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Strategies, methods, and technologies adopted on the R.V. *G.O. Sars* MAR-ECO expedition to the Mid-Atlantic Ridge in 2004

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Abstract

The MAR-ECO project aimed to gather information on mid-ocean ridge macro- and megafaunal assemblages and their distribution patterns in relation to the abiotic environment, and the target area extended from Iceland to the Azores, comprising waters associated with the Mid-Atlantic Ridge. Strategies and methods adopted on the 2004 international expedition on the R.V. *G.O. Sars* and M.S. *Loran* were selected in order to maximise data and sample collection in all pelagic and benthic habitats to a maximum depth of 3500 m, spanning the organism size range from mm to metres. The approach selected was to combine (1) *Continuous sampling* along the ship's track; (2) *Point observations* using a pre-defined set of samplers at pre-determined sites; and (3) *Opportunistic sampling* to study particular phenomena or carry out exceptional tasks.

A wide range of nets and mid-water and bottom trawls were mobilised in order to collect biological samples. Hull-mounted, lowered and towed optical and acoustical instruments collected data and images. Two remotely operated vehicles (ROVs) were used for pelagic and demersal studies, and moored echosounders and cameras on benthic landers collected vessel-independent information. Observation of whales and seabirds were made from a custom-built observation area on top of the wheelhouse. Using a range of technologies from the same platform efficiently provided comprehensive results and enhanced the potential for new discoveries at the organism, community, and ecosystem levels.

Keywords: Mid-ocean ridge; Station data; Sampling gear; Instruments; Hydrography; Biological data and collections

1. Introduction

The Census of Marine Life project MAR-ECO (Bergstad and Godø, 2003; www.mar-eco.no) aimed to gather new information on macro- and megafaunal assemblages in the area extending from Iceland to the Azores, in waters associated with the Mid-Atlantic Ridge (MAR). A major effort of the project was the international expedition on the R.V. *G.O. Sars* and the chartered long-liner M.S. *Loran* in June–July 2004, and the following is a description of strategies and methods adopted on that expedition.

Working in mid-ocean waters and at great depths and in rugged topography is technologically challenging and expensive. MAR-ECO's strategy was to mobilise relevant experts, instruments and ships from several countries in order to achieve a satisfactory competence and capacity to meet the many and varied challenges at an acceptable cost. During planning meetings in 2001–2003, the scientific team recognised that using a range of technologies on the same platform would provide more comprehensive results and enhance the potential for new discoveries. The aim was to sample and/or observe organisms within the size range from mm to metres (e.g., small zooplankters to whales); hence a range of samplers adapted to collect this kind of information in the most accurate and efficient way was needed. In order to sample all relevant depths, the technologies would ideally need to function from surface

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waters to at least 3500 m, preferably to about 4500 m to reach the bottom of the deepest fractures. These considerations formed the basis for the strategies and methodologies selected for the 2004 MAR-ECO expedition.

The MAR-ECO experience is an example of how a comprehensive exploratory faunistic and ecological investigation of rather unknown mid-ocean habitats and communities can be conducted. The objective in this paper is to provide a reference account of strategies, technologies, procedures, and the resulting datasets, but not to provide data nor a final evaluation of the success or failure of the strategy and operations. An evaluation would be premature given that many scientific analyses based on the data and material sampled on the expedition have yet to be reviewed and published.

This account describes strategies, technologies, and methods used on the research vessel. R.V. *G.O. Sars* is 77.5 m long and constructed and equipped as a multipurpose platform for marine research (physical and chemical oceanography, marine biology including fisheries, and marine geology). When fully equipped for marine biological investigations, the vessel can operate a multitude of samplers and instruments on the same cruise, and she is particularly well fitted with permanent hydroacoustic instruments. With a general noise-reducing design, the diesel-electric propulsion (2×3000 kW), and transducers mounted on a protruding keel, the vessel meets International Council for the Exploration of the Sea (ICES) requirements for noise emission. Further details on the vessel can be found on the website (http://www.uib.no/forskningsfartoy/english/specs/index.html). The vessel was launched in 2003 and committed to MAR-ECO by the Institute of Marine Research and the University of Bergen, Norway.

M.S. *Loran* deployed commercial longlines in rugged terrain inaccessible to bottom trawl sampling by the research vessel. The operation constituted a significant supplement to the sampling of demersal fish by other means. Methods and strategy for that vessel is not included in this paper, but a full description of the *Loran* operation was given in the cruise report by Dyb and Bergstad (2004) (available at www.mar-eco.no/sci), and in Fossen et al. (2008).

2. Strategy and approach

The MAR-ECO effort was specifically designed to gather information on species assemblages and how these were distributed spatially and in relation to the abiotic environment.

In order to achieve quasi-synoptic information on the Iceland to Azores spatial scale, the MAR-ECO project adopted a combination of (1) *Continuous sampling* along the ship's track; (2) *Point observations* using a pre-defined set of samplers at pre-determined sites; and (3) *Opportunistic sampling* in order to study particular phenomena or carry out exceptional tasks. Ship-time constraints limited the 2004 MAR-ECO sampling effort to the ridge axis and waters off the ridge on either side to bottom depths of about 3500 m.

2.1. Sampling design and operations

The ship's track was pre-defined with the objective of gathering information within the Ridge-associated area mentioned above (partially excluding the northernmost waters of the Reykjanes Ridge that had been sampled in previous years by the Icelandic vessel R.V. *Arni Fridriksson*). Knowledge of the spatial patterns of fauna from previous cruises was very limited; hence strict adherence to a certain sampling strategy or survey design was inappropriate.

The expedition was divided into two legs of approximately equal duration. Leg 1 was dedicated to pelagic sampling, and Leg 2 mainly to demersal sampling but with some zooplankton observations and sampling using acoustics, optics, and ROV. A midpoint call in Horta in the Azores marked the end of Leg 1 and start of Leg 2.

The locations selected for point sampling on Legs 1 and 2 are shown in Figs. 1 and 2, respectively, and further details are given in Table 1 and Appendix A. These locations are referred to as "superstations", and a "superstation" (SS) is defined as a collection of activities within a given location or section of the ship's track. Each activity, e.g., a trawl tow, plankton net, CTD-cast, belonging to a given superstation, is identified uniquely by a "serial number" or a "local station" (LS) number. The benefit of this arrangement is that in the database, all activities from the same location can be selected by reference to the superstation number.

2.2. Leg 1

The decision, reached after extensive pre-survey discussion, was to conduct a zig–zag track, including several cross-ridge transects. This procedure ensured a reasonably even sampling effort in the entire target area during the 3 weeks of ship-time available for a pelagic survey. Large-scale physical features in addition to the MAR proper were the Charlie-Gibbs Fracture Zone (CGFZ) and the subpolar frontal zone located near or just south of the CGFZ. The survey lines were placed so as to achieve several crossings of these features (Fig. 1).

2.2.1. Underway sampling along ship track

The collection of data during steaming, *continuous sampling*, had two aims:

(1) to document the large-scale features of the physical environment, fluorescence, and weather;
(2) to map the horizontal and vertical distribution of biological backscattering in the upper 2000–3000 m.

The sampling equipment used included:

- Split-beam echosounders with vessel-mounted transducer transmitting at five frequencies (18, 36, 70, 120, and 200 kHz) (SIMRAD EK60). The transducers were mounted on a protruding keel, and the vessel was silent,

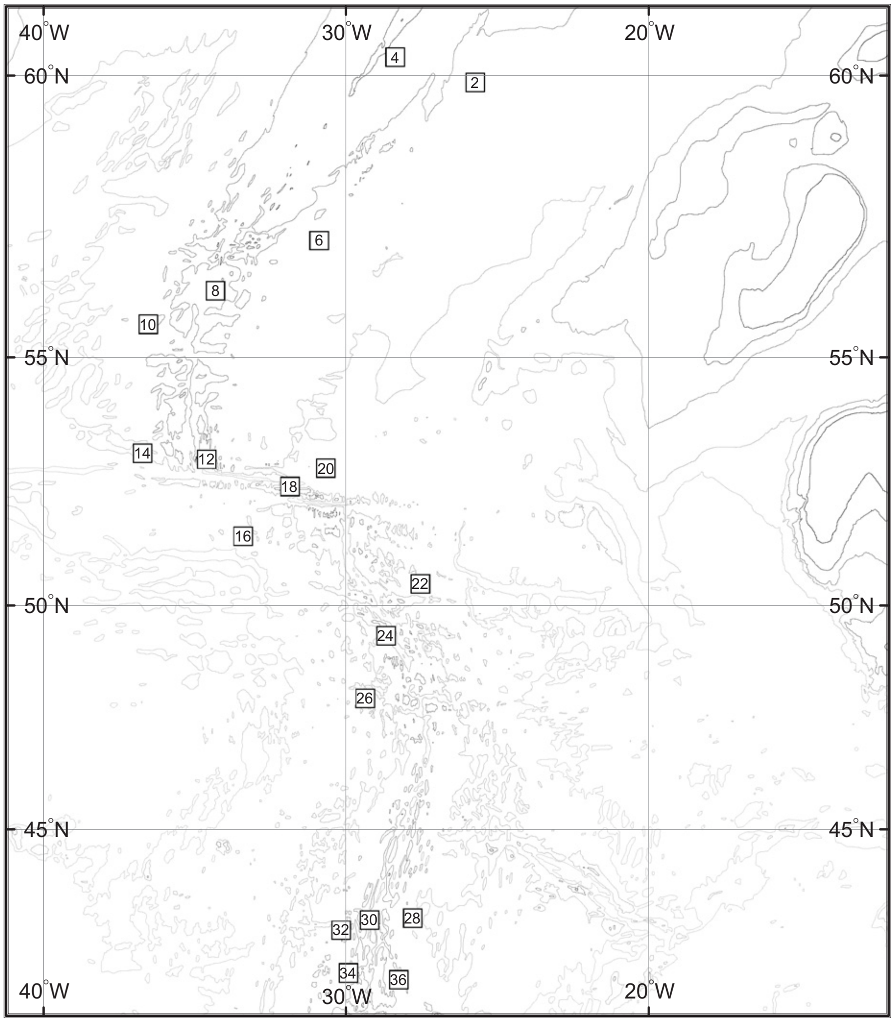

Fig. 1. Pre-defined locations for point sampling on Leg 1 of the 2004 MAR-ECO expedition (referred to as "superstations", SS). In addition to these pre-selected locations, a few additional sites were visited. See gear-specific tables below, and full details on activity on each superstation in Appendix A.

hence observations of high quality were obtained from a wide depth range, sometimes to 3000 m.

- Acoustic Doppler Current Profiler (ADCP, 75 kHz) continuously logged current flow in the epi- and mesopelagial (depth range 0–700 m).
- A thermosalinograph (SBE21) recorded surface temperature, salinity, and fluorescence. The water intake for the thermosalinograph was at 6 m below the sea surface, and a secondary temperature sensor was mounted close to the intake.
- Weather recording system (Vaisala MILO) continuously logged in addition cruise data, such as position, speed and time, weather data: air temperature, relative humidity, water temperature, wind speed, wind gust, wind direction, air pressure, and PAR radiation.
- Cruise log system (RLS) continuously logged cruise track, ship data (position, depth, heading, etc.), superstations, local stations, and activities.
- Multi-beam (EM 300) recording to the Olex database system. The Olex system recorded bathymetry and hardness of the substrate during the whole cruise track.

During daylight hours a visual census of mammals and seabirds was conducted according to established protocols by skilled personnel.

2.2.2. *Point sampling at pre-determined locations*

At pre-determined locations, *point sampling* was conducted (Table 1). The number of stations occupied was a compromise between maximising efforts within the available ship-time and the desire to conduct comprehensive sampling at all stations. The resulting number of locations was 18, close to the original target number, and the geographical distribution of point sampling along the pre-determined survey line provided comparable information throughout the study area. Whether this database constitutes a sufficient or ideal number of stations cannot be assessed at this stage.

The following gears and technologies were used:

Net sampling:

- Two different double-warp *multi-codend mid-water trawls* (a medium-sized pelagic fish trawl and a macrozooplankton trawl). Maximum sampling depths 2500–3000 m.

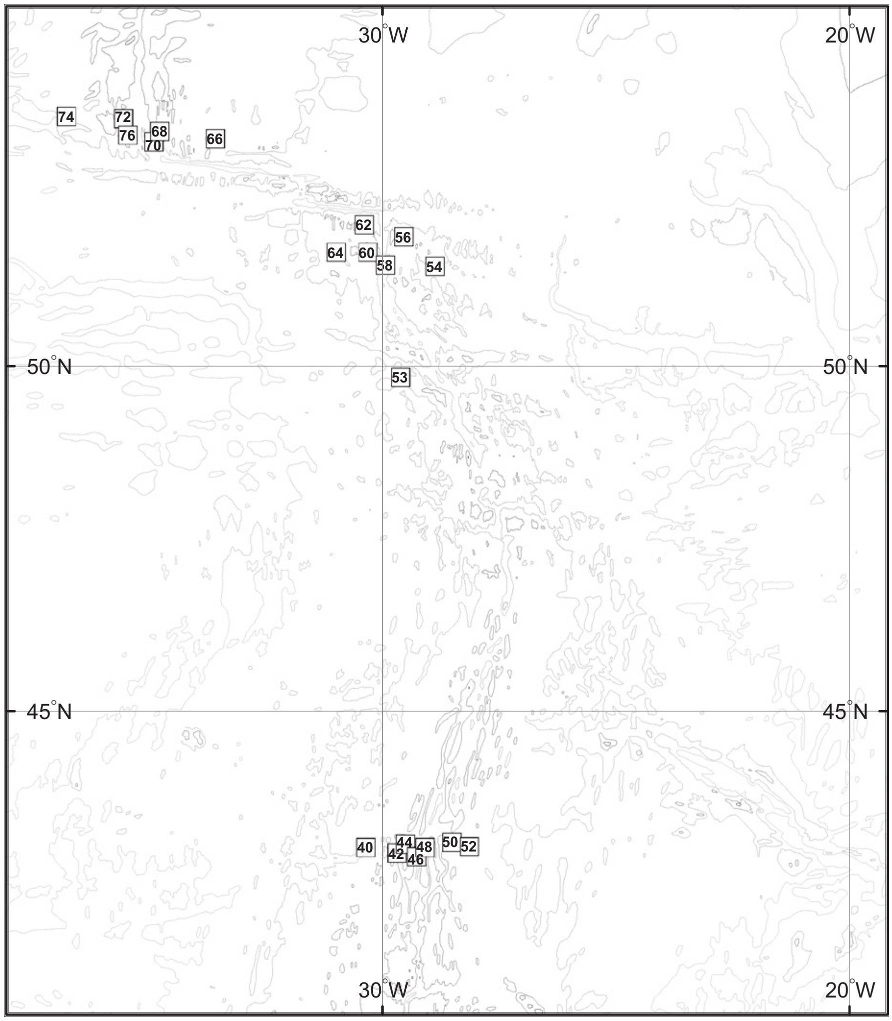

Fig. 2. Pre-defined locations for point sampling on Leg 2 of the 2004 MAR-ECO expedition (referred to as "superstations", SS). In addition to these pre-selected locations, a few additional sites were visited. See gear-specific tables below, and full details on activities on each superstation in Appendix A.

- *The Multinet* mesozooplankton sampler. Maximum sampling depth 2500 m.
- *Ringnet attached to roof of mid-water trawl*. Depth range as used by pelagic fish trawl or bottom trawl.

Acoustics:

- *Echosounders* of various designs/characteristics (hull- and keel-mounted as well as towed vehicle transducers connected to SIMRAD EK60). The hull- and keel-mounted instruments were the same as described above. The towed transducer was used at or near stations to record target strength of particular scatterers, and to provide more detailed support information for interpreting the recordings on the echograms received from the keel-mounted transducers.
- *The Bergen Acoustic Lander*, essentially an upward-looking multi-frequency echosounder and an ADCP. This free-fall lander was battery-powered and designed to be recovered after weeks or months of independent operation. The transducers were currently depth-rated to 1000 m, hence the lander provided information on the epi- and mesopelagic scatterers.

Optics, sensors, and samplers:

- The *Underwater Video Profiler* (UVP). The UVP comprised two separate cameras and CTD systems. Operating depth was 0–1000 m. It recorded images of suspended particles as well as pelagic organisms, and computed their size and abundance.
- *Remotely operated vehicles* (two ROVs, *Aglantha and Bathysaurus*) were equipped with video cameras, CTD and collecting devices. Operating depths were 0–2500 m; *Bathysaurus* was designed to operate to 5000 m, but this capability was not utilised due to a malfunction of thrusters.

Oceanographic instruments:

- *CTD* system with rosette of water samplers (24 10-L bottles). The CTD system had dual sets of temperature

Table 1
Predefined study locations on Legs 1 and 2 of the 2004 MAR-ECO expedition on the R.V. *G.O. Sars*

Superstation	Leg	Type of station	Latitude (N)	Longitude (W)
2	1	Long station	59°53′	25°44′
4	1	Long station	60°18′	28°23′
6	1	Short station	57°09′	30°53′
8	1	Short station	56°15′	34°19′
10	1	Long station	55°37′	36°32′
12	1	Long station	53°01′	34°36′
14	1	Long station	53°08′	36°43′
16	1	Long station	51°28′	33°24′
18	1	Short station	52°28′	31°51′
20	1	Long station	52°50′	30°40′
22	1	Short station	50°28′	27°33′
24	1	Short station	49°21′	28°41′
26	1	Long station	47°60′	29°22′
28	1	Long station	42°53′	27°48′
30	1	Short station	42°51′	29°13′
32	1	Long station	42°36′	30°10′
34	1	Short station	41°32′	29°56′
36	1	Long station	41°22′	28°15′
38		Call at Horta	38°32′	28°36′
40	2	Standard station	42°54′	30°22′
42	2	Standard station	42°49′	29°42′
44	2	Standard station	42°57′	29°31′
46	2	Standard station	42°46′	29°17′
48	2	Standard station	42°54′	29°06′
50	2	Standard station	42°59′	28°32′
52	2	Standard station	42°55′	28°09′
54	2	Standard station	51°21′	28°53′
56	2	Standard station	51°45′	29°33′
58	2	Standard station	51°22′	29°56′
60	2	Standard station	51°33′	30°19′
62	2	Standard station	51°55′	30°24′
64	2	Standard station	51°33′	30°60′
66	2	Standard station	53°02′	33°35′
68	2	Standard station	53°08′	34°46′
70	2	Standard station	52°59′	34°54′
72	2	Standard station	53°18′	35°33′
74	2	Standard station	53°19′	36°46′
76	2	Standard station	53°05′	35°27′

The locations are denoted 'superstations' and each represent polygons within which one or more activities occurred. Activities for these and additional *ad hoc* superstations are given in Appendix A. The coordinates given represent the centre of the polygon. See Table 2 for explanation of terms "short station" and "long station".

and conductivity probes, an Aquatracker III fluorometer, and a SeaBird oxygen sensor (SBE43). Water samples were collected for assessments of nutrients and chlorophyll. Analyses were performed after the cruise.

- *Lowered ADCP* (150 kHz). RDI 300 kHz Monitor WorkHorse ADCPs were mounted on the CTD carousel, one looking down and one looking up.
- *Satellite data* on surface colour and temperature were provided by the University of the Azores, DOP, at intervals during the expedition.

A sampling programme was pre-determined for the fixed stations (Table 1). The same gears except the Multinet were deployed at "short" and "long" stations. The Multinet was deployed only at "long" stations. Based on the experience from the first stations, and to save time, the long stations included only one set with the Multinet.

Table 2
Activities at point-sampling superstations during Leg 1 of the 2004 MAR-ECO expedition

	Maximum deployment depth (m)
"Long" stations (duration 20 h)	
Towbody (variable depth)	1500
CTD/ADCP (0-bottom)	3000
UVP	1000
Multinet, deployment 1	2500
Multinet, deployment 2	1000
Macrozooplankton trawl	2500
Pelagic fish trawl (Aakratrawl)	3000
"Short" stations (duration16 h)	
Towbody	1500
CTD/ADCP	3000
UVP	1000
Macrozooplankton trawl	2500
Pelagic fish trawl (Aakratrawl)	3000

"Long" stations were shortened half way through the cruise by excluding one of the multinet deployments.

Pelagic dives with the ROVs *Bathysaurus* and *Aglantha* also were made at pre-determined locations, but primarily during the Leg 2 near the pelagic sampling locations described above.

2.2.3. Opportunistic sampling

This practise satisfied the need for extra sampling such as:

- Tows with a large mid-water trawl (Egersund trawl, mouth opening 90 + m) to collect large mobile organisms such as fish and cephalopods.
- Extra targeted tows using the standard mid-water trawls to validate acoustic recordings.
- Whale sighting and tagging requiring excursions off the pre-determined course. These studies also included local sonar tracking of whales and sonar observation of others scatterers in areas of high whale density.

2.3. Leg 2

Whereas the primary objects of investigations on Leg 1 were pelagic nekton and zooplankton communities throughout the MAR-ECO area from south of Iceland to the Azores, the primary aim on Leg 2 was to collect data and material on demersal animals in specific limited Subareas (Bergstad and Godø, 2003). In addition, zooplankton studies emphasising gelatinous organisms, studied and sampled by ROVs and UVP, were accommodated. Early in the planning phase it was realized that there was insufficient time on Leg 2 to study all three MAR-ECO sub-areas. The northern waters of the Reykjanes Ridge had been studied rather extensively on earlier cruises; hence it was decided to focus effort in the middle and southern sub-areas (Fig. 2).

Most activities were concentrated at pre-determined locations, seven in the southern and 13 in the middle sub-area. These had been selected so as to sample different depths on either side of the ridge axis. To locate suitable sites, the best available charts were used, but in many cases these proved inaccurate. The list of stations is given in Table 1 and Appendix A.

On an *ad hoc* basis, two trawls were made on Faraday (SS 53) and one on Hecate Seamount (SS 65) in an effort to collect additional material from relatively shallow grounds. Between station sampling included continuous acoustic recording, and hydrographical measurements of the surface water and current profiles as during Leg 1.

A standard superstation was defined as a $4.6 \times 4.6\,\mathrm{km}^2$. However, this area was sometimes expanded, primarily due to discovery of unsuitable ground for trawling using multi-beam mapping. Within the area, the aim was to conduct several activities in succession:

- Deployment of a free-fall baited photographic lander (ROBIO, see below).
- A CTD, water sample, and LADCP profile, including also on many stations an instrument to record vertical distribution of bioluminescence (ISIT, see below).
- Bathymetry mapping of the entire area by SIMRAD EM 300 multi-beam echosounder.
- A 0–1000 m UVP cast.
- An ROV dive, either only pelagic or both pelagic and demersal. Demersal dives were to include two perpendicular 400-m-long transects, and additional exploratory excursions.
- A bottom trawl tow of duration depending on bottom conditions determined from the bathymetry survey.
- A plankton net tow, using a net attached to the roof of the bottom trawl.
- Retrieval of the ROBIO lander.

On a more *ad hoc* basis, additional instruments were used at a few stations. This included:

- A towed 38-kHz split-beam transducer, used in an attempt to resolve single-target echoes near the bottom. This was only used at the first station but was thereafter abandoned.
- A floating upward-looking self-recording echosounder (Bergen Acoustic Buoy) for observation of surface-layer targets. This was used on two stations in the southern sub-area.

Further details on the samplers and procedures are given below.

In addition to the work on stations, three Bergen Acoustic Landers, and the University of Aberdeen OCEANLAB DOBO lander deployed on Leg 1 were retrieved on Leg 2. One of the Bergen Acoustic Landers was re-deployed after being fitted with new and more batteries. This lander would stay out for a year after the cruise.

3. Samplers and operations

3.1. Abiotic data collection

The physical environment was observed both underway and on stations. In addition, satellite data on sea-surface temperature was obtained and current measurements from meters mounted on the short- and long-term acoustic moorings.

3.1.1. Hydrography (CTD operation)

At almost all fixed stations, vertical profiles from surface to the near-bottom zone were made with a CTD. The CTD stations are listed in Appendix A. A SBE 911plus, with a 24-bottle (10 L) carousel water sampler was used. The CTD had dual sets of temperature and conductivity sensors, an Aquatracker III fluorometer and a SeaBird oxygen sensor (SBE43). All the SeaBird sensors were calibrated by SeaBird just prior to the cruise, and the performance of the temperature and conductivity sensors were very good, with only 0.002 difference in salinity between the two sensor pairs. Water samples were collected on all stations for calibration of the conductivity. The final calibration and quality control was completed after the cruise.

At most stations 24 water samples from the whole profile were drawn and conserved with chloroform for nutrient analysis in the chemistry laboratory at Institute of Marine Research after the cruise. About 8–10 water samples from the top 200 m were filtered and the filters frozen for chlorophyll analysis in the laboratory.

In addition to the CTD measurements the surface ($\sim$4 m) temperature, salinity, and fluorescence were recorded continuously along the complete track of the cruise using a ship-mounted thermosalinograph (SBE21). The water intake for the thermosalinograph was located about 6-m below the sea surface. Comparing the results from the thermosalinograph with the CTD showed only insignificant offsets. The measurements are recorded both with position.

3.1.2. Currents (ADCP, LADCP, and moored current meters)

A pair of RDI 300-kHz Monitor WorkHorse ADCPs were mounted on the CTD carousel, one looking down and one looking up. The data were transferred in real time to the ship by a fibre optic cable. Due to problems with the fibre optic connection LADCP profiles were not obtained on CTD stations 391–395, and due to other problems no LADCP data were collected on Leg 2. Observations were obtained from 13 of the CTD stations. The LADCP data were processed using Version 7 of Martin Visbecks' analysis software, Lamont-Doherty Earth Observatory of Columbia University.

A 75-kHz RDI Ocean Surveyor ADCP was operated along the entire cruise track. The ADCP was run in the narrow band (NB) mode with 45 vertical bins each 20 m long. During most of the cruise good data were obtained to 750–800 m depth. The ADCP was triggered from the Simrad EK60 echosounder system on the ship. Since most of the cruise was conducted in deep water this gave a low ping rate, 3–5 s, but for most of the time interference was avoided between the two instruments. Without trigging the ADCP will disturb the echosounder, and the send signal of the echosounder ruins the ADCP data in given depth intervals. The RDI software WmDas was used for data acquisition and the CODAS system was used for post-cruise processing of the data. (The CODAS software is available from the "Currents" group at University of Hawaii, SOEST: http://currents.soest.hawaii.edu).

On the acoustic lander deployed at Superstation 13 north of the CGFZ an Aanderaa RDCP 600 current meter provided by Aanderaa Instruments A/S was mounted on the frame. An Aanderaa RCM8 was mounted on the mooring line of the lander on Superstation 30.

3.1.3. Satellite sea-surface temperature

The Oceanography group at DOP, University of Azores in Horta provided SST images from the NOAA satellites. The satellite data were downloaded and processed at DOP and distributed via Internet to RV *G.O. Sars*. Composite high spatial resolution images for the cruise region were provided as graphical files (EPS format) and as data files in the HDF format for use onboard in GIS systems, and thus in combination with other observations. A total of 12 composite images were provided in both formats. The southern region was for the most part cloud free, but in the north-western region heavy cloud cover prevented good images at the beginning of the cruise.

3.2. Biotic data

3.2.1. Nets and trawls

3.2.1.1. Bottom trawl and trawl stations. The following gear description is extracted from a full account given by Huse in the expedition report (Bergstad and Godø, 2004 on www.mar-eco.no/sci). The bottom trawl used was a Campelen 1800 shrimp trawl (Engås, 1991) towed on double warps at a speed of around 2 knots (1 m/s). The trawl had four net panels and three bridles. The total distance between the doors and the wing ends was 50 m. Horizontal opening between the upper bridles at the wing tips was 17 m at 50-m door-spread, while the distance between Danlenos at the tips of the ground gear was 12 m. Vertical opening was 4.5 m at 50-m door-spread. The vertical opening was maintained using eight 50-cm diameter plastic encapsulated glass floats evenly spaced along the headrope. The codend had 40-mm stretched square meshes, but was equipped with a liner of 22-mm knotless square meshes.

The ground-gear (rockhopper type, with discs of 35-cm-diameter) travelled 3.5 m behind the headrope in the centre of the trawl. There was 10 m of chain as a first part of the lower bridles in front of the Danlenos. According to video recordings made by means of camcorders and lamps in deep-water housings attached to the headrope, the rock-hoppers travelled within the normally soft substrate, more than halfway submerged, so that most of the fish and epifauna resting on the bottom were caught. Of the six trawl nets taken onboard, two were damaged beyond shipboard repair. Three were torn and mended on board.

The trawl doors (otter boards) used were standard Steinshamn W9 bottom V doors with an area of 6.7 m^2 and a weight of 2250 kg. The winch drums held 5000 m of 24-mm wire, and this permitted trawling to 3500 m.

To monitor the trawl configuration and performance a full suite of newly developed wireless SCANMAR deep-water sensors was used. The package included door-spread sensors with built-in depth sensors, door-angle sensors, depth sensors, temperature sensors, and trawl sounders with ground-gear clearance, and headrope distance from the bottom. Presented on the SCANBAS display the sensors gave a sufficient and generally satisfactory presentation of the trawl geometry during all trawl hauls.

Charts proved imprecise or inaccurate, hence at sea real-time bathymetry mapping using a multi-beam sounder was used to locate a suitable trawling path within the pre-determined superstations. A Kongsberg Simrad EM 300 30-kHz $1^\circ \times 2^\circ$ multi-beam bottom profiling sounder provided data for a detailed 3-D mapping of each superstation, normally with a swath width of around 2800–4600 m. In good weather these data could be collected at a vessel speed of 5 knots. Rawdata were transferred to and presented in real time by the Olex navigational plotting system, and 3-D maps of the superstations at user-selected perspective angles and orientations.

By this two-stage process, 22 locations were mapped and trawled. Of the 22 tows, 17 were considered valid based on an assessment of the technical quality of the operation (Table 3).

The processing of the catches from the bottom trawl corresponded to that for pelagic nekton described in Section 3.2.1.4.1.

3.2.1.2. Medium-sized pelagic fish trawl (Aakratrawl). The medium-sized pelagic fish trawl used routinely was a Norwegian "Aakratrawl" (Fig. 3) with a vertical net opening 20–35 m, door-spread 110 m, mesh size in codend 22 mm stretched. The one used for MAR-ECO sampling was a modified version equipped with a multisampler to collect fauna from three depth strata consecutively during one haul (three codends in one tow). This net was used routinely for sampling large- and medium-sized mid-water

Table 3
Locations sampled by bottom trawl during Leg 2 of the 2004 MAR-ECO expedition

Sub-areas sampled	Super-station	Local Stn. no.	Date	Sampling location		Trawling depth (m)			Average towing speed (knots)
				Latitude (°N)	Longitude (°W)	Mean	Max.	Min.	
Southern MAR-ECO sub-area	40	367	07.07.2004	42°55′	30°20′	2961	2968	2954	1.7
	42	368	08.07.2004	42°48′	29°38′	2078	2107	2063	2.1
	44	369	09.07.2004	42°55′	29°32′	1742	1767	1702	1.9
	46	370[a]	10.07.2004	42°45′	29°16′	3046	3068	3024	
	48	371[a]	11.07.2004	42°52′	29°06′	1072	–	–	
	46	372	11.07.2004	42°46′	29°16′	3031	3050	3005	1.8
	50	373	12.07.2004	43°01′	28°33′	2600	2607	2593	2.0
	52	374	13.07.2004	42°55′	28°08′	2977	2979	2973	2.1
Faraday seamount	53	375	15.07.2004	49°51′	29°37′	990	1003	981	2.4
	53	376	15.07.2004	49°51′	29°37′	985	1019	966	2.4
Middle MAR-ECO sub-area, south	54	377	16.07.2004	51°19′	28°52′	3512	3527	3505	1.8
	56	378	17.07.2004	51°45′	29°33′	1916	1950	1872	2.2
	60	379	19.07.2004	51°33′	30°18′	1263	1296	1237	2.4
	62	380	20.07.2004	51°55′	30°25′	1910	1959	1872	2.5
	64	381	21.07.2004	51°32′	30°58′	3461	3465	3452	2.2
	65	382[a]	23.07.2004	52°16′	31°00′	753	979	607	
Middle MAR-ECO sub-area, north	66	383	24.07.2004	53°01′	33°36′	3030	3071	2995	1.6
	68	384	25.07.2004	53°08′	34°46′	2350	2374	2306	1.5
	70	385	26.07.2004	52°58′	34°52′	1650	1670	1630	2.2
	72	386	27.07.2004	53°16′	35°31′	2548	2567	2522	1.8
	74	387[a]	28.07.2004	53°17′	36°46′	3055	3063	3048	
	74	388[a]	28.07.2004	53°17′	36°47′	3058	3065	3047	

[a]Trawls with problems, excluded from analyses.

fishes and cephalopods. The list of trawl tows is given in Table 4. The mean towing speed of the vessel was 2.8 knots. Some hauls were oblique between a maximum and minimum depth, others horizontal. It is not considered valid to estimate volume filtered for this gear type, but distances and durations of the tow for each codend are available in the database.

Gelatinous fauna are easily damaged during the long period of fishing tows. This problem, however, was partly overcome as a metal-box sampler was fitted onto one of the three codends. Specimens retained in this box were not damaged by ropes, meshes or during deck handling. During the *G.O. Sars* expedition this codend collected a number of delicate mid-water animals such as fishes, cephalopods, crustaceans, and medusae. Until the Local Station no. 350 the box was used on the deepest net (codend no. 3), thereafter on the middle net (codend no. 2).

Contamination between codends seemed to be a minor problem. If animals caught in the early stages of the tow got stuck in the forenet or just in front of the multisampler, there is a risk that some may end up in the wrong bag late in the tow. This problem cannot be entirely avoided but was taken into account when designing the multisampler. It was assumed that the contamination was very small compared with the overall catch collected correctly from a given depth interval.

Specimens collected from the forenet or any other area of the trawl in front of the multisampler was kept as a separate sample, i.e. "the fourth net" in Table 4 representing the entire depth range of the tow.

3.2.1.3. Large mid-water fish trawl (Egersundtrawl). A large mid-water trawl was deployed a few times to target large organisms or identify targets located acoustically. The net used was a Norwegian "Egersundtrawl", a standard trawl used in commercial fisheries targeting deep-pelagic resources such as redfish. The vertical net opening is 90–180 m, door-spread 150 m, and the mesh size in the codend liner is 50 mm stretched. The station list is given in Table 5. Mean towing speed was 2.9 knots.

3.2.1.4. Macrozooplankton trawl ("krill trawl").

3.2.1.4.1. Processing of demersal and pelagic nekton catches (and zooplankton taken in mid-water trawls). Catches from each net deployment were kept separate on deck by net number, corresponding to the depth stratum sampled, and taken to the fish laboratory for further processing. Catches were sorted one at a time to prevent

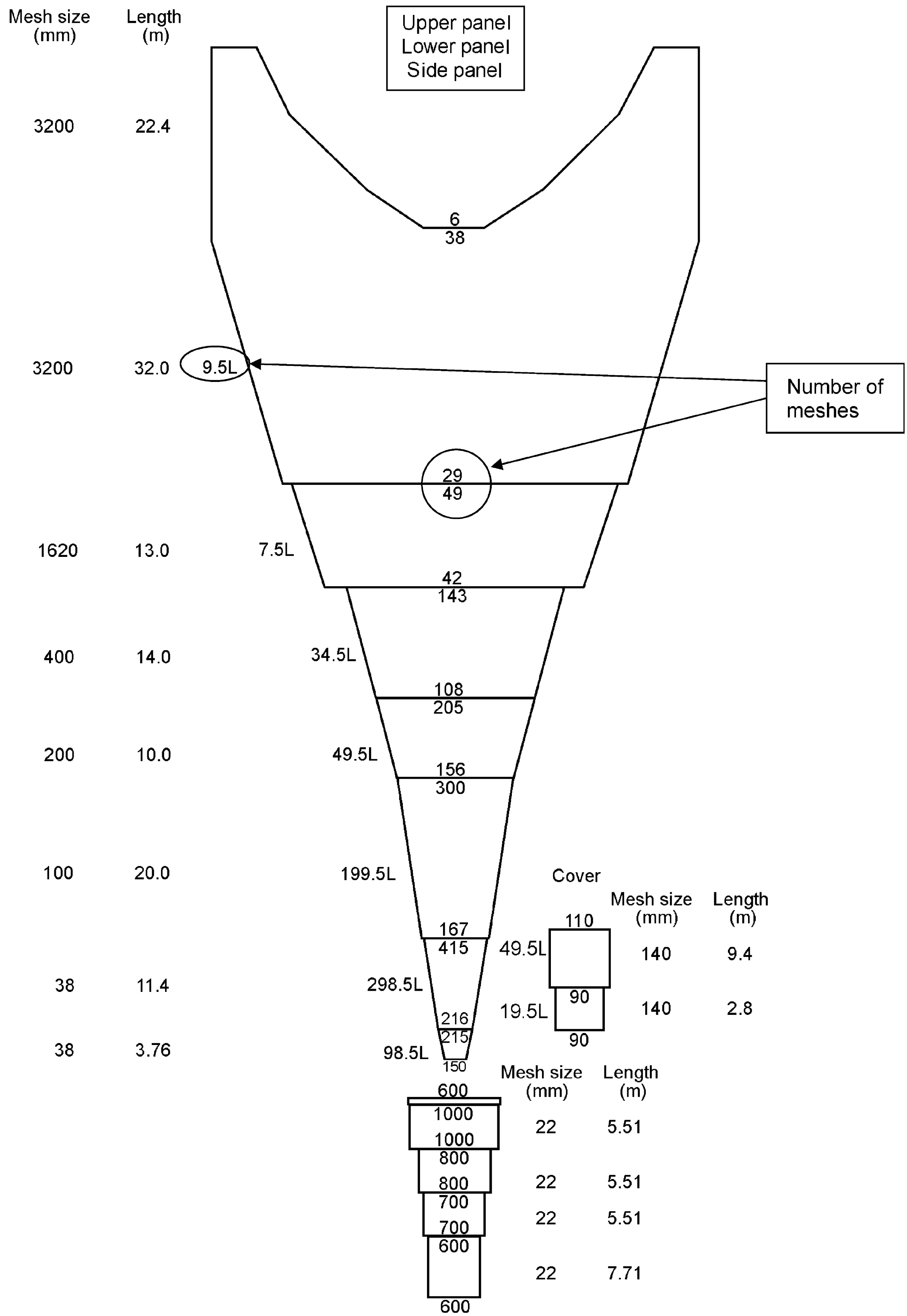

Fig. 3. Manufacturer's diagram of the "Aakratrawl", the medium-sized pelagic fish trawl used routinely for depth-stratified sampling during Leg 1 of the 2004 MAR-ECO expedition. The diagram shows dimensions and stretched mesh sizes and numbers for one of the four equal net panels that the trawl consists of, plus the codend and protective cover. Three equal codends were used and these were attached to a multisampler that facilitated opening and closing during the tow.

Table 4
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.

Table 5
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

potential mixing of specimens from different depth strata. When several depths were sampled in the same tow, the deepest net catch was routinely sorted first, while the other catches were stored in a cold room to prevent sample degradation. The total weight of each catch was recorded, and then the entire catch was rough-sorted by major taxonomic group. In some cases (e.g., southernmost stations) sample sorting and identification was quite time consuming, and a preliminary analysis will be needed to determine if some components (e.g., myctophids) are still viable for time-sensitive studies such as feeding and biochemistry.

Cnidaria were separated first, as these often represented a large fraction of each catch. Cnidaria were sorted into three categories: *Periphylla, Atolla*, and Cnidaria (all others). Salps were separated when abundant. Unidentified cnidarians were photographed before fixation. *Periphylla periphylla* and *Atolla* where counted, weighted, and then discarded. In some samples, individual umbrella diameters where measured. Tissue samples of medusae were frozen at −80 C for molecular studies. Salps were separated when abundant.

Macrocrustacea (decapod shrimps, large amphipods, euphausiids) were either preserved in a single lot in 4% (v/v) borax-buffered formaldehyde or split into equal halves, with one-half preserved in formaldehyde and one-half preserved in ethanol for genetic and biochemical analyses.

Fishes were rough-sorted by major group, and then identified to species by the attending taxonomic specialists. Samples were either frozen in lots by species, with an appropriate volume of seawater, or preserved in formaldehyde in cases of rarity or taxonomic uncertainty. Tissue samples for genetic analyses were taken for most species and preserved in 95% ethanol. In cases where species determination was not feasible in a time appropriate to prevent sample degradation, specimens were frozen or preserved in lots by family, with species determination pending further examination at the Bergen Museum.

All cephalopod specimens were identified to the lowest possible taxon and, when the mantle was not too damaged, dorsal mantle length (ML) was measured. Large specimens were weighed as well. Tissue samples were taken and fixed in 96% ethanol for post-cruise analyses of DNA sequences, with the goal of compiling multiple samples from as broad a spectrum of diversity as possible. Digital photographs were taken of the freshly collected whole animals, taxonomic characters, and other anatomical features. Then specimens were selected for fixation in formalin. (The fixed specimens were later transferred to alcohol, either 50% isopropanol or 70% ethanol, at the Bergen Museum for permanent archival.) Selection of archival specimens was based on rarity and condition, with preference given to specimens vouchering rare species, taxonomic problems, and tissue samples.

3.2.1.5. Multinet. Depth-stratified mesozooplankton samples from 2500 to the surface, was obtained from 11 stations by the Multinet (Hydro-Bios Multi Plankton Sampler, Fig. 4). In addition, a depth-integrated sample from 1000 to 0 m was collected.

The Multinet (50×50 cm mouth opening, 180 μm mesh size) was towed vertically with hauling speed 40 m min^{-1}. The Multinet is equipped with five nets that are opened and closed on command from the ship; however, the last net (net number 5) cannot be closed, but enters the surface as open. Net changing is controlled from a Deck Command Unit, which also registers the actual net number, filtered volume and depth. The volume of water filtered by the nets and their filtering efficiency were measured with Hydro-Bios Electronic Flowmeters, on both inside and outside the net frame. For the depth-stratified samples, the volume of filtered water ranged between 15 and 55 m^3 per net. The sampling intervals for the Multinet deployments was set to correspond to the maximum range of the UVP (1000 m), in order to make comparisons between the two datasets possible. At Superstations 2, 4, 10, 12, and 14 the Multinet was deployed twice, thereby obtaining up to 10 depth-stratified samples, depth allowing (Table 6). On 17 June, it was decided to deploy the sampler only once at the remaining stations in order to save time. The reduction meant that only five depth strata were sampled at Superstations 16, 20, 26, 28, 32, and 36.

3.2.1.5.1. Processing of multinet samples. All samples from the Multinet, except for the depth-integrated sample (1000–0 m), were immediately preserved in 4% borax-buffered formaldehyde for later species identification and enumeration.

The depth-integrated sample (1000–0 m) was treated in the following way: chaetognaths and pteropods were

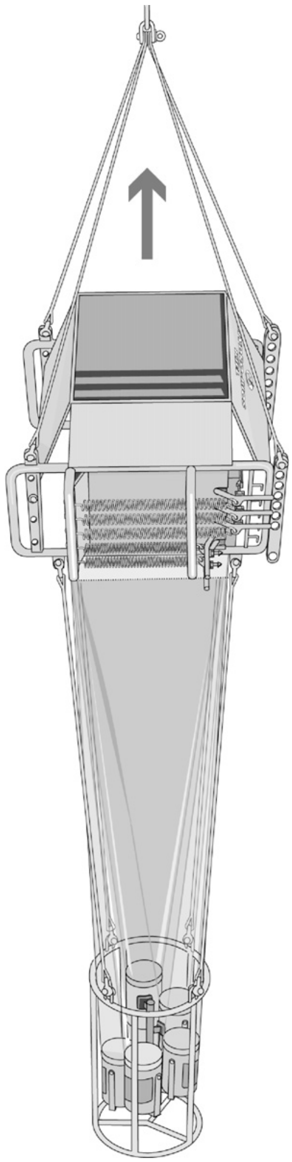

Fig. 4. Sketch of the Multinet used for depth-stratified sampling of mesozooplankton during the 2004 MAR-ECO expedition. *Source*: HYDRO-BIOS Apparatebau GmbH.

removed and fixed for molecular analysis. Chaetognaths were fixed in acetone and pteropods on ethanol. About 50 *Calanus finmarchicus* were picked out and put into small glass tubes containing a 2:1-solution of chloroform and methanol and frozen (−80 °C) for analysis of fatty acids. In addition, a part of the sample was put into plastic bags and frozen for analysis of total lipids/lipid classes and stable isotopes. The rest of the integrated samples were put in 96% non-denaturated ethanol for molecular analysis. At Superstation 4, the integrated sample was used for providing specimens for an egg production experiment (Gislason et al., 2008), and nothing was fixed on ethanol at this station.

3.2.1.6. Juday net. A Juday net (2 m^2 mouth area, 375 μm mesh size), fitted with a non-filtering codend, was used in order to catch live animals on selected stations (Appendix A). The net was lowered to a depth of 100 m and hauled back at a speed of 30 m min^{-1}.

On retrieval the contents of the codend were gently emptied into a ~15-L bucket containing surface water, for the collection of live animals. The animals were used for the measurement of gut fluorescence and for carrying out incubations for egg production rates of *Calanus* spp. (*C. finmarchicus* and *C. helgolandicus*). Live fish eggs, fish larvae, and chaetognaths also were sorted out from this sample. The rest of the sample was either put on 96% ethanol, 4% buffered formaldehyde, or frozen.

Table 6
Multinet sampling depths on superstations during Leg 1 of the 2004 MAR-ECO expedition

Net number	Depth (m)	Superstation										
		2	4	10	12	14	16	20	26	28	32	36
First deployment												
1	2500–2300					x						
2	2300–1900	x				x						
3	1900–1500	x		x	x	x						
4	1500–1000	x	[a]	x	x	x						
5	1000–0[b]	x[b]	x[b]	x[b]	x[b]	x[b]						
Second deployment												
1	1000–800	x	x	x	x	x						
2	800–500	x	x	x	x	x						
3	500–200	x	x	x	x	x						
4	200–100	x	x	x	x	x						
5	100–0	x	x	x	x	x						
1	2500–1500						x	x	x	x	x	x
2	1500–1000						x	x	x	x	x	x
3	1000–500						x	x	x	x	x	x
4	500–100						x	x	x	x	x	x
5	100–0						x	x	x	x	x	x

[a]Net failed.
[b]Depth-integrated sample.

3.2.1.7. Zooplankton ring net on trawls. A ring net (1 m diameter, 750 μm mesh size) was mounted on the roof of the Macrozooplankton trawl and the bottom trawl just behind the headline. The ring net provided a record of the species occurring in the entire water column (0–3000 m) and in the bentho-pelagic layer. The tow list is given in Table 7.

This net caught macrozooplankton from 2 to 20 mm including chaetognaths, pteropods, large copepods, fish eggs, and fish larvae. The data cannot be used for quantitative assessments of assemblages nor their depth distribution patterns, but was useful for collecting material for molecular studies.

Chaetognaths from the ring net were fixed in acetone, and pteropods in ethanol for molecular studies. The remaining sample was split in two parts: one-half was fixed in 4% borax-buffered formaldehyde and the other half in 96% ethanol.

Table 7
Station list for the ring net used on the roof of the bottom trawl and macrozooplankton trawl during the 2004 MAR-ECO expedition

Superstation	Local station	Latitude (N)	Longitude (W)	Fishing depth (m) Max.
Bottom trawl				
40	367	42°55′	30°20′	2670
42	368	42°49′	29°38′	2107
44	369	42°56′	29°32′	1767
46	370	42°46′	29°16′	3068
48	371	42°46′	29°16′	
46	372	42°52′	29°06′	3050
50	373	43°02′	28°33′	2607
52	374	42°55′	28°08′	2979
53	375	49°52′	29°38′	1003
53	376	49°52′	29°38′	1019
54	377	51°20′	28°52′	3527
56	378	51°45′	29°33′	1950
60	379	51°34′	30°19′	1296
62	380	51°55′	30°25′	1959
64	381	51°33′	30°58′	3465
65	382	52°16′	31°01′	979
66	383	53°02′	33°37′	3071
68	384	53°08′	34°46′	2374
70	385	52°59′	34°52′	1670
72	386	53°17′	35°32′	2567
74	387	53°18′	36°47′	3063
74	388	53°18′	36°46′	3065
Macrozooplankton trawl				
2	327	59°58′	25°45′	2141
4	329	60°18′	28°26′	1329
6	331	57°10′	31°07′	2155
8	333	56°19′	34°16′	1337
10	335	55°37′	36°34′	1928
12	338	53°06′	34°35′	1457
14	340	53°06′	36°43′	2534
16	343	51°27′	33°27′	3008
18	345	52°24′	31°49′	2660
20	347	53°03′	30°52′	2526
22	349	50°36′	27°30′	2731
24	351	49°35′	28°29′	2768
26	353	48°12′	29°32′	2570
28	356	42°54′	27°45′	2202
30	358	42°53′	29°18′	2383
32	362	42°31′	30°09′	1828
34	363	41°46′	30°00′	1981
36	365	41°30′	28°27′	1980

3.2.1.8. Macrozooplankton trawl ("krill trawl"). The macrozooplankton trawl was the other mid-water trawl used routinely. This trawl, designed at the Institute of Marine Research, Norway, has a $6 \times 6\,m^2$ mouth opening, and net with 3×3 mm (6 mm stretched) opening diamond-shaped mesh from the front of the net to the codend (Fig. 5). Theoretically, the square-shaped mouth opening is $36\,m^2$; however, since the trawl does not have a frame, this value will vary depending on the shape of the opening during trawling. In order to avoid variation in door-spread, a restrictive rope (strapping) is attached some distance in front of the doors. The trawl height has been measured to be 6 m during trawling (Valdemarsen, IMR, Bergen, pers. commun.), indicating that the theoretical value is valid. The total trawl length is 45 m, and the trawl is operated with standard pelagic trawl doors, 70 m sweeps, and 150 kg weights on the lower wingtips, and an 8 m rope between the upper wingtips. During the MAR-ECO expedition the gear was equipped with a multisampler (remotely operated multiple codends) with five 30-m-long codends allowing sampling of five depth strata consecutively during one haul. Each codend was equipped with a 7-L collection bucket, in order to reduce mechanical damage of animals. The trawl also had SCANMAR sensors, providing data on actual codend number, geographical position, time (UTC), and depth. The list of tows is given in Table 8.

Sampling was made along an oblique trajectory from 3000 m to the surface, while nets were opened and closed on command from the ship. The trawl was towed at 2 knots (mean speed across all tows: 2.2 knots) and retrieved at a rate of 25 m/min. The duration of each tow was 10–40 min per depth stratum and calculated volume of water filtered was 20×10^3–$120 \times 10^3\,m^3$ per depth stratum (Table 8).

Catches from each net deployment were processed as described in Section 3.2.1.4.1 for the larger mid-water trawls.

The volume of water filtered (V) by the macrozooplankton trawl was calculated for each codend by assuming that the trawl was moving at constant speed along an oblique trajectory (Fig. 6). The volume filtered by each codend was calculated as

$$V_i = T_i m,$$

where T_i is the towing distance at depth interval i, and m is the area of the mouth opening of the trawl (assumed to be $36\,m^2$).

The oblique towing distance T_i was calculated as

$$T_i = \sqrt{(D_i^2 + H_i^2)},$$

where D_i is the height of the depth interval i, and H_i is the horizontal distance covered while trawling at depth interval i. The horizontal trawling distance was estimated from trawl positions (geographical coordinates) recorded by SCANMAR sensors on the trawl.

3.2.2. Acoustics

Acoustics were used to study distribution and abundance of organisms, to measure currents in the upper water column, and for mapping bathymetry. The strategy and instrumentation was introduced above, and the following is a somewhat more detailed account of the along-track data collection and analyses using echosounders. The current meter (ADCP) recording and bathymetry mapping has been described elsewhere in this paper and by Søiland et al. (2008). Further details on the acoustic studies of organisms may be found in Opdal et al. (2008).

3.2.2.1. Instruments and data collected. Acoustic data were collected along the entire track of the vessel *Bergen-Horta-Bergen*. A five-frequency (18, 38, 70, 120, and

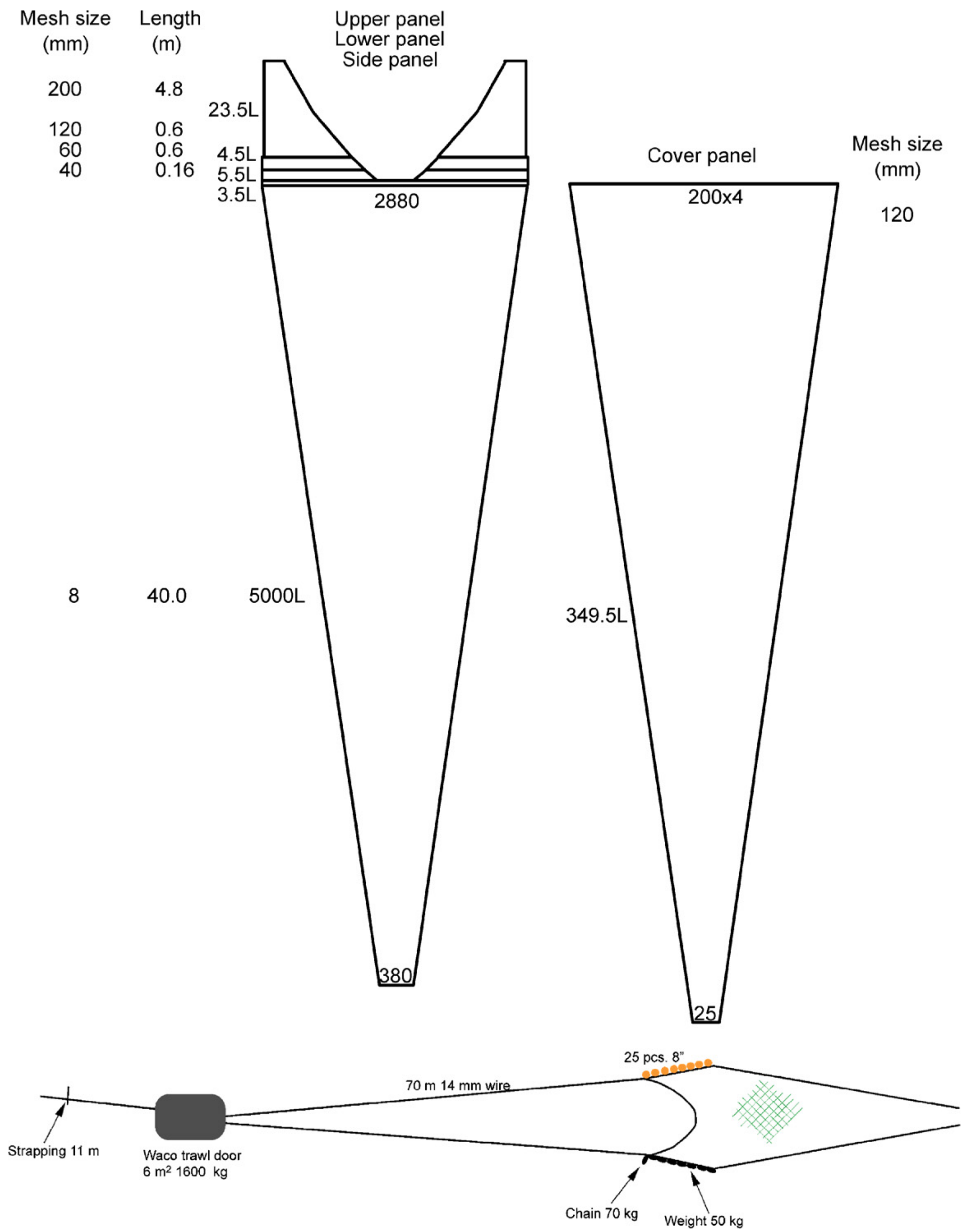

Fig. 5. Manufacturer's diagram of the macrozooplankton trawl used routinely for depth-stratified sampling of macrozooplankton and micronekton on Leg 1 of the 2004 MAR-ECO expedition. The diagram shows dimensions and stretched mesh sizes and numbers for one of the four equal net panels that the trawl consists of, plus the protective cover. The main 8 mm mesh size net and codends had diamond-shaped meshes with 6 mm (3×3 mm) stretched mesh opening. The rigging with strapping, trawl doors, bridles, floats, and weights are shown below the net diagrams. Elements not shown are the multisampler with the five 30-m long codends and collection buckets.

200 kHz), Simrad EK-60 echosounder synchronized with the ADCP, and the Simrad EM-300 multi-beam sonar was used. The pulse interval rate was set above 4 s to allow time for echoes to return from depth and to minimise noise interference from other acoustic instruments. Raw data were logged to a computer hard disc to facilitate analyses with a variety of post-processing software.

On Leg 1 target strength data from individual animals within scattering layers were measured using a deep towbody (towed transducer) equipped with a dual

Table 8
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^3)
						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							

Table 8 (*continued*)

Superstation	Local station	Serial number	Date	Latitude (N)	Longitude (W)	Fishing depth (m)		Filtered volume (m^3)
						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).

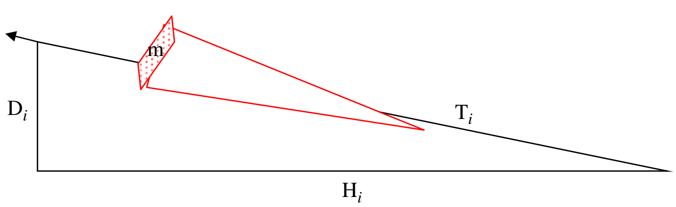

Fig. 6. Calculation of volume filtered water by the macrozooplankton trawl: T_i = towing distance at depth interval i, m = area of the mouth opening of the trawl (36 m^2), D_i = height of the depth interval i, and H_i = horizontal distance covered while trawling at depth interval i.

frequency (38, 120 kHz), EK-60 scientific sounder. This was done regularly after completing the net sampling at each superstation. The towbody was lowered to within 1000 m of the bottom or to a depth below the lowest observed scattering layer when no deep targets were present. At the deepest depth, the range was set to 1000 or 250 m depending on the presence or absence of acoustically visible targets on the 18-kHz Sv echogram. The logging system was typically started near the deepest point of each dive, and the towbody was retrieved at a rate of 1 ms^{-1} until reaching the surface. Pulse repetition rate was set at 0.7 s. Pulse duration was set at 512 ms to increase the ability to resolve individual targets. Depth, pitch, and roll of the towbody were continuously monitored and recorded for the duration of each deployment.

The 18-kHz echosounder could easily detect the seabed at 3000 m. However, the propeller produces noise when it is partially decoupled as the vessel pitches, and during normal cruising this causes disturbance on the echograms at depths below 1200–2000 m dependent on the weather conditions. Therefore special attention was paid to deep-water observation down to 3000 m at the towbody station when vessel speed was low.

3.2.2.2. Problems and assumptions. Particular attention was paid to effects of changing availability of the organisms, layer boundaries, and the frequency and quality of mid-water trawl sampling to correctly identify species composition and acoustic target strength.

Particularly, in the southern part of the area the vertical migration towards the surface at night made a substantial portion of the biomass unavailable to the vessel's echo sounders (transducer depth 8 m). Another potential problem with the use of backscatter layers to define acoustic regions was the subjective assigning of layer boundaries. Diurnal migration of the entire or parts of layers to surface waters, the subsequent descent, and the resulting mixing of species may add a temporal component to layer composition. To address the potential mixing of constituents within backscatter layers, the frequency-response, i.e. frequency-dependent backscatter, was used (adopting the program KORONA) to categorize each pixel and use a probability-derived discriminant function analysis to objectively define layer categories and boundaries.

An added challenge was the lack of acoustic size-to-organism length conversion regression equations for many of the species encountered. Target strength to animal length conversions had to be obtained from the literature for similar species, estimated using general equations, or modelled based on anatomical measurements. This could subsequently be compared with the on-station *in situ* measurements of target strength.

3.2.2.3. Post-processing and analyses. Backscatter data from the hull-mounted transducers were analysed using KORONA to categorize each analytic cell. Only data when the vessel was on transect, defined as a vessel speed of 8 knots or greater, was included in the analysis. Categorisation of the pixels was used to define layer boundaries and to proportion acoustic backscatter energy (i.e. area-backscattering coefficient values) to species or species groups. This step required matching the location of trawl hauls within acoustic records to determine which catches could be used to characterize layers, layer species compositions, and species-specific length frequency data from appropriate samples.

The Bergen Echo Integrator (BEI) was used to scrutinise the 18-kHz backscatter data from transects. Arbitrary layers and species codes were used in this initial analysis. Determination of layer boundaries and conversion of relative to absolute density or biomass would be finished after trawl data and KORONA categorisations became available and completed.

Target strengths of individual animals from deep towbody data were used to convert acoustic sizes to organism lengths or to compile probability distributions of in situ target strengths. The location of single-target depths was matched to the location of identified acoustic backscattering layers.

3.2.3. Optics (the Underwater Video Profiler, UVP)

The UVP is well adapted to count and measure fragile aggregates such as marine snow as well as delicate zooplankton. The instrument has two important features:

(a) it does not disturb the recorded particles or organisms;
(b) it allows quick data retrieval and processing.

The UVP model 4 used on the R.V. *G.O. Sars* 2004 is a vertically lowered instrument mounted on a galvanised steel frame ($1.1 \times 0.9 \times 1.25$ m). The model has been developed for the enumeration and measurements of fragile aggregates ($>60\,\mu$m) and zooplankton from 0 to 1000 m (Gorsky et al., 2000).

The lighting is based on two 54 W Chadwick Helmuth stroboscopes (pulse duration 30 μs) illuminating a 8-cm thick slab. Two cameras are positioned perpendicular to the light slab and illuminated particles are recorded simultaneously. Camera 0 targets copepod-like particles >1 mm ESD (Equivalent Spherical Diameter), in a volume of 1.25 L. Camera 1 targets particles >5 mm ESD in a volume of 10.5 L.

The instrument is autonomous and was lowered vertically (up to 1.5 m/s) to 1000 m on the hydrographic wire of the RV *G.O. Sars*. Most of the deployments were made during night in order to avoid sun light perturbation on images. Depth, temperature and conductivity data were acquired using a Seabird Seacat 19 CTD probe (S/N 1539) with fluorometer and nephelometer (both from Chelsea Instruments Ltd.).

Processing of images obtained by the UVP is automated and made by the system during the recovery by a customised software. The objects in each image were detected, enumerated, and measured. Identified objects were sorted into the following groups:

copepods (>1 mm ESD), sarcodines (with two sub-groups), non-copepod crustaceans (>5 mm ESD), chaetognaths, lobate and cydippid ctenophores, siphonophores, medusae (with three sub-groups, *Aeginura grimaldi*, *Aglantha* spp., and others), appendicularians, thaliaceans, fishes, molluscs, unidentified zooplankton, unidentified spheres, and diatom-like objects.

Further details on the UVP4 were provided by Stemmann et al. (2008).

3.2.4. Landers

3.2.4.1. Bergen acoustic landers. Three acoustic free-fall landers containing upward-looking echosounders were used for monitoring of sound scatterers in the water column from near the seabed to the surface. The landers consist of a stainless steel frame with flotation and containers for batteries and electronics. The landers, which had about 300-L positive buoyancy, were suspended above the bottom from a 1000-kg disposable ballast with an acoustic release for retrieval.

The necessary buoyancy was obtained by a series of 40-cm diameter glass spheres in plastic cover, fixed to the frame. Batteries installed in glass spheres supplied power to the electronics, and the numbers of batteries depended on deployment duration. A transceiver and a computer with echosounder software were installed in one of the spheres, and a 38-kHz split-beam transducer was installed on top of the lander, facing upwards. A sensor container collected data on depth, tilt, roll, and compass heading of the transducer beam. The landers were also designed to carry other types of payload, and on one of the landers an Aanderaa current meter was installed.

On Leg 1 of the R.V. *G.O. Sars* 2004 cruise, three landers were deployed on Superstations 13 and 21 near the CGFZ and on SS 30 north of the Azores. All landers were placed at around 1000 m, i.e. on the ridge crest. The lander placed on SS 13 had an Aanderaa RDCP 600 current meter on the frame, the one on SS 30 had an Aanderaa RCM8 on the mooring line. The three landers were retrieved during Leg 2, but one was red-eployed after being reloaded with the maximum capacity of batteries. This latter lander placed on SS 62 was successfully retrieved by the R.R.S. *James Clark Ross* nearly 1 year after the deployment.

3.2.4.2. Intensified silicon intensifier target (ISIT). The ISIT Lander has been designed to research spontaneous and stimulated bioluminescence in the water column and benthic boundary layer to depths in excess of 4000 m.

The lander consists of a low light level (ISIT) camera mounted on an aluminium frame. The version used on the MAR-ECO expedition (Leg 2, see Appendix A) was profiling vertically by stimulating bioluminescence with a mesh screen. The mesh screen and camera was mounted on the CTD-rosette (Heger et al., 2008).

3.2.4.3. Robust biodiversity lander (ROBIO). The ROBIO is a photographic lander for taking still photographs of animals attracted to a bait (Jamieson and Bagley, 2005). The version used on the MAR-ECO expedition (King et al., 2006) is a tripod equipped with a downward facing digital stills camera, a flash unit, a current meter, and a twin acoustic ballast release system. When deployed, the lander was suspended 2 m above the seabed by ballast. Further details on the deployments and results were given by King et al. (2006). ROBIO was used as a standard instrument on almost all superstations on Leg 2 (see Appendix A), and each deployment lasted the duration of all activities on a superstation (Fig. 7).

3.2.4.4. Deep Ocean Benthic Observatory (DOBO). The DOBO is a titanium lander capable of long-term deployments (Jamieson and Bagley, 2005). On the MAR-ECO expedition the DOBO was fitted with a sequential bait release system and operated in a single location at abyssal depth in the CGFZ from deployment on Leg 1 (SS 15) until retrieval towards the end of Leg 2 (SS 71). Further details are provided by Kemp et al. (2008).

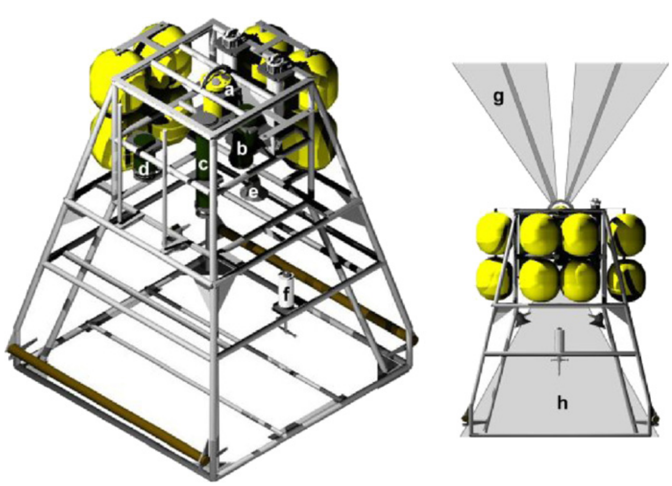

Fig. 7. The DOBO lander. The DOBO is equipped with an acoustic Doppler current profiler (ADCP) (a), 35 mm stills camera in time-lapse mode (capacity 1400 frames) (b), battery (c), controller (d), flash system (e), FSI current meter (f), and bait system (not shown). The upward-looking ADCP records current velocity and direction in 3-m depth cells above the lander (g). The camera photographs the bait system arranged at the base of the lander (h). *Source*: OCEANLAB, University of Aberdeen.

3.2.5. Remotely operated vehicles (ROVs)

The R.V. *G.O. Sars* was equipped with two ROVs, the Norwegian *Aglantha* and *Bathysaurus* (Argus Remote Systems, Bergen). On Leg 1, the ROV *Aglantha* was used to inspect acoustic mooring after deployment (Superstations 13 and 21), and on Leg 2 both instruments were used for pelagic and demersal dives to study habitats and fauna, and to collect samples of medusae for respiration experiments.

Table 9 gives the specifications and configuration details of the ROVs, and Table 10 lists the ROV dives from Leg 2. The intention was to conduct ROV deployments on every

Table 9
Characteristics and configuration of ROVs *Bathysaurus* and *Aglantha* used on the 2004 MAR-ECO expedition

ROV Bathysaurus
Size without tooling skid
Length: 170 cm
Width: 130 cm
Height: 130 cm
Weight: ca. 1100 kg
Payload: 150 kg
Forward/backward speed: 3 knots.
Lateral speed: 2 knots.
Vertical speed: 2 knots.
Depth-rating: 5000 msw

Electrical thrusters
8×850 W horizontal
5×850 W vertical

Hydraulics
$1 \times$ Hydraulic powerpack
$1 \times$ Hydraulic valvepack (7 functions)
$1 \times$ Hydro-lek 4 function manipulator arm

Camera
$4 \times$ Black/white camera
$1 \times$ Colour/black-white video camera with focus/zoom (Sony FCB-471), controlled via RS-232 with possibility to control Iris and White balance manually

Lights
$4 \times$ Halogen lights 500 W
$4 \times$ HID lights á 150 W
$2 \times$ Parallel Lasers on the Pan/Tilt for scaling

Sonar: Mesotech MS1000 (675 kHz)

- Electric pan & tilt and tilt unit
- Mesotech altimeter
- Saiv CTD with salinity, temperature, density, turbidity, oxygen, chlorophyll
- Saiv depthsensor
- KVH FOG Fibre Optical Gyro
- KVH C-100 Fluxgate Compass
- Roll/pitch sensor
- Simrad MPT324 Transponders used with ship's Hipap 500 system

Samplers

- Suction sampler from Harbor Branch Oceanographic Institutions (HBOI) with 12 samplers
- $4 \times$ D-Samplers from HBOI

Table 9 (*continued*)

ROV Aglantha

Size without tooling skid
Length: 200 cm
Width: 125 cm
Height: 115 cm
Weight: ca. 800 kg
Payload: 150 kg
Forward/backward speed: 3 knots
Lateral speed: 2 knots
Vertical speed: 2 knots
Depth-rating: 2000 msw

Electrical thrusters
4 × 1.5 kW horizontal
2 × 4 kW vertical

Hydraulics
1 × Hydraulic powerpack
2 × Hydraulic valvepacks (8 functions)
1 × Hydraulic pan/tilt unit
1 × Hydralek 5 function manipulator arm

Camera
4 × Black/white camera
1 × Colour/black–white video camera with focus/zoom (Sony EVI-401)

Lights
4 × Halogen lights 500 W
4 × HID lights á 150 W
4 × IR—lights
2 × Parallel lasers on the pan/tilt for scaling

Sonar: Mesotech MS1000 (675 kHz)
- Tritech Altimeter
- Saiv CTD with salinity, temperature, density, turbidity, oxygen, chlorophyll
- Saiv depthsensor
- KVH FOG Fibre Optical Gyro
- KVH C-100 Fluxgate Compass
- Roll/pitch sensor
- Simrad MPT324 Transponders used with ship's Hipap 500 system

Samplers
- Suction sampler from HBOI with 12 samplers
- 4 × D-samplers from HBOI

superstation on Leg 2, and the dive strategy was predetermined to include transect sampling and exploration. However, many dives became interrupted or had to be abandoned due to malfunction of thrusters or other units, and the less than specified depth capability of ROV *Bathysaurus*.

4. Databases and collections

4.1. MAR-ECO biotic database

All biotic data are stored in the "MAR-ECO biotic database". The fields and format of this database are similar to those used in the Institute of Marine Research

Table 10
Dives with the remotely operated vehicles (ROVs) during Leg 2 of the 2004 MAR-ECO expedition

Superstation	Date	St_revised	Depth (m)	Comment
13	17.06.2004	ROV-Aglanta	1129	Lander inspection
21	22.06.2004	ROV-Aglanta	850	Lander inspection
42	08.07.2004	ROV-Aglanta	1886	
44	09.07.2004	ROV-Aglanta	1425	
44	09.07.2004	ROV-Aglanta	1438	
44	14.07.2004	ROV-Aglanta	1152	
54	16.07.2004	ROV-Aglanta	3506	
56	22.07.2004	ROV-Aglanta	1388	
58	18.07.2004	ROV-Aglanta	3578	
60	19.07.2004	ROV-Aglanta	896	
62	21.07.2004	ROV-Aglanta	1685	
66	24.07.2004	ROV-Aglanta	3038	
70	26.07.2004	ROV-Aglanta	1471	
74	28.07.2004	ROV-Aglanta	3051	
44	11.07.2004	ROV-Bathysaurus	1198	
48	10.07.2004	ROV-Bathysaurus	1048	
48	11.07.2004	ROV-Bathysaurus	1091	
50	12.07.2004	ROV-Bathysaurus	2017	
58	23.07.2004	ROV-Bathysaurus	3221	
58	23.07.2004	ROV-Bathysaurus	3242	
62	22.07.2004	ROV-Bathysaurus	1664	
68	25.07.2004	ROV-Bathysaurus	2308	

(IMR) sampling programme "RegFisk" and the SPD 3.15 coding system. The SPD 3.15 format is described in the, "Handbook for Sampling Fish and Crustaceans", published internally at IMR (Mjanger et al., 2006). But there are additional MAR-ECO specific fields, and these are described in the document, "Field description for MAR-ECO db.pdf", provided to users of the MAR-ECO database. This additional information is also included in the database as a report that can be generated directly from the database.

The database is relational (RMDB) with replication. There are four main tables:

Local station table	Station information
Sampling table	Catch information (e.g., taxon, catch in numbers and weight etc.)
Specimen table	Specimen information (data for individual organisms)
Sub-sample table	Sub-sample information (specimens selected for particular processing, e.g., chemical analyses)

In addition, there are a few other tables for look-up and further combining of the data. A key number and a foreign key number combine the main tables.

For convenience there are built-in facilities for exporting data to Excel format. One export function will dump all the raw table data into four Excel sheets. Another produces an Excel file with different sheets, containing data from different queries. A query will combine data from different tables in different ways (e.g., making a table containing catch data with station data such as longitude and latitude).

4.2. Other MAR-ECO databases

The MAR-ECO abiotic database contains all CTD, thermosalinograph and current meter data.

The MAR-ECO GIS database is structured as a Geodatabase, and is a useful tool for those using GIS tools. The database contains static data and not data that are frequently updated. Cruise tracks with vessel information such as speed, depth, direction, etc., and data about superstations and activities is available. Similarly, weather data from the Ships Weather System (Vaisala MILO) and nutrients data are stored in the GIS database.

The MAR-ECO video database contains metadata for all video footage generated within the project. The database describe general metadata for the contents, tape type, etc. In addition, the database contains the detailed ROV observations made during the 2004 expedition.

During the planning and field phase of MAR-ECO over 12,000 images were produced by project partners. All these images has been stored and structured in a logical file-structure (physical) and organised in a MAR-ECO Image Management system. All the images are available on a password protected FTP server. The majority of the images are from the 2004 expedition, but there are also many pictures from the R.V. *Smolensk*, MIR-dives and other events from 2003 onwards.

4.3. Museum collections

The majority of the samples from the 2004 expedition was curated by the Bergen Museum, Norway, acting as the central facility for provision of samples for post-expedition analyses. Only surplus material, mainly frozen samples of abundant species, are kept by the Institute of Marine Research, Bergen.

Appendix A

See Table A1 for the activities on individual 'superstations' with point sampling of MAR-ECO expedition on the R.V. *G.O. Sars* during June–July 2004.

Table A1
Activities on individual 'superstations' with point sampling of MAR-ECO expedition on the R.V. *G.O. Sars* during June–July 2004

SS: 2	LS
Akra trawl	326
CTD, nutrients, and LADCP	391
Deep-towed vehicle	0
Macrozooplankton trawl	327
Multinet	1
Multinet	2
Plankton-net	1
UVP	1
SS: 4	LS
Akra trawl	328
CTD, nutrients, and LADCP	392
Deep-towed vehicle	0
Macrozooplankton trawl	329
Multinet	4
Multinet	3
Plankton-net	2
UVP	3
SS: 5	LS
CTD, nutrients, and LADCP (59°42′ N, 29°51′ W)	393
UVP (59°42′ N, 29°51′ W)	4
SS: 6	LS
Akra trawl	330
CTD, nutrients, and LADCP	394
Deep-towed vehicle	3
Macrozooplankton trawl	331
Plankton-net	3
UVP	5
SS: 7	LS
Egersund trawl	332
SS: 8	LS
Akra trawl	334
CTD, nutrients, and LADCP	395
Deep-towed vehicle	4
Macrozooplankton trawl	333
Plankton-net	4
UVP	6
SS: 10	LS
CTD, nutrients, and LADCP	396
Deep-towed vehicle	5
Macrozooplankton trawl	335
Multinet	5
Multinet	6
Plankton-net	5
UVP	7
SS: 11	LS
Egersund trawl	336
Egersund trawl	337
SS: 12	LS
Akra trawl	339
CTD, nutrients, and LADCP	397
Deep-towed vehicle	6
Macrozooplankton trawl	338
Multinet	7
Multinet	8
Plankton-net	6
UVP	8
SS: 13	LS
Acoustic lander (53°06′ N, 35°28′ W)	1
ROV-Aglanta	−2
SS: 14	LS
Akra trawl	341
CTD, nutrients and LADCP	398
Deep-towed vehicle	7
Macrozooplankton trawl	340
Multinet	10

Table A1 (*continued*)

Multinet	9
UVP	9
SS: 15	LS
DOBO (52°42′ N, 35°15′ W)	1
Egersund trawl	342
SS: 16	LS
Akra trawl	344
CTD, nutrients, and LADCP	399
Macrozooplankton trawl	343
Multinet	11
UVP	10
SS: 18	LS
Akra trawl	346
CTD, nutrients, and LADCP	400
Deep-towed vehicle	8
Macrozooplankton trawl	345
Plankton-net	7
UVP	11
SS: 20	LS
Akra trawl	348
CTD, nutrients, and LADCP	401
Macrozooplankton trawl	347
Multinet	12
Plankton-net	8
UVP	12
SS: 21	LS
Acoustic lander (51°31′ N, 30°20′ W)	3
CTD, nutrients, and LADCP	402
Deep-towed vehicle	9
ROV-Aglanta	−1
SS: 22	LS
Akra trawl	350
CTD, nutrients, and LADCP	403
Deep-towed vehicle	10
Macrozooplankton trawl	349
Plankton-net	9
UVP	13
SS: 24	LS
Akra trawl	352
CTD, nutrients, and LADCP	404
Deep-towed vehicle	11
Macrozooplankton trawl	351
UVP	14
SS: 26	LS
Akra trawl	355
Akra trawl	354
CTD, nutrients, and LADCP	405
Multinet	13
UVP	15
SS: 28	LS
Akra trawl	357
CTD, nutrients, and LADCP	406
Deep-towed vehicle	12
Macrozooplankton trawl	356
Multinet	14
Plankton-net	10
UVP	16
SS: 30	LS
Acoustic lander (42°52′ N, 29°07′ W)	2
Akra trawl	359

Table A1 (*continued*)

CTD, nutrients, and LADCP	407
Macrozooplankton trawl	358
UVP	17
SS: 31	LS
Egersund trawl	360
SS: 32	LS
Akra trawl	361
CTD, nutrients, and LADCP	408
Macrozooplankton trawl	362
Multinet	15
Plankton-net	11
UVP	18
SS: 34	LS
Akra trawl	364
CTD, nutrients, and LADCP	409
Deep-towed vehicle	14
Macrozooplankton trawl	363
UVP	19
SS: 36	LS
Akra trawl	366
CTD, nutrients, and LADCP	410
Deep-towed vehicle	15
Macrozooplankton trawl	365
Multinet	16
Plankton-net	12
UVP	20
SS: 40	LS
Bottom trawl	367
CTD, nutrients, and LADCP	411
Deep-towed vehicle	0
SS: 42	LS
Bergen Acoustic Bouy (BAB)	0
Bottom trawl	368
CTD, nutrients, and LADCP	412
ROBIO	1
ROV-Aglanta	0
UVP	21
SS: 44	LS
Bergen Acoustic Bouy (BAB)	2
Bottom trawl	369
CTD, nutrients, and LADCP	413
ROV-Aglanta	3
ROV-Aglanta	1
ROV-Aglanta	2
ROV-Bathysaurus	2
UVP	22
SS: 46	LS
Bottom trawl	370
Bottom trawl	372
CTD, nutrients, and LADCP	414
ROBIO	2
UVP	23
SS: 48	LS
Bottom trawl	371
ROBIO	3
ROV-Bathysaurus	1
ROV-Bathysaurus	0
UVP	24
SS: 50	LS
Bottom trawl	373

Table A1 (*continued*)

CTD, nutrients, and LADCP	415
ROBIO	4
ROV-Bathysaurus	3
UVP	25
SS: 52	LS
Bottom trawl	374
CTD, nutrients, ISIT, and LADCP	416
ROBIO	5
UVP	26
SS: 53	LS
Bottom trawl	375
Bottom trawl	376
CTD, nutrients, ISIT, and LADCP	417
SS: 54	LS
Bottom trawl	377
CTD, nutrients, ISIT, and LADCP	418
ROBIO	11
ROV-Aglanta	4
UVP	27
SS: 56	LS
Bottom trawl	378
CTD, nutrients, ISIT, and LADCP	419
ROBIO	10
ROV-Aglanta	12
UVP	28
SS: 58	LS
Bottom trawl	382
CTD, nutrients, ISIT, and LADCP	420
ROBIO	9
ROV-Aglanta	5
ROV-Bathysaurus	1
ROV-Bathysaurus	2
UVP	29
SS: 60	LS
Bottom trawl	379
CTD, nutrients, ISIT, and LADCP	422
CTD, nutrients, ISIT, and LADCP	421
ROBIO	8
ROV-Aglanta	6
UVP	30
SS: 62	LS
Acoustic lander (51°32′ N, 30°20′ W)	4
Bottom trawl	380
ROBIO	7
ROV-Aglanta	11
ROV-Bathysaurus	0
UVP	22
UVP	21
SS: 64	LS
Bottom trawl	381
CTD, nutrients, ISIT, and LADCP	423
ROBIO	6
UVP	31
SS: 66	LS
Bottom trawl	383
CTD, nutrients, ISIT, and LADCP	424
ROBIO	17
ROV-Aglanta	13
UVP	23

Table A1 (*continued*)

SS: 68	LS
Bottom trawl	384
CTD, nutrients, ISIT, and LADCP	425
ROBIO	16
ROV-Bathysaurus	3
UVP	24
SS: 70	LS
Bottom trawl	385
CTD, nutrients, ISIT, and LADCP	426
ROBIO	15
ROV-Aglanta	14
UVP	25
SS: 72	LS
Bottom trawl	386
CTD, nutrients, ISIT, and LADCP	427
ROBIO	13
SS: 74	LS
Bottom trawl	387
Bottom trawl	388
CTD, nutrients, ISIT, and LADCP	428
ROBIO	12
ROV-Aglanta	15
UVP	26
SS: 76	LS
CTD, nutrients, ISIT, and LADCP	429
ROBIO	14

SS—superstation number, LS—local station number.

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