

## Ecology of the midwater fish family Melamphaidae over the Mid-Atlantic Ridge

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### ***Abstract***

The 2004 MAR-ECO expedition over the northern Mid-Atlantic Ridge aimed, in part, to describe the overlying pelagic macro- and megafauna and their roles in mid-ocean ecosystems. The month-long cruise sampled portions of the ridge between Iceland and the Azores at 36 stations. One of the dominant pelagic fish families along the sampled segment of the ridge was the family Melamphaidae. Melamphaid species abundance and biomass data were examined with respect to depth, altitude above the ridge, and local area (Reykjanes Ridge, Charlie-Gibbs Fracture Zone, Faraday Seamount Zone or Azorean Zone). Highest species numbers and abundances occurred at depths between 750-1500 m. Some individuals were found above 200 m, setting new minimum depth of occurrence records for the family. Large-scale shifts in species composition were observed relative physical oceanographic features; for example, the genus *Scopelogadus* shifted from *S. beanii* dominance north of the Subpolar Front to *S. m. mizolepis* southward. Trawls less than 400 m above the bottom depth showed a trend towards higher melamphaid abundance and biomass in southern stations than northern stations. Given the high relative abundance in this survey, and their reported consumption of gelatinous prey, the Melamphaidae may represent a previously unknown trophic linkage between fishes and gelata in bathypelagic systems. Results of ongoing trophic analyses will be presented to assess the magnitude of this linkage along the northern Mid-Atlantic Ridge.

Keywords: Mid-Atlantic Ridge; MAR-ECO; Melamphaidae; relative abundance; species composition; mesopelagic; bathypelagic

## ***Introduction***

The Mid-Atlantic Ridge (MAR) is a unique habitat in the deep sea. The ridge is a series of abrupt topographic features formed by the separation of continental plates. It has been shown that seamounts and ridge systems are areas of high biomass. The MAR could provide an area of high energy due to so-called “seamount effects” (Dower and Mackas 1996, Haury *et al.* 2000, Genin 2004). One theory as to why fish aggregate around seamounts is that seamounts create localized upwelling while simultaneously creating anticyclonic vortices in which plankton are entrained (Dower and Mackas 1996, Mullineaux and Mills 1997, Haury *et al.* 2000). The interactions of the local upwelling and injection of new nutrients by vortices may increase primary production above the ridge, and thus augment higher trophic levels (Dower and Mackas 1996).

Another theory is that the ridge could act to concentrate vertically migrating prey, which would increase predator concentrations near the ridge (Isaacs and Schwartzlose 1965, Koslow 1997). The theory states that vertically migrating zooplankton are transported over ridge systems by currents and get trapped in areas where it is shallower than their normal diel migrations (e.g. seamounts like the MAR). Ridges have also been shown to be feeding grounds and/or navigational landmarks for large predators such as *Sphyrna lewini* and *Physeter macrocephalus* (Klimley *et al.* 2002, Moulins and Würtz 2005, Skov *et al.* 2008). Ridges like the MAR may represent unique deep-sea ecosystems where the interactions of multiple pelagic and benthic trophic levels can occur over a relatively concentrated area.

MAR-ECO ([www.mar-eco.no](http://www.mar-eco.no)) is a field project of the Census of Marine Life, aiming to describe the biodiversity and ecology of organisms over the northern MAR, from Iceland to the Azores. Sixteen nations are working together to understand the organisms and processes from the surface layer all the way down to the abyssal zone. The scientists of MAR-ECO aim to understand how a mid-ocean ridge system such as the MAR may affect the interactions of benthic and pelagic communities, which are usually separated by great distances. This consortium of experts in biology, oceanography and engineering not only allows for focus on specific groups of organisms but their relation to one another and their environment.

Sutton *et al.* (2008) described a biomass maximum below 1000 m along the northern MAR. This deep biomass maximum is rare as fish are usually most abundant in the top 1000 m of the water column (Angel and Baker 1982). The family Melamphaidae was not only one of the most abundant and biomass-dominant fish families caught during the MAR-ECO cruise, but is also one of the least studied of all fish families. Lack of distinguishing morphological characters, low sample size of study material, and unstable taxonomic status make the Melamphaidae a challenging family to study (Ebeling 1962; Keene 1987). Ebeling (1962) showed that the melamphuids were one of the most abundant families of the deep sea and the data from the MAR-ECO cruise supports that statement. In this paper we present information on the distribution, abundances and biomass of the melamphaid fishes over the MAR their contribution to the deep lying biomass maximum and discuss possible reasons for their success in this ecosystem.

## ***Materials and Methods***

Sample material was collected on Leg 1 of the MAR-ECO cruise aboard the Norwegian research vessel *G.O. Sars* along the northern Mid-Atlantic Ridge (from Iceland to the Azores), beginning 5 June and ending 3 July 2004 (Figure 1). The specific goal of the first leg of the MAR-ECO cruise was “to collect data for describing the diversity and distribution patterns of the plankton and nekton of the pelagic ecosystem of the MAR” (Godø 2004).

The northern MAR stretches from the southern coast of Iceland to the Azores (between 36°42'W - 25°57'W and 59°46'N - 38°37'N). The peaks of the ridge system rise from the surrounding abyssal plains to depths above 1000 m. The continuity of the ridge is broken in an area called the Charlie-Gibbs Fracture Zone (between 35°00'W - 32°00'W and 52°30'N - 52°00'N) which is a transverse fault in the otherwise linear MAR (Figure 1).

Samples were caught using a variety of nets. Each net contained a different mesh size that selected for certain-sized nekton. Macrozooplankton, Åkra and Egersund trawls were used to collect samples along the MAR, their mouth size and door spread are listed in Table 1. Information about each net deployment is found in Appendices 1-4, and additional details can be found in Wenneck et al. (2008). The Åkra and macrozooplankton trawls were outfitted with multiple cod ends (three and five, respectively), making it possible to sample discrete depth strata.

The samples collected were frozen at sea, thawed at the Bergen Museum, fixed in a 10% formalin:seawater mixture and then stored in 70% ethanol. In lab, specimens were patted dry and weighed to the nearest 0.01 g (wet weight). Standard length (the length from the tip of the snout to the end of the caudal peduncle) of each specimen was measured to the nearest 0.01 mm using a pair of calipers. In order to aid in species identification, each fish had the first gill arch removed from their right side and their gill rakers were counted.

### *Dissection*

For extraction of the gut contents, an incision was made down the ventral midline of each fish. This window makes it easier to separate the internal organs from the mesentery sac that attaches the organs to the dorsal and anterior portions of the body cavity. Once the body is opened, the mesenteries were cut. Cutting the mesenteries is essential to identifying the gender of the fish; if the internal organs are pulled out and are still attached to the abdominal wall, there is a good chance that the gonads will tear and be unidentifiable, as they are made of a very soft tissue.

Sex was determined based on the visual description of gonads in the works of Ebeling and Weed (1963) and Keene (1970). These descriptions were largely based on coloration of gonads which is not a good diagnostic character for specimen stored in alcohol, as the

alcohol tends to leach out color in tissues. With this in mind, modifications were made to the existing gonad descriptions in order to accurately identify the two sexes. Gonads were saved in separate vials of ethanol after initial determination of sex. Saved gonads will be examined microscopically for the presence of oocytes or spermatocytes.

### *Gut Content Analysis*

Identification of non-gelatinous prey items inside the stomachs were done by analyzing any hard parts found in the stomachs. Hard parts were taken out of the stomach and intestines and placed on a microscope slide or in separate vials, depending on size. Identification to the lowest taxonomic level possible will be done by examining hard parts for diagnostic characters.

Identification of soft organisms was done by applying a methylene blue dye to the tissues. The dye stains the muscle bands found in the pelagic tunicate prey on which melamphaid are thought to feed (Gartner and Musick 1989). If the gelatinous prey was neither Salpida nor Doliolida, then other diagnostic characters (e.g. nematocysts) were used to identify gelatinous prey to the lowest possible taxonomic level. Slides of gelatinous tissues were made in order to search for identifiable microscopic characteristics.

### **Results**

The four most abundant melamphaid species (*Poromitra crassiceps*, *Scopeloberyx robustus*, *Scopelogadus beanii*, *Scopelogadus mizolepis mizolepis*) accounted for 11.8% of the total biomass and 2.25% of the total number of fishes caught from 0-3000 m along the northern MAR. Highest species abundance occurred at depths between 750-1500 m (Figure 2) which coincides with previous estimates of melamphaid habitat ranges (Ebeling 1962; Ebeling and Weed 1963; Keene 1970; Keene 1987). Total biomass was highest in Depth Zone 4 between 1500-2300 m (Figure 3). This means that larger melamphaid tend inhabit deeper water, which supports the findings of Ebeling and Cailliet (1974). Several species were caught above 200 m (Depth Zone 1 in Figures 2 and 3) at several stations, setting new minimum depth of occurrence records for the family. High abundances and biomass at, and below, 1000 m depth suggest that melamphaid make up a significant proportion of the biomass maximum described by Sutton et al. (2008).

Large-scale shifts in species composition were observed relative physical oceanographic features; for example, the genus *Scopelogadus* shifted from *S. beanii* dominance north of the Subpolar Front to *S. m. mizolepis* southward (Figure 4). Though it is unknown what causes this shift in species composition, it is consistent with similar shifts in the fish (Sutton et al. 2008) and euphausiid (unpublished data) communities. Other slight North-to-South trends were seen in the total abundances and biomass for the family. Trawls less than 400 m above the bottom depth (Near Bottom) showed a trend towards higher melamphaid abundance and biomass in southern stations than northern stations (Figures 5 and 6). Though trawls greater than 400 m above the bottom depth (Far From Bottom)

showed no significant change in abundance between the northern and southern stations, they did show a trend towards smaller biomass totals in the south (Figures 5 and 6). Values for both abundance and biomass of the near and far stations showed peaks at or near the borders of the Reykjanes Ridge and Charlie-Gibbs Fracture Zone and the Faraday Seamount Zone and the Azorean Zone. The total number of stations considered to be “Near Bottom” is much smaller in comparison to the number of “Far From Bottom” stations due to the sampling technique and the Charlie-Gibbs Fracture zone. Discrete depth samples were taken as the net was traveling away from the bottom depths. At most, two “Near Bottom” samples were taken per station whereas up to five “Far From Bottom” samples were taken at certain stations. The depth of the Charlie-Gibbs Fracture zone also made it impossible to reach within 400 m of the bottom depth with the equipment used. Correlations between shifts in species composition and biomass and abundances close to the bottom depth could be due to a shift in habitat preference. These shifts also suggest that the Subpolar front could act as a rigid border between two separate communities inhabiting the northern MAR.

Given the high relative abundance in this survey, and their reported consumption of gelatinous prey, the Melamphaidae may represent a previously unknown trophic linkage between fishes and gelata in bathypelagic systems. Results of ongoing trophic analyses will be presented to assess the magnitude of this linkage along the northern Mid-Atlantic Ridge.

### ***Discussion***

Data from MAR-ECO sampling has revealed that the family Melamphaidae represents an important component of the Mid-Atlantic Ridge pelagic ecosystem. With high relative abundance and biomass, melamphaidae could also represent an important link in bathypelagic energy flow through this ridge system. The research presented here highlights the need for information about the Melamphaidae. A better understanding of this family, including its species composition, biogeography, and organismal ecology will greatly improve our knowledge about the deep sea and in particular the interactions of the deep pelagic fauna with abrupt topographic features such as the MAR.

Ongoing research into the diets and taxonomy of the family Melamphaidae aims to produce more information about the family and its relationship with the ridge environment. Gartner and Musick (1989) showed that the diet of one melamphaid, *Scopelogadus beanii*, consisted primarily of gelatinous zooplankton. They found that the majority of the gelatinous contents of the stomachs they studied were of the family Salpidae (Thaliacea). It was previously thought that gelatinous zooplankton offer little nutritional value to predators, and that gelatinous zooplankton were a “dead end” in marine food webs due to the lack of natural predators, and thus energy flow to higher trophic levels (Sommer *et al.* 2002; Nelson *et al.* 2002; Arai 2005). However, recent studies have shown that gelatinous zooplankton could play a more significant role in the diets of marine vertebrates than once believed (Kashkina 1986; Purcell and Arai 2001; Cartamil and Lowe 2004; Houghton *et al.* 2006). These findings suggest that gelatinous zooplankton may provide a key link between upper and lower trophic levels in the

pelagic food web. Predation on pelagic salps, and salp aggregations, could be the reason for the success of the family Melamphaidae along the MAR.

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Table 1. Trawl type broken down by size and door spread (Wenneck *et al.* 2008)

Trawl Type	Vertical Net Opening	Door Spread	Mesh Size
Egersund	90 m – 180 m	150	50 mm
Åkratrål	20 m – 35 m	110	22 mm
Macrozooplankton	6 m	N/A	6 mm

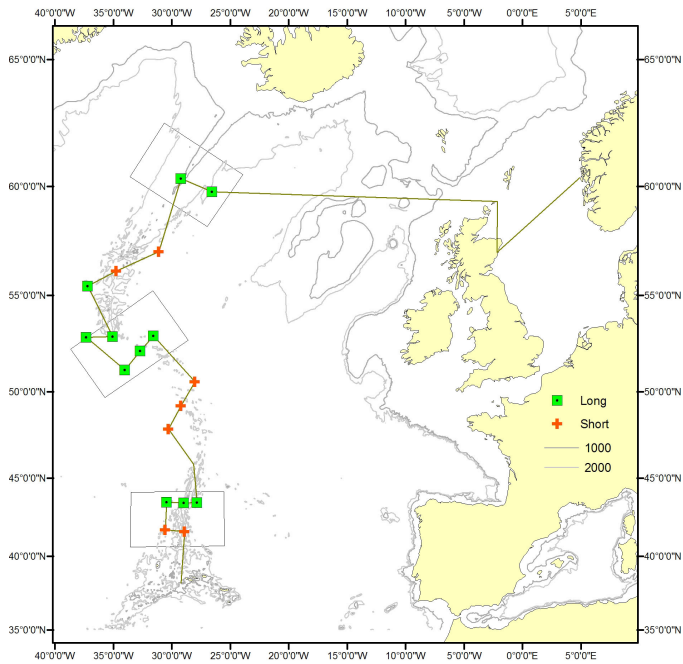


Figure 1. Mid-Atlantic Ridge including sample sites and bathymetry. Short and long station information found in Appendix 5. The boxes represent three areas of the ridge (from North to South): Reykjanes Ridge, Charlie-Gibbs Fracture Zone, and Azorean Zone.

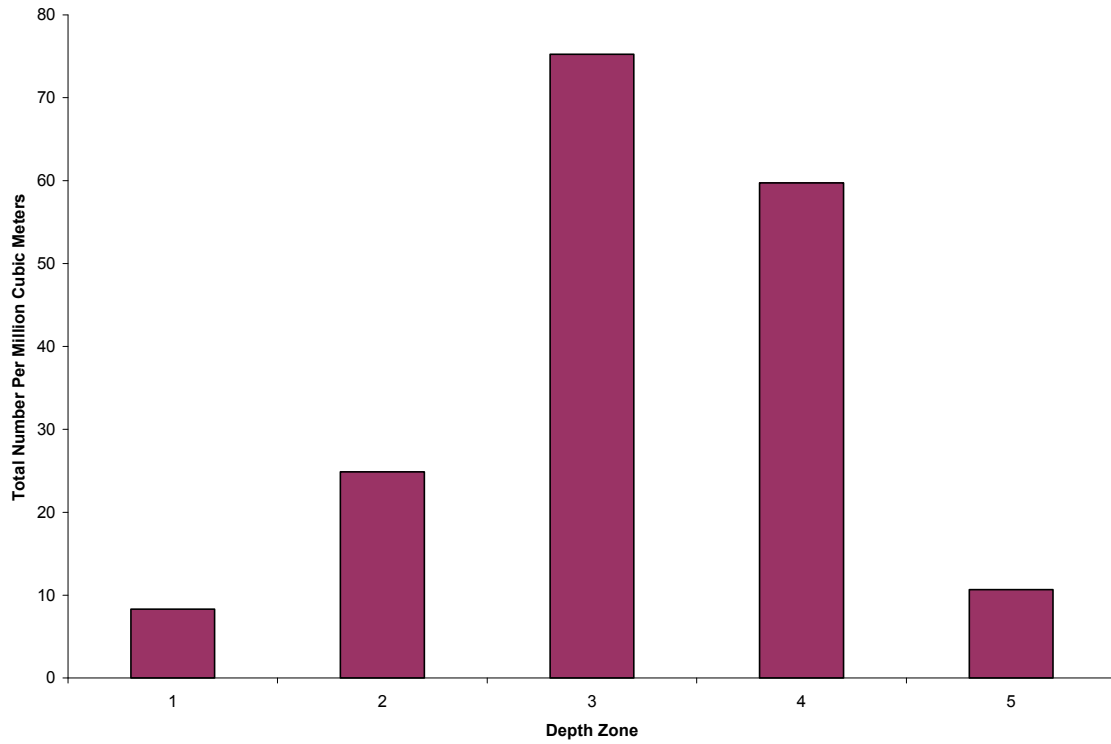


Figure 2. Total abundances at each of the five depth zones sampled over the northern Mid-Atlantic Ridge during the 2004 *G.O. Sars* expedition. Abundances are listed as total number  $\cdot 10^6 \text{ m}^{-3}$ . Depth zones: 1 = 0–200 m; 2 = 200–750 m; 3 = 750–1500 m; 4 = 1500–2300 m; 5 =  $\geq 2300$  m.

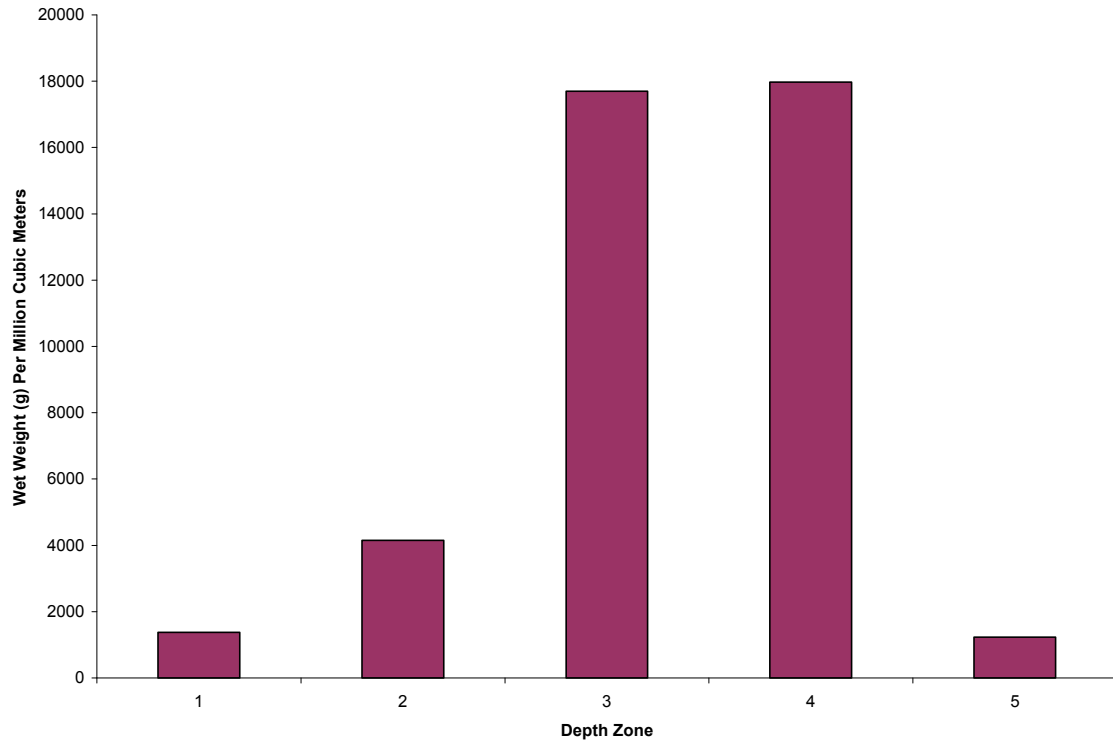


Figure 3. Total biomass at each of the five depth zones sampled over the northern Mid-Atlantic Ridge during the 2004 *G.O. Sars* expedition. Biomass is listed as wet weight (g)  $\cdot 10^6 \text{ m}^{-3}$ . Depth zones: 1 = 0–200 m; 2 = 200–750 m; 3 = 750–1500 m; 4 = 1500–2300 m; 5 =  $\geq 2300$  m.

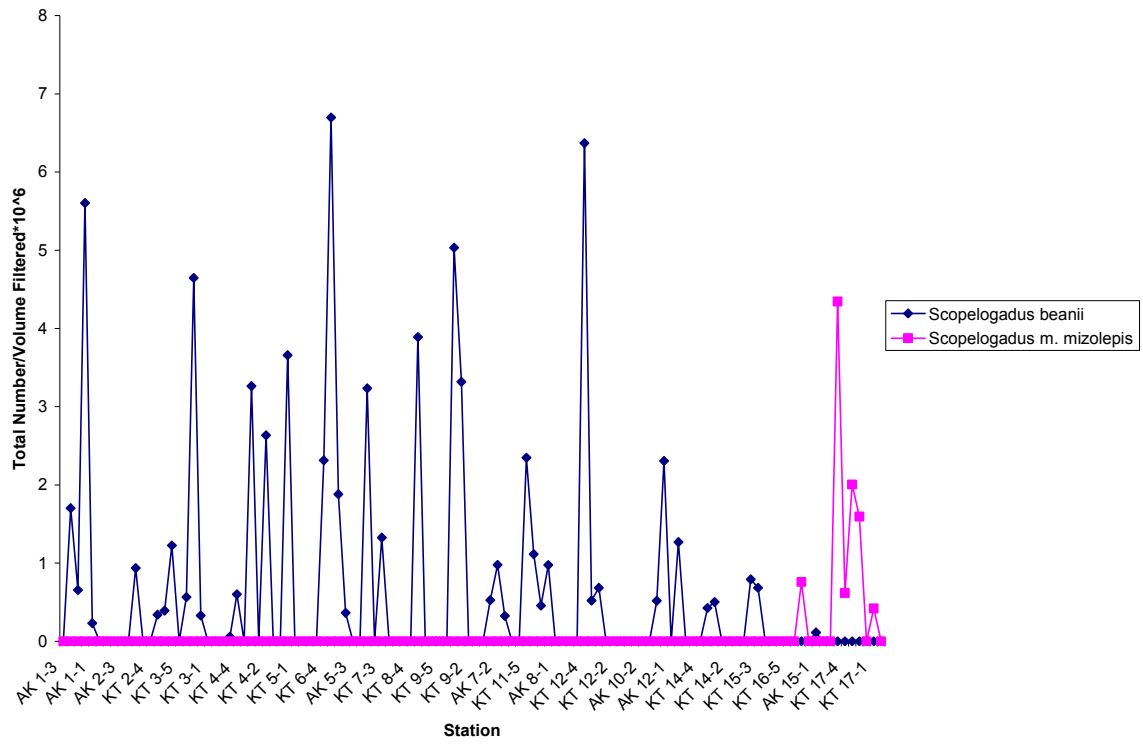


Figure 4. *Scopelogadus beanii* and *Scopelogadus mizolepis mizolepis* abundances showing the shift in dominance between *S. beanii* in the north to *S. m. mizolepis* in the south

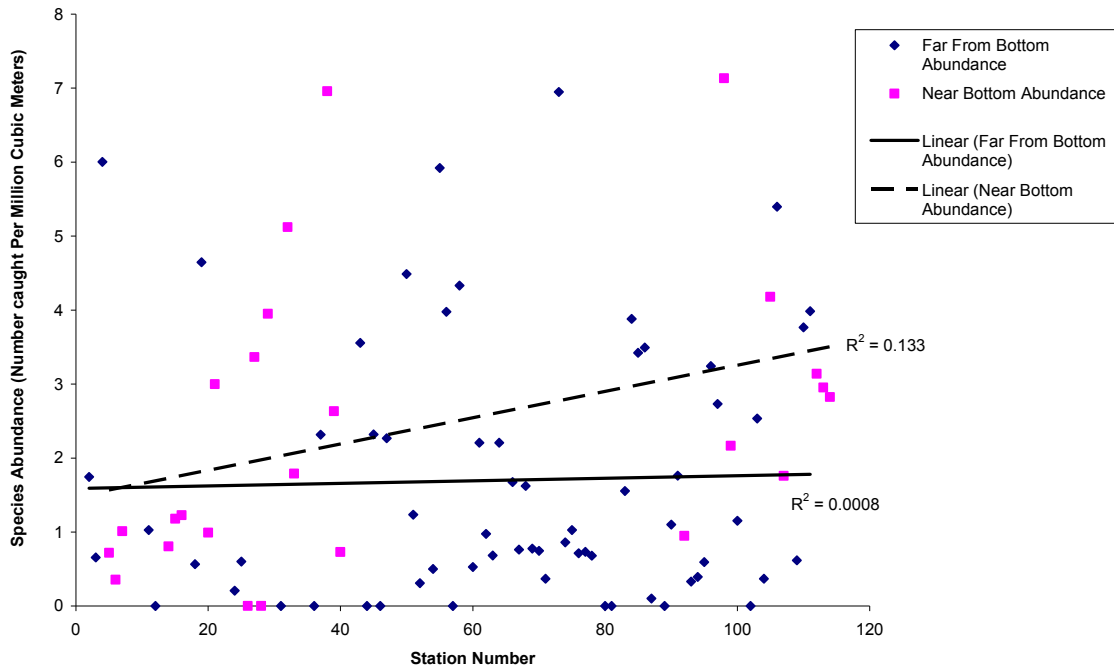


Figure 5. Species abundances compared between trawl samples taken near the bottom ( $\leq 400$  m above bottom depth) and far from the bottom ( $> 400$  m above bottom depth). Numbers on the x-axis are a numerical representation of each station. Trend line shows higher abundances in southern stations near the bottom than those in the north.

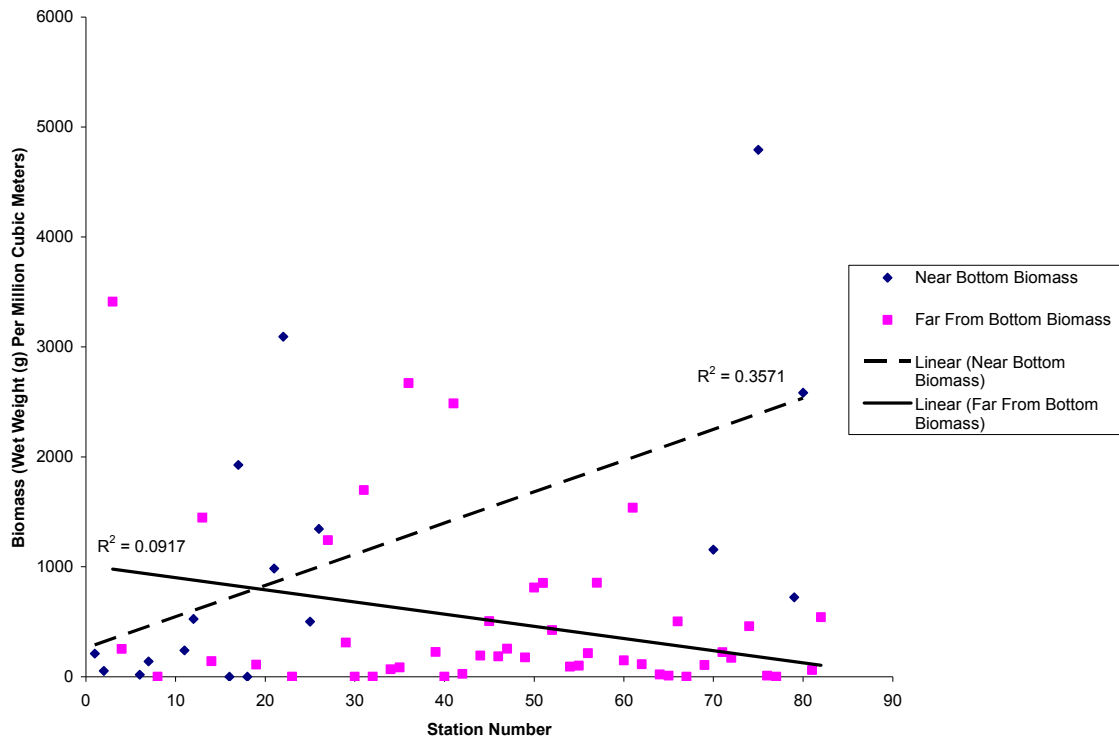


Figure 6. Total biomass of samples taken near the bottom depth and far from the bottom depth. Trendlines show a slight decline in biomass from the north to the south amongst the “Far From Bottom” stations and an increase in biomass from north to south for the “Near Bottom” stations. Numbers along the x-axis are a numerical representation of each station.

Appendix 1 (From Sutton *et al.* 2008)

Trawl samples from the 2004 MAR-ECO expedition used for deep-pelagic fish vertical distribution analysis

SS	Net no.	Sample code	Date	Latitude (°N)	Longitude (°W)	Bottom depth (m)	Max trawl depth (m)	Min trawl depth (m)	Depth zone	Solar cycle
2	AK 1-3	1	09-Jun	59.931	25.658	2260	180	0	1	D
2	AK 1-2	2	09-Jun	59.900	25.746	2314	750	370	2	D
2	AK 1-1	5	09-Jun	59.868	25.826	2264	2070	1500	4	D
2	KT 1-5	8	10-Jun	59.927	25.859	2127	200	10	1	ND
2	KT 1-4	3	10-Jun	59.934	25.838	2150	850	200	2	ND
2	KT 1-3	4	10-Jun	59.947	25.804	2187	1550	850	3	ND
2	KT 1-2	6	10-Jun	59.963	25.766	2219	1900	1550	4	N
2	KT 1-1	7	10-Jun	59.970	25.754	2222	2100	1900	bot-3.5	N
4	AK 2-3	9	11-Jun	60.314	28.302	1467	200	0	1	D
4	AK 2-2	11	11-Jun	60.319	28.356	1397	850	200	2	ND
4	AK 2-1	14	10-Jun	60.356	28.421	1419	1260	850	3	ND
4	KT 2-5	10	11-Jun	60.239	28.398	1393	175	5	1	D
4	KT 2-4	13	11-Jun	60.253	28.398	1393	475	175	2	D
4	KT 2-3	12	11-Jun	60.278	28.415	1353	740	475	2	D
4	KT 2-2	15	11-Jun	60.300	28.424	1664	1300	745	3	D
4	KT 2-1	16	11-Jun	60.307	28.428	1501	1330	1300	bot-3	D
6	KT 3-5	17	12-Jun	57.150	31.250	2315	200	0	1	N
6	KT 3-4	18	12-Jun	57.151	31.223	2321	700	200	2	N
6	KT 3-3	19	12-Jun	57.154	31.175	2357	1500	700	3	N
6	KT 3-2	20	12-Jun	57.158	31.127	2344	2140	1500	4	N
6	KT 3-1	21	12-Jun	57.159	31.116	2309	2170	2140	bot-4	N
8	AK 3-3	22	14-Jun	56.201	34.654	1344	300	0	1	D
8	AK 3-2	24	14-Jun	56.243	34.587	1315	800	300	2	ND
8	AK 3-1	27	14-Jun	56.285	34.513	1219	1050	800	bot-3	ND
8	KT 4-5	23	14-Jun	56.314	34.392	2031	200	0	1	N
8	KT 4-4	25	14-Jun	56.314	34.366	1847	760	200	2	N
8	KT 4-3	26	14-Jun	56.316	34.324	1680	1280	760	3	N
8	KT 4-2	29	14-Jun	56.320	34.275	1552	1330	1280	bot-3	DN
8	KT 4-1	28	14-Jun	56.321	34.266	1651	1335	1328	bot-3	DN
10	KT 5-5	30	14-Jun	55.536	36.558	2026	202	0	1	D
10	KT 5-4	31	14-Jun	55.552	36.560	2104	751	202	2	D
10	KT 5-2	32	14-Jun	55.604	36.569	2144	1920	1500	4	D
10	KT 5-1	33	14-Jun	55.609	36.570	2147	1985	1920	bot-4	D
12	AK 4-3	34	16-Jun	52.861	34.668	3239	293	0	1	D
12	AK 4-2	36	16-Jun	52.913	34.650	2744	800	300	2	D
12	AK 4-1	38	16-Jun	52.959	34.638	2112	1750	815	3	D
12	KT 6-5	35	16-Jun	53.047	34.629	1912	200	0	1	D
12	KT 6-4	37	16-Jun	53.060	34.616	1808	700	200	2	D
12	KT 6-3	39	16-Jun	53.081	34.597	1514	1186	700	3	D
12	KT 6-2	40	16-Jun	53.103	34.581	1636	1460	1186	bot-3	D
14	AK 5-3	41	16-Jun	53.182	36.783	3102	340	0	1	D
14	AK 5-2	43	16-Jun	53.134	36.753	3127	900	340	2	D
14	KT 7-5	42	18-Jun	53.083	36.698	3103	200	0	1	D
14	KT 7-4	44	18-Jun	53.041	36.702	3055	665	200	2	D
14	KT 7-3	45	18-Jun	53.067	36.710	3172	1480	665	3	D
14	KT 7-2	46	18-Jun	53.092	36.721	3130	2300	1500	4	D
14	KT 7-1	47	18-Jun	53.100	36.724	3153	2530	2300	5	D
16	KT 8-5	48	19-Jun	51.448	33.450	3794	238	36	1	D
16	KT 8-4	49	19-Jun	51.420	33.455	3793	678	236	2	D
16	KT 8-3	50	19-Jun	51.392	33.465	3764	1488	674	3	D
16	KT 8-2	51	19-Jun	51.364	33.474	3710	2248	1496	4	D

Appendix 1 (continued)

SS	Net no.	Sample code	Date	Latitude (°N)	Longitude (°W)	Bottom depth (m)	Max trawl depth (m)	Min trawl depth (m)	Depth zone	Solar cycle
16	KT 8-1	52	19-Jun	51.346	33.478	3688	3008	2239	5	D
18	AK 6-2	56	20-Jun	52.549	31.892	3935	1774	805	4	D
18	KT 9-5	53	20-Jun	52.983	30.771	3131	202	2	1	D
18	KT 9-4	54	20-Jun	52.995	30.790	3100	676	187	2	D
18	KT 9-3	55	20-Jun	53.014	30.821	3106	1502	685	3	D
18	KT 9-2	57	20-Jun	53.034	30.847	3095	2256	1518	4	D
18	KT 9-1	58	20-Jun	53.055	30.867	3070	2527	2256	5	D
20	AK 7-2	61	21-Jun	52.892	30.585	3167	1837	820	3	D
20	KT 10-5	59	21-Jun	52.983	30.771	3131	202	2	1	D
20	KT 10-4	60	21-Jun	52.995	30.790	3100	676	187	2	D
20	KT 10-3	62	21-Jun	53.014	30.821	3106	1502	685	3	D
20	KT 10-2	63	21-Jun	53.034	30.847	3095	2256	1518	4	D
20	KT 10-1	64	21-Jun	53.055	30.867	3070	2527	2256	5	D
22	AK 8-2	67	23-Jun	50.353	27.515	3650	1800	850	3	D
22	AK 8-1	69	23-Jun	50.395	27.497	3604	2370	1810	4	D
22	KT 11-5	65	23-Jun	50.516	27.486	3177	210	36	1	D
22	KT 11-4	66	23-Jun	50.532	27.488	3179	656	227	2	D
22	KT 11-3	68	23-Jun	50.559	27.491	3420	1487	647	3	D
22	KT 11-2	70	23-Jun	50.582	27.492	3520	2301	1774	4	D
22	KT 11-1	71	23-Jun	50.607	27.493	3705	2731	2309	5	D
24	AK 9-2	74	24-Jun	49.250	28.683	2606	1800	800	3	D
24	AK 9-1	76	24-Jun	49.288	28.662	2672	2230	1800	4	D
24	KT 12-5	72	24-Jun	49.590	28.480	3077	211	27	1	N
24	KT 12-4	73	24-Jun	49.567	28.483	3366	665	212	2	N
24	KT 12-3	75	24-Jun	49.541	28.486	3530	1776	666	3	ND
24	KT 12-2	77	24-Jun	49.516	28.485	3494	2338	1528	4	ND
24	KT 12-1	78	24-Jun	49.501	28.485	3589	2768	2314	5	ND
26	AK 10-2	81	25-Jun	47.967	29.510	3517	1746	800	3	D
26	AK 11-3	79	25-Jun	47.796	29.166	3495	250	0	1	D
26	AK 11-2	80	25-Jun	47.810	29.188	3095	603	250	2	D
28	AK 12-2	85	27-Jun	42.814	27.881	2657	1770	829	3	D
28	AK 12-1	86	27-Jun	42.809	27.825	3010	2400	1810	4	D
28	KT 13-5	83	27-Jun	42.813	27.691	2996	138	7	1	D
28	KT 13-4	84	27-Jun	42.828	27.700	2989	691	151	2	D
28	KT 13-2	87	27-Jun	42.883	27.733	2822	2308	1475	4	D
28	KT 13-1	88	27-Jun	42.901	27.743	2890	2202	2295	5	D
30	AK 13-2	91	28-Jun	42.783	29.468	2407	1800	810	3	D
30	AK 13-1	93	28-Jun	42.789	29.389	2492	2390	1800	4	D
30	KT 14-5	89	28-Jun	42.951	29.257	1949	186	36	1	D
30	KT 14-4	90	28-Jun	42.953	29.274	2443	598	175	2	D
30	KT 14-3	92	28-Jun	42.939	29.312	2718	1500	604	3	D
30	KT 14-2	94	28-Jun	42.912	29.306	2828	2283	1480	4	D
30	KT 14-1	95	28-Jun	42.890	29.303	2839	2383	2265	5	D
32	AK 14-2	97	29-Jun	42.678	30.197	2532	1800	800	3	D
32	AK 14-1	99	29-Jun	42.720	30.215	2542	2300	1800	4	D
32	KT 15-4	96	29-Jun	42.442	30.145	2364	675	188	2	DN
32	KT 15-3	98	29-Jun	42.467	30.144	2289	1523	652	3	DN
32	KT 15-2	100	29-Jun	42.492	30.145	2411	2005	1495	4	D
32	KT 15-1	101	29-Jun	42.515	30.148	2287	1828	2031	bot-4	D
34	AK 15-2	104	30-Jun	41.517	29.909	2230	1800	800	3	D
34	AK 15-1	106	30-Jun	41.560	29.924	2335	2000	1800	4	D
34	KT 16-5	102	30-Jun	41.684	29.999	1927	203	0	1	N
34	KT 16-4	103	30-Jun	41.698	29.999	2317	684	205	2	N
34	KT 16-3	105	30-Jun	41.721	29.999	2177	1494	674	3	N
34	KT 16-2	108	30-Jun	41.746	30.002	2154	1887	1490	4	N
34	KT 16-1	107	30-Jun	41.769	30.007	2524	1981	1887	4	N
36	KT 17-5	109	30-Jun	41.486	28.346	2698	180	0	1	N
36	KT 17-4	110	30-Jun	41.489	28.364	2524	729	218	2	N
36	KT 17-3	112	30-Jun	41.494	28.392	2602	1493	725	3	N
36	KT 17-2	115	30-Jun	41.498	28.425	2441	2036	1489	4	N
36	KT 17-1	114	30-Jun	41.499	28.453	2654	1980	2042	4	N
36	AK 16-2	111	1-Jul	41.239	28.238	2616	1800	800	3	D
36	AK 16-1	113	1-Jul	41.295	28.244	2722	2400	1800	4	D

SS – SuperStation (see Fig. 1). Net: AK = Åkra trawl sample; KT = Krill trawl sample. Sample codes are used in later figures for graphical clarity. Depth zones: 1 = 0–200 m; 2 = 200–750 m; 3 = 750–1500 m; 4 = 1500–2300 m; 5 ≥ 2300 m; bot = near-bottom trawl (depth zone of bottom). Solar cycle: D = day; N = night; DN = dusk; ND = dawn. Group no. = assemblage as defined by multivariate analysis.



## Appendix 2 (From Wenneck *et al.* 2008)

Station list for the medium-sized pelagic fish trawl (Aakratrawl) during Leg 1 of the 2004 MAR-ECO expedition

Superstation	Local station	Serial number	Date	Latitude (N)	Longitude (W)	Fishing depth (m)	
						Min.	Max.
2	326	1001	09.06.2004	59°52'	25°50'	1500	2070
2	326	1002	09.06.2004	59°54'	25°45'	370	750
2	326	1003	09.06.2004	59°56'	25°39'	0	180
2	326	8002	09.06.2004	59°52'	25°50'	0	2070
4	328	1009	10.06.2004	60°21'	28°25'	850	1260
4	328	1010	11.06.2004	60°19'	28°21'	200	850
4	328	1011	11.06.2004	60°17'	28°18'	0	200
4	328	8003	10.06.2004	60°21'	28°25'	0	1260
8	334	1031	14.06.2004	56°17'	34°31'	800	1050
8	334	1032	14.06.2004	56°15'	34°35'	300	800
8	334	1033	14.06.2004	56°12'	34°39'	0	300
8	334	8001	14.06.2004	56°17'	34°31'	0	1050
12	339	1046	16.06.2004	52°58'	34°38'	815	1750
12	339	1047	16.06.2004	52°55'	34°39'	300	800
12	339	1048	16.06.2004	52°52'	34°40'	0	293
12	339	8000	16.06.2004	52°58'	34°38'	0	1750
14	341	1055	18.06.2004	53°05'	36°43'	340	900
14	341	1056	18.06.2004	53°08'	36°45'	0	340
14	341	1057	18.06.2004	53°11'	36°47'	1060	2792
14	341	8004	18.06.2004	53°05'	36°43'	0	2792
18	346	1071	20.06.2004	52°32'	31°49'	1821	2800
18	346	1072	20.06.2004	52°33'	31°53'	805	1774
18	346	1073	20.06.2004	52°34'	31°58'	0	743
20	348	1079	21.06.2004	52°56'	30°38'	1850	2787
20	348	1080	21.06.2004	52°54'	30°35'	820	1837
20	348	1081	21.06.2004	52°51'	30°33'	0	806
20	348	8005	21.06.2004	52°56'	30°38'	0	2787
22	350	1087	23.06.2004	50°24'	27°30'	1810	2370
22	350	1088	23.06.2004	50°21'	27°31'	850	1800
22	350	1089	23.06.2004	50°18'	27°32'	0	780
22	350	8006	23.06.2004	50°24'	27°30'	0	2370
24	352	1095	24.06.2004	49°17'	28°40'	1800	2230
24	352	1096	24.06.2004	49°15'	28°41'	800	1800
24	352	1097	24.06.2004	49°12'	28°43'	0	800
24	352	8007	24.06.2004	49°17'	28°40'	0	2230
26	354	1103	25.06.2004	48°00'	29°34'	1800	2600
26	354	1104	25.06.2004	47°58'	29°31'	800	1746
26	354	1105	25.06.2004	47°57'	29°26'	0	788
26	354	8008	25.06.2004	48°00'	29°34'	0	2600
26	355	1106	25.06.2004	47°50'	29°13'	600	825
26	355	1107	25.06.2004	47°49'	29°11'	250	603
26	355	1108	25.06.2004	47°48'	29°10'	0	250
28	357	1114	27.06.2004	42°49'	27°50'	1810	2400
28	357	1115	27.06.2004	42°49'	27°53'	829	1770
28	357	1116	27.06.2004	42°49'	27°57'	0	800
28	357	8009	27.06.2004	42°49'	27°50'	0	2400
30	359	1122	28.06.2004	42°47'	29°23'	1800	2390
30	359	1123	28.06.2004	42°47'	29°28'	810	1800
30	359	1124	28.06.2004	42°47'	29°32'	0	795
32	361	1125	29.06.2004	42°43'	30°13'	1800	2300
32	361	1126	29.06.2004	42°41'	30°12'	800	1800
32	361	1127	29.06.2004	42°38'	30°10'	50	800
32	361	8010	29.06.2004	42°43'	30°13'	50	2300
34	364	1138	30.06.2004	41°34'	29°55'	1800	2000
34	364	1139	30.06.2004	41°31'	29°55'	800	1800
34	364	1140	30.06.2004	41°28'	29°54'	0	800
34	364	8011	30.06.2004	41°34'	29°55'	0	2000
36	366	1146	01.07.2004	41°18'	28°15'	1800	2400
36	366	1147	01.07.2004	41°14'	28°14'	800	1800
36	366	1148	01.07.2004	41°11'	28°14'	0	800
36	366	8012	01.07.2004	41°18'	28°15'	0	2400

For each superstation, each tow produced depth-stratified catches from three codends. The fourth "net", that sampled the entire depth range of the tow, is the sample derived from the forenet of the trawl.

### Appendix 3 (from Wenneck *et al.* 2008)

Station list for large pelagic fish trawl (Egersundtrawl) during Leg 1 of the 2004 MAR-ECO expedition

Superstation	Local station	Serial number	Date	Latitude (N)	Longitude (W)	Fishing depth (m)	
						Min.	Max.
7	332	1025	13.06.2004	57°05'	31°22'	1180	1530
11	336	1039	15.06.2004	55°28'	36°28'	1000	1500
11	337	1040	15.06.2004	55°20'	36°18'	1000	1450
15	342	1057	18.06.2004	52°45'	35°57'	1800	2015
31	360	1199	28.06.2004	42°47'	30°05'	1434	1434

## Appendix 4 (from Wenneck *et al.* 2008)

Station list for the macrozooplankton trawl during Leg 1 of the 2004 MAR-ECO expedition

Superstation	Local station	Serial number	Date	Latitude (N)	Longitude (W)	Fishing depth (m)		Filtered volume (m <sup>3</sup> )
						Max.	Min.	
2	327	1004	09.06.2004	59°58'	25°45'	1843	2141	35,655
2	327	1005	09.06.2004	59°58'	25°46'	1555	1803	101,738
2	327	1006	10.06.2004	59°57'	25°48'	880	1546	89,929
2	327	1007	10.06.2004	59°56'	25°50'	180	844	54,831
2	327	1008	10.06.2004	59°56'	25°52'	11	174	23,409
4	329	1012	11.06.2004	60°18'	28°26'	1304	1329	29,349
4	329	1013	11.06.2004	60°18'	28°25'	744	1302	91,568
4	329	1014	11.06.2004	60°17'	28°25'	472	729	107,075
4	329	1015	11.06.2004	60°15'	28°24'	172	464	60,264
4	329	1016	11.06.2004	60°14'	28°24'	5	164	19,529
6	331	1020	12.06.2004	57°10'	31°07'	2135	2155	24,013
6	331	1021	12.06.2004	57°10'	31°08'	1493	2124	109,070
6	331	1022	12.06.2004	57°09'	31°10'	834	1476	108,503
6	331	1023	12.06.2004	57°09'	31°13'	171	811	63,655
6	331	1024	12.06.2004	57°09'	31°15'	2	165	28,613
8	333	1026	13.06.2004	56°19'	34°16'	1328	1337	21,338
8	333	1027	13.06.2004	56°19'	34°17'	1249	1330	109,381
8	333	1028	13.06.2004	56°19'	34°19'	762	1244	96,255
8	333	1029	13.06.2004	56°19'	34°22'	169	762	59,937
8	333	1030	13.06.2004	56°19'	34°23'	0	173	22,226
10	335	1034	14.06.2004	55°37'	36°34'	1986	1928	20,110
10	335	1035	14.06.2004	55°36'	36°34'	1489	1997	98,392
10	335	1036	14.06.2004	55°35'	36°34'	744	1480	115,106
10	335	1037	14.06.2004	55°33'	36°34'	189	736	66,332
10	335	1038	14.06.2004	55°32'	36°33'	7	189	21,052
12	338	1041	16.06.2004	53°06'	34°35'	1532	1457	16,885
12	338	1042	16.06.2004	53°06'	34°35'	1179	1529	98,817
12	338	1043	16.06.2004	53°05'	34°36'	680	1181	95,720
12	338	1044	16.06.2004	53°04'	34°37'	206	660	62,196
12	338	1045	16.06.2004	53°03'	34°38'	7	183	22,897
14	340	1049	17.06.2004	53°06'	36°43'	2304	2534	31,768
14	340	1050	17.06.2004	53°06'	36°43'	1496	2284	106,524
14	340	1051	17.06.2004	53°04'	36°43'	665	1478	108,691
14	340	1052	17.06.2004	53°02'	36°42'	175	668	54,945
14	340	1053	17.06.2004	53°02'	36°42'	25	175	19,435
16	343	1058	19.06.2004	51°27'	33°27'	2239	3008	116,674
16	343	1059	19.06.2004	51°25'	33°27'	1496	2248	116,531
16	343	1060	19.06.2004	51°24'	33°28'	674	1488	120,300
16	343	1061	19.06.2004	51°22'	33°28'	236	678	73,743
16	343	1062	19.06.2004	51°21'	33°29'	36	238	20,657
18	345	1066	20.06.2004	52°24'	31°49'	2320	2660	108,037
18	345	1067	20.06.2004	52°25'	31°47'	1444	2316	118,900
18	345	1068	20.06.2004	52°27'	31°46'	702	1440	121,619
18	345	1069	20.06.2004	52°28'	31°44'	177	716	72,010
18	345	1070	20.06.2004	52°29'	31°43'	11	186	33,267
20	347	1074	21.06.2004	53°03'	30°52'	2256	2526	97,829
20	347	1075	21.06.2004	53°02'	30°51'	1518	2256	105,408
20	347	1076	21.06.2004	53°01'	30°49'	685	1502	110,656
20	347	1077	21.06.2004	52°60'	30°47'	188	674	68,308
20	347	1078	21.06.2004	52°59'	30°46'	2	202	18,771
22	349	1082	23.06.2004	50°36'	27°30'	2309	2731	97,861
22	349	1083	23.06.2004	50°35'	27°29'	1774	2301	96,557
22	349	1084	23.06.2004	50°34'	27°29'	647	1487	110,879
22	349	1085	23.06.2004	50°32'	27°29'	227	656	64,547
22	349	1086	23.06.2004	50°31'	27°29'	36	210	15,339
24	351	1090	24.06.2004	49°35'	28°29'	2314	2768	105,943
24	351	1091	24.06.2004	49°34'	28°29'	1528	2338	98,426
24	351	1092	24.06.2004	49°32'	28°29'	666	1776	105,224
24	351	1093	24.06.2004	49°31'	28°29'	212	665	62,181
24	351	1094	24.06.2004	49°30'	28°29'	27	211	21,070
26	Failed tow							

Appendix 4 (continued)

Superstation	Local station	Serial number	Date	Latitude (N)	Longitude (W)	Fishing depth (m)		Filtered volume (m <sup>3</sup> )
						Max.	Min.	
28	356	1109	27.06.2004	42°54'	27°45'	2295	2202	353,377
28	356	1110	27.06.2004	42°53'	27°44'	1474	2308	113,381
28	356	1111	27.06.2004	42°51'	27°43'	699	1476	112,869
28	356	1112	27.06.2004	42°50'	27°42'	151	691	69,452
28	356	1113	27.06.2004	42°49'	27°41'	7	138	60,855
30	358	1117	28.06.2004	42°53'	29°18'	2265	2383	91,439
30	358	1118	28.06.2004	42°55'	29°18'	1480	2283	109,229
30	358	1119	28.06.2004	42°56'	29°19'	604	1500	143,030
30	358	1120	28.06.2004	42°57'	29°16'	175	598	51,004
30	358	1121	28.06.2004	42°57'	29°15'	36	186	23,304
32	362	1128	29.06.2004	42°31'	30°09'	2030	1828	93,626
32	362	1129	29.06.2004	42°30'	30°09'	1495	2008	99,716
32	362	1130	29.06.2004	42°28'	30°09'	652	1523	105,441
32	362	1131	29.06.2004	42°27'	30°09'	188	675	60,606
32	362	1132	29.06.2004	42°26'	30°09'	1	195	19,314
34	363	1133	30.06.2004	41°46'	30°00'	1887	1981	93,402
34	363	1134	30.06.2004	41°45'	30°00'	1490	1887	102,346
34	363	1135	30.06.2004	41°43'	29°60'	674	1494	97,902
34	363	1136	30.06.2004	41°42'	29°60'	205	684	56,691
34	363	1137	30.06.2004	41°41'	29°60'	0	203	23,817
36	365	1141	30.06.2004	41°30'	28°27'	2042	1980	85,369
36	365	1142	30.06.2004	41°30'	28°26'	1489	2036	101,932
36	365	1143	30.06.2004	41°30'	28°24'	725	1493	90,335
36	365	1144	01.07.2004	41°29'	28°22'	218	729	58,311
36	365	1145	01.07.2004	41°29'	28°21'	0	180	24,865

Each tow (local station number) had five samples (codends with separate serial numbers).