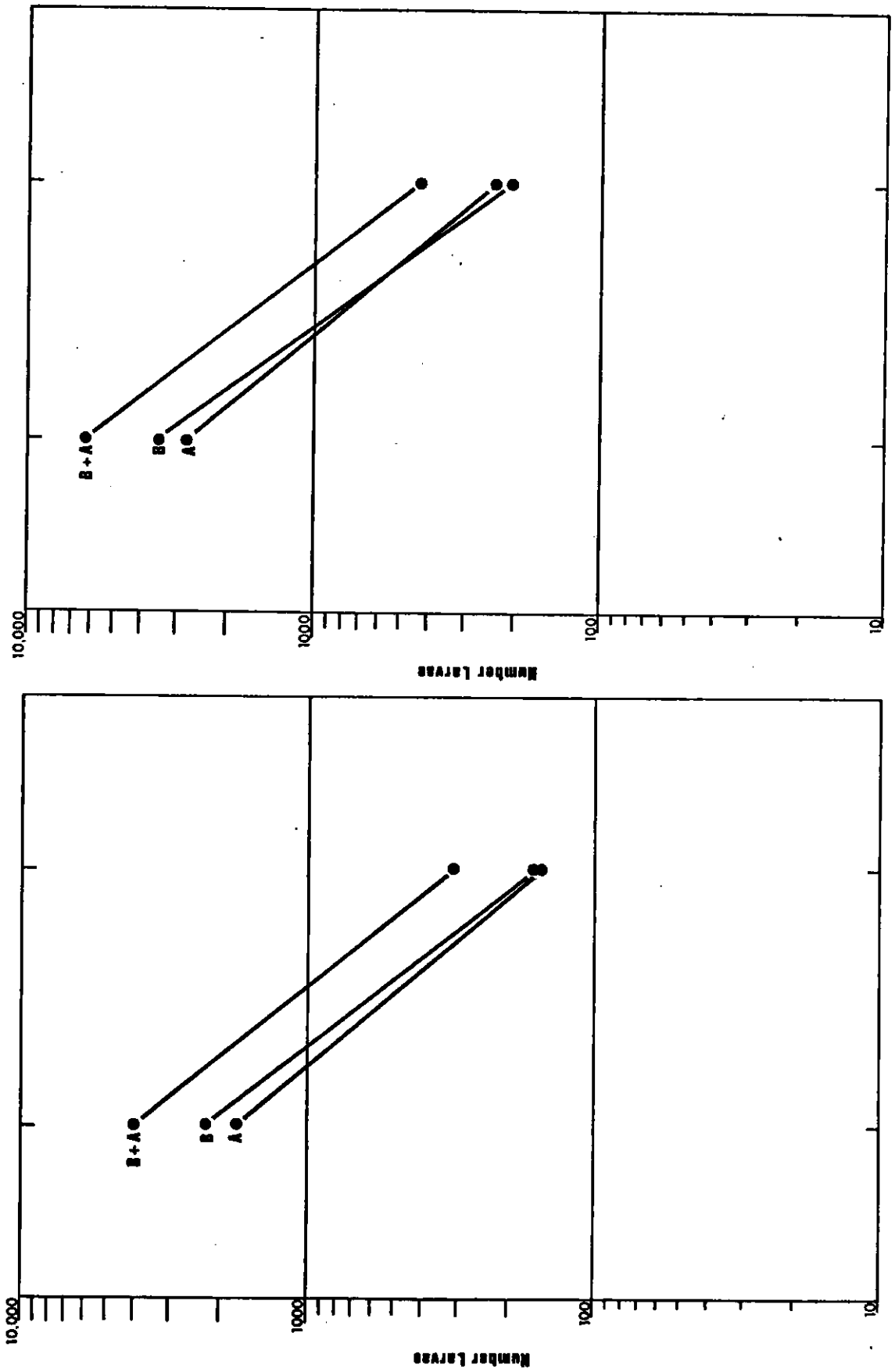


Figure 15. Logarithmic (base 10) plots of the dominant length modes (A,B) of Georges Bank herring larvae for December-February, 1973-74, and 1974-75. The number of larvae at each mode represents the sum total per 10 m^2 within each respective mode.

Figure 16.

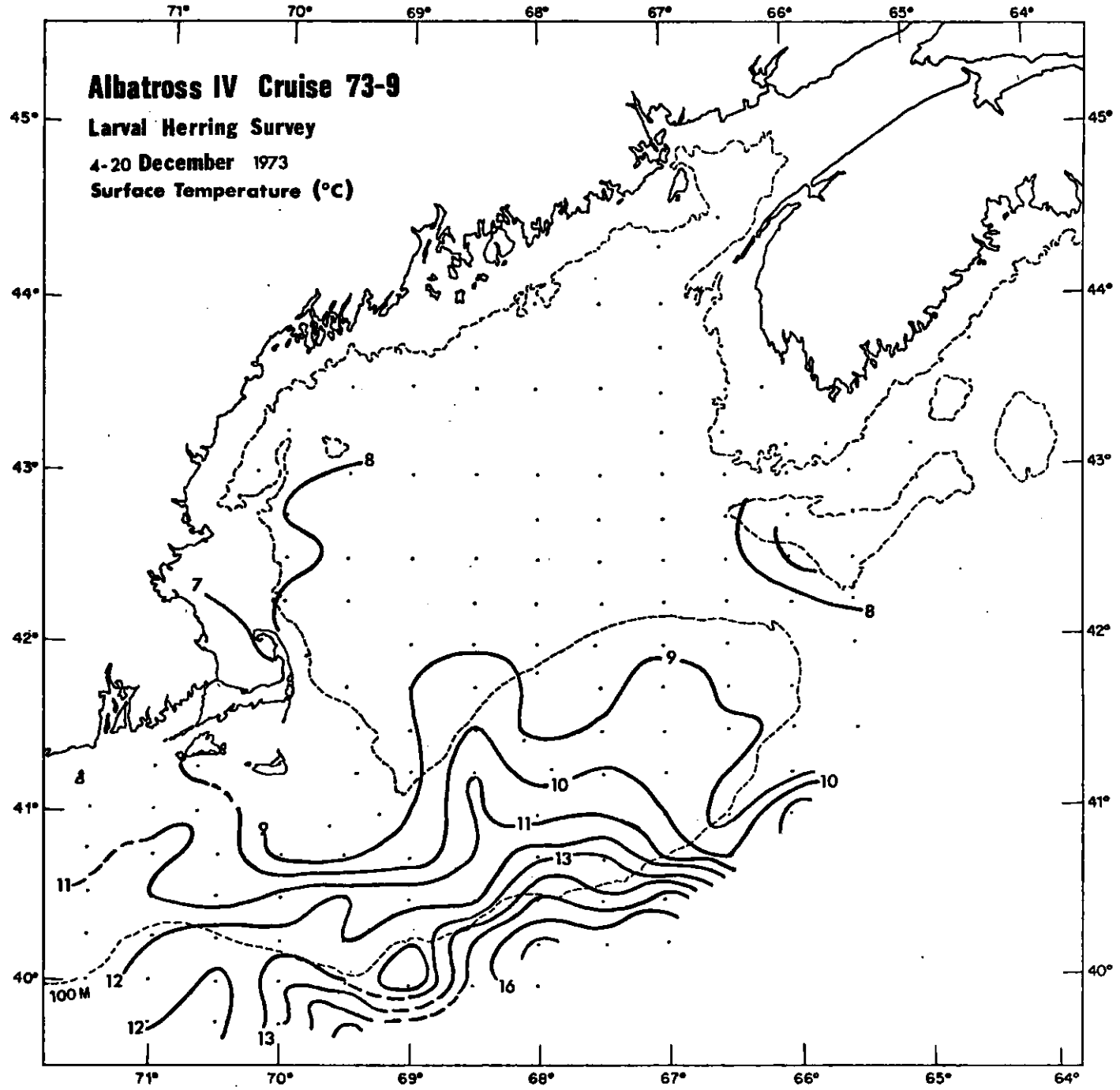

Albatross IV Cruise 73-9
Larval Herring Survey
4-20 December 1973
Surface Temperature (°C)
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
100 M
7
8
8
8
9
9
10
10
11
11
12
12
13
13
16

Figure 17.

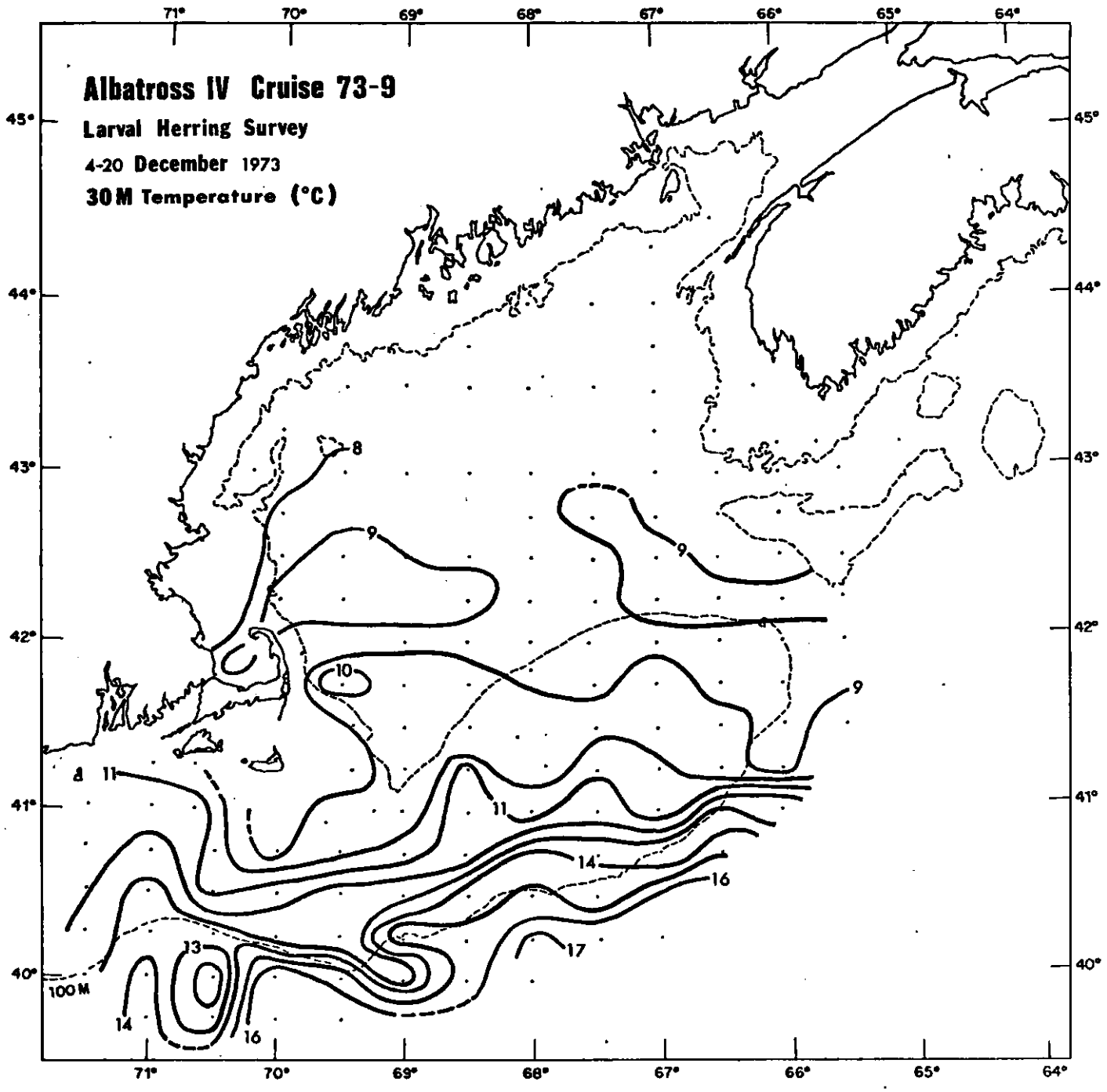

Albatross IV Cruise 73-9
Larval Herring Survey
4-20 December 1973
30M Temperature (°C)
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
8
9
10
11
13
14
16
17
100M

Figure 18.

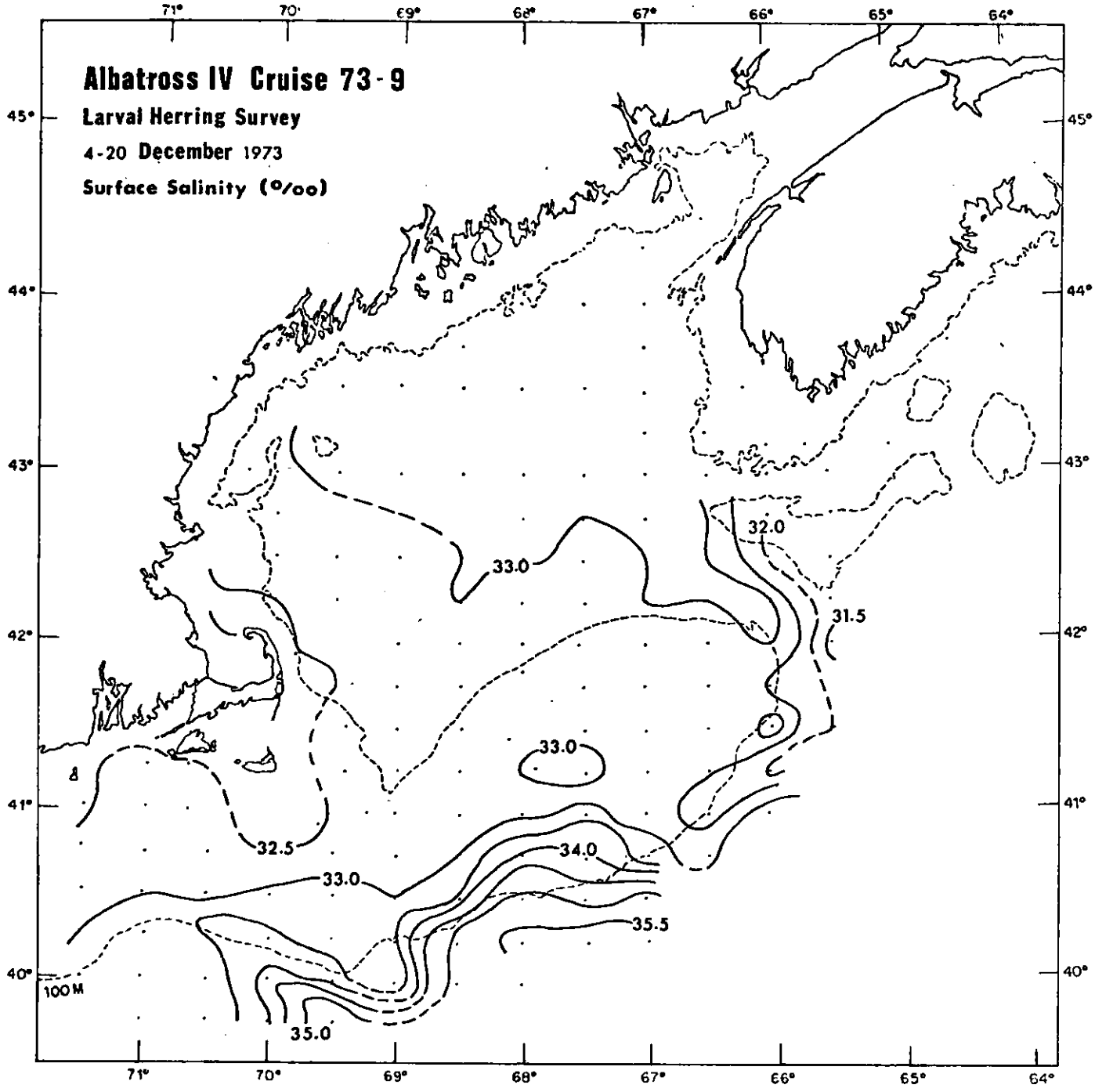

Albatross IV Cruise 73-9
Larval Herring Survey
4-20 December 1973
Surface Salinity (°/oo)
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
32.0
31.5
33.0
33.0
32.5
34.0
33.0
35.5
35.0
100 M

Figure 19.

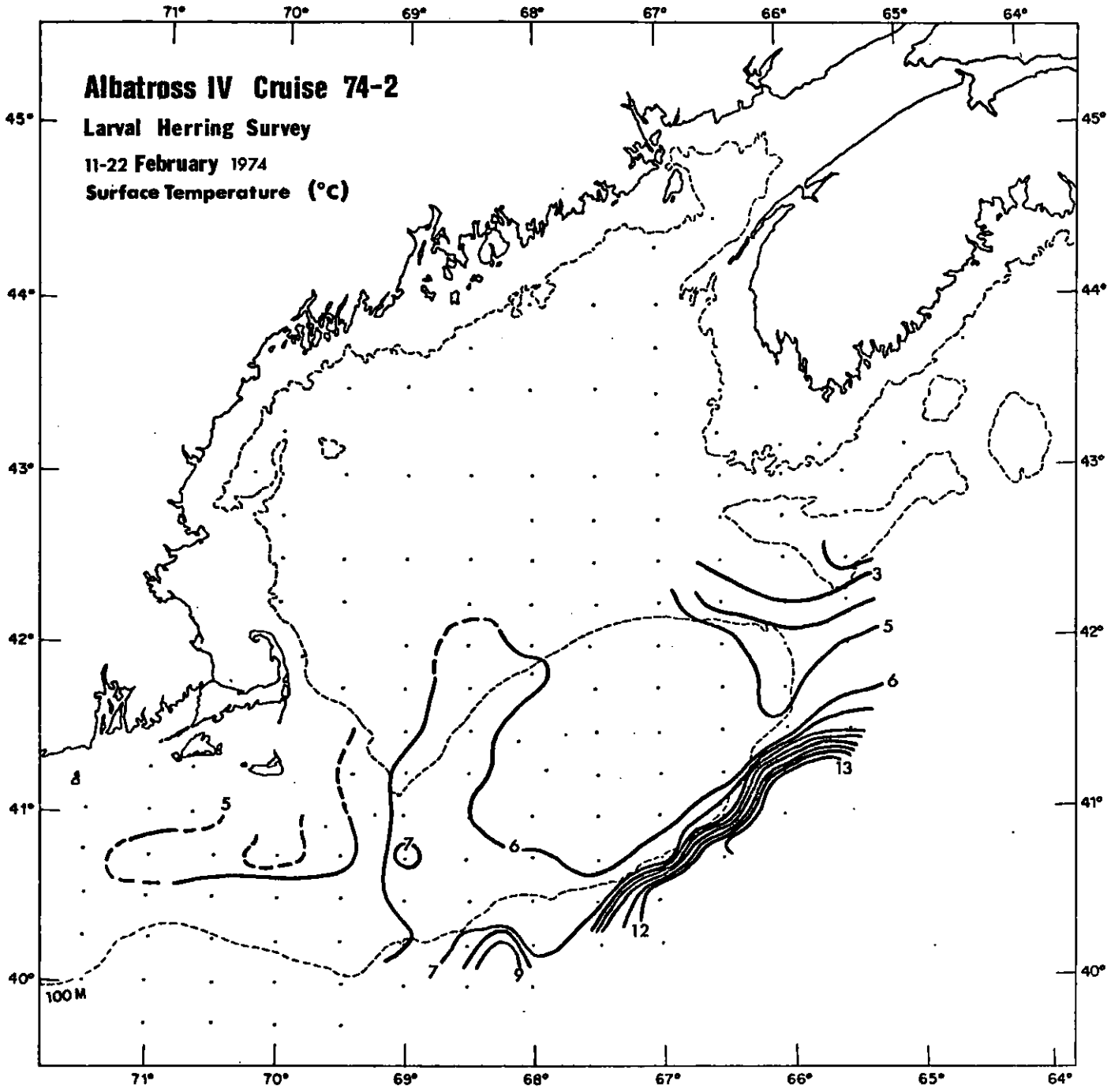

Albatross IV Cruise 74-2
Larval Herring Survey
11-22 February 1974
Surface Temperature (°C)
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
100 M
3
5
6
13
12
7
9

Figure 20.

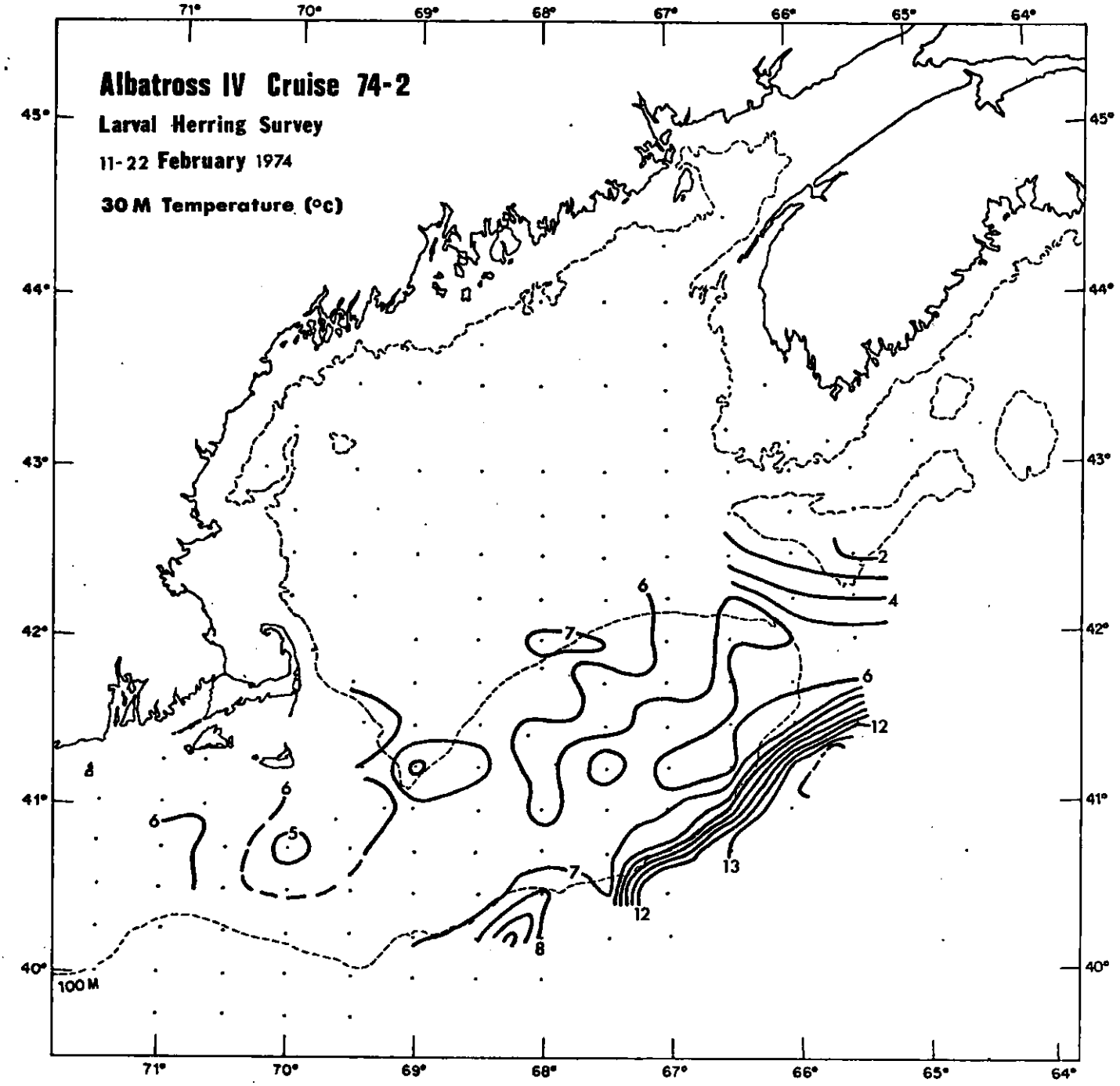

Albatross IV Cruise 74-2
Larval Herring Survey
11-22 February 1974
30 M Temperature (°c)
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
100 M
2
4
6
7
6
12
8
6
6
5
7
13
12
8

Figure 21.

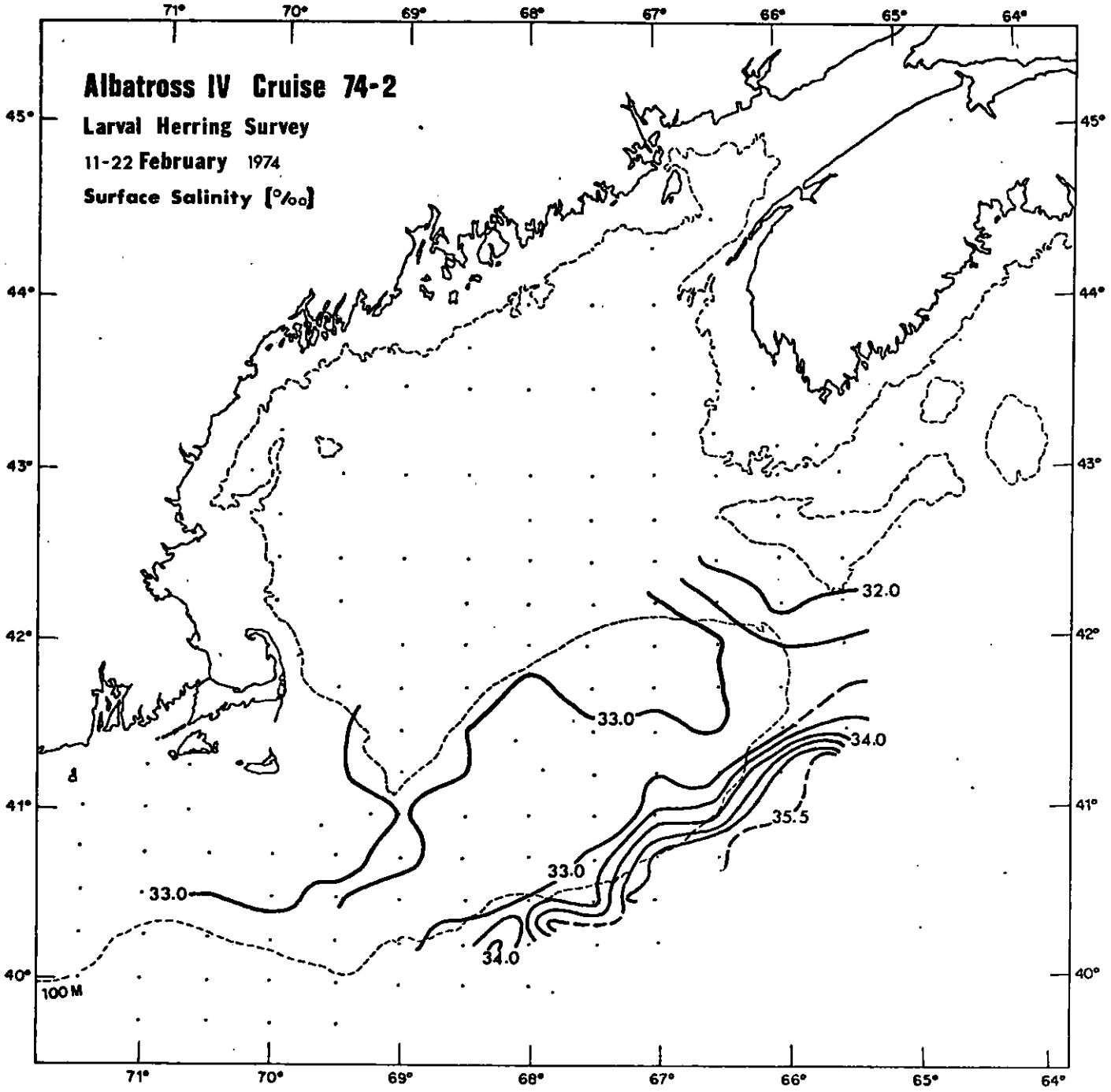

Albatross IV Cruise 74-2
Larval Herring Survey
11-22 February 1974
Surface Salinity (‰)
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
32.0
33.0
34.0
35.5
33.0
33.0
34.0
100 M

Figure 22.

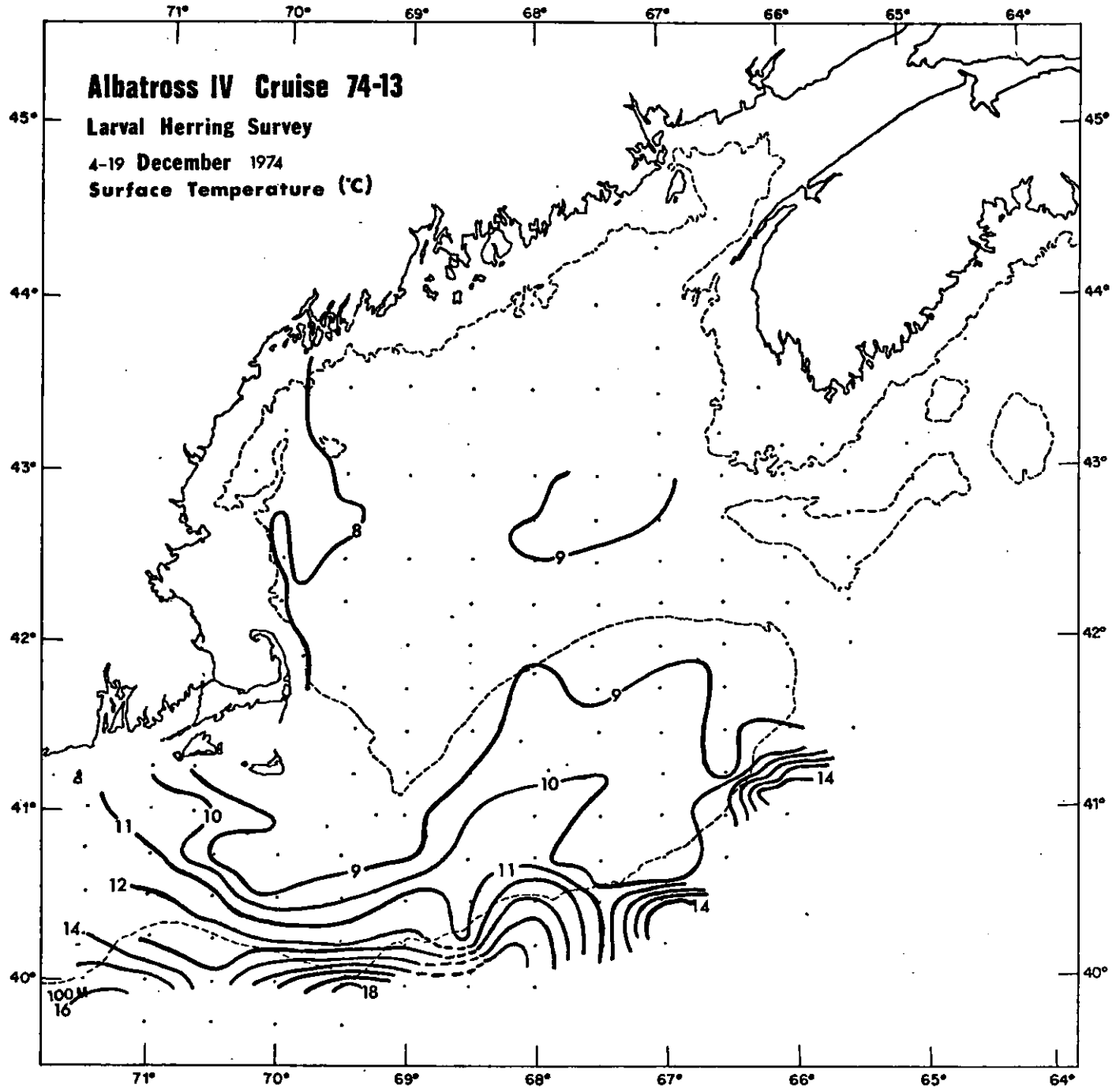

Albatross IV Cruise 74-13
Larval Herring Survey
4-19 December 1974
Surface Temperature (°C)
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
8
9
10
11
12
14
16
18
100 M

Figure 23.

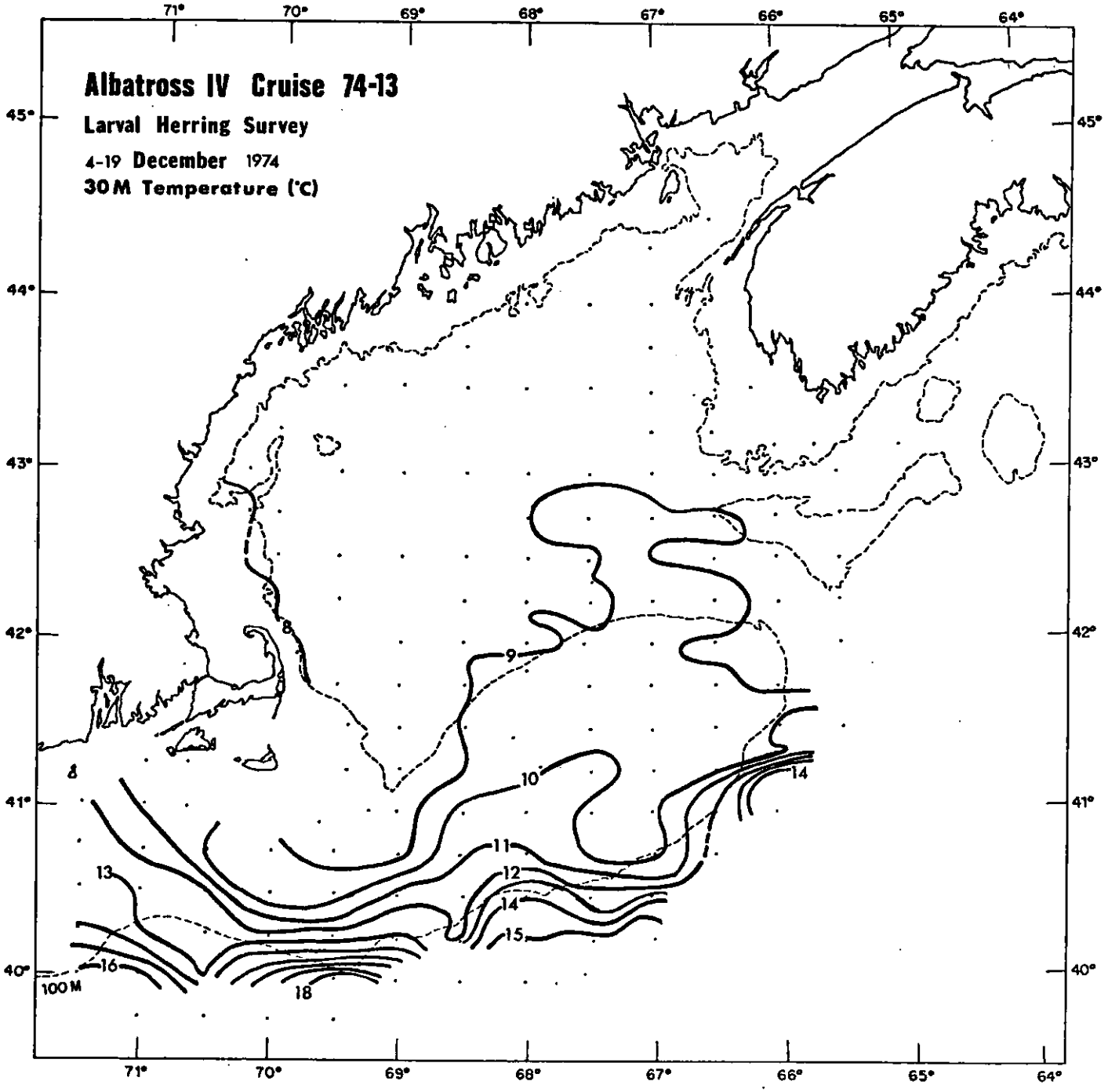

Albatross IV Cruise 74-13
Larval Herring Survey
4-19 December 1974
30M Temperature (°C)
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
8
9
10
11
12
13
14
15
16
18
100 M

Figure 24.

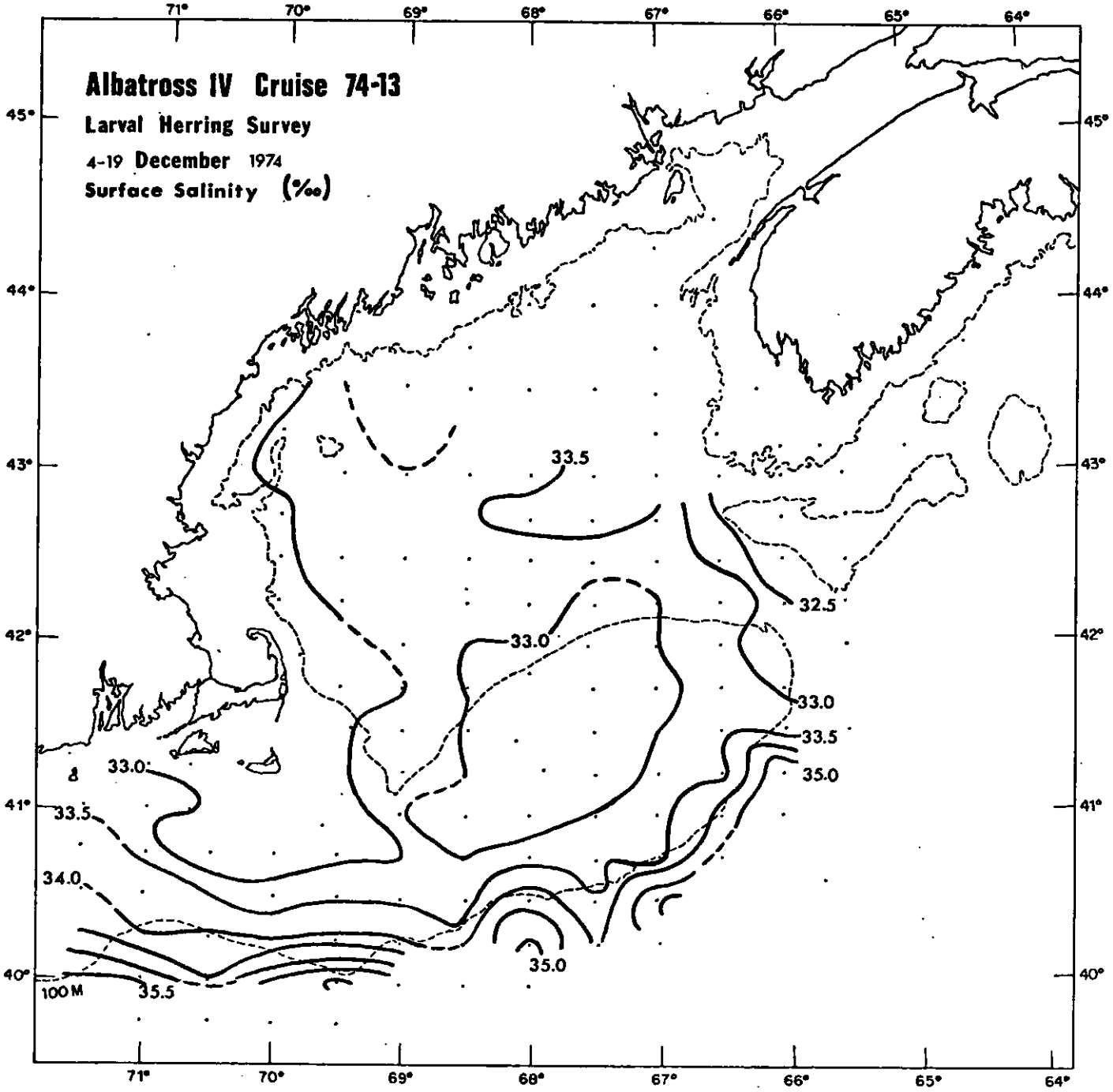

Albatross IV Cruise 74-13
Larval Herring Survey
4-19 December 1974
Surface Salinity (‰)
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
33.5
32.5
33.0
33.0
33.5
35.0
33.0
33.5
34.0
35.0
100 M
35.5

Figure 25.

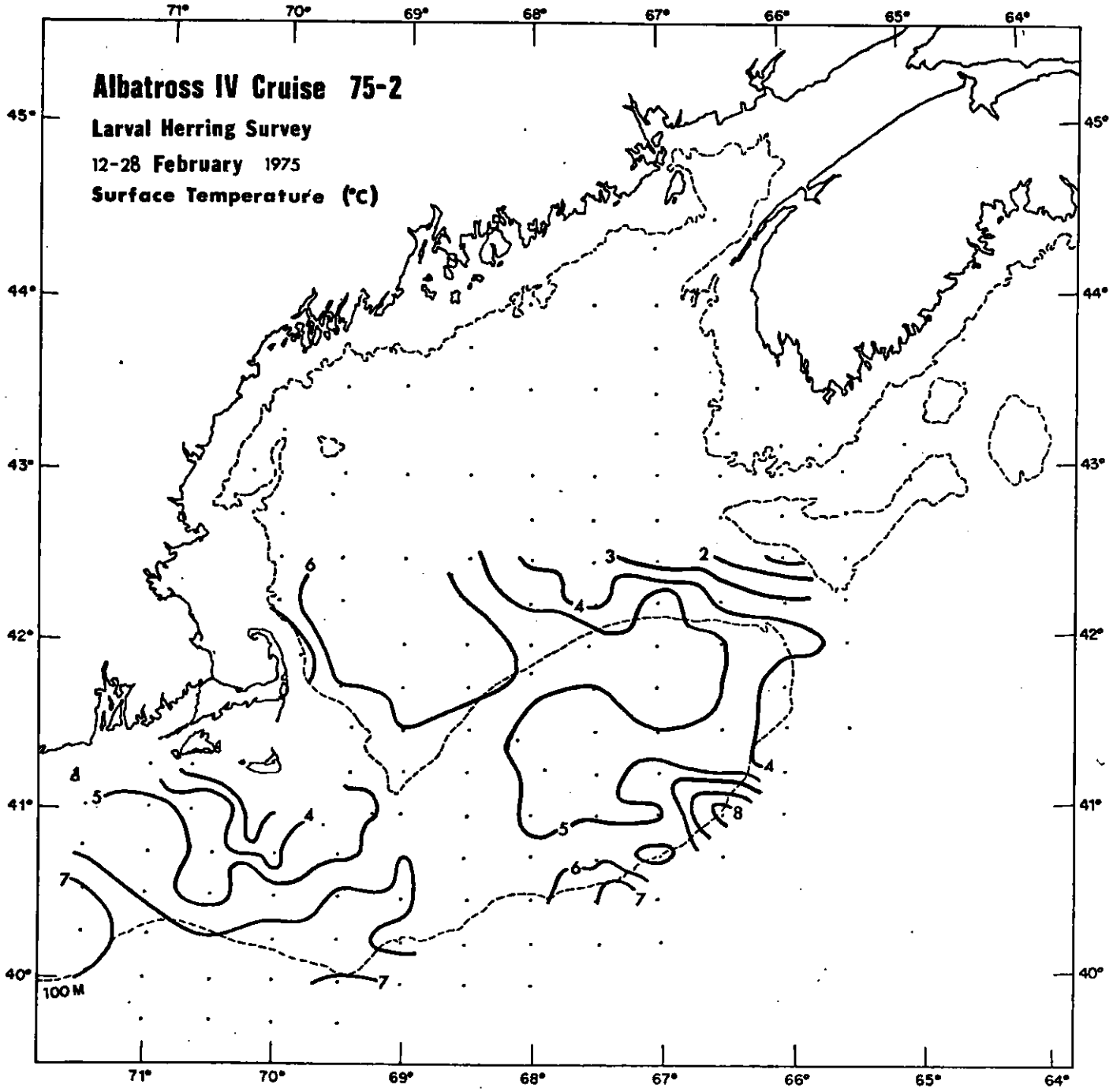

Albatross IV Cruise 75-2
Larval Herring Survey
12-28 February 1975
Surface Temperature (°C)
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
100 M

Figure 26.

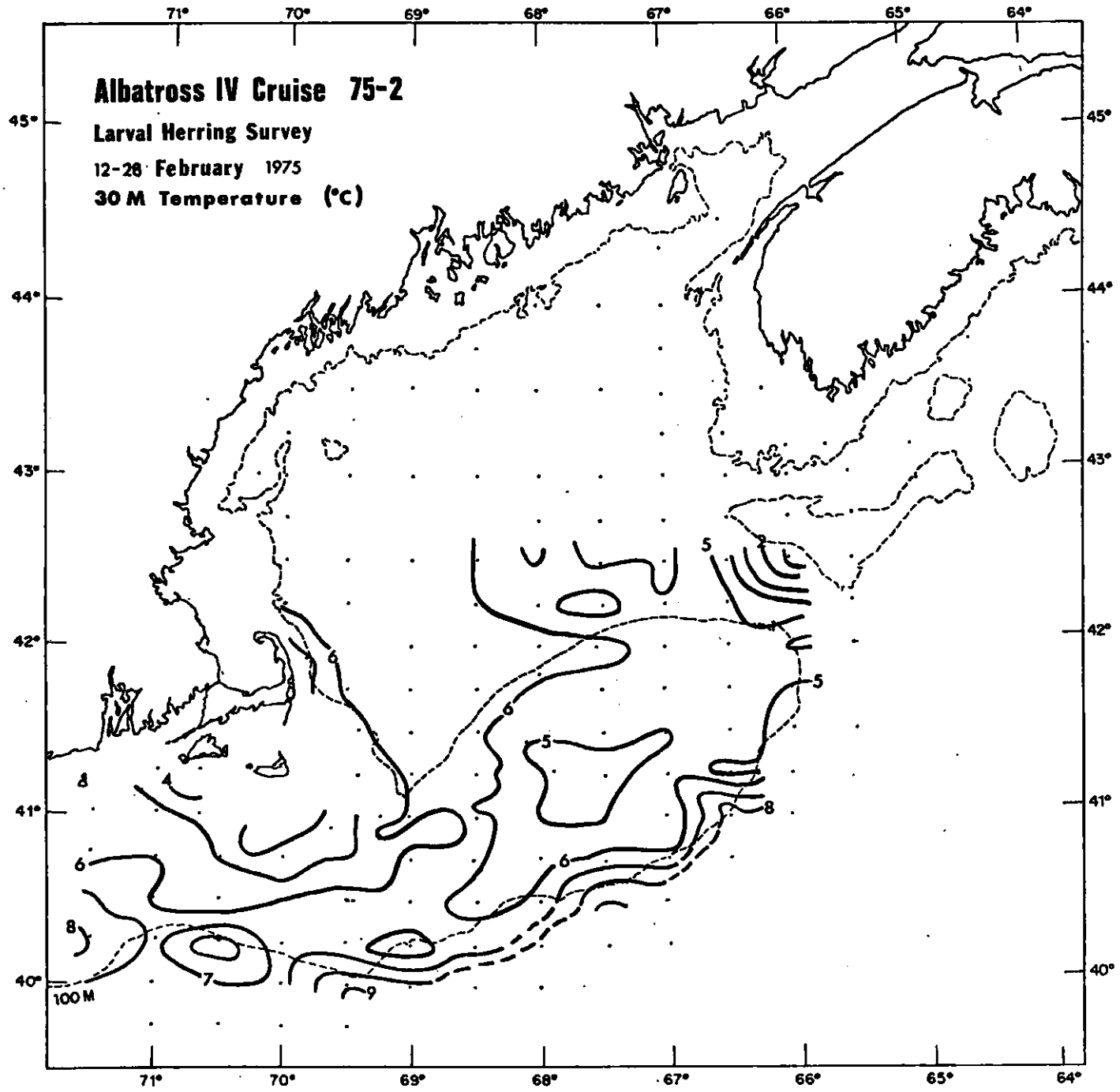
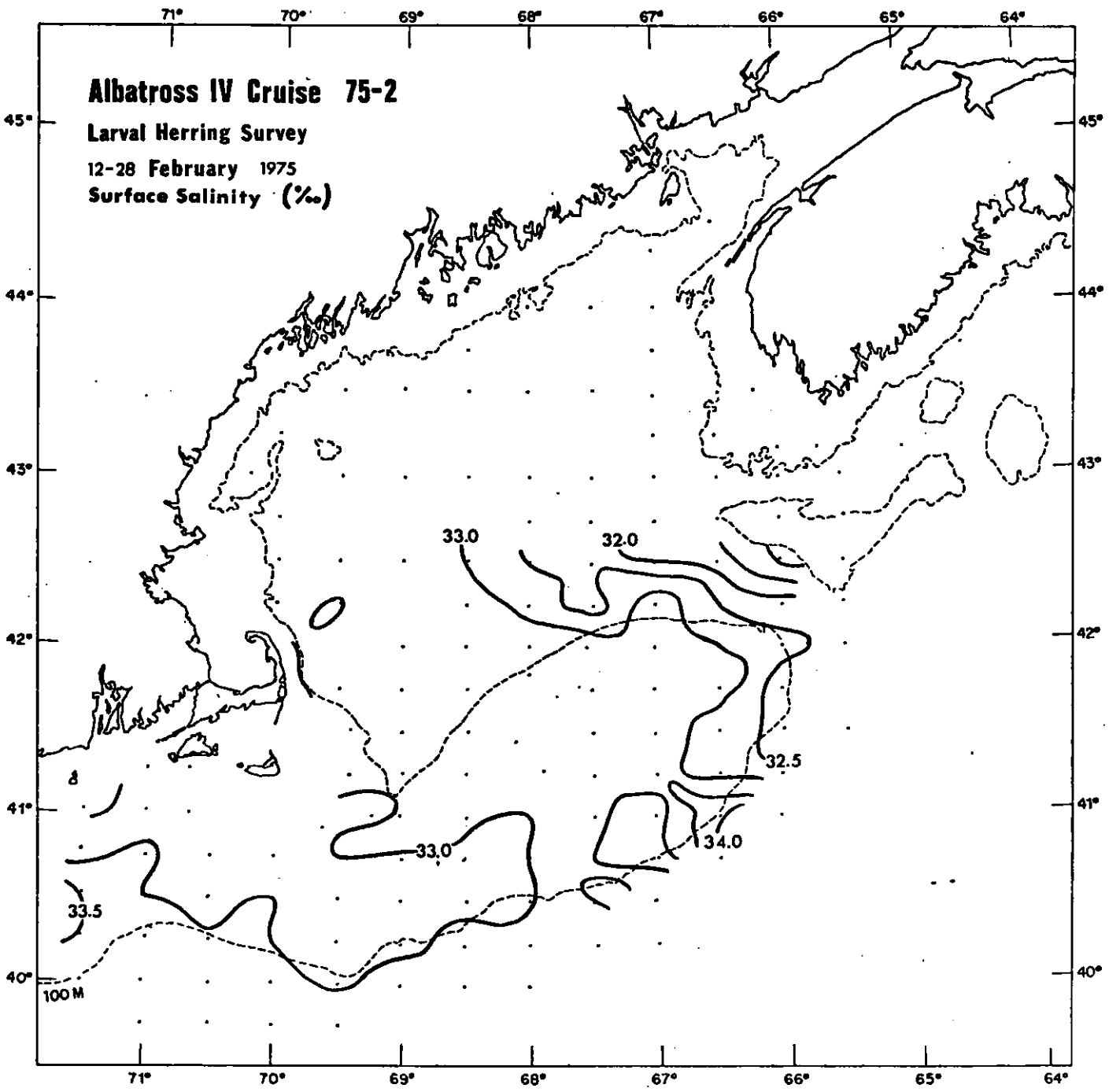

Albatross IV Cruise 75-2
Larval Herring Survey
12-28 February 1975
30 M Temperature (°C)
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
100 M

Figure 27.


Albatross IV Cruise 75-2
Larval Herring Survey
12-28 February 1975
Surface Salinity (‰)
71°
70°
69°
68°
67°
66°
65°
64°
45°
44°
43°
42°
41°
40°
33.0
32.0
32.5
34.0
33.0
33.5
100 M