

NEW RECORDS OF FISH AND SQUIDS ON THE MID-ATLANTIC RIDGE IN 1985

MAREK R. LIPINSKI* AND JERZY JANUSZ

Janusz J, Lipinski MR. New records of fish and squids on the Mid-Atlantic Ridge in 1985

During 31 March – 18 April 1985, R/V "Professor Siedlecki" conducted research between coordinates 48-54°N 25-32°W (Mid-Atlantic Ridge). *Maurolicus muelleri* was discovered in a layer between 100 and 300 m during the day. In the area of 91 440 Mm² the density of this layer was estimated as 4.8t/Mm², which is low when compared with the densities of this layer (mainly *M. muelleri*) in other parts of the Atlantic Ocean. The DSL layer was located between 400-600 m during the day, with migrating and non-migrating components. *Maurolicus muelleri*, mesopelagic fishes, cephalopods and crustaceans were found in the DSL (the latter two in small numbers). Catches of this mesopelagic fauna were small (3.2 – 43.4 kg per trawl). New zoogeographical records (extending the occurrence range northwards) included *Trigonolampa miriceps*, *Flagellostomias bourei*, *Polyipnus polii*, *Evermanella balboi* (fishes) and *Octopoteuthis danae* (squid). In the plankton copepods dominated, euphausiids were important in the northern part of the region, and larval fish were scarce. Oceanographic observations revealed fairly typical ranges of parameters, including strong presence of AIW and Polar Front.

Marek R. Lipinski* & Jerzy Janusz, Sea Fisheries Institute, ul. Kollataja 1, 81-332 Gdynia,
Poland

*Present address: Marine and Coastal Management Branch, DEAT, Private Bag X2,
Roggebaai 8012, Cape Town, South Africa.

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records

Introduction

Mid-Atlantic Ridge, especially in its northern part (north of the Azores) is subject to dynamic oceanographic regime, in which relatively warm waters of the North Atlantic Current and Irminger Current in the north interfere with polar, Arctic water masses from the far north. Emerging fronts are the source of nutrient-rich environment, in which elaborate trophic pyramids may develop (Pickard & Emery 1990). In the open waters of Mid-Atlantic Ridge species such as redfish (*Sebastes mentella*) or roundnose grenadier (*Coryphaenoides rupestris*) were subject to heavy exploitation by fisheries, and themselves utilized substantial food base: copepods and myctophids (Lipinski et al. subm., Janusz et al. subm. Gorelova & Borodulin 1997). The other very abundant species in this region is *Maurolicus muelleri*, which was investigated previously in the Southern Atlantic (Kalinowski & Linkowski 1983). Role of this abundant but somewhat elusive species in the ecosystem of the open waters of the mid-Atlantic has yet to be elucidated.

Materials and Methods

All research was conducted by the R/V Professor Siedlecki (89 m length, 2798 BRT, 2500 hp) in 1985 (31 March-18 April). Research was conducted between coordinates 48-54°N and 25-32°W (Table 1). In this area, priorities of research were *Maurolicus muelleri* and mesopelagic fishes and cephalopods. There was 2046 Mm of hydroacoustic transects, 57 oceanographic stations, 18 plankton stations and 15 pelagic trawling stations.

The large-mesh low-resistance mid-water trawl WP-54/132x50/108 was used on 15 trawling stations (Fig. 1). The opening surface of this trawl was about 800-1000 m². At

the same time, there was 6 mm liner in the cod-end, which retained small mesopelagic organisms. Vertical opening was 40 m and horizontal was 29 m, and filtration 3 million m³/h during trawling 2.5 kn assuming no currents and other independent water movements. Trawling was conducted with speed of 2.5-3.0 kn. The Simrad EK-38 (main system) with the echo-integrating system QMMK II, Simrad EK-50 (as a net-sonde), and sonar SU 2 were used. Main aim of the hydroacoustic transects (Fig. 2) was to locate and calculate the biomass of mesopelagic fish, mainly *Murollicus muelleri* (assumed TS_{kg} for the latter = -26.8dB, after Kalinowski & Linkowski 1983). The EK-38 was calibrated before research commenced.

The oceanographic research was conducted using CTD Bisset-Berman 9040 to the depth 1100 m. The Bisset-Berman was calibrated to the mean square error $\pm 0.025^{\circ}\text{C}$ (temperature) or $\pm 0.012 \times 10^{-3}$ (salinity). Oceanographic stations and profiles are shown on Fig. 3.

Normal meteorological observations included: atmospheric pressure, direction and force of the wind, air temperature and water t on the surface (i.e. 4.5 m, where the probe was), state of the sea, weather characteristics and cloud cover. Plankton collection was made using standard Bongo net (61 cm) with the mesh 0.505 mm in both nets. Procedure of collection was close to standard (double oblique tow, ship's speed 2.5-3.0 kn, net speed when lowering 50 m/min, and hauling back 20 m/min). The maximum depth was m. Water flow was measured by one flowmeter (HydroBios, Germany) and depth by the bathythermograph unit. Samples were sorted immediately into main systematic groups, as follows: Cnidaria, Copepoda, Ostracoda, Amphipoda, Euphausiacea, Pteropoda, Chaetognatha and Pisces. Their abundance was calculated in ml/1000 m³.

The catch mass was measured using the deck dynamometer (up to 5 t) or estimated based on a first weight if more than 5 t. Small catches were weighed using various mechanical and electronic scales. Whole catch or a sub-sample was sorted into species and a taxonomic identification carried out as far as possible.

The whole catch or a random sub-sample was taken for the ichthyological analysis. Length frequency (TL) distributions of mesopelagic fish (including *Maurolicus muelleri*) were taken to nearest mm. Mantle length (ML) was taken for cephalopods. The length – weight relationship was calculated according to the standard formula $W = a \cdot L^b$ where W is weight in kg, L is length in cm, and a, b are the appropriate coefficients.

Results

Hydroacoustic observations and trawling results

There were five longitudinal hydroacoustic transects. During the continuous observations, characteristic continuous echoes were detected on 99% of the transect mileage. Shape and structure of these recordings was variable. During the day, it was detected between 100-300 m, and during the night close to surface. Catches indicated overwhelming presence of *Maurolicus muelleri* and jellyfish, interspersed by mesopelagic fish, and very little of cephalopods and crustaceans (mainly shrimps). The total biomass of this layer, calculated using TS for *Maurolicus muelleri* (see Materials and Methods), was 451 633 tonnes on the area of 91 440 Mm² ($4.8 \text{ t/Mm}^2 = 1.4 \text{ g/m}^2$). This result indicates relatively large dispersal of the organisms, which constituted this layer, which cannot be described as a proper DSL. Typical DSL was located between 400-600 m during the day; during the night part of it migrated to the surface, where it formed

irregular layer 150 m thick, and the other part stayed on the original depth. *Maurolicus muelleri* was found in the catches targeting typical DSL as well. Sometimes during the night, a third layer was detected at 250-350 m.

Identification results and distribution of fish and cephalopods

Seven trawls, directed at *Maurolicus muelleri*, were done during the day at 20-280 m. Only five of these trawls (Table 2) yielded measurable sample: two recorded zero catches, although there was *M. muelleri* in the wings, and in one case >70% of the catch was washed overboard (trawl #20). Catches (*M. muelleri*: 2.2 – 23.5 kg; total catch ~ 5 – 50 kg) were not compatible with the density, thickness and general characteristics of the schools, detected hydroacoustically. It is suspected, that the used trawl was not suitable for catching large quantities of *M. muelleri*. The length frequencies of *M. muelleri* are shown on Fig. 4, and the length-weight relationship on Fig. 5.

Eight trawls (among 12 successful trawls in this part of the cruise), directed at mesopelagic fauna, were done during the night at 380-1000 m (Tables 3-4 and Appendix). Total catches ranged from 3.2 to 43.4 kg. Most frequently caught species were listed in Table 5. Length frequencies of the two species from the top of this table were given on Fig. 6-7. By far the most common fish was myctophid *Benthosema glaciale*. For only two trawls (#12 and 21) detailed list of cephalopods is available (Table 6). Cephalopods were rather scarce and did not warrant a special treatment during the analysis of the material. Only presence of *Octopoteuthis danae* (identified according to key in Nesis 1987) is probably the farthest northern record (49°07.5'N 25°00.5W, depth 700 m) of this species.

Among 70 species of mesopelagic fish, caught and identified during the Mid-Atlantic Ridge research in 1985, no new species were found. However, for some species zoogeographical boundary was moved much northward.

The most interesting specimen belonged to *Trigonolampa miriceps* (Melanostomiidae; SL = 308 mm) found in trawl 21 (51°02'N, 29°58'W). This is the largest specimen of all five known to science (previous one SL = 208 mm), and found in most northward position. In the same trawl *Flagellostomias bourei* (Melanostomiidae) was found, which was known previously from subtropical & tropical waters.

In the trawl #23 (48°56'N, 30°04'W) there was *Polyipnus polli* (Sternoptychidae), which is generally South Atlantic fish; single findings came from North-West African waters, and from the Iberian Basin.

There were numerous findings of *Evermannella balboi* (Evermannellidae) in the trawls 12, 18, 19, 21, 23 and 26 (most northern being 52°23'N, 28°21'W). So far all findings were south of 40°00'N.

Also, the following species were found beyond or on the boundary of their geographical distribution:

Opisthoproctus soleatus (Opisthoproctidae) (trawl #26); *Bonapartia pedaliota* (Gonostomatidae) (trawls # 12,17,19,23); *Margarethia obtusirostrata* (Gonostomatidae) (trawl # 24); *Sternoptyx diaphana* (Sternoptychidae) (trawls # 12,14,16,17,18,19,23,24, 26); *Argyropelecus hemigymnus* (Sternoptychidae) (trawls # 12,16,17,19,21,24,26); *A. olfersi* (Sternoptychidae) (trawls # 12,16,17,18,23); *Vinciguerria attenuate* (Photichthyidae) (trawls # 12,24); *Poromitra megalops* (Melamphaidae) (trawls # 12,16,19,21,23); *Melamphaes suborbitalis* (Melamphaidae) (trawls # 19,21,24).

Plankton

The general plankton abundance and distribution is shown on Fig. 8, and the same for various systematic groups on Figs 9-15. Copepods dominated in the whole area. Euphausiids were abundant in the north. Fish larvae were scarce and practically limited to the southern area of the region.

Oceanographic observations

During the period of research, there was a clear link between meteorological observations (Fig. 16) and temperature disturbance in the surface layer of the ocean, caused by strong winds and heat energy transfer from the water to the air. Therefore, biggest temperature gradient was observed at 200 dbar and not at the surface, whereas salinity stayed similar on both levels. Also, maximum temperature gradients were predictably observed in the Polar Front (Fig. 17-20). This front was localized around 52°N, on the border between Arctic Intermediate Water (AIW) and North Atlantic Central Water (NACW) (Fig. 21-24). To the north of the Front there was Labrador Water, coming from the west. Because of the changes in the relative density, AIW was sinking deeper and moving to the south. Most complicated hydrology was observed on profile B, where Labrador Water mixed with AIW, was dividing NACW along about 60 Mm. Generally, the greatest variability and instability was observed in the Polar Front zone, where considerable changes in the oxygenation were observed between the surface and 200 dbar level (Fig. 25-26).

Discussion

The described results may be considered to represent fairly typical oceanographic and biological phenomena over the investigated region of the Mid-Atlantic Ridge (Sverdrup et al. 1942; Rossof & Kislyakov 1972; Worthington 1975; Tourbillon 1983). Water masses in this area move quickly, creating high dynamics along and in the vicinity of the developed fronts, of which most important is the Polar Front, where the water masses from the south border the water masses from the north and north-west. This is a very productive area, but only for the species which can withstand intrusion of the cold water masses and the violent dynamics of the region. To the north, there are stocks of redfish *Sebastes mentella* (Lipinski et al. subm.); over the underwater domes associated with the Mid-Atlantic Ridge there are stocks of roundnose grenadier (Janusz et al. subm.). Both are making use of the ample food in the form of plankton, macroplankton and micronekton, such as myctophids, along with the *Maurolicus muelleri*, dominant in the area investigated. Concentration of the schools of *M. muelleri* may have been fairly poor over the Mid-Atlantic Ridge (1.4 g/m^2), but they occur over a very large area. For comparison, the density of *M. muelleri* north of the Azores was estimated as 16.7 t/Mm^2 ($= 4.87 \text{ g/m}^2$) (Linkowski & Lipinski, own observations during R/V "Professor Siedlecki" expedition in 1984). In the South Atlantic, similar values were $91\text{-}504 \text{ t/Mm}^2$ ($26\text{-}147 \text{ g/m}^2$) (Kalinowski & Linkowski 1983). Dynamic character of the environment allows for the occurrence of species normally distributed far south. How permanent is their occurrence in the region, needs to be investigated in the monitoring-type studies. Even then it will be difficult to draw solid conclusions, as they may well be regular visitors to the area, which breed in the south but regularly occur in the north.

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Table 1. Trawl station and catch data summary from r/v "Profesor Siedlecki" survey (for mesopelagic fishes) in the Mid-Atlantic Ridge in 1985

Haul no.	Date	Shoot a net time	Duration (min)	Hauling in position		Depth of the net		Catch kg.	Mean depth to bottom (m)	Water temp. (C)	
				Lat. N	Long W	from (m)	to (m)			surface	at depth
12	31.03.85	22 35	60	49 07	025 00		700	12.6	3700		
13	01.04.85	10 10	50	50 21	025 01	170	165	0	3850		
14	02.04.85	19 00	85	53 52	024 59	95	150	14.4	3700		8.5
15	03.04.85	09 15	30	53 57	026 28	140	160	4.9	3550		8.9
16	03.04.85	22 20	45	52 41	026 38		560	43.4	3700		
17	05.04.85	23 25	65	48 24	026 31		1000	3.2	3080		
18	07.04.85	06 35	130	48 44	028 21		550	23.9	2600		
19	09.04.85	21 00	60	52 25	028 19		600	15.9	3700		
20	10.04.85	12 20	60	53 41	028 14	130	150	47.5	3220		8.5
21	13.04.85	22 15	60	51 03	029 58		400	14.4	3600		
22	14.04.85	21 30	5	48 55	030 01	20	20		3500	10.25	
23	14.04.85	23 05	60	48 58	030 04		650	24	3500		
24	15.04.85	18 00	80	47 59	031 20		230	9.3	3950		
25	16.04.85	13 50	60	49 34	031 39	220	230	23.5	3500	9.5	9
26	16.04.85	23 50	85	49 53	031 04		580	31.4	3080		

Table 2. *Maurolicus muelleri* data from some hauls during r/v "Profesor Siedlecki" survey in the Mid-Atlantic Ridge in 1985

Haul no.	Date	Catch (kg)	M muelleri catch to total catch (%)	M muelleri biomass (g/m ³)	Length from - to (mm)	Mean length (mm)	Mean weight (g)
14	02.04.85	5.0	35.3	0.001	24 - 55	32.5	0.35
15	03.04.85	3.7	74.6	0.002	22 - 44	30.7	0.32
20	10.04.85	10.0	21.1	0.003	25 - 49	34.5	0.46
24	15.04.85	2.2	23.7	0.0004	23 - 55	37.7	0.62
25	16.04.85	23.5	100.0	0.008	23 - 54	38.7	0.60

Table 3. CPUE (kg/h) and concentration of biomass (g/m³) during r/v "Profesor Siedlecki" survey

Haul no.	Date	Local time	Hauling in position		Max depth (m)	CPUE (kg/h)	Biomass (g/m ³)
			Lat. N	Long W			
12	31.03.85	22 35	49 07	025 00	700	12.60	0.004
14	02.04.85	19 00	53 52	024 59	150	10.16	0.003
15	03.04.85	09 15	53 57	026 28	160	9.80	0.003
16	03.04.85	22 20	52 41	026 38	560	57.87	0.019
17	05.04.85	23 25	48 24	026 31	1000	2.95	0.001
18	07.04.85	06 35	48 44	028 21	550	11.03	0.004
19	09.04.85	21 00	52 25	028 19	600	15.90	0.005
21	13.04.85	22 15	51 03	029 58	400	14.40	0.005
23	14.04.85	23 05	48 58	030 04	650	24.00	0.008
24	15.04.85	18 00	47 59	031 20	230	6.98	0.002
25	16.04.85	13 50	4 934	031 39	220	23.50	0.008
26	16.04.85	23 50	49 53	031 04	580	22.16	0.007

Table 4. Species composition of catches (in %) during r/v "Profesor Siedlecki" survey

Haul no.	CPUE (kg/h)	Jellyfish	Salps	Euphausid s Mysids	Shrimps	Fishes	Cephalopods
12	12.60	0.7	1.6	2.5	3.4	91.0	0.8
14	10.16	64.7	0.0	0.0	0.0	35.3	0.0
15	9.80	23.7	0.0	1.7	0.0	74.6	0.0
16	57.87	76.1	0.0	6.4	1.1	16.2	0.2
17	2.95	22.4	1.3	0.7	5.4	65.1	5.1
18	11.03	57.8	0.0	1.0	2.0	29.2	10.0
19	15.90	56.4	0.0	0.9	1.8	25.8	15.1
21	14.40	37.1	0.0	0.5	2.6	58.7	1.1
23	24.00	73.7	0.0	2.5	1.6	21.3	0.9
24	6.98	0.2	0.0	35.8	0.0	62.8	1.2
25	23.50	0.0	0.0	0.0	0.0	100.0	0.0
26	22.16	80.1	0.0	0.0	2.8	17.1	0.0

Table 5. More abundant fish species caught in 8 deep water hauls during r/v "Professor Siedlecki" survey in the Mid-Atlantic Ridge in 1985.

No.	Species	No hauls	%
<u>Myctophidae</u>			
1	<i>Benthoosema glaciale</i>	8	54.3
2	<i>Notoscopelus kroeyeri</i>	7	3.8
3	<i>Myctophum punctatum</i>	7	1.8
4	<i>Lampanyctus macdonaldi</i>	8	1.4
5	<i>Electrona risso</i>	7	1.1
6	<i>Ceratoscopelus maderensis</i>	5	0.7
7	<i>Lampadena speculigera</i>	5	1.2
8	<i>Lobianchia gemellari</i>	4	0.4
9	<i>Notoscopelus bolini</i>	2	0.5
10	<i>Diaphus effulgens</i>	2	0.1
11	<i>Symbolophorus veranyi</i>	1	0.05
12	<i>Diaphus rafinesqui</i>	1	0.1
<u>Other mesopelagic</u>			
13	<i>Cyclothone braueri</i>	7	7.5
14	<i>Chauliodus sloani</i>	8	2.1
15	<i>Scopelogadus beani</i>	7	6.2
16	<i>Bathylagus compusus</i>	6	1
17	<i>Argyropelecus hemigymnus</i>	8	0.8
18	<i>Normichthys operosus</i>	7	0.5
19	<i>Melamphaes suborbitalis</i>	2	0.3

Table 6. Cephalopods caught in two trawls over the Mid-Atlantic Ridge in March-April 1985.

Date	Trawl No.	Position	Depth	Species	Mantle length
31/03	12/63	49°07.5N	700m	<i>Teuthowenia megalops</i>	100 mm
		25°00.5W		<i>Gonatus fabricii</i>	18 & 40 mm
				<i>Mastigoteuthis schmidti</i>	31, 32, 37, 38 mm
13/04	21/115	51°63.5N	400m	<i>Onychiteuthis banksi</i>	48mm
		29°58.5W		<i>Octopoteuthis danae</i>	106mm, female
				<i>Histioteuthis bonnellii</i>	40mm
				<i>Ommastrephid juv.</i>	23mm
				<i>Abraliopsis hoylei pfefferi</i>	22, 23, 28, 28, 29, 30, 30, 32 mm

Figure Explanations

- Fig. 1. The distribution of trawling stations during the cruise of R/V "Professor Siedlecki in March-April 1985.
- Fig. 2 Hydroacoustic transects and density of insonified layer over northern Mid-Atlantic Ridge
- Fig. 3 Oceanographic profiles over northern Mid-Atlantic Ridge
- Fig. 4 Length frequency of *Maurolicus muelleri* in April 1985 over northern Mid-Atlantic Ridge
- Fig. 5 Length-weight relationship for *Maurolicus muelleri* over northern Mid-Atlantic Ridge
- Fig. 6 Length frequency of *Benthoosema glaciale* in April 1985 over northern Mid-Atlantic Ridge
- Fig. 7 Length frequency of *Notoscopelus kroyerii* in April 1985 over northern Mid-Atlantic Ridge
- Fig. 8 Overall plankton distribution in the northern Mid-Atlantic Ridge region
- Fig. 9 Distribution of Cnidaria in the northern Mid-Atlantic Ridge region
- Fig. 10 Distribution of Copepoda and Ostracoda in the northern Mid-Atlantic Ridge region
- Fig. 11 Distribution of Amphipoda in the northern Mid-Atlantic Ridge region
- Fig. 12 Distribution of Euphausiacea in the northern Mid-Atlantic Ridge region
- Fig. 13 Distribution of Pteropoda in the northern Mid-Atlantic Ridge region
- Fig. 14 Distribution of Chaetognatha in the northern Mid-Atlantic Ridge region
- Fig. 15 Distribution of Pisces in the northern Mid-Atlantic Ridge region
- Fig. 16 Results of meteorological observations over northern Mid-Atlantic Ridge
- Fig. 17 Temperature profile A (refer to the Fig. 3) in the northern Mid-Atlantic Ridge

Fig. 18 Temperature profile B (refer to the Fig. 3) in the northern Mid-Atlantic Ridge

Fig. 19 Temperature profile C (refer to the Fig. 3) in the northern Mid-Atlantic Ridge

Fig. 20 Temperature profile D (refer to the Fig. 3) in the northern Mid-Atlantic Ridge

Fig. 21 Distribution of the three water masses over the northern Mid-Atlantic Ridge on profile A (refer to the Fig. 3)

Fig. 22 Distribution of the three water masses over the northern Mid-Atlantic Ridge on profile B (refer to the Fig. 3)

Fig. 23 Distribution of the three water masses over the northern Mid-Atlantic Ridge on profile C (refer to the Fig. 3)

Fig. 24 Distribution of the three water masses over the northern Mid-Atlantic Ridge on profile D (refer to the Fig. 3)

Fig. 25 Oxygen distribution on 0 dbar level over the northern Mid-Atlantic Ridge

Fig. 26 Oxygen distribution on 200 dbar level over the northern Mid-Atlantic Ridge.

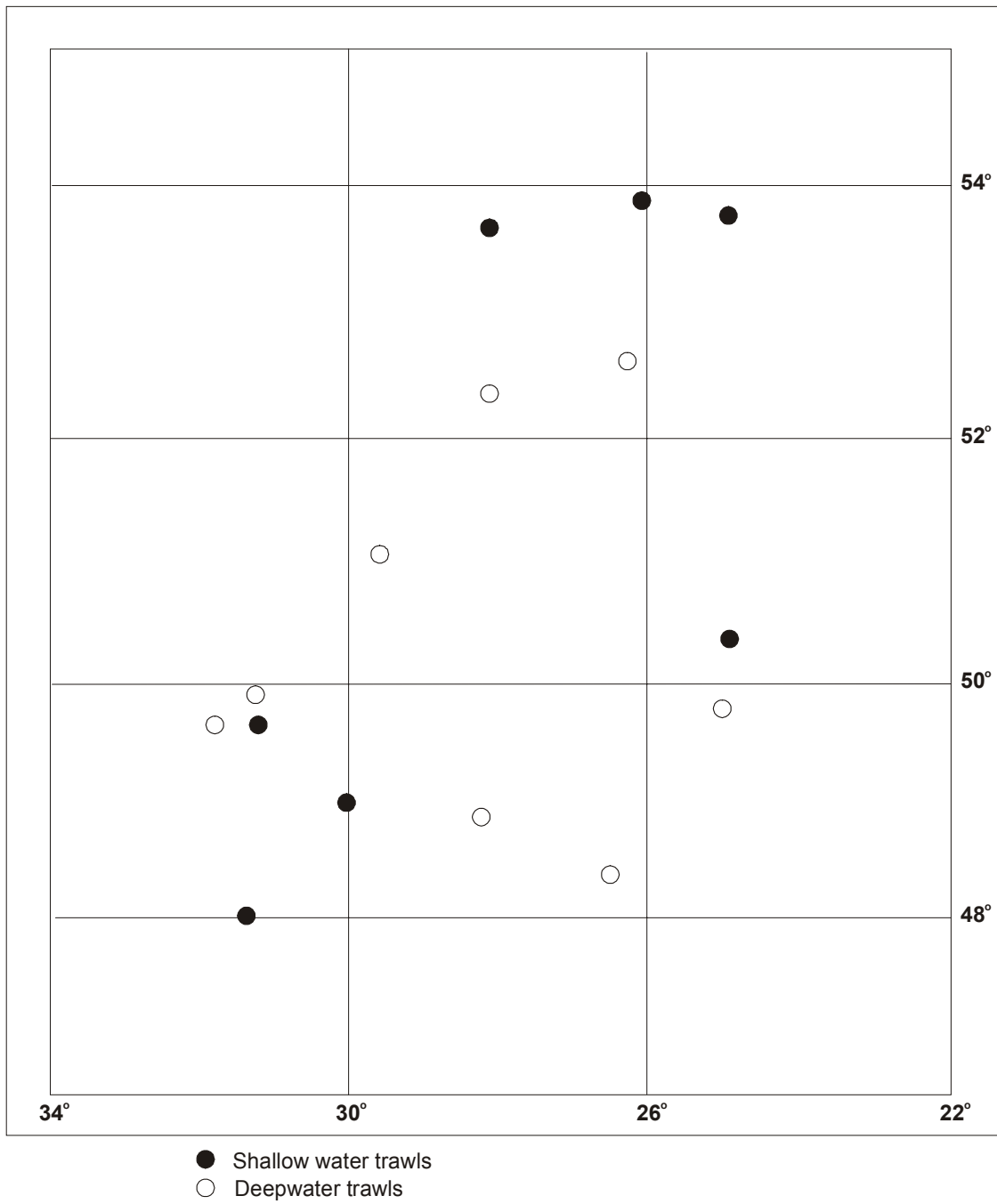


Fig. 1. The distribution of trawling stations during the cruise of R/V "Professor Siedlecki in March-April 1985.

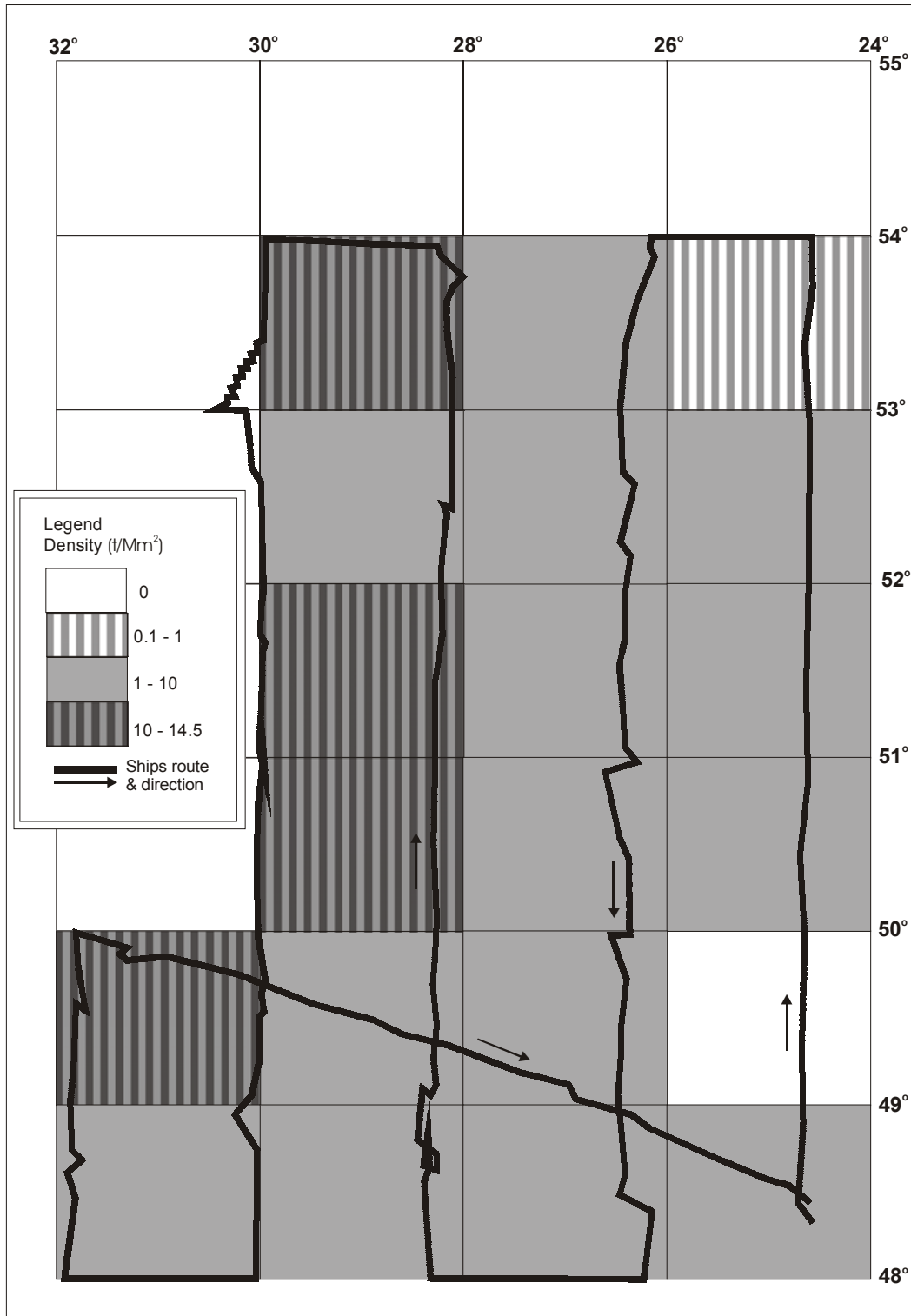


Fig. 2 Hydroacoustic transects and density of insonified layer over northern Mid-Atlantic Ridge

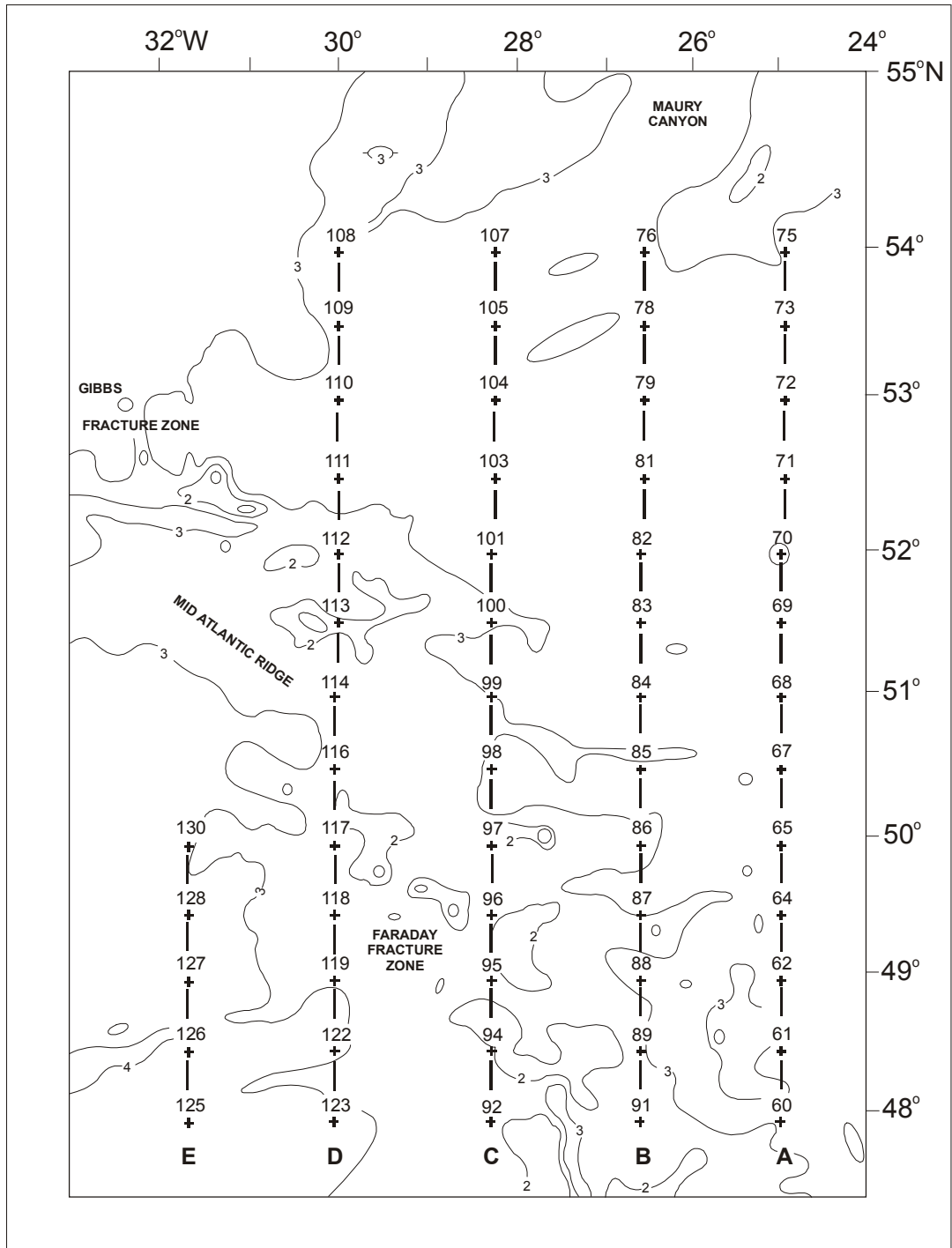


Fig. 3 Oceanographic profiles over northern Mid-Atlantic Ridge

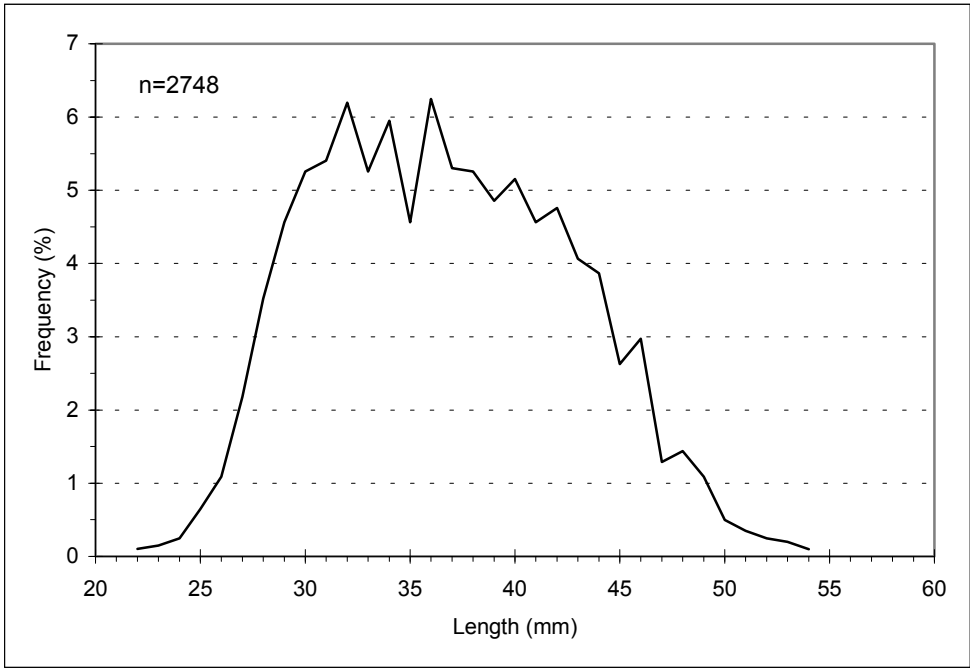


Fig. 4 Length frequency of *Maurolicus muelleri* in April 1985 over northern Mid-Atlantic Ridge

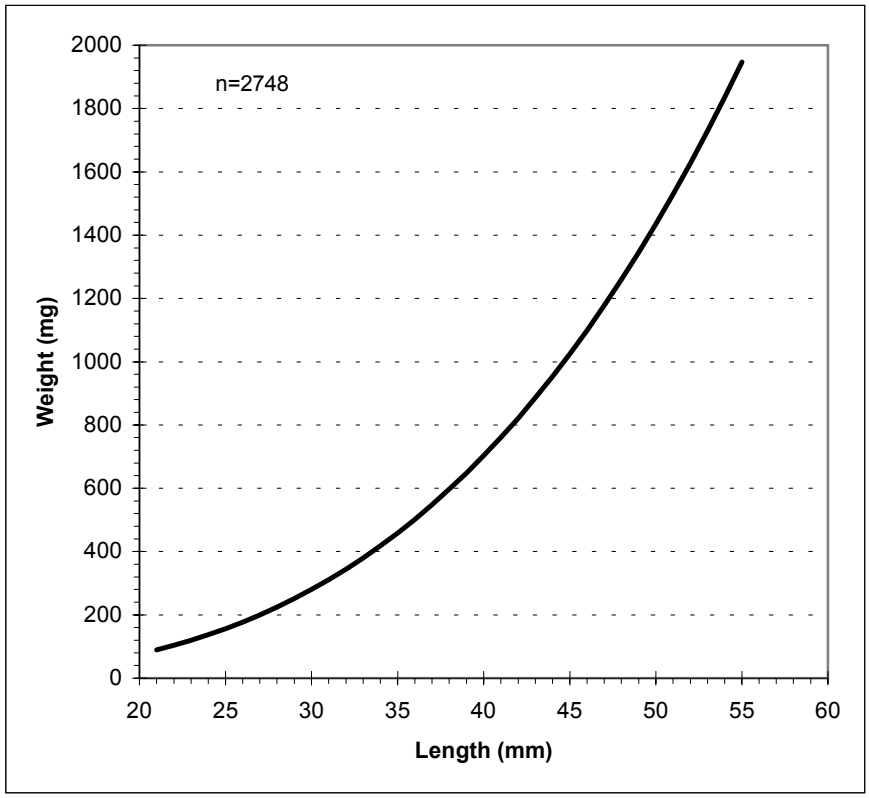


Fig. 5 Length-weight relationship for *Maurolicus muelleri* over northern Mid-Atlantic Ridge

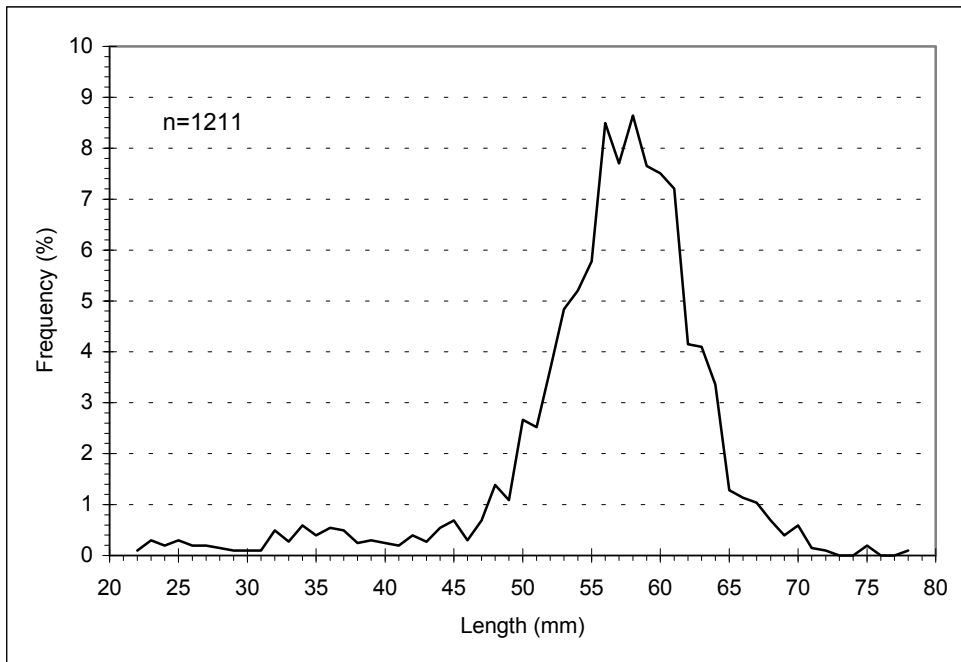


Fig. 6 Length frequency of *Benthosema glaciale* in April 1985 over northern Mid-Atlantic Ridge

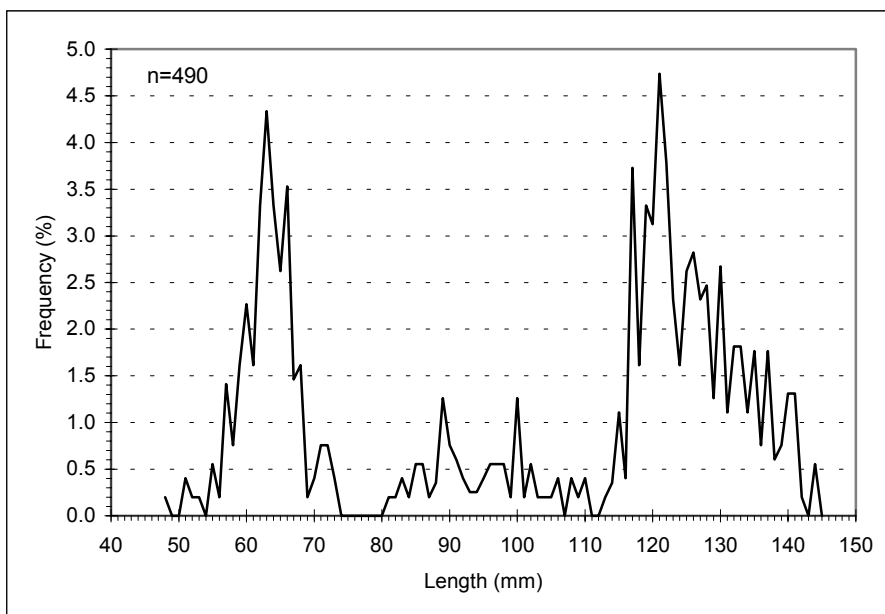


Fig. 7 Length frequency of *Notoscopelus kroyerii* in April 1985 over northern Mid-Atlantic Ridge.

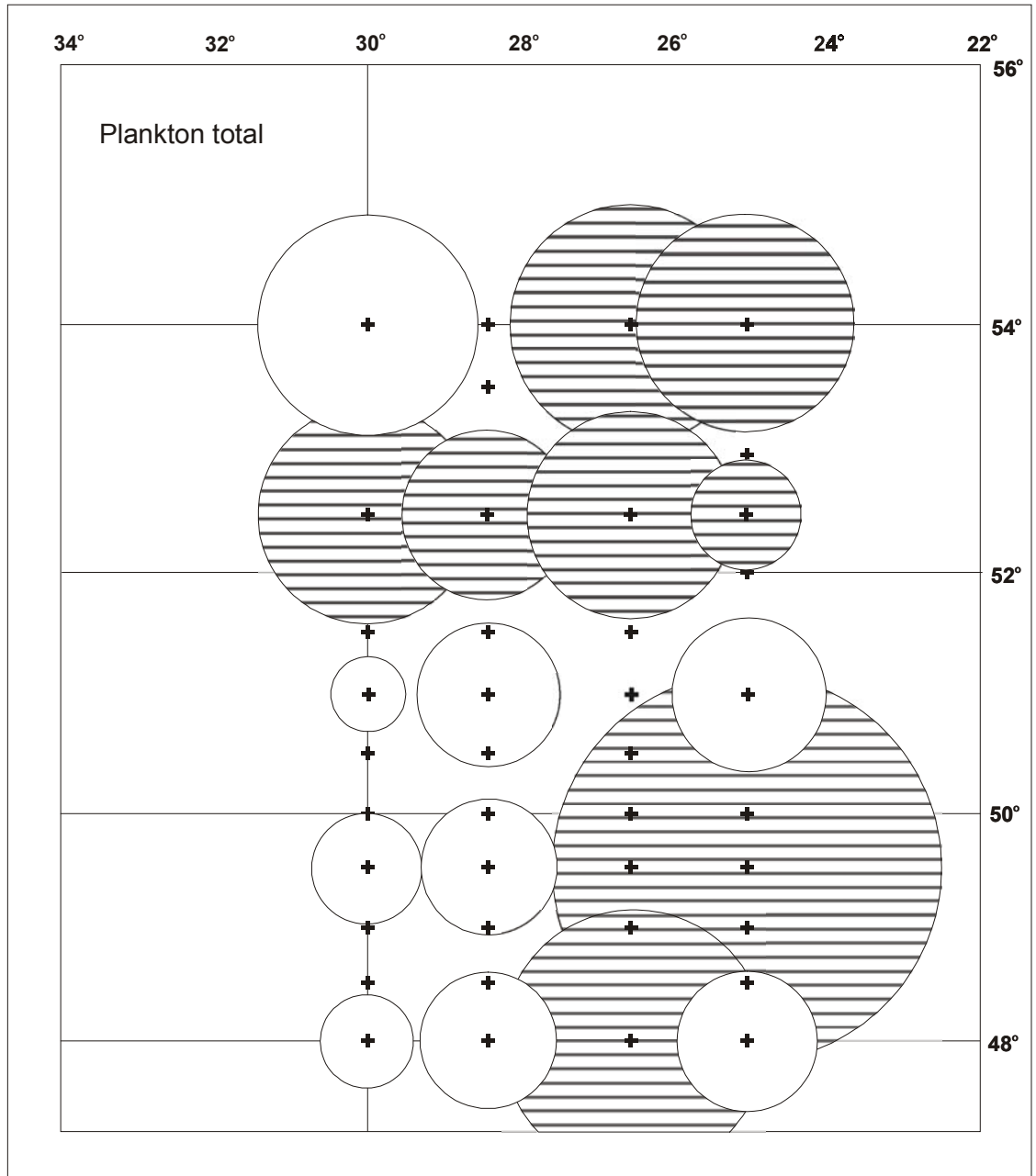


Fig. 8 Overall plankton distribution in the northern Mid-Atlantic Ridge region

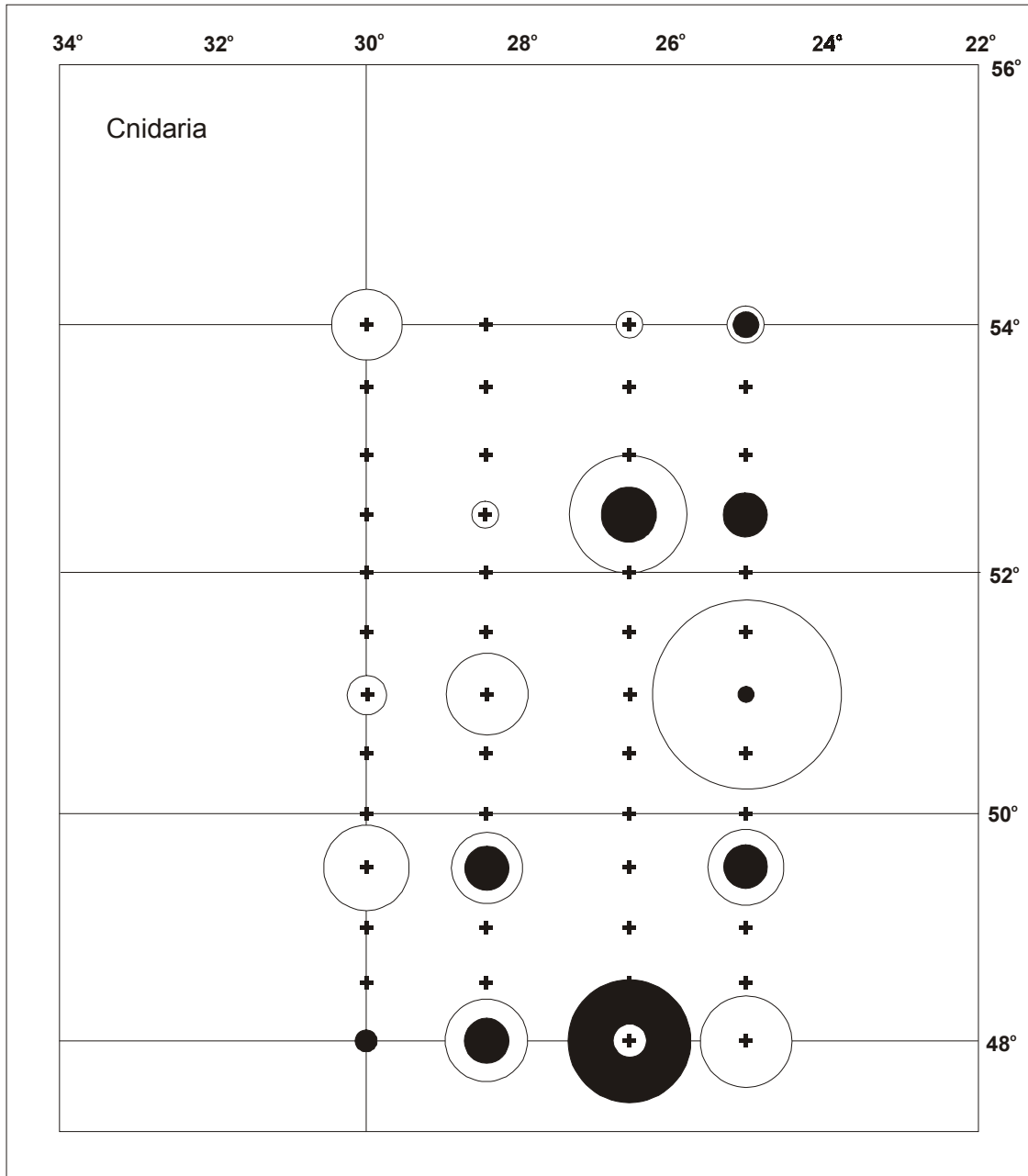


Fig. 9 Distribution of Cnidaria in the northern Mid-Atlantic Ridge region

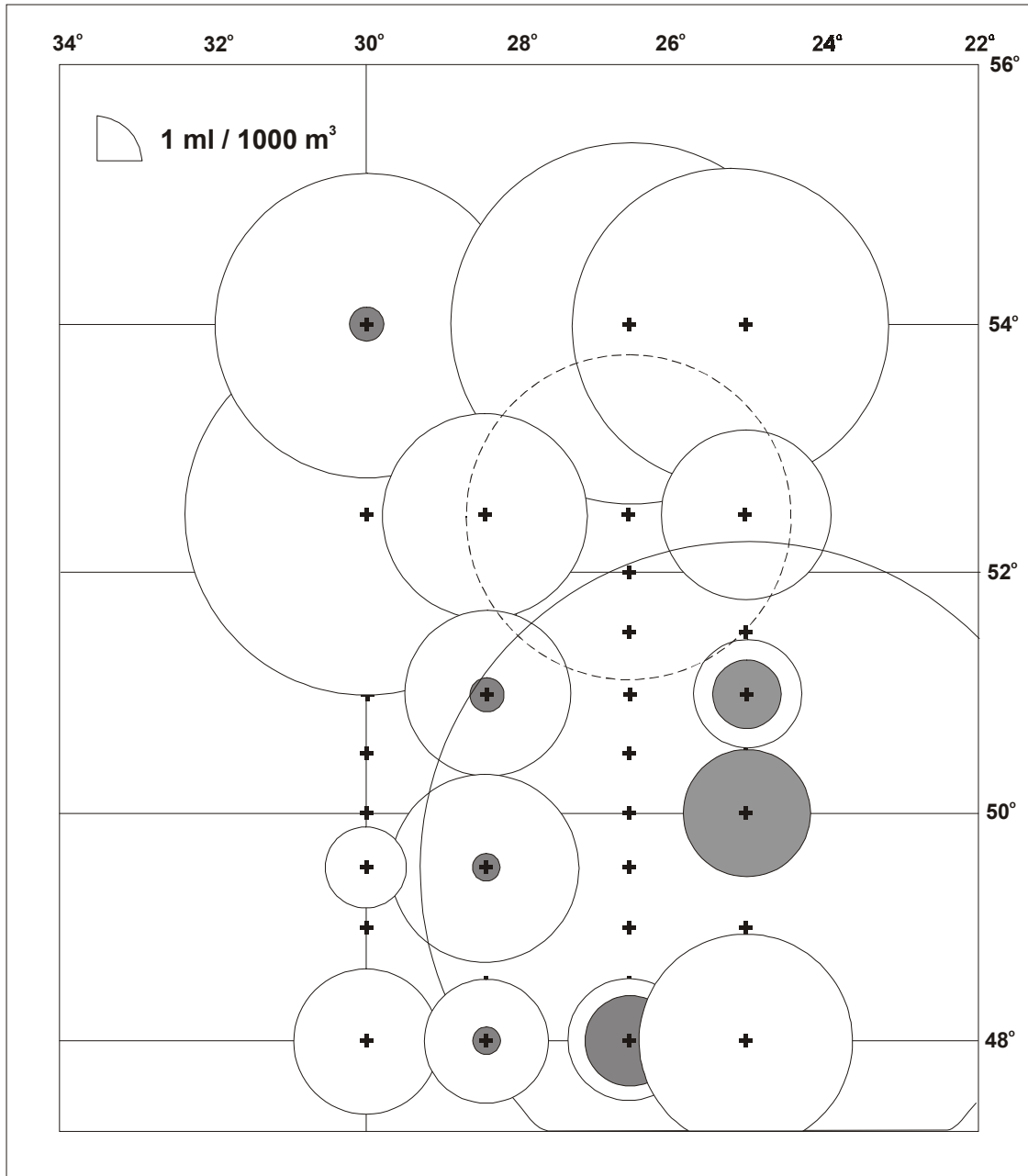


Fig. 10 Distribution of Copepoda and Ostracoda in the northern Mid-Atlantic Ridge region

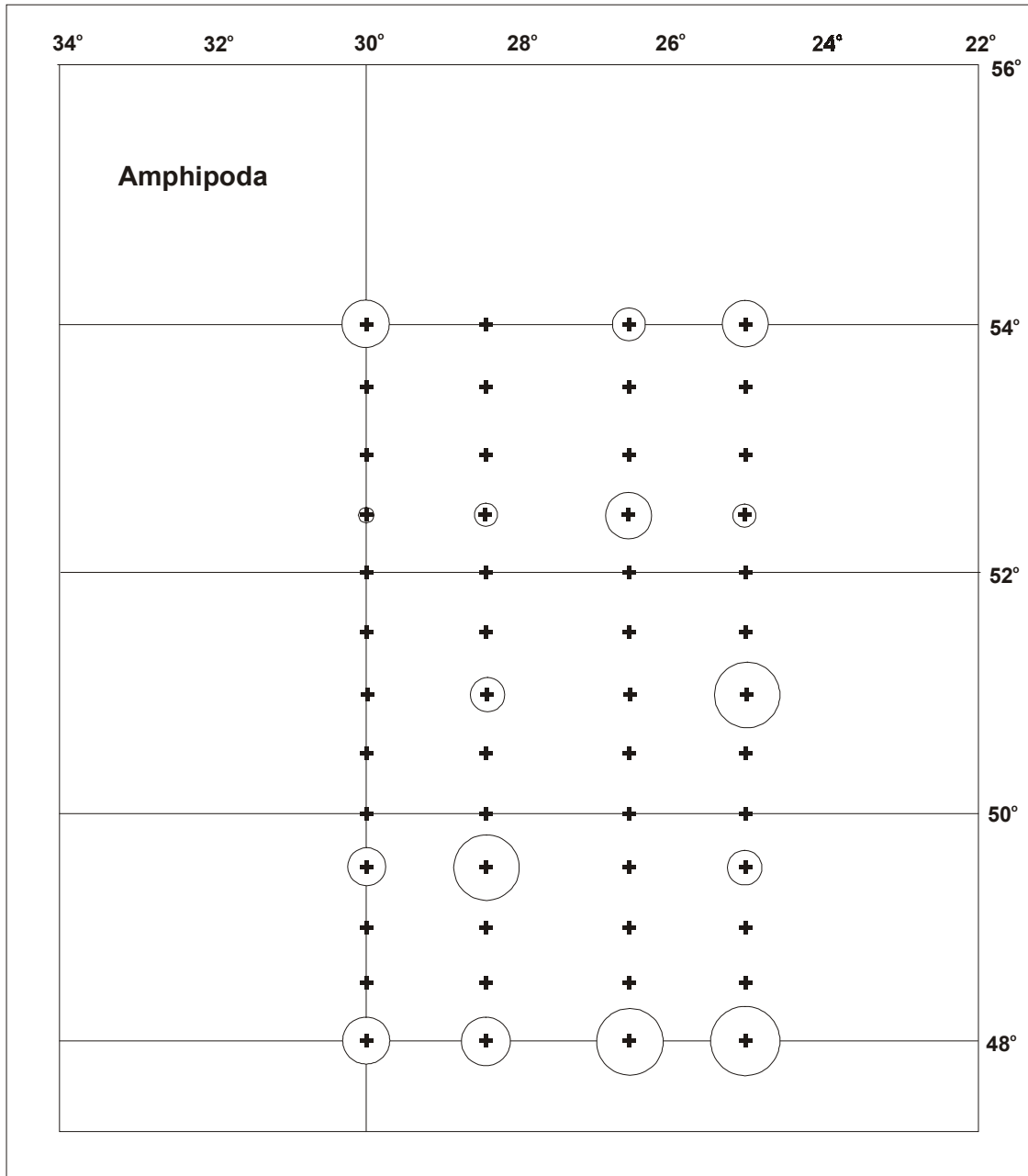


Fig. 11 Distribution of Amphipoda in the northern Mid-Atlantic Ridge region

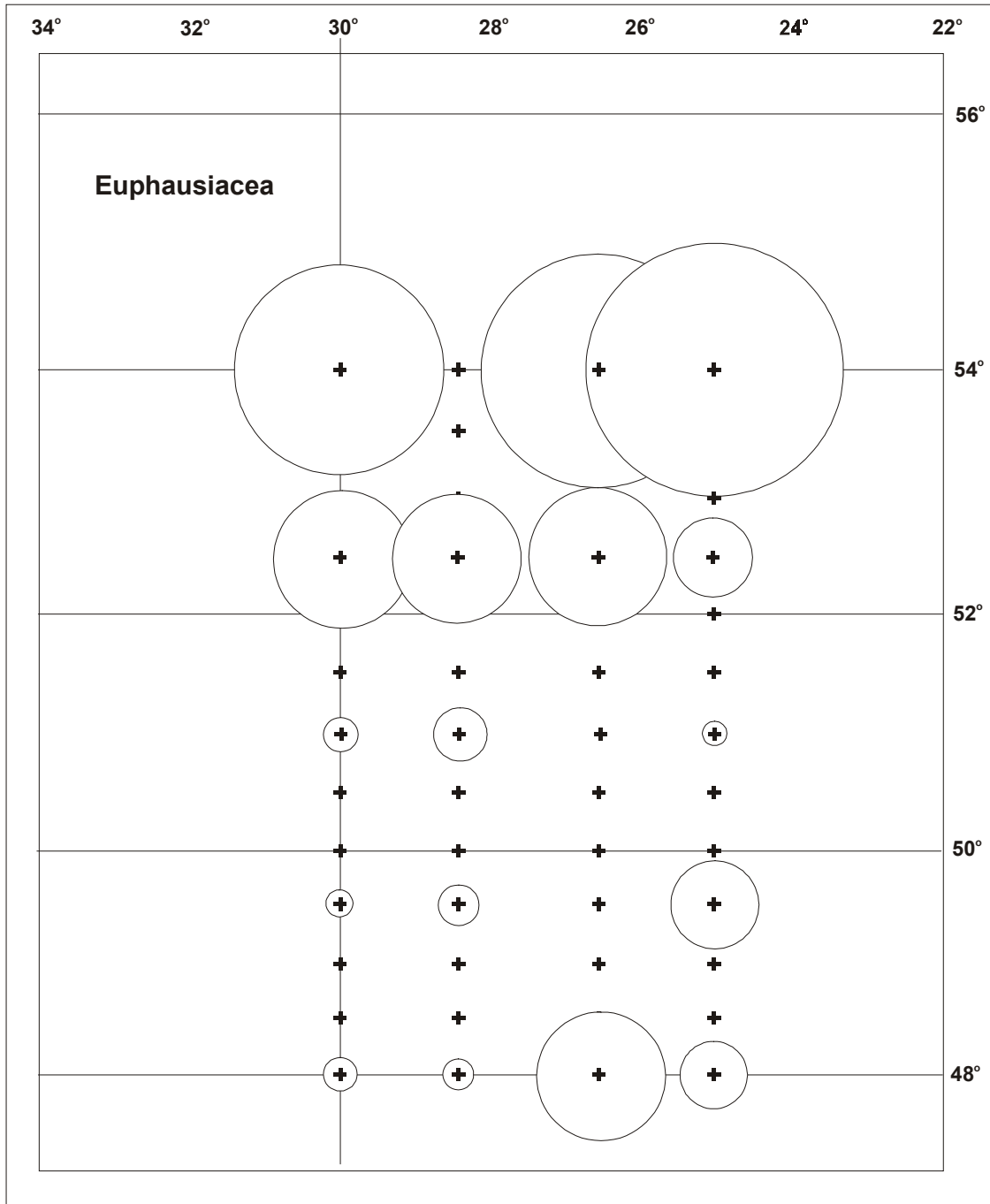


Fig. 12 Distribution of Euphausiacea in the northern Mid-Atlantic Ridge region

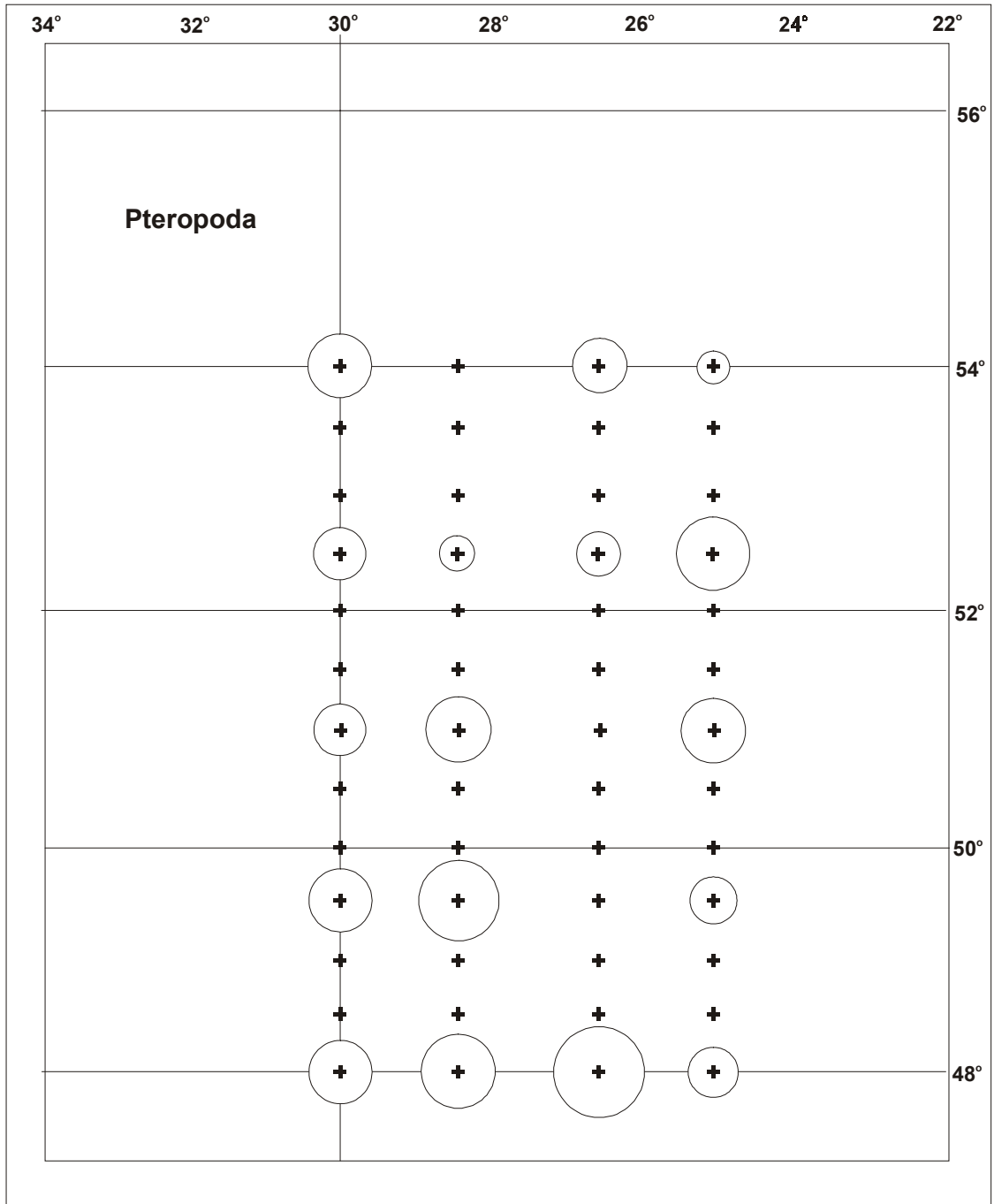


Fig. 13 Distribution of Pteropoda in the northern Mid-Atlantic Ridge region

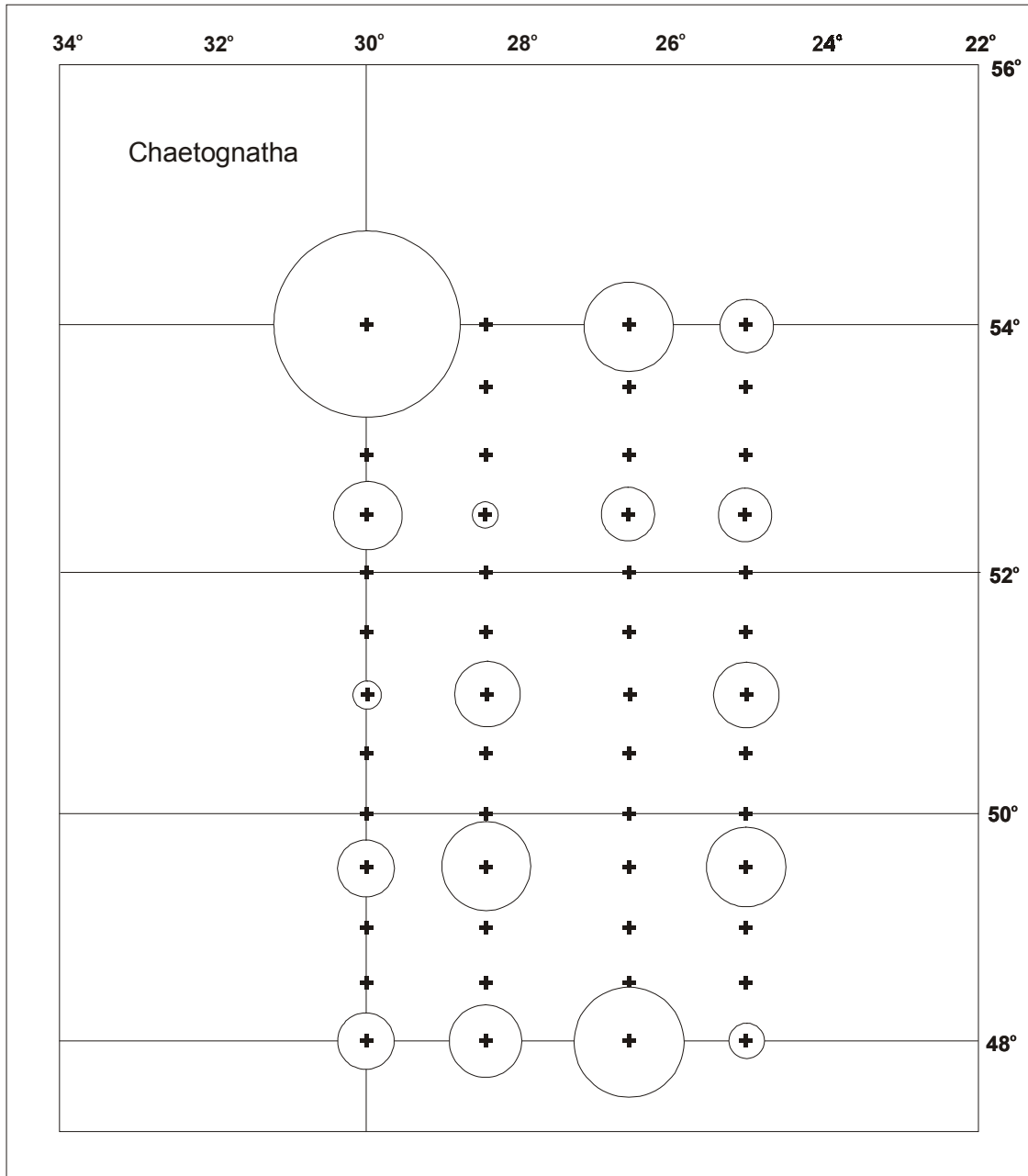


Fig. 14 Distribution of Chaetognatha in the northern Mid-Atlantic Ridge region

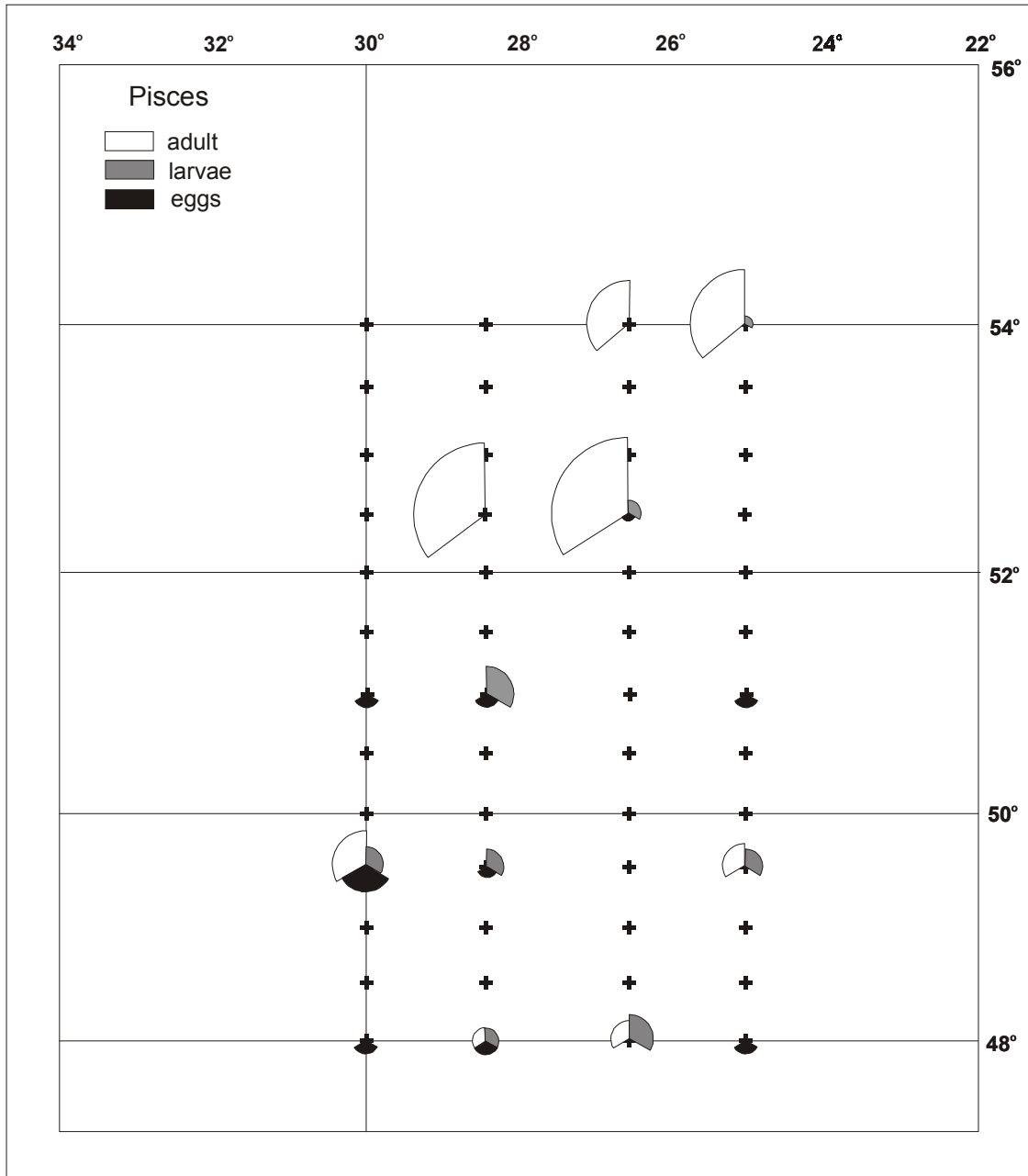


Fig. 15 Distribution of Pisces in the northern Mid-Atlantic Ridge region

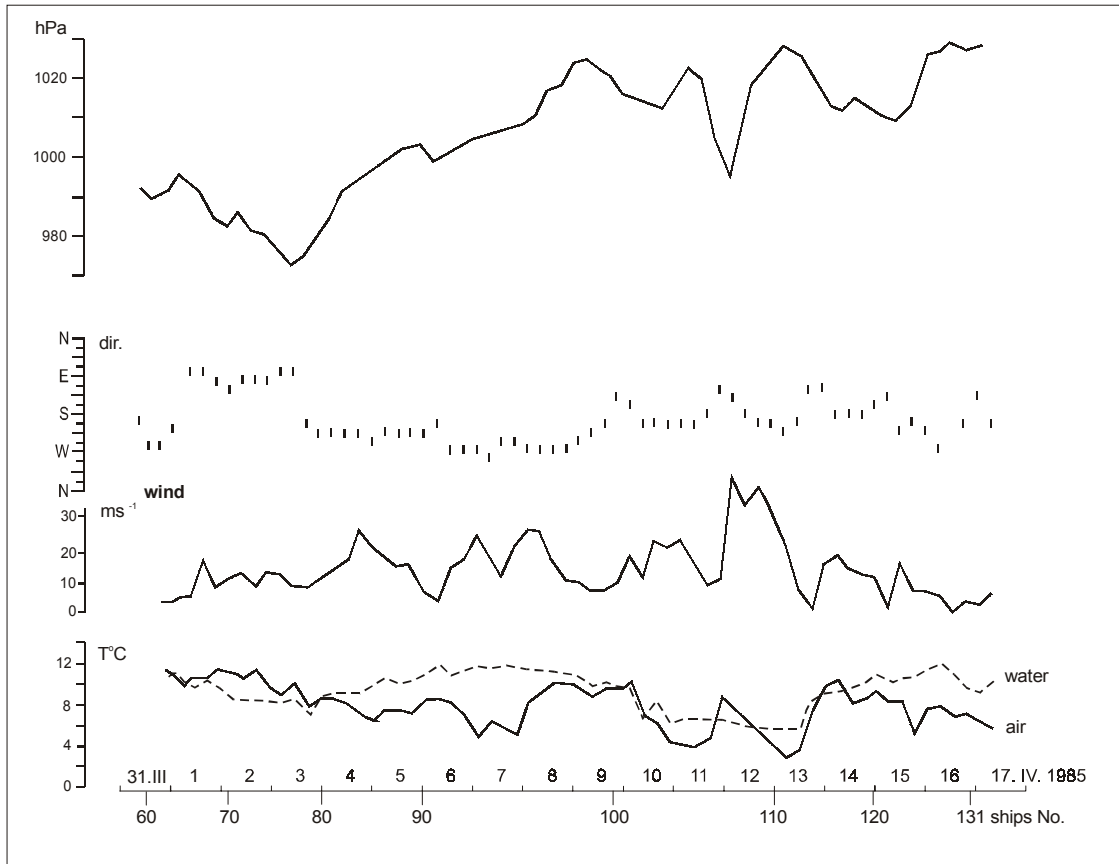


Fig. 16 Results of meteorological observations over northern Mid-Atlantic Ridge

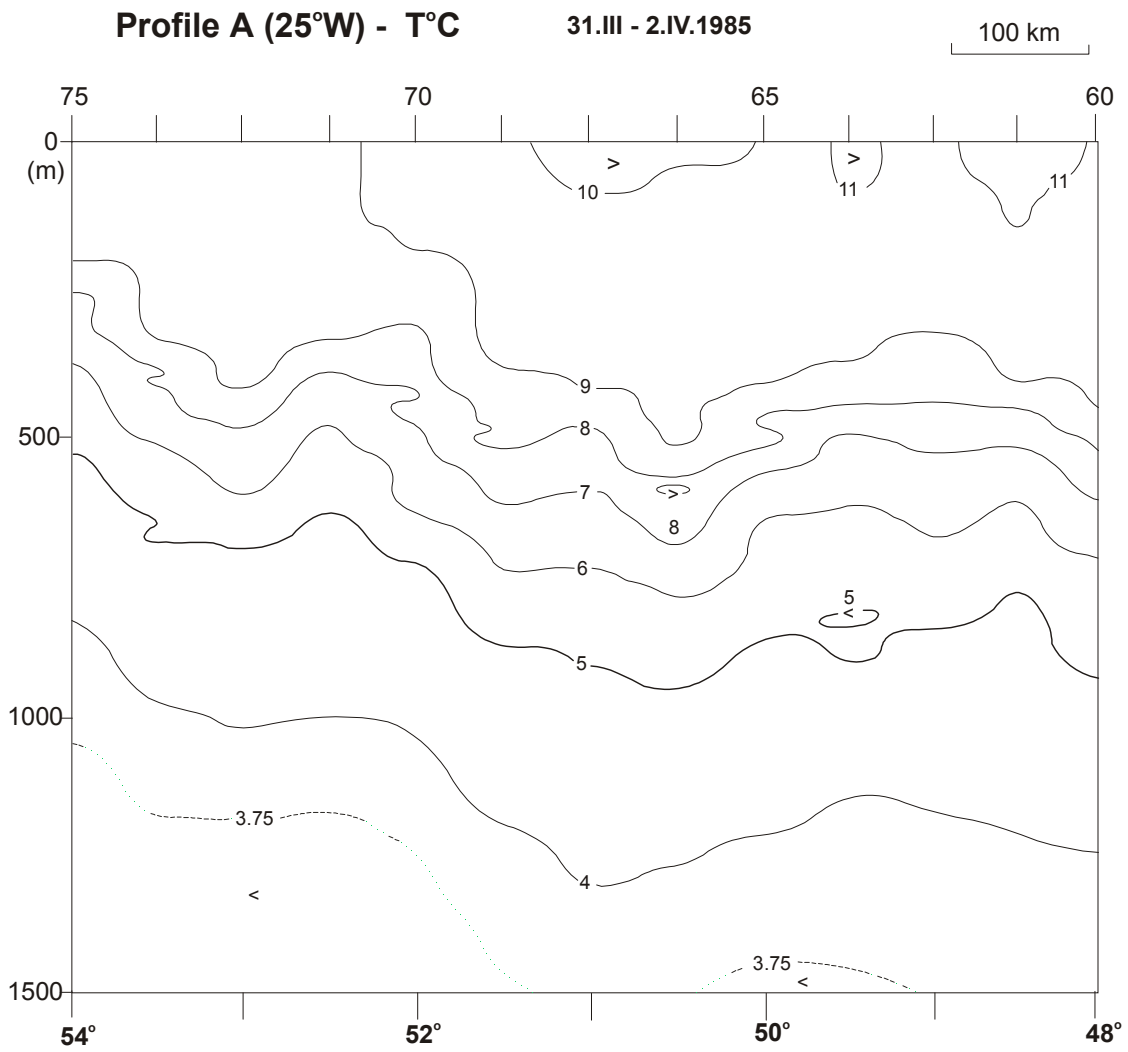


Fig. 17 Temperature profile A (refer to the Fig. 3) in the northern Mid-Atlantic Ridge

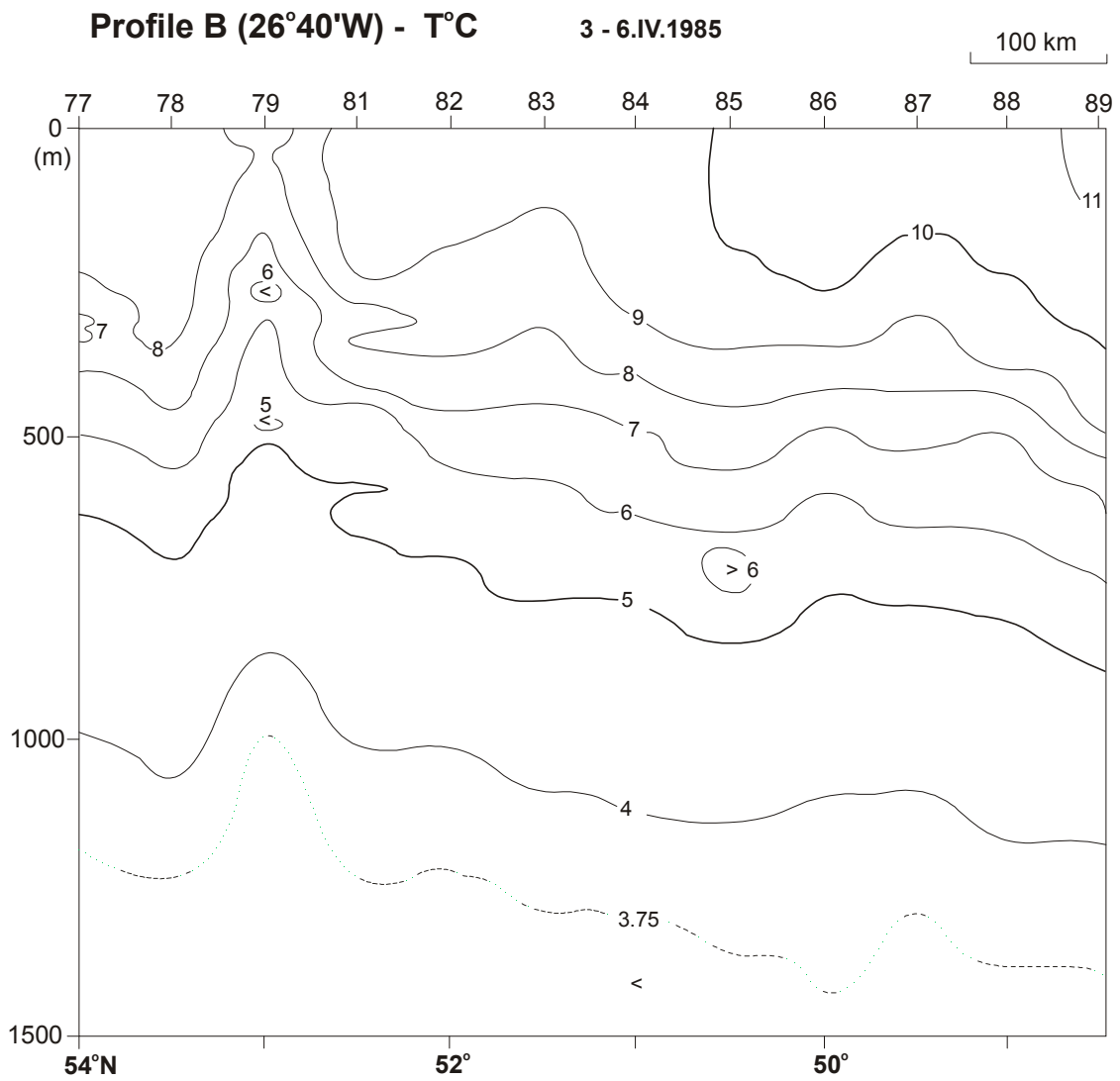


Fig. 18 Temperature profile B (refer to the Fig. 3) in the northern Mid-Atlantic Ridge

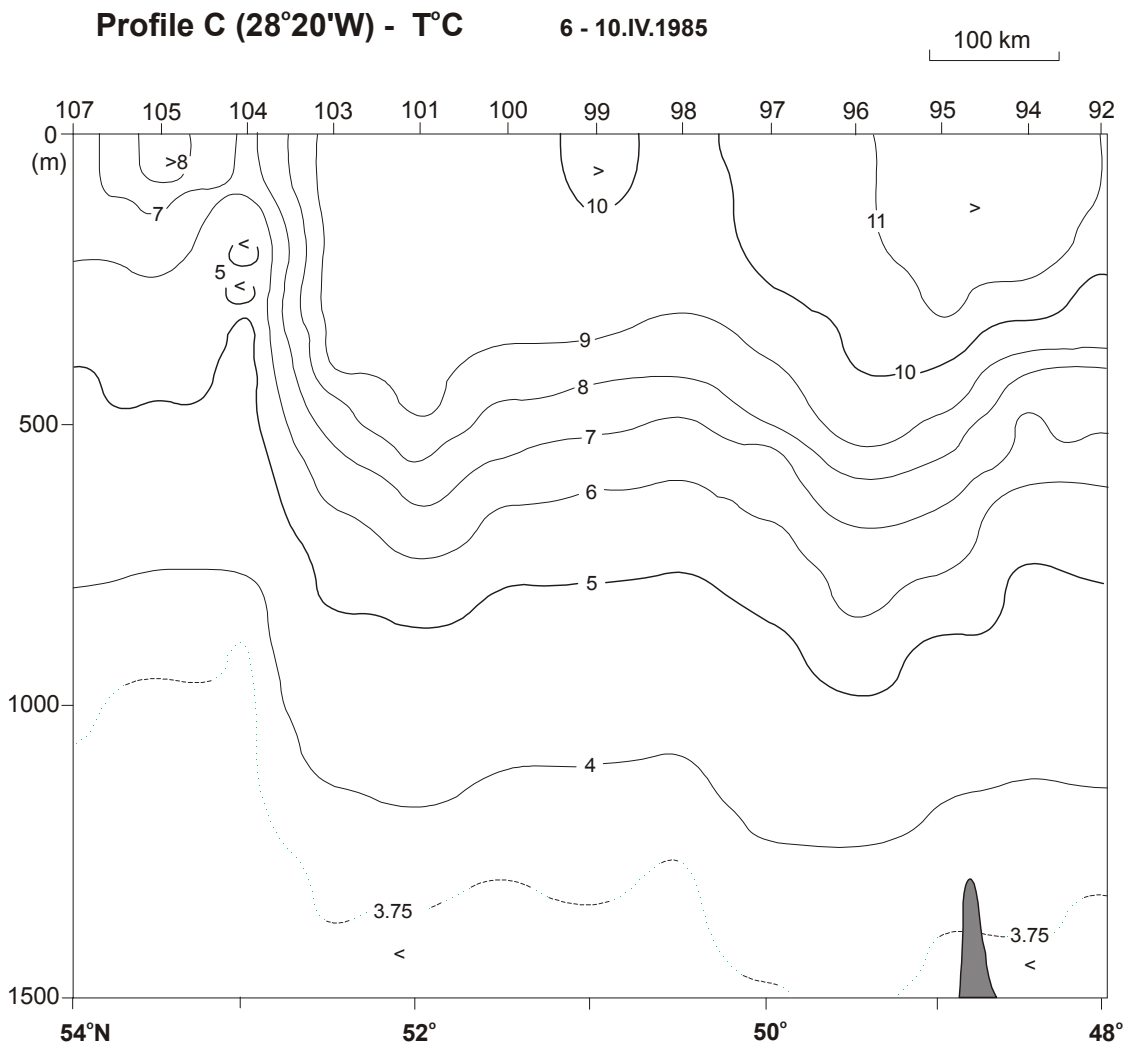


Fig. 19 Temperature profile C (refer to the Fig. 3) in the northern Mid-Atlantic Ridge

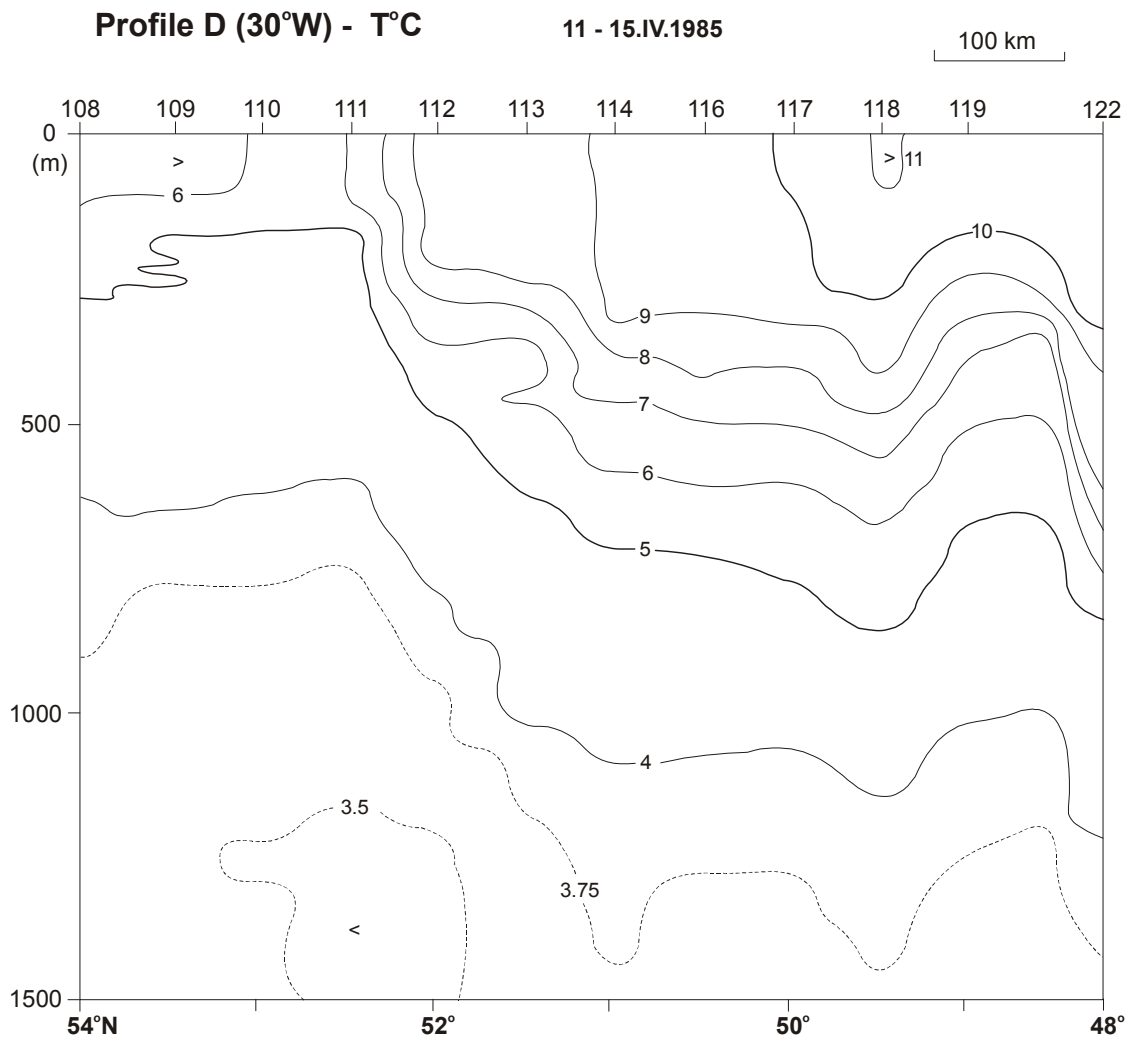


Fig. 20 Temperature profile D (refer to the Fig. 3) in the northern Mid-Atlantic Ridge

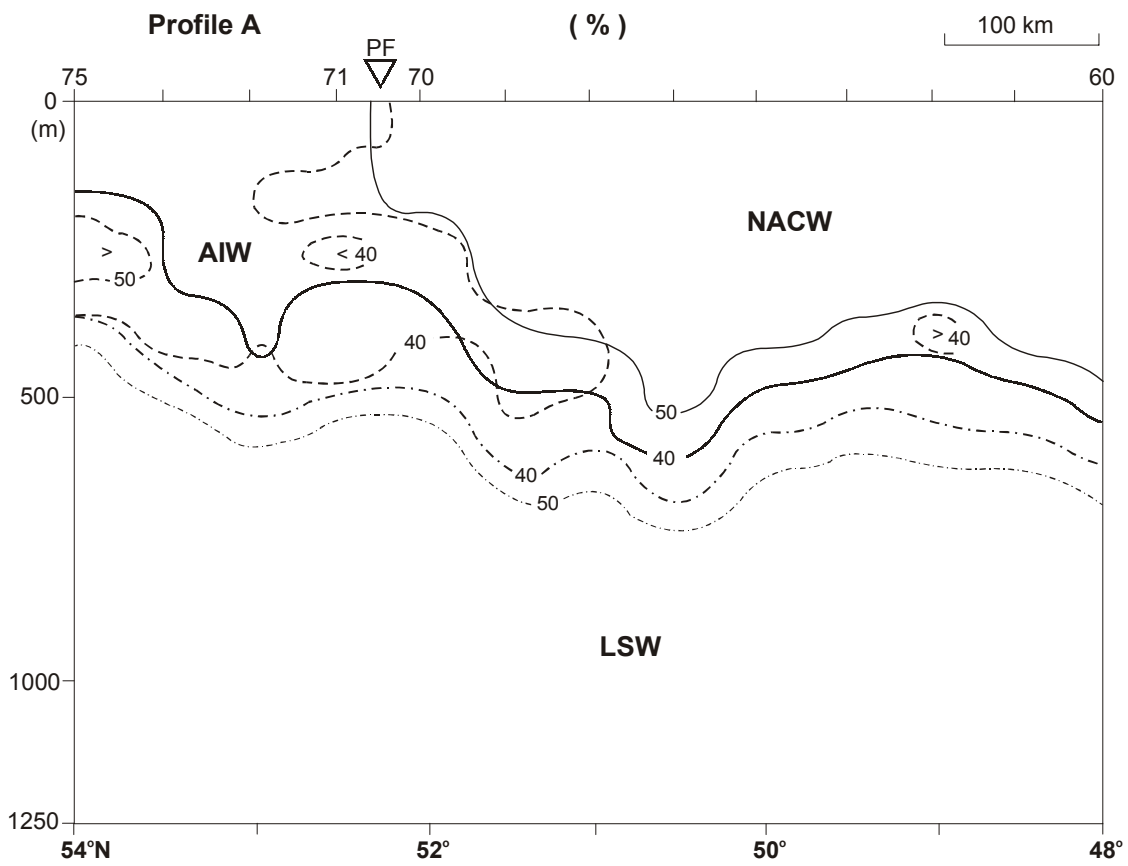


Fig. 21 Distribution of the three water masses over the northern Mid-Atlantic Ridge on profile A (refer to the Fig. 3)

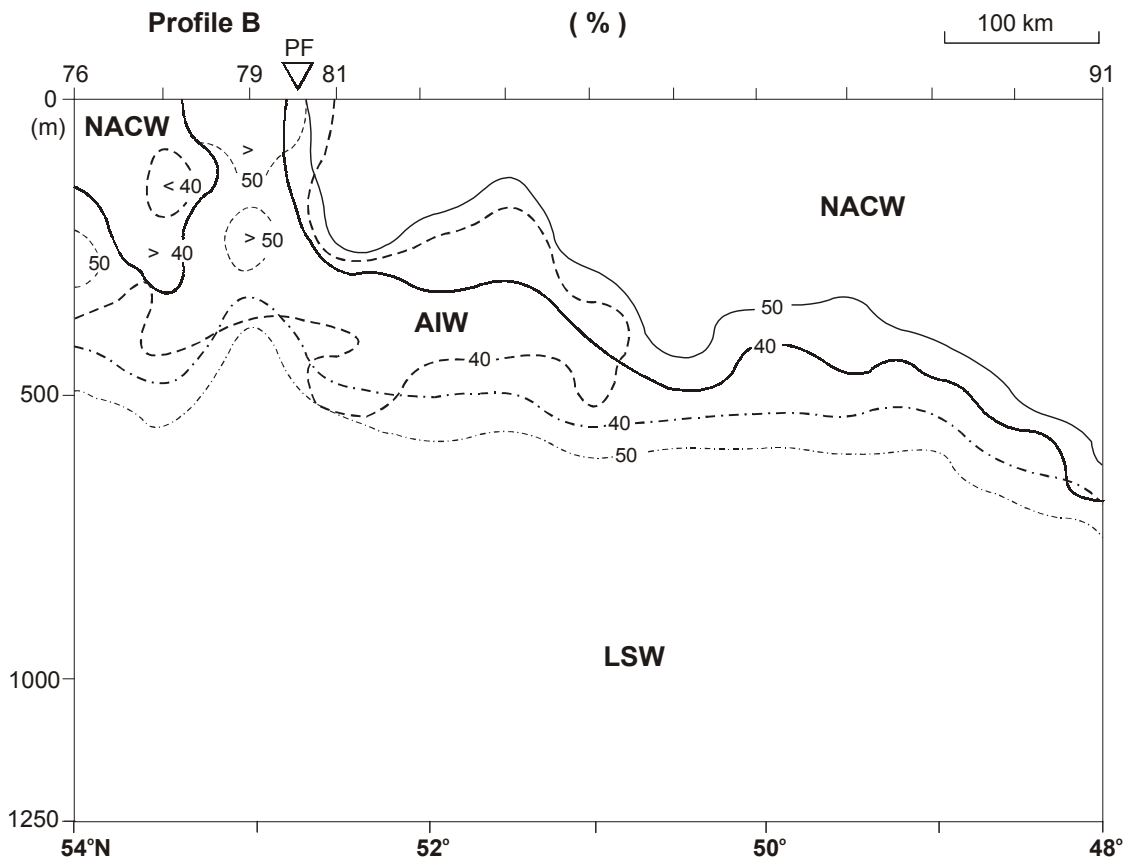


Fig. 22 Distribution of the three water masses over the northern Mid-Atlantic Ridge on profile B (refer to the Fig. 3)

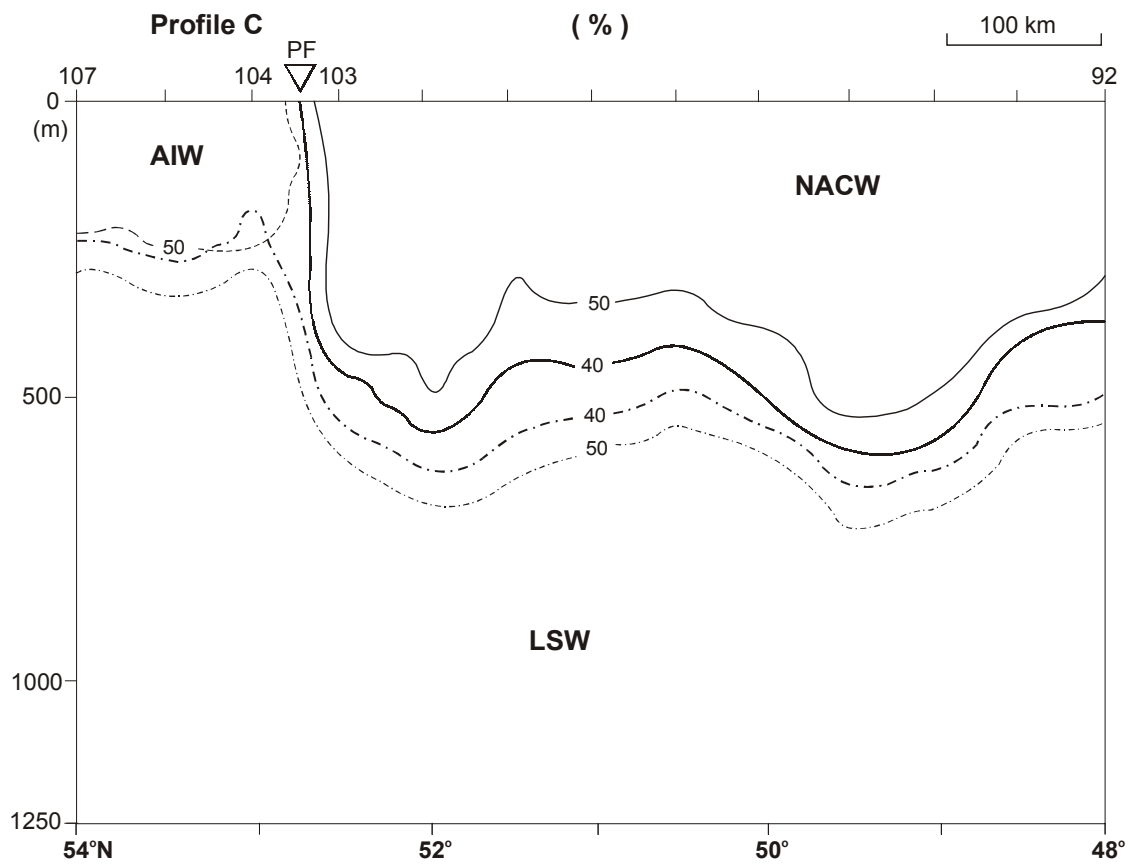


Fig. 23 Distribution of the three water masses over the northern Mid-Atlantic Ridge on profile C (refer to the Fig. 3)

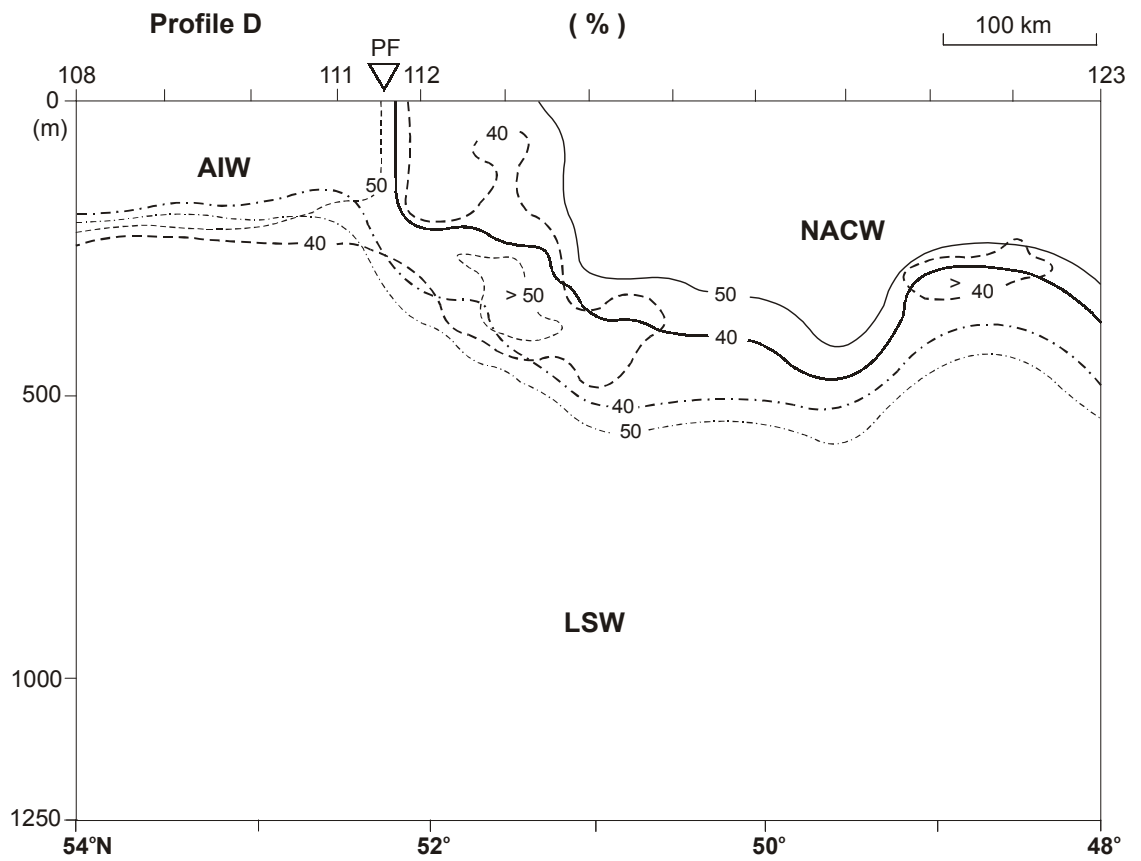


Fig. 24 Distribution of the three water masses over the northern Mid-Atlantic Ridge on profile D (refer to the Fig. 3)

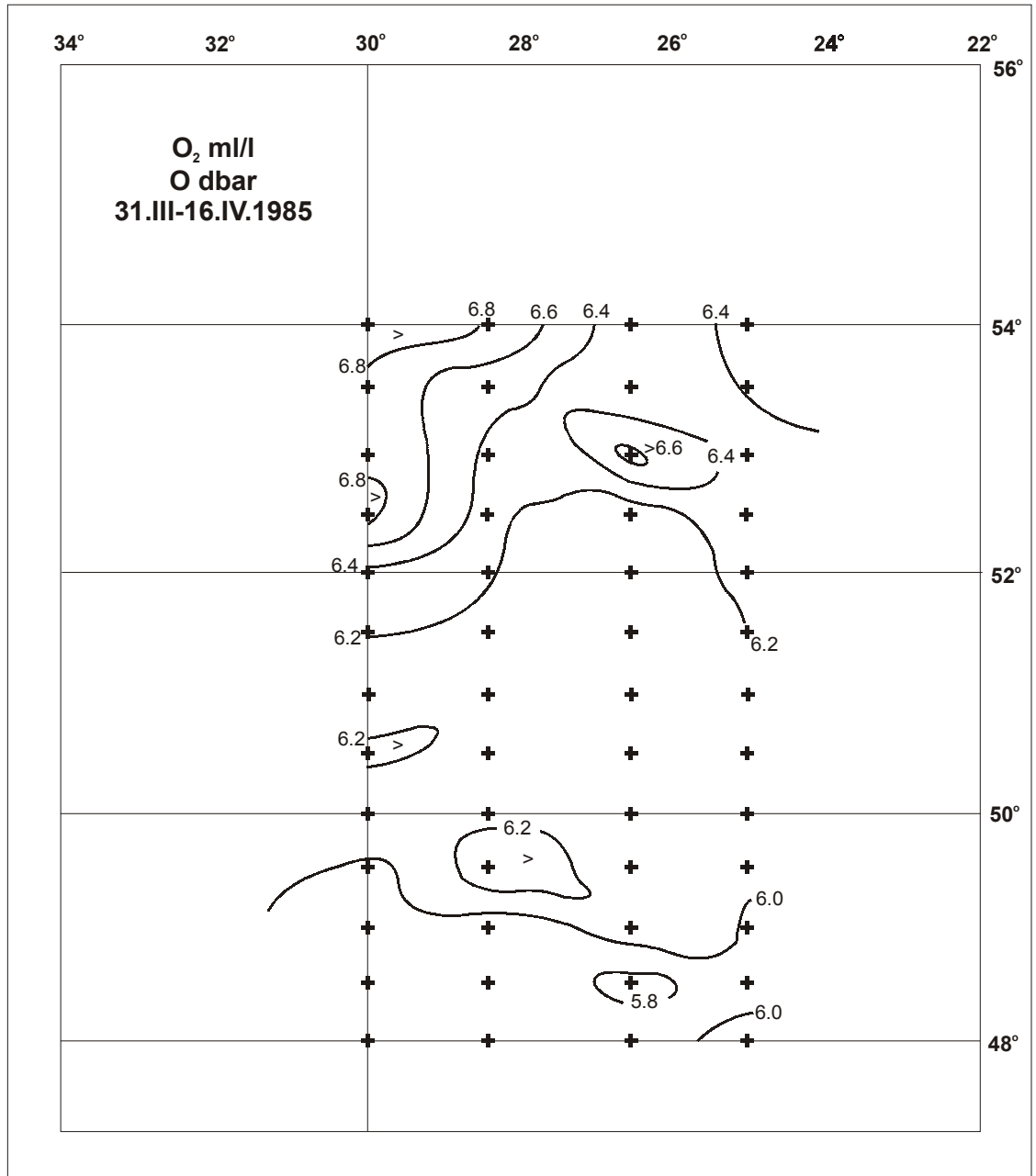


Fig. 25 Oxygen distribution on 0 dbar level over the northern Mid-Atlantic Ridge

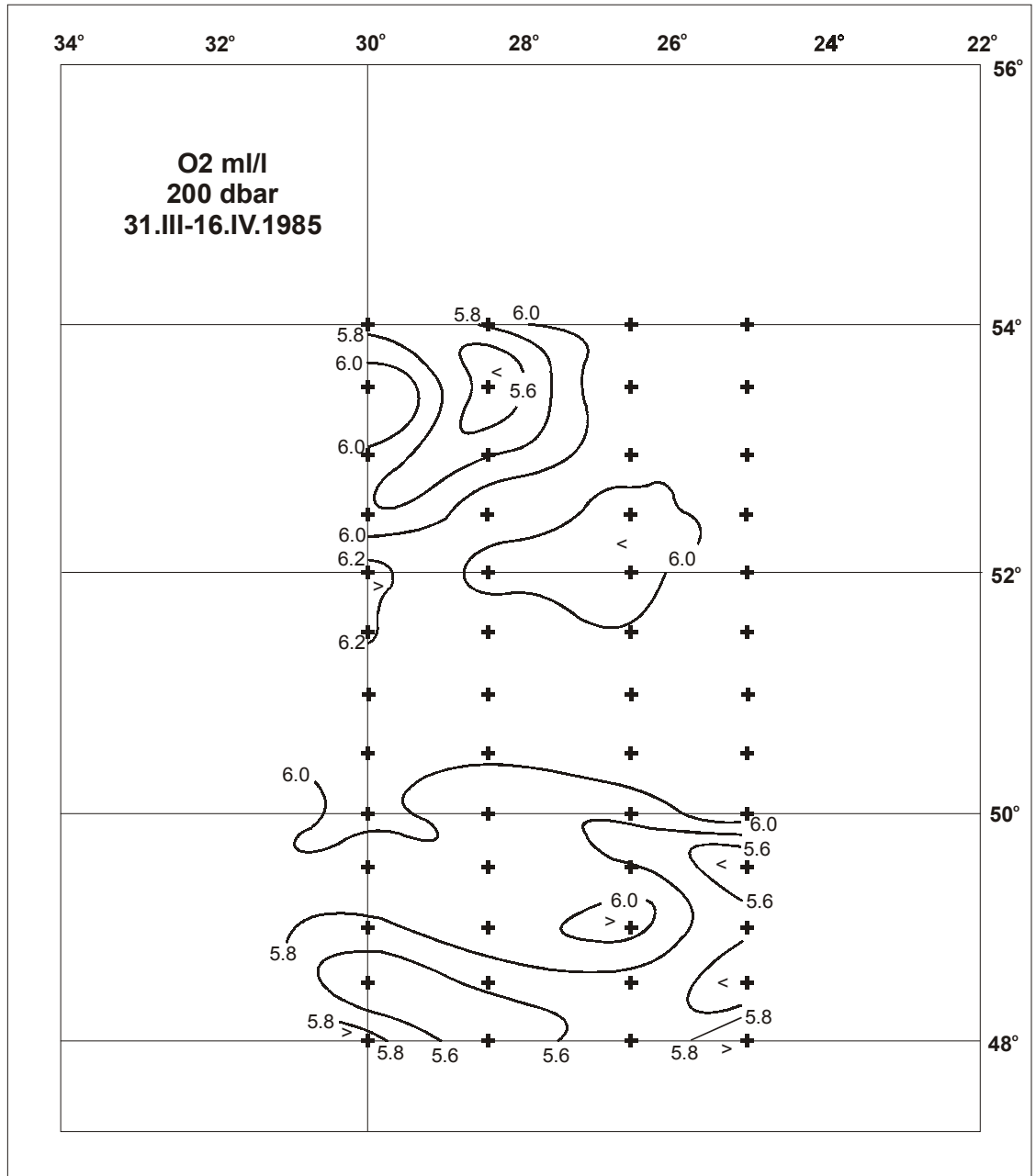


Fig. 26 Oxygen distribution on 200 dbar level over the northern Mid-Atlantic Ridge.