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Vertical and horizontal distribution of mesopelagic fishes along a transect across the northern Mid-Atlantic Ridge

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Abstract

A research cruise was made in the Irminger Sea west and southwest of Iceland and adjacent waters on the Icelandic vessel *Árni Friðriksson*, from 03 Jun-04 Jul 2003. The main purpose was to study distribution and abundance of deepwater redfishes, *Sebastes mentella et* sp., other pelagic fishes, zooplankton, phytoplankton and the hydrography of the area. Part of the cruise was devoted to a special study on community structure at transect over the northern part of the Mid-Atlantic Ridge (Reykjanes Ridge). In this paper, an overview is given on the composition of the pelagic fish community, both vertically and horizontally, over the northern part of the Reykjanes Ridge. In total, nine trawl hauls were made with a "GLORIA" midwater trawl outfitted with a small mesh size (9-mm) cod-end. Three hauls were made at three different depths west of the Ridge, three above it and three East of the Ridge. A total of 230 nautical miles separated hauls taken west of the Ridge and east of it. A minimum total of 44 species were identified from 23 families. Lanternfishes (Myctophidae), pearlsides (Sternoptychidae), barracudinas (Paralepididae), dragonfishes (Stomiidae) and deep-sea smelts (Microstomatidae) dominated fish catches. Results show that the total number of fishes caught was lowest east of the Ridge, coinciding with warmer deep waters. At all positions both number of species and families increased with depth as the number of individuals decreased with depth.

Keywords: Mid-Atlantic Ridge, MAR-ECO, mesopelagic, Irminger Sea

Introduction

The international research project MAR-ECO stands to date as the largest-scale exploration of life above and on a non-chemosynthetic mid-ocean ridge system. The overall goal of the MAR-ECO project is to gain a better understand of the patterns and processes of the ecosystems of the northern mid-Atlantic, from Iceland to the Azores (Bergstad and Godø, 2003; Bergstad and Falkenhaug, 2005). The major field campaigns of MAR-ECO include the Norwegian-led *G.O. Sars* expedition (2004; Reykjanes Ridge to the Azores), the United Kingdom-led ECOMAR expeditions (2007-2010; Charlie-Gibbs Fracture Zone) and the Icelandic *Árni Friðriksson* expedition (2003; Reykjanes Ridge and adjacent Irminger Sea). The goal of the latter Icelandic expedition was to examine the organization, trophic structure, and energy flow of the pelagic ecosystem over the Reykjanes Ridge, from phytoplankton to fish as apex predators (MAR-ECO project Z4, A. Gislason Principal Investigator). Target groups included copepods, euphausiids, chaetognaths and fishes. In this paper we present data on the assemblage structure, abundance and distribution of mesopelagic fishes, the conspicuous components of an extensive deep-scattering layer (Sigurðsson et al., 2002) observed between 300-800 m depth over the far northern mid-Atlantic.

Materials and Methods

MAR-ECO is a network effort being carried out by an international cadre of scientists, students and technicians. The success of the project owes largely to ship-time and personnel commitments from a variety of sources that were secured during the early planning phases. Material for this study was secured through an early commitment by Iceland to extend their 03 Jun-04 Jul 2003 Irminger Sea redfish (*Sebastes mentella et* sp.) survey onto the Reykjanes Ridge section of the northern Mid-Atlantic Ridge (MAR hereafter). A multidisciplinary team of scientists and engineers with expertise in taxonomy, biological and technical sampling methods, hydroacoustics and physical oceanography participated in the month-long cruise, five days of which were committed to a cross-ridge transect (Fig. 1) to sample an area of interest to MAR-ECO. A total of five stations were sampled using a variety of collecting gear, with continuous hydroacoustic surveying between stations (Fig. 2).

Hydrographic data for stations along the MAR-ECO transect, as well as the adjacent Irminger Sea, were recorded with a Sea Bird Electronics SBE-911 plus CTD. Seawater for phytoplankton measurements (chl *a* and primary production) and zooplankton were also collected at each station; these data will be presented elsewhere (see Petursdottir et al., Gudfinnson et al., this volume). Hydrographic data as relevant to pelagic fish distributions will be presented here.

A GLORIA-type #1024 midwater trawl (maximum circumference of ~ 1020 m, vertical opening ~ 45 m) lined with 9-mm mesh net was used to sample pelagic fishes, cephalopods, and large gelatinous zooplankton. This trawl had a very large mesh size (~32 m) in the front end of the trawl in order to ‘herd’ the highly mobile target taxon (*Sebastes mentella*). Hence, fish abundance data per trawl will be presented as relative to each other rather than abundance per volume filtered (please see ‘catchability’ discussion in Sutton et al., 2008, for further detail). Three one-hour hauls were made at three different depth strata between 100-900 m depth west of the ridge, three above it and three east of the ridge (Table 1). A total of 230 nautical miles separated hauls taken west and east of the ridge. After each haul catches were sorted, identified to species, enumerated, and all or a subsample of all species were measured (nearest mm) and weighed on a motion-compensating scale (± 1 g wet weight). Acoustic data were collected via a SIMRAD EK 500 split beam echosounder with three transducers (38, 120, 200 kHz) in a protruding keel. Data were processed with a BI500 post-processing system (Bodholt et al., 1989; Foote et al., 1991).

Results

Hydroacoustic results

Example echograms showing the distribution of the deep-scattering layer (DSL) across the Reykjanes Ridge at the same time of day (near solar noon) are shown in Figure 3. With a distance of approximately 230 nautical miles between stations, clear differences can be seen in the nature of the DSL, with the western site showing a more compact, shallower DSL than either the central (over ridge axis) and eastern stations. The latter two stations exhibit similar backscatter characteristics, with a more diffuse DSL occurring mainly between 400-700 m, and a maximum backscatter between 600-700 m. Likely faunal constituents of these DSLs contributing to these two general patterns are addressed in the following section. Backscatter values could not be converted to biomass, as the backscattering coefficients for the species making up these layers are not known.

Species composition and distribution

A total of 282505 specimens from minimally 44 species (23 families) were collected during the MAR-ECO cross-ridge survey (Table 2). When prorated for effort (no. nautical mile trawled^{-1}), the glacier lanternfish, *Benthosema glaciale* (Myctophidae), was by far the numerically dominant fish sampled with this gear in the top 800 m of the water column (91.5% of the total assemblage). It should be noted that the bristlemouth, *Cyclothone microdon* (Gonostomatidae), the numerically dominant fish sampled during the 2004 *G.O. Sars* expedition (Sutton et al., 2008), was likely excluded by the large forenet mesh-size and/or shallow depth scheme adopted during this survey. The Greenland argentine, *Nansenia groenlandica* (Microstomatidae), and the deepwater redfish, *Sebastes mentella* (Sebastidae), were the only other species contributing greater than 1% of assemblage numbers (3.1 and 2.3%, respectively).

With respect to depth stratum, *Benthosema glaciale* again dominated the upper layer (< 300 m), contributing 90.1% of assemblage numbers. The lanternfish *Protomyctophum arcticum* ranked second, contributing 6.6% of assemblage numbers, though this species was found primarily (99.7%) west of the ridge axis. The snake pipefish, *Entelurus aequoreus* (Syngnathidae) ranked third, contributing 2.7% of assemblage numbers. No other species contributed more than 0.17% of assemblage numbers. Fifteen species were sampled in this stratum. In intermediate depths (350-600 m) the catches were dominated even more by *B. glaciale* (99.9% of numbers), suggesting that this species spans these depth intervals during the diel cycle. It should be noted that GLORIA trawls are open and do fish during deployment and retrieval, obfuscating the vertical resolution of the sampling scheme. In total, 29 species were collected in mid-depth samples. In the deepest stratum sampled (600-900 m), dominance by *B. glaciale* was much less pronounced (39.9% of total), and nine species contributed at least 0.8% of assemblage numbers. The second- and third-most abundant species, *Nansenia groenlandica* and *Sebastes mentella* (26.6 and 19.1% of assemblage numbers, respectively) were found in this stratum, and almost exclusively over the ridge axis (>99.6% of both species numbers). Species richness was maximal in this stratum, with 39 species collected.

With respect to horizontal distribution, there was a general trend in decreasing abundance from west to east of the ridge (Fig. 4), with much of this pattern resulting from nearly all (99.88%) of *B. glaciale* specimens, the numerically dominant fish species, being collected west of the ridge axis. This distribution pattern is also exhibited by the deep-living, biomass-dominant species *Bathylagus euryops* (Sutton et al., 2008), with 94.3% of specimens collected west of the ridge. Other species showing highest abundance (% of species numbers in parentheses) west of the ridge include: *Protomyctophum arcticum* (99%), Gonostomatidae (98%, mostly damaged *Cyclothone*), *Lampanyctus macdonaldi* (94%), *Holtbyrnia anomala* (92%), *Serrivomer beanii* (84%), *Malacosteus niger* (82%), and *Stomias boa ferox* (70%). All of these species are among the biomass dominant deep-pelagic fishes over the MAR from Iceland to the Azores (Sutton et al., 2008). Among the possible causal variables for this pattern, temperature would appear to be a likely candidate; temperatures at depth are significantly lower west of the Reykjanes Ridge than over or east of it (Fig. 5a, b).

Other taxa, such as the aforementioned *Nansenia groenlandica* and *Sebastes mentella*, were caught almost exclusively over the ridge. Additional common species showing highest abundances directly over the ridge include: *Myctophum punctatum* (99%), *Nemichthys scolopaceus* (99%), *Schedophilus medusophagus* (99%), *Chauliodus sloani* (85%), *Notoscopelus kroeyeri* (78%), and *Normichthys operosus* (76%). Only one species, the snake pipefish *Entelurus aequoreus,* was found in highest abundance east of the ridge (97%).

Discussion

In this study we have presented data on the abundance and distribution of mesopelagic fishes over and adjacent to the Reykjanes Ridge, representing the "northern box" of the MAR-ECO field project (www.mar-eco.no). We found that with the large pelagic gear used in this study the lanternfish, *Benthosema glaciale,* was by far the dominant fish numerically, agreeing with previous studies using the same or similar gear (Sigurðsson et al., 2002). In a related study, Sutton et al. (2008) found the bristlemouth, *Cyclothone microdon,* to be the numerical dominant fish over the MAR, from Iceland to the Azores, with *B. glaciale* ranking second. The differences found in their study with this study are likely a function of gear (they used a range of trawls with smaller mesh-sizes) and trawl depth (they sampled to 3600 m, not possible over the Reykjanes Ridge). Once these differences are taken into account, the catches appear quite similar (see Table 2, p. 171 in their paper).

A key difference between the 2003 REDFISH/MAR-ECO expedition and the 2004 *G.O. Sars* expedition is the level of sampling over the Reykjanes Ridge. The 2004 expedition sampled but one station east of the Reykjanes Ridge and one station over it before heading south, the rationale being that the 2003 expedition previously sampled this section. Thus, the results presented here represent a significant contribution to our understanding of pelagic nekton over the MAR as related to the overall goals of MAR-ECO. Sutton et al. (2008) found a surprising relationship between fish biomass and depth over the MAR (Iceland to the Azores); instead of the expected exponential decline of biomass with depth that has been reported in other open ocean systems (Angel and Baker, 1982; Angel and Boxshall, 1990), they found a deep-pelagic fish biomass maximum between 1500-2300 m, corresponding to the ridge crest depths for most of the extent of the northern MAR. One 'problem' with their study was that time and geographical constraints required a close-knit, 'zig-zag' pattern of stations during Leg 1 of their expedition (see Wenneck et al., for more sampling detail). In other words, the 2004 expedition did not get far enough away from the MAR to compare samples taken over the ridge with those away. Indeed, Sutton et al. (2008) found no statistical differences in samples taken on the eastern, central, or western stations (relative to the ridge axis) in the 2004 expedition. In this study we find that there are dramatic differences both the nature of the DSL and in the faunal structure/abundance of pelagic fishes as a function of geographical location relative to the axis of the Reykjanes Ridge. With respect to the DSL, we found a densely packed, shallower layer west of the ridge between 200-500 m, compared to the more diffuse, deeper DSL over and east of the ridge. Trawl samples suggest that this difference is primarily due to the increased abundance of the lanternfish, *Benthosema glaciale*, as well as other dominant taxa, coincident with colder water. It is likely that the topography of the Reykjanes Ridge contributes to this pattern, as it is the shallowest section of the MAR and thus serves to separate the region hydrographically. Results from this study also provide corollary evidence for the finding of enhanced pelagic fish biomass over the MAR from the 2004 *G.O. Sars* expedition. Eight species found in this study, including the biomass-dominant species *Sebastes mentella*, were found exclusively over the ridge (or nearly so) relative to stations east or west. These findings would appear to support previous conclusions that special hydrodynamic and biotic features of ridge systems cause changes in the ecological structure of deep-sea fish assemblages relative to abyssal ecosystems (Fock et al., 2004; Sutton et al., 2008), and that these changes may support enhanced biomass of higher trophic levels found in the near-ridge fauna.

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Table 1. Trawl sample data for the 2003 REDFISH/MAR-ECO survey over the Reykjanes Ridge

Date	station	Position				bottom	time	Temp.	Depth	Type
	number	lat start	lon start	lat end	lon end	depth		°C	range	
06.17.03	430	594440	261630	594350	261160	2151	18:18	6.9	600-700	Deep
06.18.03	432	594030	261510	594200	261730	2147	22:32	7.8	475-475	Mid
06.18.03	436	593820	260990	594070	261210	2207	08:00	9.2	90-110	Shallow
06.19.03	443	602680	284110	602600	283710	915	08:57	7.9	325-340	Shallow
06.19.03	444	602520	283840	602490	284240	1026	11:08	7.6	550-600	Mid
06.19.03	445	602290	283660	602240	283230	1177	13:41		700-900	Deep
06.21.03	456	614170	321400	614390	321840	2493	22:30	5.8	195-165	Shallow
06.21.03	457	614290	321890	614040	321450		00:49	5.0	350-400	Mid
06.21.03	458	614040	321100	614290	321580	2550	03:21	4.1	700-820	Deep

Table 2. Trawl catch data for REDFISH/MAR-ECO survey of the Reykjanes Ridge, June 2003. Abundance values are standardized as number per nautical mile trawled

Species	Region relative to Reykjanes Ridge										
	Central-4	Central-5	Central-6	East-4	East-5	East-6	West-4	West-5	West-6	Total	% of total
Anoplogaster cornuta (Valenciennes, 1833)									1.0	1.0	0.0004
Aphanopus carbo Lowe, 1839						1.0				1.0	0.0004
Arctozenus rissoi (Bonaparte, 1840)	28.0	5.3	40.5	1.0	30.0	8.0		2.0	2.0	116.8	0.0484
Argyropelecus hemigymnus Cocco, 1829	12.0	8.0			5.0		2.0			27.0	0.0112
Argyropelecus olfersi (Cuvier, 1829)	1.0				1.0	3.0			1.0	6.0	0.0025
Barbantus curvifrons (Roule & Angel, 1931)									1.0	1.0	0.0004
Bathylagus euryops Goode & Bean, 1896			7.8			14.0		252.0	111.0	384.8	0.1594
Benthosema glaciale (Reinhardt, 1837)	6.0	223.9	14.0	3.0	8.0	6.0	20964.0	188435.0	11289.0	220948.9	91.5403
Borostomias antarcticus (Lönnberg, 1905)		60.8	133.3			2.0			12.0	208.1	0.0862
Chaenophryne longiceps Regan, 1925									1.0	1.0	0.0004
Chauliodus sloani Schneider, 1801		349.9	314.6	1.0	13.0	14.0	12.0	57.0	24.0	785.5	0.3254
Chiasmodon niger Johnson, 1863						1.0				1.0	0.0004
Coryphaenoides rupestris (Gunnerus, 1765)									4.0	4.0	0.0017
Cyclothone microdon Günther, 1878			1.2							1.2	0.0005
Entelurus aequoreus (Linnaeus, 1758)		23.3		641.0	14.0					678.3	0.2810
Gonostomatidae		5.0	7.0						546.0	558.0	0.2312
Holtbyrnia anomala Krefft, 1980			2.0						24.0	26.0	0.0108
Holtbyrnia macrops Maul, 1957			2.0		1.2	16.0			2.0	21.2	0.0088
Lampadena speculigera Goode & Bean, 1896			10.0		5.8	9.0		1.0	3.0	28.8	0.0119
Lampanyctus crocodilus (Risso, 1810)		6.0	8.0		37.8	24.0		1.0		76.8	0.0318
Lampanyctus intricarius Tåning, 1928			19.0		21.3	10.0				50.3	0.0209
Lampanyctus macdonaldi (Goode & Bean, 1896)			10.7			3.0	1.0	2.0	214.0	230.7	0.0956
Linophryne lucifer Collett, 1886					21.3				1.0	22.3	0.0093
Magnisudis atlantica (Kröyer, 1868)						2.0				2.0	0.0008
Malacosteus niger Ayres, 1848						2.0			9.0	11.0	0.0046
Maurolicus muelleri (Gmelin, 1788)	4.0	3.0	6.1	3.0	6.3	4.0				26.4	0.0109
Melanostomias bartonbeani Parr, 1927 (43)		1.2								1.2	0.0005
Micromesistius poutassou (Risso, 1826)			12.1							12.1	0.0050
Myctophum punctatum Rafinesque, 1810		13.2	1093.1		4.0	5.0				1115.3	0.4621

Nansenia groenlandica (Reinhardt, 1840)		13.2	7552.4			2.0		1.0		7568.6	3.1357
Nemichthys scolopaceus Richardson, 1848			269.7	1.0	1.0	1.0				272.7	0.1130
Normichthys operosus Parr, 1951			89.9						29.0	118.9	0.0493
oceanic *S.mentella*							1.0	6.0	4.0	11.0	0.0046
Paralepis coregonoides Risso, 1820			106.6							106.6	0.0442
Pollichthys mauli (Poll, 1953)	1.3									1.3	0.0006
Protomyctophum (*Hierops*) *arcticum* (Lütken, 1892)	5.3	10.4					1532.0	1.0	56.0	1604.7	0.6648
Schedophilus medusophagus Cocco, 1839		1.0	216.4		1.0	1.0			3.0	219.4	0.0921
Scopelogadus beanii (Günther, 1887)								1.0	19.0	20.0	0.0083
Sebastes mentella Travin, 1951 (105)		1.0	5408.0			2.0		11.0	16.0	5438.0	2.2530
Serrivomer beani Gill & Ryder, 1884		2.0			2.0	13.0		1.0	95.0	113.0	0.0468
Sternoptyx diaphana Hermann, 1781	1.3									1.3	0.0006
Stomias boa ferox Reinhardt, 1843	4.0	7.0		3.0	1.0	6.0	31.0	14.0	6.0	72.0	0.0298
Synaphobranchus kaupi Johnson, 1862			9.3			3.0			1.0	13.3	0.0055
unid. paralepididae			8.7					1.0		9.7	0.0040
unid. Platytroctidae			3.0		2.0					5.0	0.0021
unid.Myctophidae						7.0		1.0	32.0	40.0	0.0166
Xenodermichthys copei (Gill, 1884)			17.0			9.0		1.0	2.0	29.0	0.0120
Notoscopelus (*Notoscopelus*) *kroeyeri* (Malm, 1861)	5.3	24.8	262.0		3.7	73.0	1.0	1.0	2.0	372.8	0.1544
Grand Total	68.3	759.1	15624.2	653.0	179.4	241.0	22544.0	188789.0	12510.0	241368.0	100.0000
Species Richness	10	18	24	7	18	26	8	16	28	44	

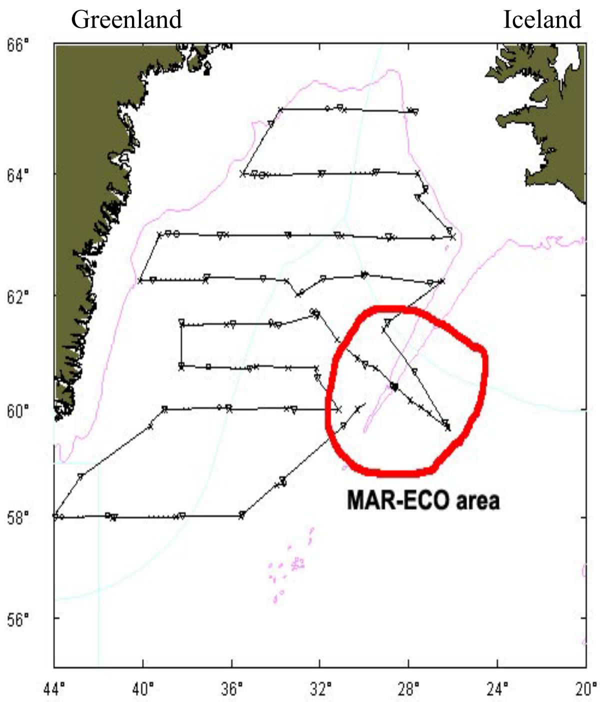


Figure 1. Cruise track for the 2003 REDFISH/MAR-ECO cruise in the Irminger Sea and adjacent Reykjanes Ridge aboard the Icelandic research vessel *Árni Friðriksson*. The cruise track extension for MAR-ECO is encircled.

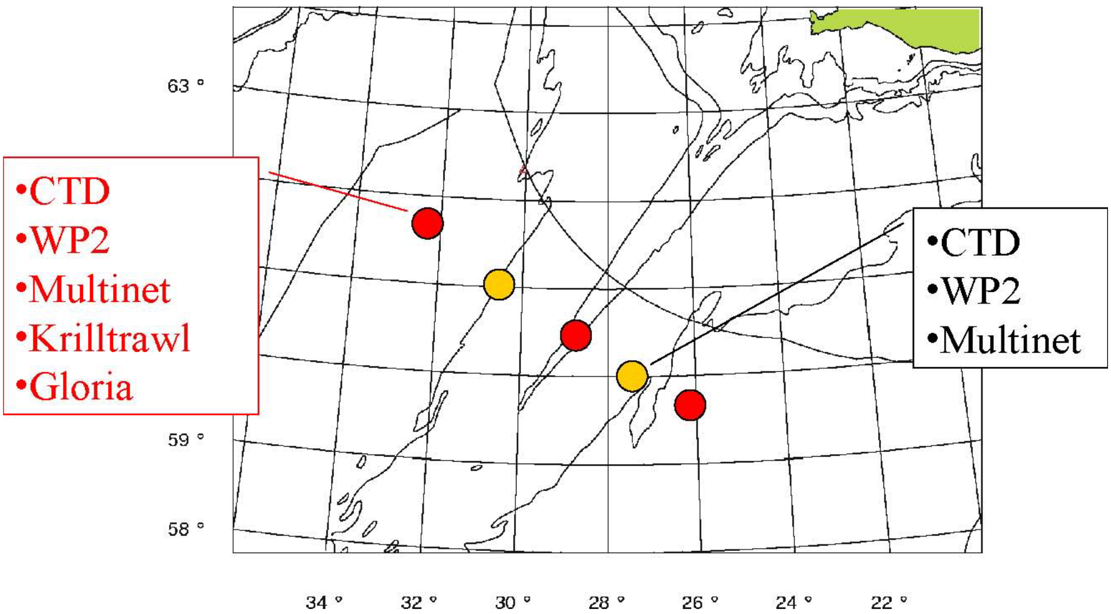


Figure 2. The Reykjanes Ridge transect of the 2003 *Árni Friðriksson* expedition. A total of 230 nautical miles separated hauls taken west of the Ridge and east of it.

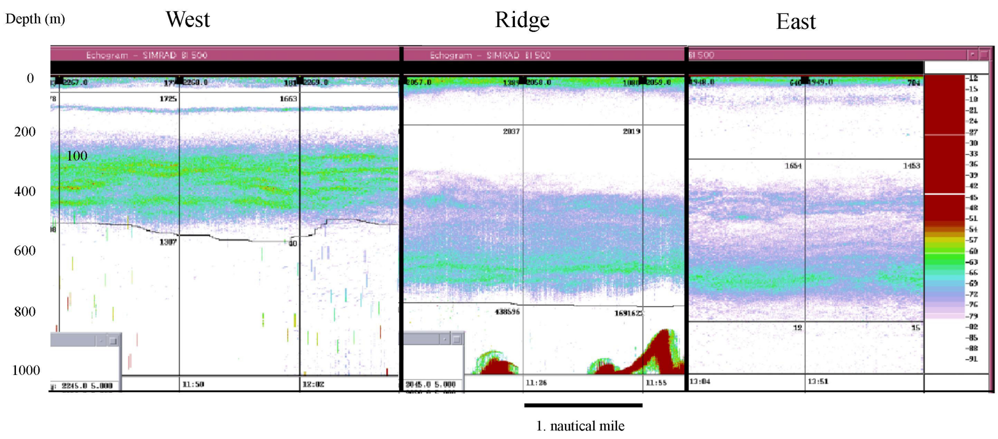


Figure 3. Examples of echograms taken during the Jun 2003 REDFISH/MAR-ECO survey across the Reykjanes Ridge (38-kHz SIMRAD EK 500 echo sounder), from the surface to 1000 m depth. All echograms are taken from the same time of day (near 1200 [approximate solar noon]). The ridge crest is shown at a depth of 900 m in the central panel.

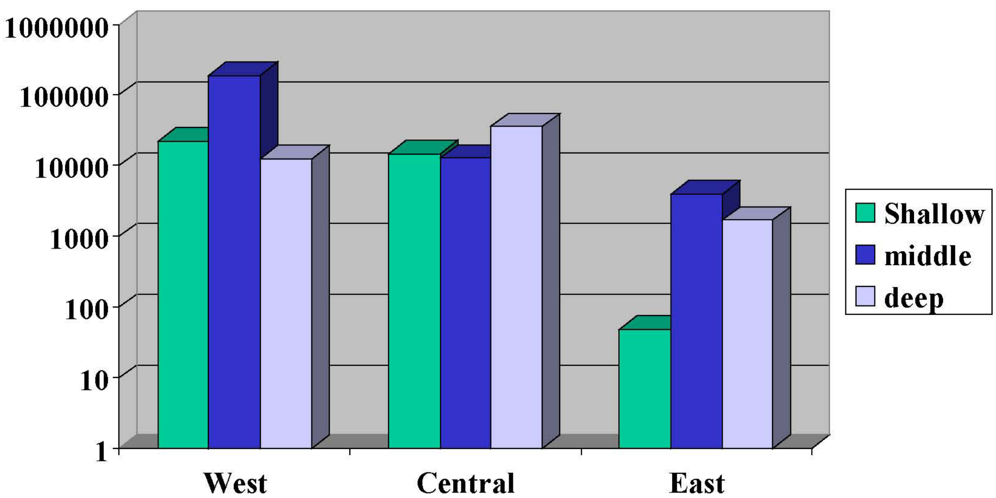
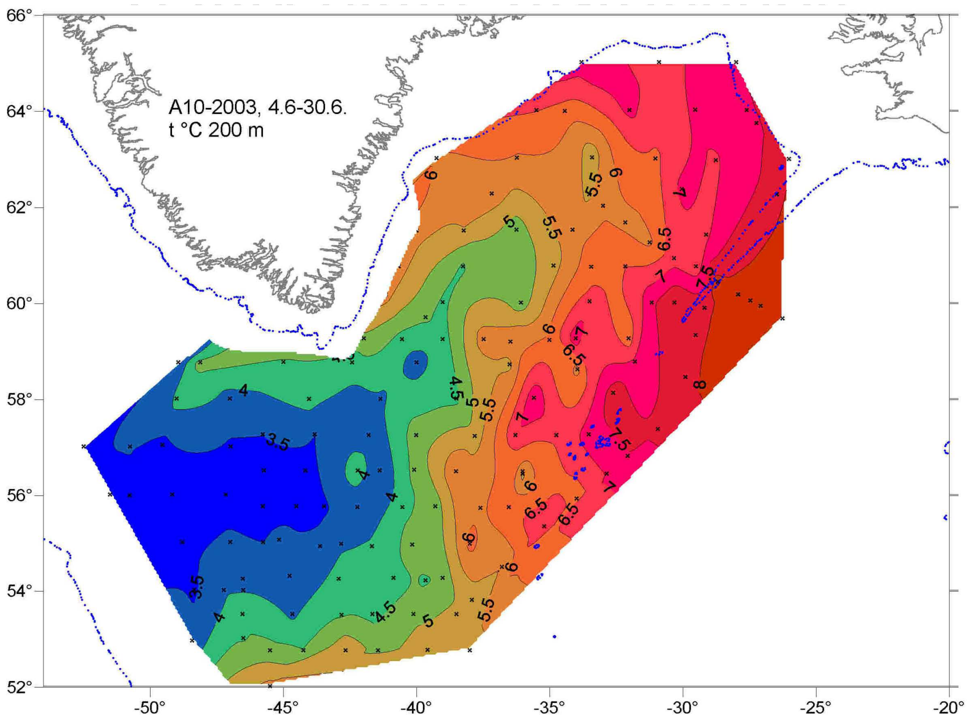


Figure 4. Total fish catch (no. nautical mile trawled^{-1}) as a function of geographical position relative to the Reykjanes Ridge during the Jun 2003 REDFISH/MAR-ECO survey. Note abundance scale is logarithmic.

a



b

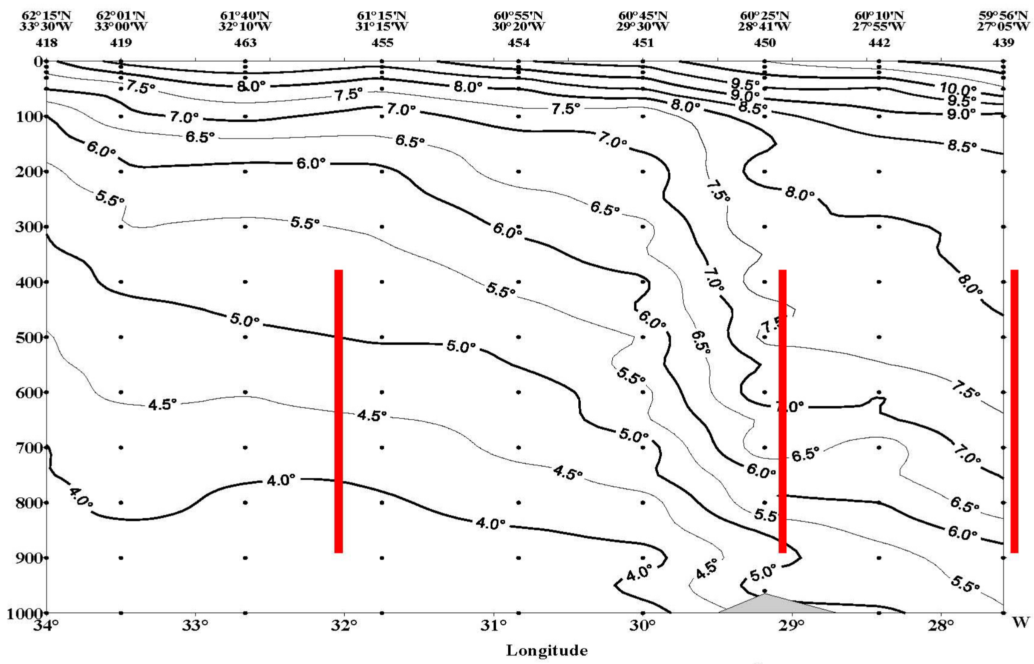


Figure 5. (a) Temperature overview at 200 m depth relative to the Reykjanes Ridge (top right), Jun 2003. (b). Temperature as a function of depth and longitude across the Reykjanes Ridge (60-62°N), Jun 2003. Position of trawl stations are plotted as solid red lines. The ridge crest can be seen as solid polygon in lower left.