ICES CM 2002/M:09

Deep scattering layer over Reykjanes Ridge and in the Irminger Sea.

by

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Abstract

In recent years, Iceland has conducted several trawl-acoustic surveys in the Irminger Sea and adjacent waters. The target species for the investigations has been pelagic redfish (*Sebastes mentella*), but all specimens caught in the "Gloria type" trawl used (40 mm codend) have been measured and/or counted. In addition to the redfish, the catch has consisted of numerous species of fishes with a modal length between 10 and 20 cm. In all the surveys, an extensive deep-scattering layer has been observed, mostly in depth between 300-800 m from the surface. In this paper, we show distribution and composition of the deep-scattering layer, based on combined information since 1996. Excluding the redfish, Myctophidae are the most common family of fish that are caught, most common species are *Lampanyctus macdonaldi, Notoscopelus kroeyeri, Lampadena speculigera*, *Benthosema glaciale* and *Myctophum punctatum*. Other common families (most common species in parenthesis) are Bathylagidae (*Bathylagus euryops*), Stomiidae (*Chauliodus sloani*, *Stomias boa ferox, Borostomias antarcticus*), Serrivomeridae (*Serrivomer beani*), Melamphaeidae (*Scopelogadus beanii, Poromitra crassiceps*), Platytroctidae (*Normichthys operosus*, *Holtbyrnia macrops*, *Holtbyrnia anomala*, *Searsia koefoedi*).

Key words: Scattering layer, Irminger Sea, midwater species, food web.

Introduction

In the Irminger Sea and adjacent waters an extensive deep-scattering layer has been observed (Magnússon et al., 1992a, b, Magnússon et al., 1994, Magnússon 1996, Magnússon et al., 1996, Sigurdsson et al., 1999, Gíslason, 2002). This layer can be described as more or less continuously distributed throughout the same area as has been investigated for pelagic redfish. In recent years, the Marine Research Institute in Reykjavík has conducted several trawl-acoustic surveys in this area aiming at redfish, often in co-operation with other institutes. The target species for these investigations has been pelagic redfish (*Sebastes mentella*), but all specimens of other fishes caught have been measured and/or counted. In the surveys, increased attention has been paid to the deep-scattering layer, which is found in very extensive area from the Reykjanes Ridge in east, to the continental shelf of Greenland and Canada in west and from the continental shelf of Iceland in the north. The south border of the distribution has not been found in these surveys mentioned above.

Scattering layers have been dealt with by many authors in various areas. Most of the studies are on zooplankton distribution and vertical movements and/or technical aspects (Magnússon, 1996). The deep scattering layer in the Irminger Sea was studied by Magnússon (1996), using information obtained during O-group surveys in 1993-1995 and information from redfish surveys in 1991-1995. He studied mostly the area north of 60°N and only few samples were collected south of 60°N. He describes a continuos distribution of a deep-scattering layer throughout the study area in the Irminger Sea and adjacent waters, occurring in various intensities and at depths of about 400-500 m and down to 700-800 m; from the continental shelves of Greenland and Iceland and to south of the investigation area. Further, he describes that the abundance varies between years and that main concentrations were observed more or less along the continental shelves with lesser densities in the centre of the Irminger Sea. In the investigation, hauls were not conducted deeper than about 600 m. Over 60 different species or groups were observed. The most common group of organisms in the deep-scattering layer were Myctophidae (8 different species), but of species, viperfish (*Chauliodus sloani* Schneider, 1801) was the most common one. As the trawl used did have relatively large mesh size in the cod-end, Magnússon assumed that small organisms such as small crustaceans, which are not caught in the trawl used, probably form the greater part of the deep-scattering layer. Of 196 species identified from the Subarctic Pacific gyres (species from the Bering Sea and the Sea of Okhotsh included) the most abundant species also did belong to the family Myctophidae (Beamish et al., 1999). Investigations by Gíslason (2002) confirm large quantity of zooplankton in the scattering layer in the northern part of the Irminger Sea, and the area is also considered to be an important wintering area for zooplankton (Gíslason & Assthorsson, 2000)

In this paper we describe the results of analyses of surveys conducted in June- July 1996, 1999 and 2001. The main purpose of the surveys were, as mentioned above, to measure abundance of pelagic redfish (*Sebastes mentella)* and those surveys have been conducted at that time of the year since early 1990's. These surveys, as well as numerous surveys conducted in the time period from September to March, have shown that June and July is the most appropriate time to conduct an acoustic survey. At that time of the year the scattering layer is not as mixed with the redfish as seems to be the case for the rest of the year.

The investigation area is from the eastern side of the Reykjanes Ridge in the Iceland Basin westwards into the Irminger Sea, the eastern and central parts of the Labrador Sea south to 51°N. The oceanographic conditions of the area depend on cyclone current, called Subpolar Gyre (Dickson *et al.*, 1988) bound to the basins involved - Irminger and Labrador Seas. This current system includes the "warm" Irminger Current along the Reykjanes Ridge and west of Iceland around the Irminger Sea, the cold East and West Greenland Currents along Greenland, the cold Labrador Current in the western part of the Labrador Sea along the Canadian coast, and at last the southern boundary of the overall current system at the "warm" northern boundaries of the North Atlantic (Bersch *et al.,* 1999).

Material and methods

All the surveys were carried out in late June – early July in 1996, 1999 and 2001. The primary material consists of biological and acoustic data collected in the Irminger Sea. The main purpose of the surveys

was to obtain abundance estimate of redfish in the Irminger Sea and adjacent waters and therefore the survey strategy and sampling was not aimed for collecting detailed information on the scattering layer.

The surveys in 1996 and 1999 were carried out by the research vessel Bjarni Sæmundsson but in 2001 both r/v Bjarni Sæmundsson and r/v Árni Friðriksson were used. In addition, information on acoustic data from German r/v Walther Herwig III and Russian r/v Atlantniro were used for drawing Figure 2. Geographical locations of trawl stations are shown in Figure 1 and more detailed information given in Table 1. A total of 142 station were taken during these 3 years, the trawling strategy was as follows:

- At depth less than 500 m from surface, in which redfish could be acoustically identified, the trawling depth varied from about 150 m down to about 450 m (depth of the headline of the trawl). Therefore it did vary whether the trawl was filtering above or inside the scattering layer. The trawling distance varied between 2.8 and 16.6 nautical miles (Table 1). In this depth category a total of 52 tows were carried out.

- At depths more than 500 m from surface, each trawl haul consisted of 3 different depth intervals (headline depth): 500-650 m, 650-800 m, 800-950 m. Trawling distance at each depth layer was about 2 nautical miles calculated with GPS, and hence the total trawling distance was usually over 6 n.m., but ranged from 2.1 to 15.0 n.m. (Table 1). A total of 90 tows were carried out at depths below 500 m.

The net used on r/v Bjarni Sæmundsson was Gloria type #896 midwater trawl (maximum circumference of about 900 m) with a vertical opening of approximately 45 m, but on r/v Árni Friðriksson, Gloria type #1024 trawl (maximum circumference of about 1020 m) was used with similar vertical opening. The cod-end was lined with fine-meshed (40 mm) net. Both trawls had a very large mesh-size in the front end of the trawl with a maximum size of 32 m (stretched).

After each haul, the catches were sorted and all fishes were identified to species whenever possible. A small sub-sample was taken for each fish species for length measurements (total length to the nearest cm) and total number of each species was registered. Invertebrates were not systematically identified.

In the analysis of species composition in the research area, distribution of the species and length distributions, data from all three surveys were compiled.

The acoustic data was obtained during ICES coordinated surveys for pelagic redfish (ICES C.M. 1996, ICES C.M. 1999, ICES CM 2002). The data used are from the Icelandic part of the surveys in 2001, along with information from German and Russian vessels. Acoustic data was collected by means of a 38 kHz SIMRAD EK 500 split beam echo sounder and a BI500 post-processing system (Bodholt et al., 1989, Foote et al., 1991). In the surveys over 400 000 square nautical miles were covered within the boundaries of about 52°N-64°N and between 20°W and 54°W. During the surveys the post-processing systems were used for scrutinising the echograms. Mean intergrated values of redfish and of the "scattering layer" were recorded for each 5 n.m. and the values obtained from that were used for preparing figure 2.

Results

Acoustic results

Example of echogram taken from the BI-500 post-processing system is shown in figure 2 and generalised overview of the distribution of the deep-scattering obtained with the acoustic instruments is shown on figure 3. As seen, the deep scattering layer has quite wide distribution both horizontally as well as vertically. The thickness of the scattering layer was more during dark hours as some part of the layer showed vertical migration throughout the day. The acoustic values (S_A values m^2/nm^2) can not be converted over to biomass as the actual species composition in the layer, as well as associated back scattering coefficients, are not known.

List of species

A total of 99 species of fish from 43 families were identified from the samples taken in the research area (Table 2). Four families accounted for 35% of the species: Myctophidae (11 species), Stomiidae (9 species), Platytroctidae (8 species) and Sternoptychidae (7 species).

Frequency of occurrence of species and distribution in the research area

A total of 25 species occurred in more than 10 % of all tows. These 25 species can be divided into 5 groups, depending on the distribution within the research area.

Group 1, most common species, distributed over the whole of the area (Figure 4):

Seven species occurred in over 50% of all tows and in over 80% of tows taken below 500 m depth (Table 3). These seven species (*Chauliodus sloani, Lampanyctus macdonaldi, Notoscopelus kroeyeri, Serrivomer beani, Bathylagus euryops, Borostomis antarcticus* and *Lampadena speculigera*) are distributed relatively uniformly throughout the area, although differing in quantity. All these species had a considerably higher occurrence and abundance below 500 m depth than above.

Group 2, less common species, distributed more or less over the area (Figure 5):

Each species of this group was found in 10-50% of all tows. Five species (*Malacosteus niger, Benthosema glacialis, Scopelogadus beanii, Nemichthys scolopaceus* and *Anoplogaster cornuta*) showed no pattern in distribution, but were found in approximately equal quantities in tows from all parts of the area. These species had a higher occurrence and abundance in waters below 500 m depth, except *Benthosema glacialis*, which was equally abundant in waters above 500 m as below.

Group 3, rare or absent from centre of research area (Figure 6):

Each species of this group was found in 10-40% of all tows. The seven species assigned to this group were mostly found along the edges of the research area, but were rare or absent in the centre. Typically, they had highest frequency of occurrence and abundance in tows taken above or close to the Reykjanes Ridge. Three species of Platytroctidae (*Normichthys operosus, Holtbyrnia anomala,* and *H. macrops*) as well as *Argyropelecus olfersi* and *Poromitra crassiceps* show this type of distribution. Also assigned to this group were *Lampanyctus crocodilus* and *Platyberyx opalescens*. All these species had a considerably higher occurrence and abundance below 500 m depth than above.

Group 4, species with northerly distribution (Figure 7):

Each species of this group was found in 10-50% of all tows, except *Micromesistius poutassou* in 4%. Four *species (Stomias boa ferox, Xenodermichthys copei, Arctozenus rissoi* and *Nansenia groenlandica*) were mostly found north off 60°N, although present at the southern part. *Micromesistius poutassou* was only found at the northeastern part of the research area.

Group 5, species with southerly distribution (Figure 7):

One species, *Myctophum punctatum*, was almost exclusively found south off 60°N.

Abundance

The most abundant species at depth below 500 m depth was *Lampanyctus macdonaldi* followed by *Bathylagus euryops, Chauliodus sloani, Notoscopelus kroeyeri* and *Serrivomer beani*, the average number caught in a towed mile ranging from 8.9-54.4 (Table 3). All these species occurred in over 80% of tows taken at those depths. Less abundant, ranging from 1.3-5.8 fish in a towed mile, were *Stomias boa ferox, Benthosema glaciale, Lampadena speculigera, Poromitra crassiceps, Scopelogadus beanii, Borostomias antarcticus* and *Myctophum punctatum*, listed in order of abundance. Abundance of other species at depths exceeding 500 m is less than one fish in a towed mile.

At depths less than 500 m, *Notoscopelus kroeyeri* was the most abundant species (6.1 fish/nautical mile), followed by *Benthosema glacialis* (4.7 fish/nautical mile), *Chauliodus sloani* (3.7 fish/nautical mile) and *Myctophum punctatum* (2.8 fish/nautical mile). Two of these species (*Benthosema glacialis* and *Myctophum punctatum*) were as abundant above as below 500 m depth. Abundance of other species in depths less than 500 m was less than one fish in a towed mile.

Length distribution

Length distribution of most common fish species is presented in Figure 8. *Chauliodus sloani* ranged in length from 11 to 33 cm, with mean length of 22.2 cm. Two species of family Myctophidae, *Lampanyctus macdonaldi* and *Notoscopelus kroeyeri*, had a resembling length distributions with mean length of 13.9 and 13.2 respectively. From the same family, *Lampadena speculigera* had average

length of 11.7 cm and *Benthosema glaciale* 6.7 cm. Length distribution of *Serrivomer beani* ranged from 27 to 83 cm, average length was 57.3 cm. *Bathylagus euryops* ranged in length from 8 to 21 cm, with average of 15.3 cm. Of tree species of family Stomiidae, *Borostomias antarcticus* was largest (average length 23.4 cm), followed by *Malacosteus niger* (19.1 cm) and *Stomias boa ferox* (15.9 cm). Two species of family Melamphaeidae, *Scopelogadus beanii* and *Poromitra crassiceps*, had a resembling length distributions with mean length of 9.7 and 9.8 cm, respectively.

Discussion

The dominating family in the fish community of the research area is Myctophidae. Of the 25 most common species in terms of frequency, 6 belong to that family: *Lampanyctus macdonaldi, Notoscopelus kroeyeri, Lampadena speculigera, Benthosema glaciale, Lampanyctus crocodilus* and *Myctophum punctatum.* In addition to these, there were five less common species of that family. As a group, Myctophidae accounted for 44% of the number of fish found below 500 m depth and 65% of fish found above that depth and had highest frequency at both depth strata (Table 4).

This dominance of Myctophidae in this area was also noted by Magnússon (1996), who identified 8 of the 11 Myctophidae species found here. However, he only identified them, no information on occurrence or abundance of individual species were presented.

The Myctophidae *Protomyctophum arcticum* was only identified from one tow. Magnússon (1996) caught *P. arcticum* by a trawl of much smaller mesh size than used in present study. Mesh size in the codend of the trawl used in our investigations was 40 mm and, consequently, the estimated relative abundance of fish species caught could be biased. Small fish species are most likely underestimated compared to larger ones due to this relative large mesh size used. It is even possible that, although present in the area, the smallest species are not caught at all. The mesh size also affects the length distribution of the species as measured from the trawl.

Species of Group 3 do show what could be described as affiliation with the immediate area above the Reykjanes Ridge. In this group are 3 species of Platytroctidae but only one Myctophidae. As seen on Figure 3, the deep scattering layer is most dense above Reykjanes Ridge. Although the faunal composition of this deep scattering layer is poorly known, its distribution suggests a biological richness over the Reykjanes Ridge. This richness is to some extent reflected in its fish fauna. In this research, no trial was made to estimate to what extent fish is responsible for the echoes seen on the echograms (Figure 2) of the deep scattering layer or what other species were involved.

Most of the species were caught below 500 m depth and most of the species had highest concentration there, although being found also closer to the surface. It is evident that there is difference between species in vertical distribution, as species such as *Benthosema glacialis* and *Myctophum punctatum* were as abundant above as below the 500 m depth. However, in view of the trawling strategy used in this research, direct comparison of species abundance between tows taken in these two depth categories cannot be made.

Although the fish community in the research area is particularly characterized by the species listed in the 5 distribution groups, there are some large predators that only were caught in low number, but could be an important part of this community. This includes species such as *Ceratias holboelli, Cryptopsaras couesi, Anotopterus pharao* and *Anarhichas denticulatus*, all of which were found sporadically throughout the area. Also included in this group of large predators are species of the families Himantolopidae, Oneirodidae and Linophrynidae.

During acoustic surveys, a cloud (scattering layer) of different thickness and shape have been observed in the research area (Reynisson, *et.al*, 1995 (ICES CM 1995, ICES C.M. 1996; ICES C.M. 1999, ICES C.M. 2002). Diurnal migration of the scattering layer in this area has also been observed and is correlated with time of the day (Reynisson *et. al*, 1995, Magnússon 1996 .)

These diurnal migrations were also observed in the data presented here. However, as the purpose of the surveys have not been to observe the scattering layer, tows have not been taken to investigate if there are any particular groups of organisms that are showing these vertical movements. Magnússon (1996) concluded that the deep-scattering layer probably consist of several sub-layers as has been observed in zooplankton communities.

Alhough fish species are the most frequent organisms in the hauls, it can not be excluded that small crustaceans form a great part of the layer as well. The gear used do however, not catch small crustaceans.

Aknowledgements

The authors wish to thank everyone who has been involved in this work and have made it possible. Special thanks to PINRO, Russia and to Federal Research Centre for Fisheries Institute for Sea Fisheries in Germany for giving access to acoustic data on the scattering layer. The surveys have been partly founded by the REDFISH project (QLK5-CT1999-01222), financially supported by the European Commission within the research framework QUALITY OF LIFE AND MANAGEMENT OF LIVING RESOURCES, Key Action 5: Sustainable Agriculture, Fisheries and Forestry.

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Table 1. List of trawling stations taken during redfish survey in Irminger Sea in June/July 1996, 1999 and 2001. Cruise identification number, date, time of day at beginning of tow (GMT), station number within the cruise i.d. number, position at beginning of tow (lat =°N, lon = °W), bottom depth, trawling depth, trawling distance and depth category (type) of station.

Cruise	date	Time	Station no.	Position		Bottom depth (m)	Trawling depth (m)		trawling distnce (n.m.)	Type
				lat	lon		start	end		
B6-96	21.6.1996	12.5	366	62.0	-37.5	2280	306	280	6.4	SHALLOW
B6-96	22.6.1996	4.3	370	61.3	-35.7		200	240	3.4	SHALLOW
B6-96	22.6.1996	13.8	372	61.3	-38.4		650	677	4.5	DEEP
B6-96	23.6.1996	6.2	375	60.5	-40.5		250	200	4	SHALLOW
B6-96	24.6.1996	0.5	380	60.4	-36.1		700	703	6.4	DEEP
B6-96	24.6.1996	4.8	381	60.3	-36.4		200	180	2.8	SHALLOW
B6-96	26.6.1996	3.2	385	60.0	-38.7		590	634	6.4	DEEP
B6-96	27.6.1996	6.2	391	59.5	-41.8		260	200	5.2	SHALLOW
B6-96	28.6.1996	1.9	396	59.2	-39.8		200	200	3.4	SHALLOW
B6-96	28.6.1996	23.0	401	59.0	-40.5		200	220	4.3	SHALLOW
B6-96	1.7.1996	1.8	412	58.5	-39.7		690	565	10.5	DEEP
B6-96	2.7.1996	5.0	419	58.0	-42.2		220	220	4	SHALLOW
B6-96	2.7.1996	22.3	424	57.4	-46.0		200	225	6.5	SHALLOW
B6-96	4.7.1996	1.5	431	56.9	-40.5		220	220	7	SHALLOW
B6-96	5.7.1996	2.3	438	56.1	-46.0		240	250	12.2	SHALLOW
B6-96	5.7.1996	23.5	443	55.7	-41.1		200	210	16.6	SHALLOW
B6-96	7.7.1996	9.8	449	59.0	-35.0		800	750	8.9	DEEP
B6-96	7.7.1996	16.9	450	59.4	-34.2		250	210	11	SHALLOW
B6-96	8.7.1996	10.4	454	61.0	-31.8		210	270	8.3	SHALLOW
B6-96	9.7.1996	11.3	460	63.1	-25.2		645	535	8	DEEP
B6-96	9.7.1996	15.0	461	63.1	-25.2		571	560	8	DEEP
B9-99	20.6.1999	11.3	390	62.5	-29.0	1617	550	760	6.8	DEEP
B9-99	20.6.1999	23.6	392	59.5	-31.0		320	335	3	SHALLOW
B9-99	21.6.1999	0.1	398	60.0	-35.1		270	300	3.3	SHALLOW
B9-99	21.6.1999	4.7	394	59.5	-31.8	1630	550	750	6	DEEP
B9-99	21.6.1999	16.3	396	59.6	-34.1		500	750	6.1	DEEP
B9-99	22.6.1999	9.3	403	60.2	-39.1		464	750	6.1	DEEP
B9-99	22.6.1999	11.8	400	60.3	-36.3		500	735	6	DEEP
B9-99	23.6.1999	4.1	407	60.9	-40.6	2280	550	750	6	DEEP
B9-99	23.6.1999	15.6	405	60.3	-39.8		290	413	3	SHALLOW
B9-99	24.6.1999	15.8	409	61.0	-37.7		550	750	6.2	DEEP
B9-99	24.6.1999	23.4	411	61.0	-36.4		210	220	6.6	SHALLOW
B9-99	25.6.1999	0.8	416	61.0	-32.3	2400	510	750	6.2	DEEP
B9-99	25.6.1999	7.2	413	60.9	-34.9	3000	550	750	6.2	DEEP
B9-99	26.6.1999	7.2	418	61.0	-31.3	2400	300	310	3.1	SHALLOW
B9-99	26.6.1999	15.3	420	61.0	-29.4	1450	550	750	6.2	DEEP
B9-99	27.6.1999	7.4	423	61.8	-27.8	1461	550	750	6.1	DEEP
B9-99	27.6.1999	21.0	426	61.9	-30.3		720	740	8.5	DEEP
B9-99	28.6.1999	5.0	429	61.7	-31.0	2297	550	750	6.2	DEEP
B9-99	28.6.1999	12.6	431	61.7	-32.5	2600	250	275	6	SHALLOW
B9-99	28.6.1999	19.3	433	61.8	-33.9		550	750	6.2	DEEP
B9-99	29.6.1999	6.4	436	61.7	-36.8	2672	550	770	6.2	DEEP
B9-99	29.6.1999	18.1	439	61.8	-39.9		550	750	6.2	DEEP
B9-99	30.6.1999	6.7	442	62.5	-38.7	2195	550	750	6.2	DEEP
B9-99	30.6.1999	16.5	443	62.5	-36.3		270	290	9	SHALLOW
B9-99	1.7.1999	0.0	445	62.5	-35.0		520	750	6.2	DEEP
B9-99	1.7.1999	6.0	447	62.5	-34.3	2785	230	230	7.4	SHALLOW
B9-99	1.7.1999	16.0	449	62.5	-31.8		550	800	6.2	DEEP
B9-99	1.7.1999	23.6	452	62.4	-30.6		640	850	6	DEEP
B9-99	2.7.1999	9.9	454	62.5	-28.4		500	800	6.2	DEEP
B9-99	2.7.1999	19.5	457	62.6	-26.5		550	770	6.2	DEEP
B9-99	3.7.1999	7.0	459	63.2	-28.1	1719	550	808	6.2	DEEP
B9-99	3.7.1999	16.7	461	63.3	-30.6	2480	550	750	6.2	DEEP
B9-99	4.7.1999	5.4	464	63.2	-33.8	2753	550	770	6.2	DEEP
B9-99	4.7.1999	11.3	465	63.3	-34.8		293	310	8.2	SHALLOW
B9-99	4.7.1999	21.5	467	63.2	-36.9	2500	500	750	6.2	DEEP
B9-99	5.7.1999	8.1	470	63.3	-39.4	1533	500	800	6.3	DEEP
B9-99	5.7.1999	23.1	472	64.0	-35.8		550	750	6.2	DEEP
B9-99	6.7.1999	9.1	474	64.0	-33.6		475	750	6.2	DEEP
B9-99	6.7.1999	21.2	477	64.9	-31.9		550	770	6.2	DEEP
B9-99	7.7.1999	4.2	482	64.0	-30.3	2409	550	780	6.2	DEEP
B9-99	7.7.1999	8.9	480	64.7	-30.3		550	760	6.2	DEEP
B9-99	8.7.1999	15.3	483	64.0	-27.9		550	790	6.2	DEEP
B8-2001	20.6.2001	20.1	259	61.7	-27.5		550	700	6	DEEP
B8-2001	21.6.2001	20.1	262	59.5	-31.4	1606	550	784	6	DEEP
B8-2001	21.6.2001	23.9	268	59.5	-37.6		550	770	6	DEEP
B8-2001	22.6.2001	7.5	264	59.5	-33.9		550	760	6	DEEP
B8-2001	22.6.2001	20.6	266	59.5	-37.3		225	220	3	SHALLOW

Cruise	date	Time	Station no.	Position		Bottom depth (m)	Trawling depth (m)		trawling distnce (n.m.)	Type
				lat	lon		start	end		
A8-2001	22.6.2001	21.5	274	62.3	-28.1	1516	700	850	2.1	DEEP
B8-2001	23.6.2001	10.9	269	59.5	-40.3		550	850	6	DEEP
B8-2001	24.6.2001	5.2	272	59.9	-41.9	1757	500	700	6	DEEP
A8-2001	24.6.2001	9.3	277	62.5	-26.0	780	300	450	4.4	SHALLOW
A8-2001	24.6.2001	15.5	278	62.5	-24.6	1183	550	850	5.9	DEEP
B8-2001	24.6.2001	21.7	274	60.3	-39.0	2500	500	800	6	DEEP
A8-2001	24.6.2001	22.5	275	62.4	-28.2	1555	550	640	12	DEEP
B8-2001	25.6.2001	2.0	275	60.3	-38.6		220	335	4	SHALLOW
B8-2001	25.6.2001	9.7	277	60.2	-36.9		210	230	4.2	SHALLOW
B8-2001	25.6.2001	13.2	279	60.3	-36.6		500	800	6	DEEP
B8-2001	26.6.2001	0.6	280	60.3	-33.6		500	800	6	DEEP
B8-2001	26.6.2001	17.0	283	60.8	-31.6		500	800	6	DEEP
A8-2001	26.6.2001	20.7	290	61.5	-26.9		550	850	5.2	DEEP
B8-2001	27.6.2001	1.3	285	61.0	-33.2		200	400	4	SHALLOW
A8-2001	27.6.2001	3.8	291	61.5	-28.6	1502	520	820	5.6	DEEP
B8-2001	27.6.2001	9.4	287	61.0	-35.1		500	800	9.9	DEEP
B8-2001	27.6.2001	13.9	288	61.0	-35.6		250	254	3.5	SHALLOW
A8-2001	27.6.2001	15.3	293	60.5	-30.4	1663	550	850	8.2	DEEP
B8-2001	27.6.2001	22.6	290	61.0	-37.8		225	225	3.3	SHALLOW
A8-2001	27.6.2001	22.8	295	60.5	-28.9	1103	200	350	3.9	SHALLOW
B8-2001	28.6.2001	1.0	291	61.0	-37.8		500	800	6	DEEP
A8-2001	28.6.2001	2.5	296	60.5	-28.2	1400	520	830	5.8	DEEP
A8-2001	28.6.2001	13.2	298	60.0	-27.4	1700	530	800	6.8	DEEP
B8-2001	28.6.2001	22.4	294	61.8	-39.6		500	800	6	DEEP
A8-2001	29.6.2001	2.3	300	58.6	-29.9	2056	170	370	3.9	SHALLOW
B8-2001	29.6.2001	11.4	296	61.7	-36.4		500	800	6	DEEP
A8-2001	29.6.2001	12.7	302	58.0	-32.2	1785	540	820	5.8	DEEP
B8-2001	29.6.2001	20.5	298	61.8	-35.1		225	240	3.4	SHALLOW
A8-2001	30.6.2001	1.1	304	58.0	-35.1	2100	520	850	5.9	DEEP
B8-2001	30.6.2001	1.8	299	61.8	-34.0		500	800	6	DEEP
B8-2001	30.6.2001	9.3	301	61.7	-32.8		225	246	3.3	SHALLOW
A8-2001	30.6.2001	12.0	306	58.1	-37.7	2920	270	200	4.9	SHALLOW
B8-2001	30.6.2001	15.9	302	61.8	-31.8		500	800	6	DEEP
A8-2001	30.6.2001	19.5	308	58.0	-39.1	3010	250	200	8.6	SHALLOW
A8-2001	30.6.2001	22.7	303	58.0	-34.8	2470	200	250	4.3	SHALLOW
A8-2001	1.7.2001	1.3	309	58.0	-40.3	3190	510	800	5.7	DEEP
B8-2001	1.7.2001	12.0	304	62.3	-29.5	1922	500	800	6	DEEP
A8-2001	1.7.2001	15.0	311	57.4	-42.0	3131	450	250	4.4	SHALLOW
B8-2001	1.7.2001	23.9	306	62.5	-31.8		275	400	4	SHALLOW
A8-2001	2.7.2001	0.9	312	56.5	-41.3	3000	520	820	5.9	DEEP
B8-2001	2.7.2001	3.8	307	62.5	-32.2		500	800	6	DEEP
A8-2001	2.7.2001	4.5	313	56.5	-41.0	3000	200	220	2.9	SHALLOW
A8-2001	2.7.2001	11.7	315	56.5	-39.7	3000	200	180	5.9	SHALLOW
B8-2001	2.7.2001	12.5	309	62.5	-33.9		280	280	3.6	SHALLOW
B8-2001	2.7.2001	22.0	311	62.5	-36.1	2500	250	260	3.3	SHALLOW
B8-2001	3.7.2001	0.3	312	62.5	-36.3		500	800	6	DEEP
A8-2001	3.7.2001	1.8	317	56.5	-36.8	3000	510	820	5.9	DEEP
A8-2001	3.7.2001	11.6	319	56.1	-35.8	1764	300	400	4.4	SHALLOW
B8-2001	3.7.2001	14.4	314	62.5	-39.1		500	800	6	DEEP
A8-2001	3.7.2001	17.3	321	55.8	-36.1	1570	560	820	4.4	DEEP
A8-2001	3.7.2001	23.5	316	56.5	-37.0	3000	290	325	4.1	SHALLOW
A8-2001	4.7.2001	0.1	326	55.8	-41.5		515	830	5.7	DEEP
A8-2001	4.7.2001	3.6	322	55.8	-38.1		510	830	5.9	DEEP
B8-2001	4.7.2001	10.2	317	63.2	-38.0	1743	500	800	6	DEEP
A8-2001	4.7.2001	14.7	324	55.8	-40.3		250	290	6.4	SHALLOW
A8-2001	4.7.2001	21.8	325	55.8	-41.5		150	150	3.9	SHALLOW
B8-2001	5.7.2001	1.6	319	63.2	-35.2		800	500	15	DEEP
A8-2001	5.7.2001	11.5	328	54.8	-42.1	3000	150	200	4.3	SHALLOW
B8-2001	5.7.2001	15.2	321	63.2	-32.8		320	330	3	SHALLOW
A8-2001	5.7.2001	20.6	330	54.0	-42.0	3000	170	170	6.1	SHALLOW
B8-2001	5.7.2001	22.5	323	63.2	-31.3		500	650	6	DEEP
A8-2001	6.7.2001	2.3	332	53.7	-41.9	3000	510	840	6.2	DEEP
B8-2001	6.7.2001	11.6	325	63.2	-27.9	1600	500	800	6	DEEP
A8-2001	6.7.2001	15.4	335	53.5	-39.5		510	850	5.9	DEEP
A8-2001	6.7.2001	23.8	331	53.9	-41.9	3000	300	450	4.1	SHALLOW
A8-2001	7.7.2001	2.3	336	54.9	-39.4	3000	150	400	3.9	SHALLOW
B8-2001	7.7.2001	2.3	328	64.0	-27.8		500	800	6	DEEP
B8-2001	7.7.2001	14.1	329	64.0	-30.8	2120	500	650	6	DEEP
A8-2001	7.7.2001	14.3	337	54.9	-36.4	2000	520	850	6.8	DEEP
A8-2001	8.7.2001	1.0	338	55.3	-34.3	1070	510	830	6.3	DEEP
B8-2001	8.7.2001	2.3	331	64.0	-33.5	2361	500	800	6	DEEP
B8-2001	8.7.2001	12.9	333	64.0	-35.9	1789	500	800	6	DEEP
A8-2001	11.7.2001	0.7	343	62.1	-27.1	1524	720	610	3.1	DEEP
A8-2001	11.7.2001	9.3	344	62.1	-27.1	1450	740	590	4.6	DEEP

Table 2. Species of fish caught by midwater trawl during redfish surveys in Irminger Sea in June-July 1996, 1999 and 2001.

Dalatiidae
Somniosus microcephalus (Bloch & Schneider, 1801)

Notacanthidae
Notacanthus chemnitzii Bloch, 1788

Derichthyidae
Nessorhampus ingolfianus (Schmidt, 1912)

Nemichthyidae
Nemichthys scolopaceus Richardson, 1848

Serrivomeridae
Serrivomer beani Gill & Ryder, 1884

Eurypharyngidae
Eurypharynx pelecanoides Vaillant, 1882

Microstomatidae
Nansenia groenlandica (Reinhardt, 1840)

Bathylagidae
Bathylagus euryops Goode & Bean, 1896
Bathylagus longirostris Maul, 1948
Bathylagus sp.

Alepocephalidae
Alepocephalus agassizii Gode & Bean, 1883
Photostylus pycnopterus Beebe, 1933
Xenodermichthys copei (Gill, 1884)

Platytroctidae
Barbantus curvifrons (Roule & Angel, 1931)
Holtbyrnia anomala Krefft, 1980
Holtbyrnia macrops Maul, 1957
Maulisia mauli Parr, 1960
Normichthys operosus Parr, 1951
Platytroctes apus Günther, 1878
Sagamichthys schnakenbecki (Krefft, 1953)
Searsia koefoedi Parr, 1937

Gonostomatidae
Cyclothone spp.
Gonostoma bathyphilum (Vaillant, 1888)
Gonostoma denudatum Rafinesque, 1810
Gonostoma elongatum Günther, 1878

Sternoptychidae
Argyropelecus gigas Norman, 1930
Argyropelecus hemigymnus Cocco, 1829
Argyropelecus olfersi (Cuvier, 1829)
Maurolicus muelleri (Gmelin, 1788)
Polyipnus polli Schultz, 1961
Sternoptyx diaphana Hermann, 1781
Sternoptyx pseudobscura Baird, 1971

Stomiidae
Borostomias antarcticus (Lönnberg, 1905)
Rhadinesthes decimus (Zugmayer, 1911)
Stomias boa ferox Reinhardt, 1843)
Chauliodus sloani Schneider, 1801
Chirostomias pliopterus Regan & Trewavas, 1929
Melanostomias bartonbeani Parr, 1927
Pachystomias microdon (Günther, 1878)
Trigonolampa miriceps Regan & Trewavas, 1930
Malacosteus niger Ayres, 1848

Scopelarchidae
Benthalbella infans Zugmayer, 1911

Notosudidae
Scopelosaurus lepidus (Krefft & Maul, 1955)

Paralepididae
Arctozenus rissoi (Bonaparte, 1840)
Magnisudis atlantica (Kroeyer, 1868)
Paralepis coregonoides Risso, 1820

Anotopteridae
Anotopterus pharao Zugmayer, 1911

Evermannellidae
Evermannella balbo (Risso, 1820)

Myctophidae
Benthosema glaciale (Reinhardt, 1837)
Electrona rissoi (Cocco, 1829)
Myctophum punctatum Rafinesque, 1810
Protomyctophum arcticum (Lütken, 1892)
Ceratoscopelus maderensis (Lowe, 1839)
Lampadena speculigera Goode & Bean, 1896
Lampanyctus ater Tåning, 1928
Lampanyctus crocodilus (Risso, 1810)
Lampanyctus intricarius Tåning, 1928
Lampanyctus macdonaldi (Goode & Bean, 1896)
Notoscopelus (Notoscopelus) kroeyerii (Malm, 1861)

Trachipteridae
Trachipterus arcticus (Brünnich, 1771)

Bythitidae
Thalassobathia pelagica Cohen, 1963

Macrouridae
Coryphaenoides rupestris Gunnerus, 1765

Nezumia aequalis (Günther, 1878)

Phycidae
Onogadus argentatus (Reinhardt, 1837)

Gadidae
Micromesistius poutassou (Risso, 1826)

Lophiidae
Lophius piscatorius Linnaeus, 1758

Caulophrynidae
Caulophryne jordani Goode & Bean, 1896

Himantolophidae
Himantolophus albinares Maul, 1961
Himantolophus groenlandicus Reinhardt, 1837
Himantolophus mauli Bertelsen & Krefft, 1988

Oneirodidae
Chaenophryne draco Beebe, 1932
Chaenophryne longiceps Regan, 1925
Dolopichthys longicornis Parr, 1927
Oneirodes eschrichtii Lütken, 1871
Spiniphryne gladisfenae (Beebe, 1932)

Ceratiidae
Ceratias holboelli Kroeyer, 1845
Cryptopsaras couesi Gill, 1883

Linophrynidae
Haplophryne mollis (Brauer, 1912)
Linophryne lucifera Collett, 1886

Melamphaeidae
Melamphaes microps (Günther, 1878)
Poromitra crassiceps (Günther, 1878)
Poromitra megalops (Lütken, 1877)
Scopelogadus beanii (Günther, 1887)

Rondeletiidae
Rondeletia loricata Abe & Hotta, 1963

Barbourisiidae
Barbourisia rufa Parr, 1945

Cetomimidae
Cetostoma regani Zugmayer, 1914

Anoplogasteridae
Anoplogaster cornuta (Valenciennes, 1833)

Diretmidae
Diretmus argenteus Johnson, 1863

Scorpaenidae
Sebastes marinus (Linnaeus, 1758)
Sebastes mentella Travin, 1951

Cyclopteridae
Cyclopterus lumpus Linnaeus, 1758

Liparidae
Careproctus reinhardti Kroeyer, 1862
Liparis fabricii Kroeyer, 1847
Paraliparis bathybius (Collett, 1879)
Paraliparis copei Goode & Bean, 1896

Caristiidae
Platyberyx opalescens Zugmayer, 1911

Anarhichadidae
Anarhichas denticulatus Kroeyer, 1845

Chiasmodontidae
Chiasmodon bolangeri Osorio, 1909
Chiasmodon niger Johnson, 1863

Trichiuridae
Aphanophus carbo Lowe, 1839
Benthodesmus simonyi (Steindachner, 1891

Table 3. Occurrence (number of stations where the species was caught) and abundance (average number of fish in 10 nautical miles towed) of 25 most prominent fish species (excluding redfish) caught by midwater trawl during redfish survey in Irminger Sea in June-July 1996, 1999 and 2001 (N = 90 for tows at depts > 500 m; N = 52 for tows at depts < 500 m).

		Depth > 500 m		Depth < 500 m		Total	
code	Species	Nu. of st.	mean nu./ 10 nm	Nu. of st.	mean nu./ 10 nm	Nu. of st.	mean nu./ 10 nm
138	*Chauliodus sloani*	84	151.0	24	36.6	108	109.1
243	*Lampanyctus macdonaldi*	81	543.7	18	5.6	99	346.6
204	*Notoscopelus (Notoscopelus) kroeyeri*	75	117.1	20	61.1	95	96.6
154	*Serrivomer beani*	75	88.6	17	8.7	92	59.3
136	*Bathylagus euryops*	77	359.9	8	1.7	85	228.7
106	*Borostomias antarcticus*	75	16.1	9	1.3	84	10.7
222	*Lampadena speculigera*	74	37.6	3	0.5	77	24.0
120	*Malacosteus niger*	55	7.1	12	1.6	67	5.1
127	*Stomias boa ferox*	53	57.8	11	3.6	64	38.0
209	*Benthosema glaciale*	48	48.1	16	46.9	64	47.7
104	*Xenodermichthys copei*	52	2.3	1	0.0	53	1.5
123	*Arctozenus rissoi*	38	3.9	8	1.5	46	3.0
226	*Scopelogadus beanii*	36	22.9	5	0.4	41	14.7
103	*Nemichthys scolopaceus*	34	5.4	7	0.8	41	3.7
241	*Poromitra crassiceps*	36	23.8	2	0.1	38	15.2
212	*Normichthys operosus*	26	6.7	4	0.9	30	4.6
116	*Nansenia groenlandica*	29	1.9	1	0.0	30	1.2
111	*Platyberyx opalescens*	27	0.7	1	0.0	28	0.4
218	*Holtbyrnia macrops*	25	1.6	2	0.1	27	1.0
211	*Holtbyrnia anomala*	23	4.3	2	0.1	25	2.8
131	*Argyropelecus olfersi*	15	0.5	8	0.9	23	0.6
223	*Lampanyctus crocodilus)*	19	8.4	3	4.0	22	6.8
227	*Anoplogaster cornuta*	21	0.6	0	0.0	21	0.4
232	*Myctophum punctatum*	12	13.0	8	28.1	20	18.6
157	*Searsia koefoedi*	15	0.8	0	0.0	15	0.5

Table 4. Relative abundance of most common families of fish (combined average number of fish of the family, expressed as a percentage of total number of fish and occurrence (percentage of stations where a fish of that family was caught) in midwater tows taken during redfish surveys in Irminger Sea in June-July 1996, 1999 and 2001. Data on redfish are excluded.

Deeper

Fam	Nu./nm	Prop stations
Myctophidae	44%	93%
Bathylagidae	21%	86%
Stomiidae	13%	94%
Gonostomatidae	11%	0%
Serrivomeridae	5%	83%
Melamphaeidae	3%	72%
Platytroctidae	1%	81%
Paralepididae	0%	62%
Alepocephalidae	0%	58%
Nemichthyidae	0%	38%
Microstomatidae	0%	32%
Caristiidae	0%	30%
Others	1%	

Shallow

Fam	Nu./nm	Prop stations
Myctophidae	65%	52%
Stomiidae	19%	52%
Gadidae	9%	4%
Serrivomeridae	4%	33%
Sternoptychidae	1%	21%
Paralepididae	1%	25%
Bathylagidae	0%	15%
Platytroctidae	0%	21%
Nemichthyidae	0%	14%
Melamphaeidae	0%	14%
Anarhichadidae	0%	14%
Others	2%	

Figures

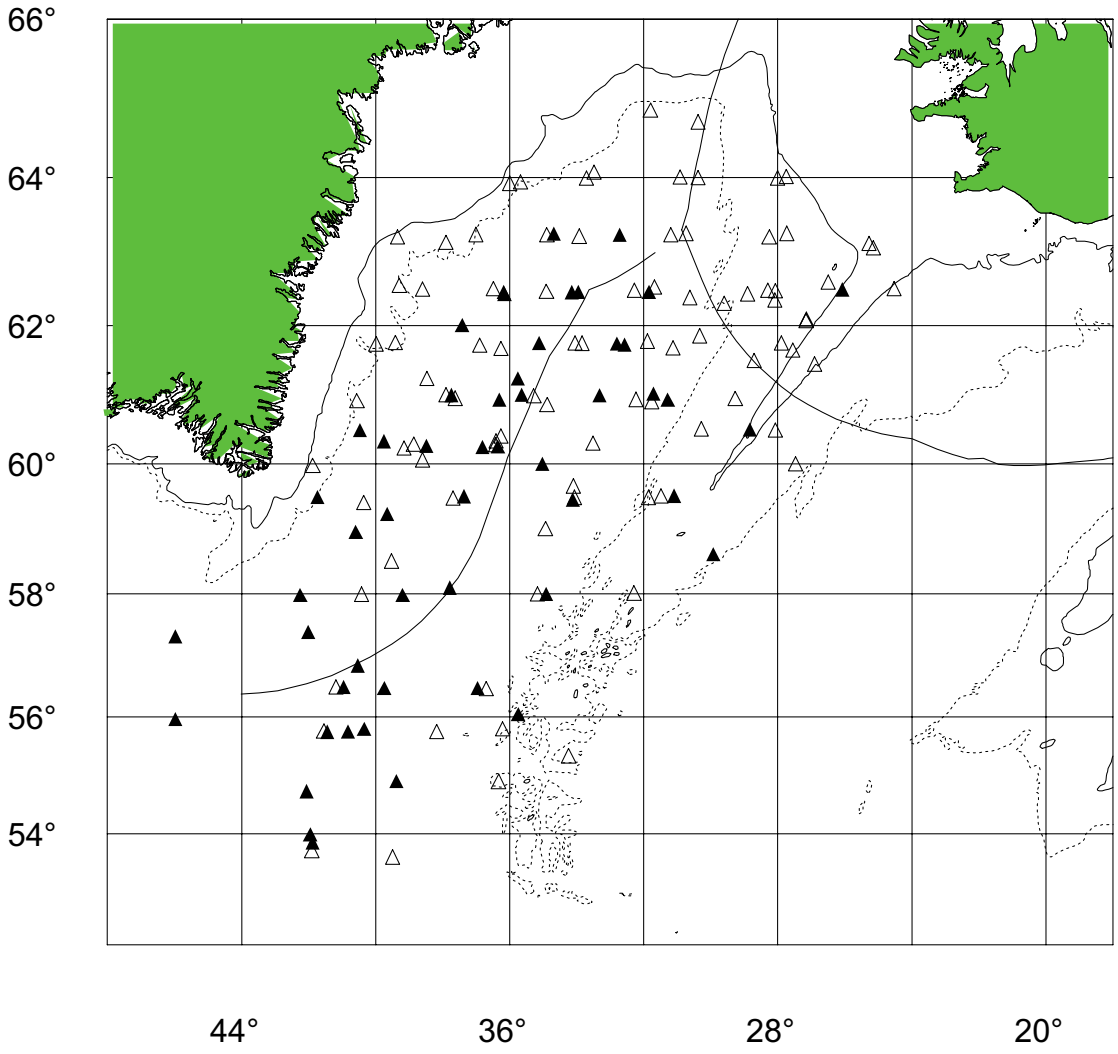

Figure 1. Positions of trawl stations during redfish surveys in the Irminger Sea in June-July 1996, 1999 and 2001. ▲ = trawling depth shallower than 500 m d; Δ = trawling depth more than 500 m.

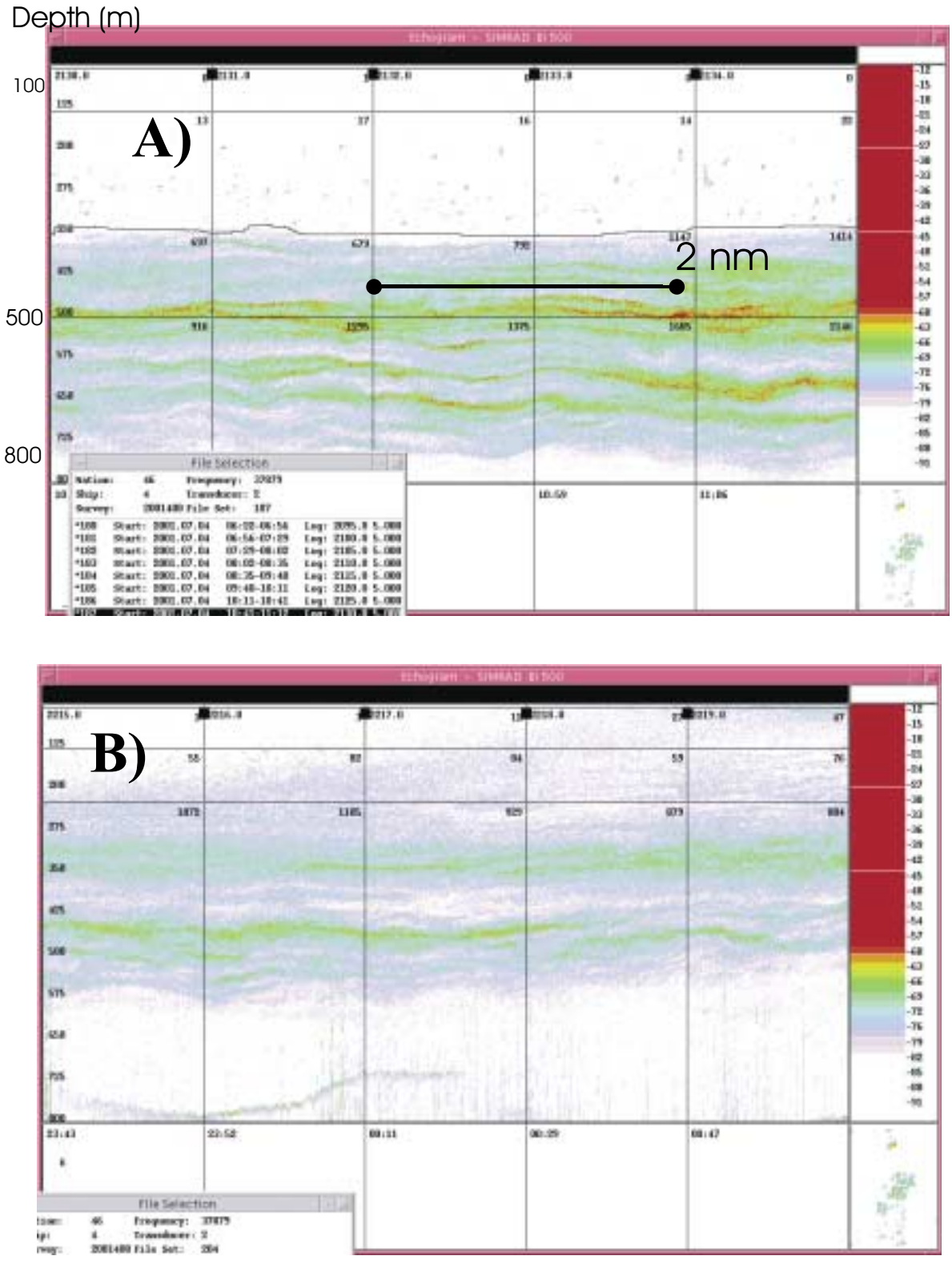

Figure 2. Example of echograms obtained during the June/July survey in 2001. The figures is from 3-4. July and figure A) shows registration during daytime (at 55°46N-37°30W, from 10:41-11:06 on on 4th of July) and B) during dark hours (at 55°45N-40°50W, from 23:43 on 3. July to 00:47 on 4th). The figures shows distance of 5 n.m. from 50 m depth down to 850 m.

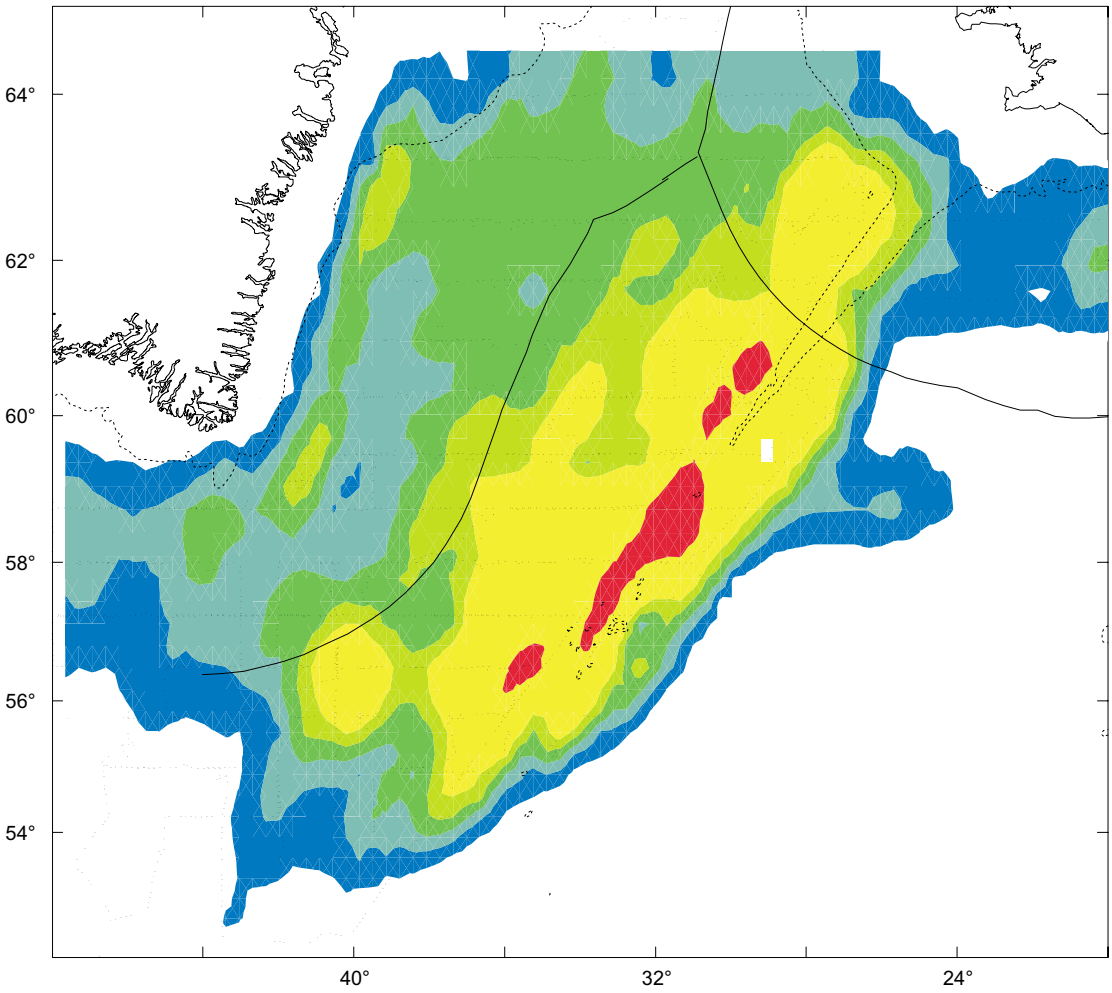

Figure 3. Relative distribution of the deep scattering layer as interpreted on the SIMRAD EK 500 and BI-500 post-processing system. Data from r/v Bjarni Sæmundsson (Iceland), r/v Walther Herwig (Germany), r/v Árni Friðriksson (Iceland) and r/v Atlantniro (Russia) form June/July 2001. Red color indicates highest abundace as the blue indicates the least. When scrutinising the echosounder data, all scatter from organisms that were not judged as "redfish" was grouped as "scattering layer". The dotted lines on the figure shows the cruise tracks.

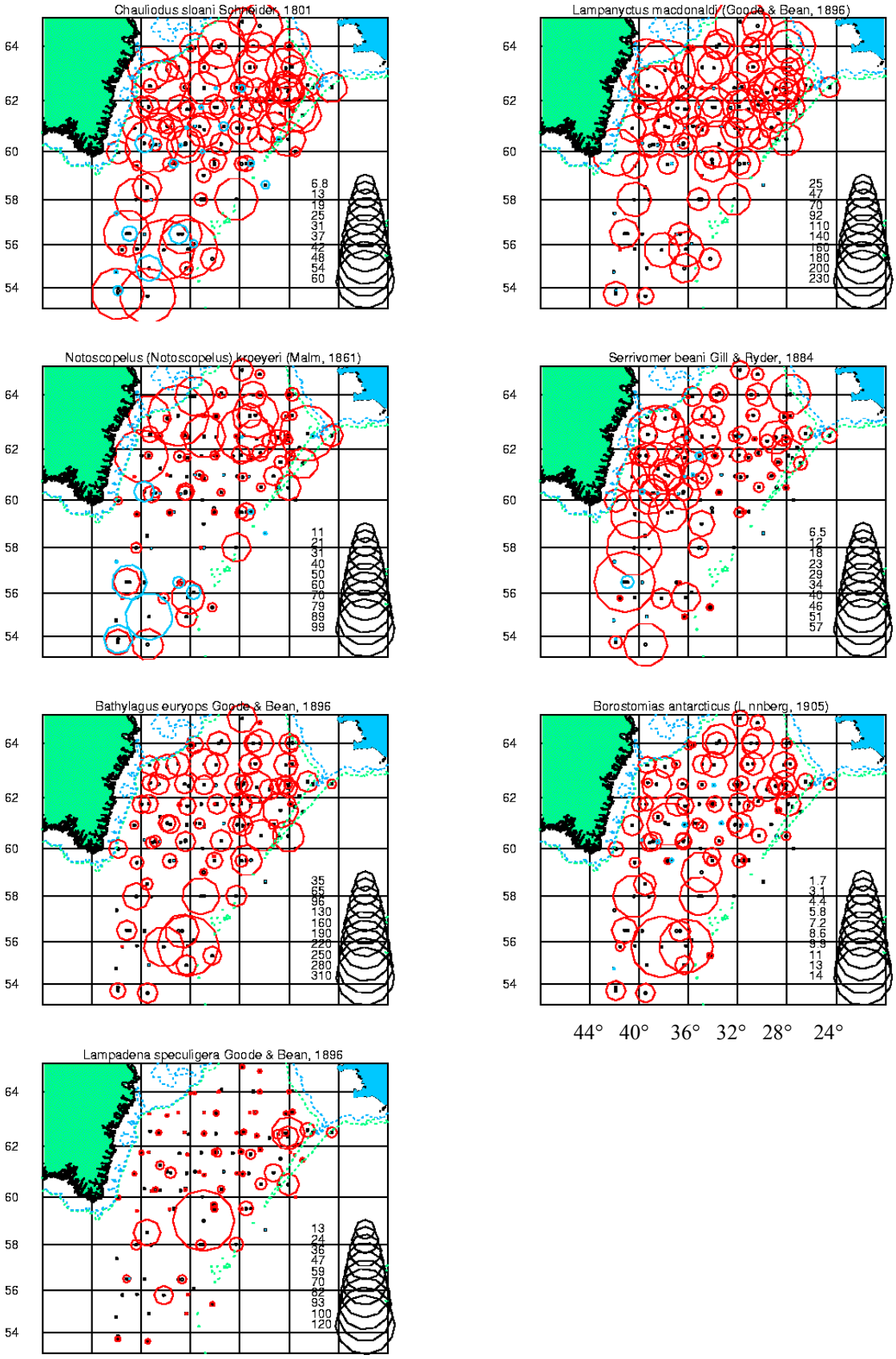

Figure 4. Group 1 species – most common species, distributed over the whole area. Size of rings relative to number of fish caught in a nautical mile, note different scale on the figures. Red: Depth > 500 m. Blue: Depth < 500 m.

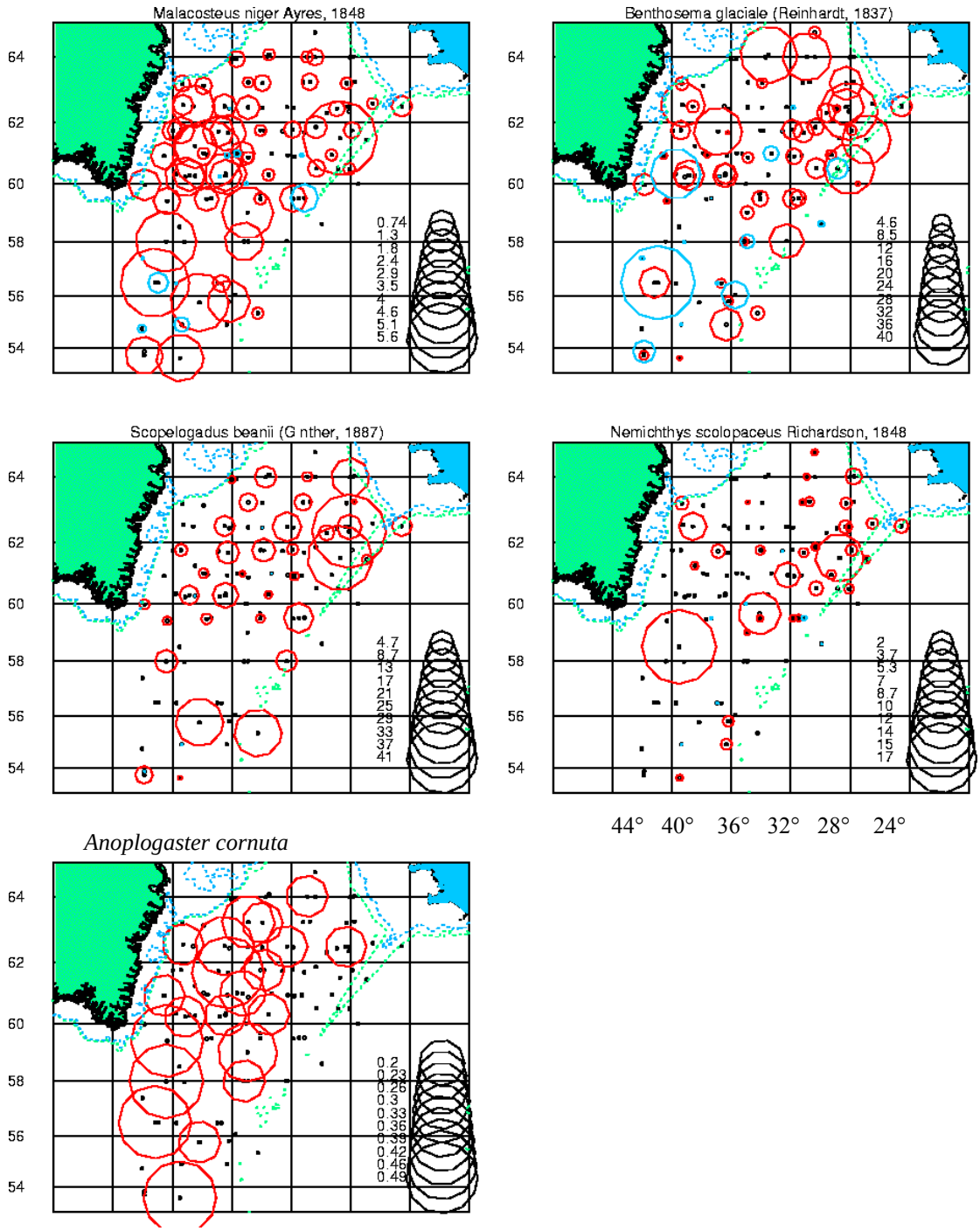

Figure 5. Group 2 species – less common species, distributed over the whole area. Size of rings relative to number of fish caught in a nautical mile, note different scale on the figures. Red: Depth > 500 m. Blue: Depth < 500 m.

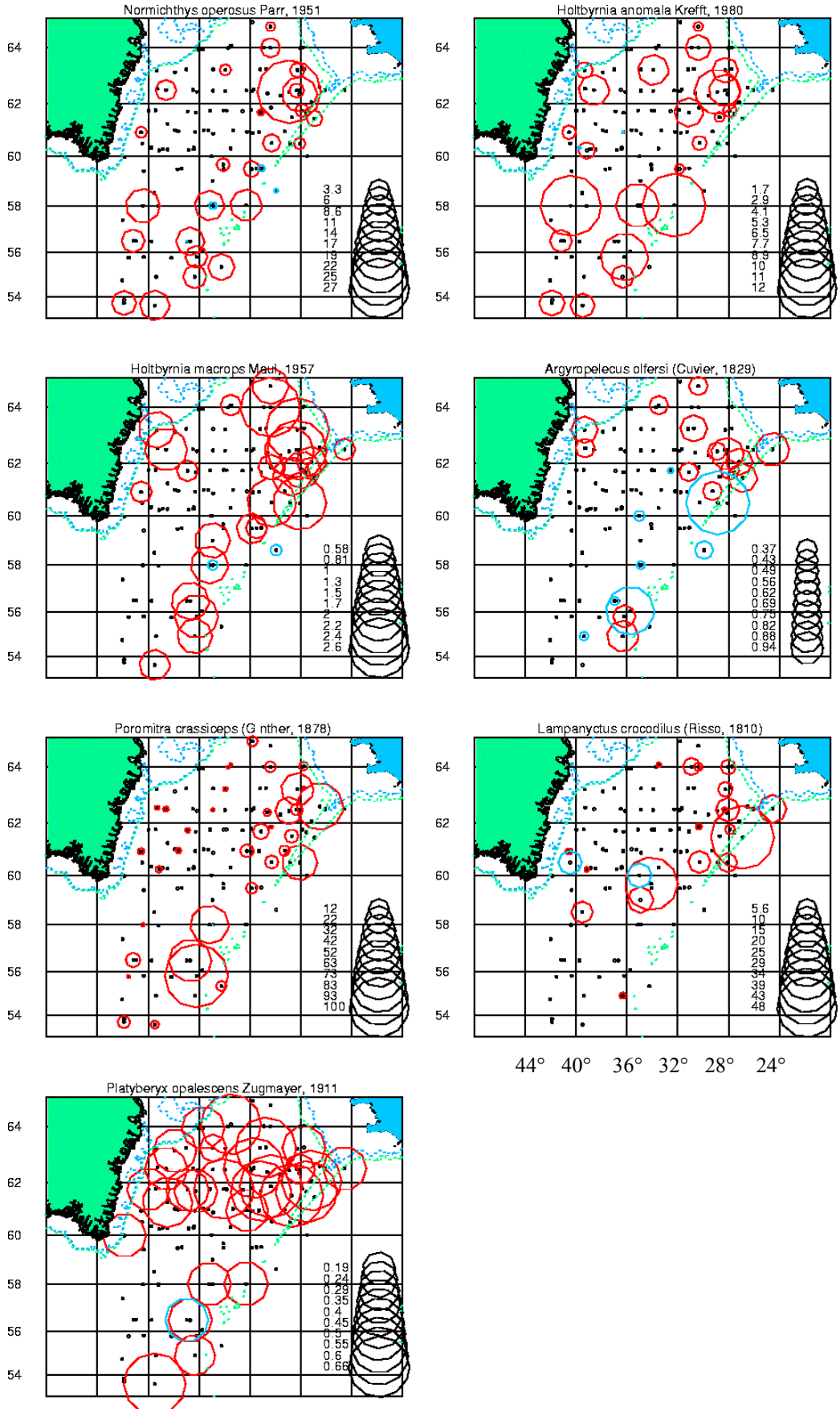

Figure 6. Group 3 species – rare or absent from the center of the research area. Size of rings relative to number of fish caught in a nautical mile, note different scale on the figures. Red: Depth > 500 m. Blue: Depth < 500 m.

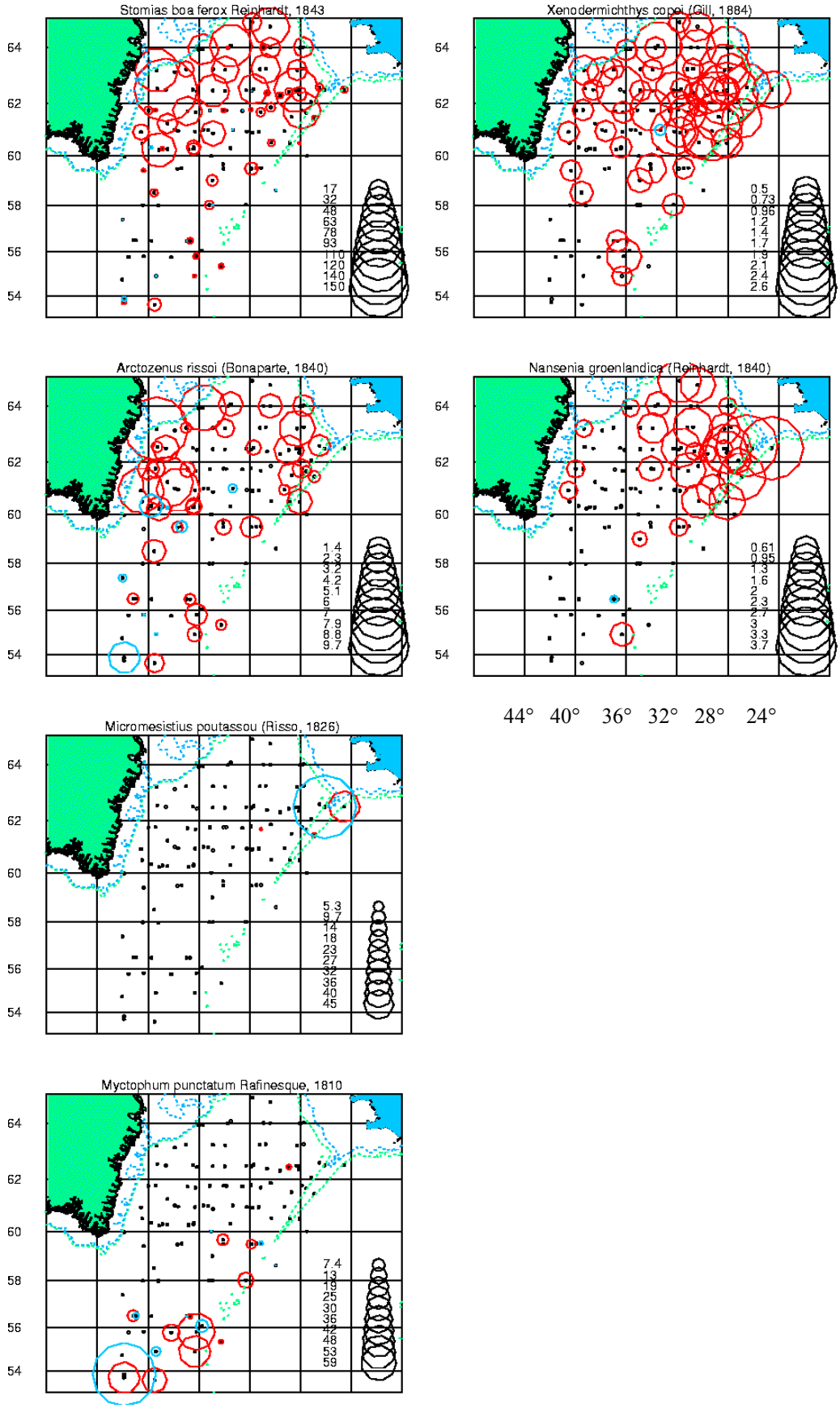

Figure 7. Group 4 and group 5 species – Species with northerly or southerly distribution Size of rings relative to number of fish caught in a nautical mile, note different scale on the figures. Red: Depth > 500 m. Blue: Depth < 500 m.

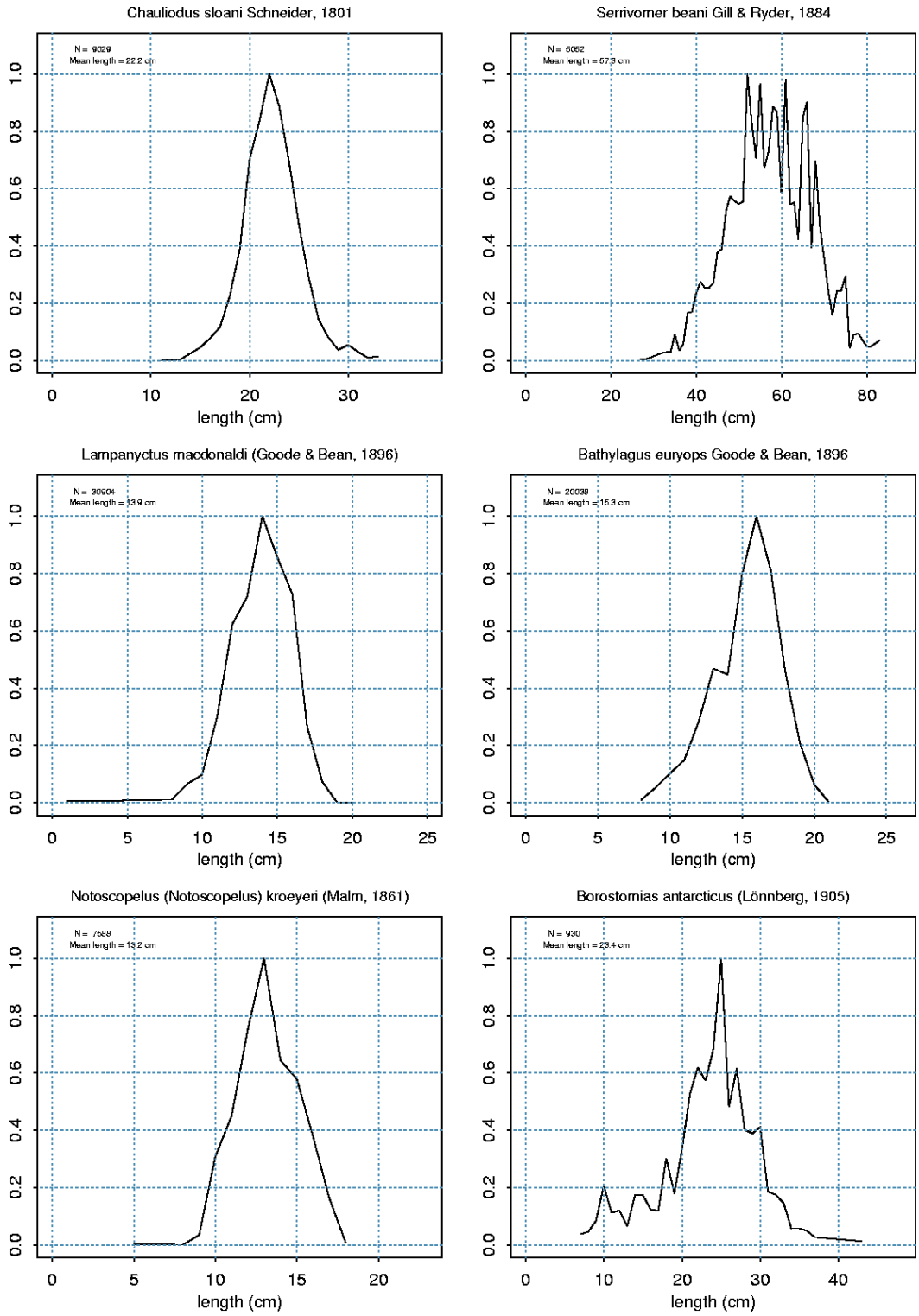

Figure 8a. Length distribution of most common species. N = total number caught.

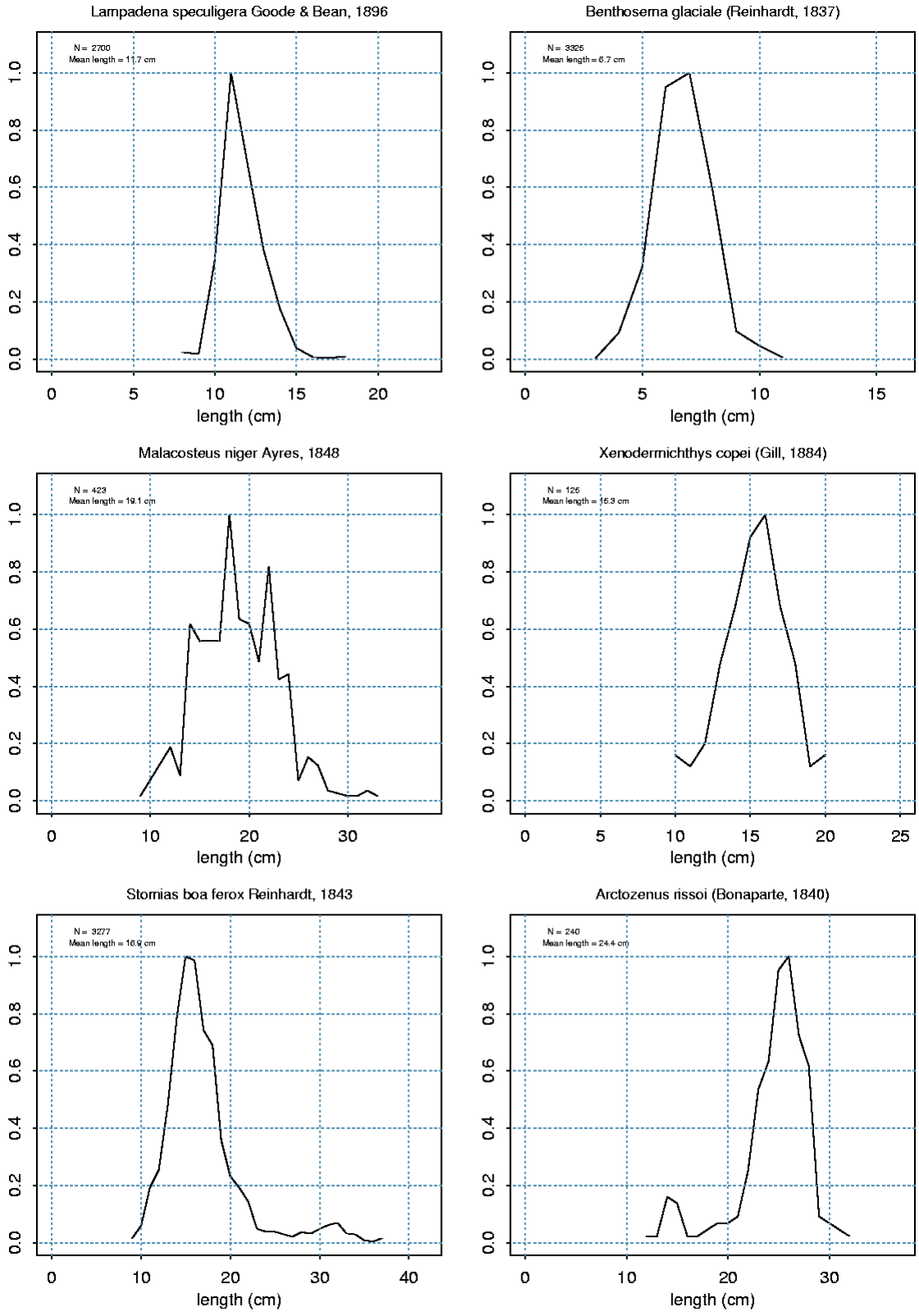

Figure 8b. Length distribution of most common species. N = total number caught.

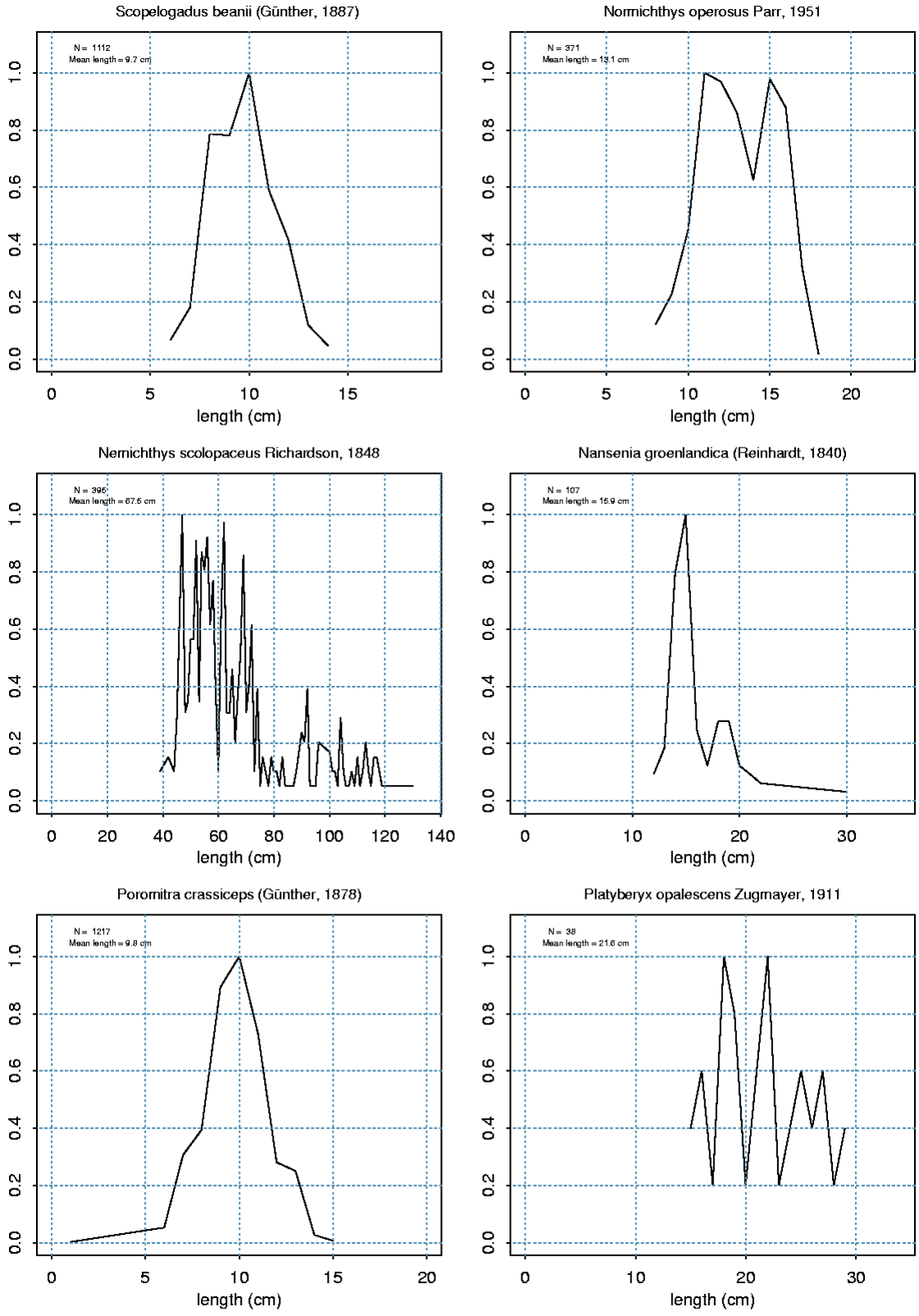

Figure 8c. Length distribution of most common species. N = total number caught.