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Cruise Report - RV G.O. Sars, June 2004

MAR-ECO CRUISE TO THE MID-ATLANTIC RIDGE

ICELAND-AZORES

Version 2
G.O. Sars
29 June 2004.

Table of Contents

Please see WWW.MAR-ECO.NO for overall MAR-ECO Science Plan, component project descriptions, and earlier draft plans for the RV *G.O. Sars* cruise 2004.

1. Introduction (ORG)

The G. O. Sars cruise on the northern Mid Atlantic Ridge (MAR) is a major field initiative under the Mar-Eco project (www.mar-eco.no), which again is a component project under Cnesus of Marine Life (www.coml.org). There are several other cruises organized from several countries that will supply data for the project over the period 2003-2006?. The G.O. Sars cruise is the only large scale coverage of the MAR and thus represent an important basis for the overall data interpretation and understanding of the MAR ecosystem.

The G. O. Sars cruise is divided in two parts. Leg 1 aims at giving an overall coverage of the pelagic fauna between Iceland and the Azores while Leg 2 will concentrate the effort in two sub areas with focus on the demersal nekton and epibentic fauna. Extensive use of ROV and bottom trawl limit the area that potentially can be coverage. To improve sampling coverage indepednet of bathymetry, Leg 2 of the cruise will also be supported with sampling from fixed gears by the Norwegian longliner F/V Loran.

G.O. Sars departed Bergen on 5 June 12:00 a.m. and Leg 1 ended in Horta on 3 July 00:00. PI during the cruise was Olav Rune Godø, Institute of Marine Research, Norway. A scientific crew from 10 countries counted totally 30 persons (see list in APPENDIX I).

Main goal of the Mar-Eco project is to describe and understand the patterns of distribution, abundance and trophic relationships of the organisms inhabiting the mid-oceanic North Atlantic, and identify and model ecological processes that cause variability in these patterns.

Specific goal for this cruise is to collect data for describing the diversity and distribution patterns of the plankton and nekton of the pelagic ecosystem of the MAR.

Tasks and priorities:
To produce an overall quantitative assessment of the plankton and nekton associated with the Mid-Atlantic Ridge.
To collect biological samples in support of the Mar-Eco component projects Z1, Z4, PN1, PN2 and PN3.
Add effort at opportunity for cetacean and bird studies (PN3).
Launch moorings and rigs for long-term physical and acoustic data logging. (3 acoustic landers and 1 video lander (DOBO).

The Mar-Eco project emphasize on the public outreach as an integrated activity following the progress of the project. As part of this strategy we invited an artist, Ørnulf Opdahl, on Leg 1 of the G.O. Sars cruise. A view of the scientist at work and the results of their efforts from different perspective can possibly be a source of inspiration to both parties, and the resulting art may stimulate the interest among the general public in a way not possible by traditional means. A TV team of two followed the Leg 1 cruise activities with a focus on the artist and his interaction with science and the scientists. A documentary will be produced before the end of the year.

2. Sampling equipment and strategies (ORG)

2.1. Vessel

R/V G.O. Sars is 77.5 m long and has a diesel-electric propulsion (2x3000 kW). The vessel meets the ICES requirement for noise emission and has a protruded keel for the acoustic instrumentation (see G.O. Sars web site). G.O. Sars is a multi purpose vessel equipped for marine research in general with emphasis on fisheries and environment related studies.

2.2. Sampling

We classified our sampling in three types:

The collection of data during steaming, ***continuous sampling*****,** is used to produce the large scale distribution patter of the physical environment as well as the horizontal and vertical distribution of biological backscattering in the upper 2000-3000 m. The sampling equipment used:

- Echosounders with vessel-mounted (protruded keel) transducer transmitting at 5 frequencies (18 – 200 kHz).
- ADCP (Acoustic Doppler Current Profiler) 75 kHz for continuous logging of current
- Surface temperature and chlorophyll recorder
- Bottom mapping with multi-beam echo sounder (EM 300)

A set of predetermined stations was used in a ***point sampling*** program. A systematic design secured comparable information throughout the covered area and a variety of sampling gears on each location ensure coverage of different individual sizes and distribution depths down to 3000 m.

- Mid-water trawls and nets of different sizes and designs (medium sized pelagic trawl, macrozooplankton trawl, Multinet, Juday net)
- ROV
- Acoustic and optic landers.
- Echosounders of various designs/characteristics (hull- and keel-mounted, and towed vehicle transducers).
- CTD mounted on the ADCP (150 kHz)
- UVP (Underwater Video Profiler)
- See G.O. Sars website for permanent instrumentation and facilities.

The last type data accumulation came from ***opportunistic sampling***. This covered the need for extra sampling with the large pelagic trawl (Egersund trawl), validation of acoustic recordings with any kind of gear, ad hoc effort for whale sighting and whale tagging. The last involved adjustments of course and/or speed to identify observed animals, and use of a small boat for tagging and biopsy sampling. Occasionally we run additional sampling with sonars to map the biological environment of areas with high concentration of animals.

The pelagic trawls used during point sampling have a multisampler; a unit at the end of the net with an opening - closing device. For the medium sized trawl and for the macrozooplankton respectively, we thus could collect samples from three and five different depth intervals in separate codends. This not only saves a lot of time, but also gives a better separation of catches by depth without the contamination during trawl shooting and retrieval.

A list of the gears and technologies are given in APPENDIX II.

Table 1. Fixed station program "long" (upper panel) and short (lower panel) stations with estimated time budget. Long stations were shortened half way through the cruise by excluding one of the multinet hauls.

12 "Long" stations a´ 20 hours	Max. depth (m)	Total time (min)	Total time (hrs)
o Towed body	1500	60	
o CTD/ADCP	3000	180	
o UVP	1000	45	
o Multinet 0-2500	2500	155	
o Multinet 0-1000	1000	80	
o Macrozooplankton trawl	2500	224	
o Pelagic fish trawl	3000	340	
Sum		***1084***	***18,07***

16 "Short" stations a´ 16 hours:	Max. depth (m)	Total time (min)	Total time (hrs)
o Towed body	1500	60	
o CTD/ADCP	3000	180	
o UVP	1000	45	
o Macrozooplankton trawl	2500	224	
o Pelagic fish trawl	3000	340	
Sum		***849***	***14,15***

2.3. Narrative (map of cruise track and stations)

G.O. Sars followed the cruise track shown in Figure 1. Totally ?? stations were completed distributed on the different gears as shown in Table 2. All sampling is associated with a Superstation number. Change of Superstation number occurred at arrival on and departure from fixed stations.

Figure 1. Map with cruise track and stations

2.4. Content of long and short stations

A sampling program was predetermined for the fixed stations (Table 1). Short and long station applied the same sampling gears except multinet which was only used on ling stations. Based on the experience from the first stations, and to save time, the long stations were cut to include only one set with the multinet.

3. Data overview

3.1. Bathymetry mapping (HPK)

3.1.1. Data collected

The bottom depth has been logged continuously along the track line during the entire survey with a Simrad EK60 split beam echo sounder. Depth data from EK60 are stored in the vessel "reference log system".

In addition, Kongsberg EM300 multibeam echo sounder has been used most of the time. This echo sounder has 135 beams athwart ship, each with 1 by 2 degrees beam width. The swath width is dependent of the depth and bottom type, but generally it is about 3 km at a bottom depth of 2000 metres. The data from EM300 are stored in the Olex chart system. This system can present a 3D seabed image along the survey track line.

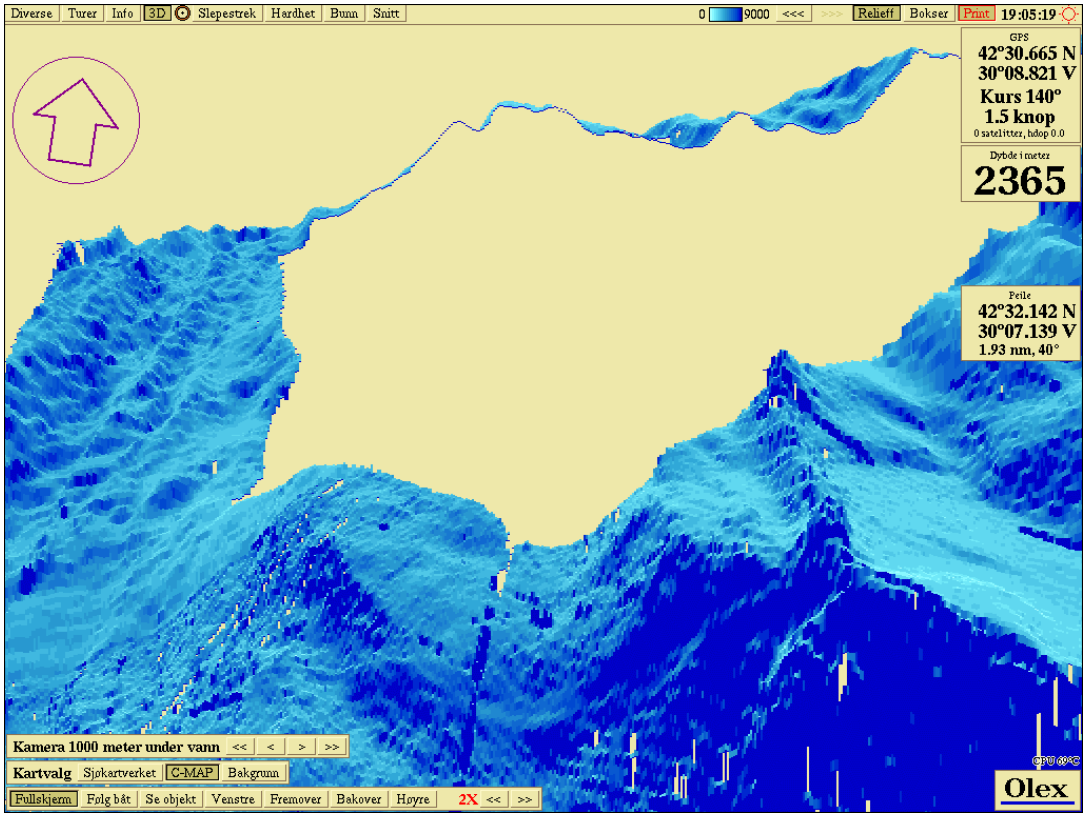

Figure 1. Example of seabed imaging along the survey track as displayed in the Olex system.

In addition to general data collection along the cruise track more detailed information was collected on the locations chosen for the acoustic landers. We could thus secure positioning on a safe location at correct depth, which is not a trivial task under such varying bottom depths.

3.1.2. Problems and assumptions

The different echo sounders and ADCP are synchronized, and EK60 is set up as master. Therefore the ping rate of the EM300 is determined by the ping rate of EK. Vessel speed is

varying from normal survey speed at 11 knots to trawl speed at 2 – 3 knots. Neither ping rate nor the vessel speed is optimal for running the EM300. The quality of the data from EM300 is also varying with weather conditions.

3.1.3. Planed progress of work

The data will be stored and made available under the Mar-Eco data management system.

3.2. Oceanographic data (HS)

- Data collected
- Problems and assumptions
- Planed progress of work

3.3. Sighting data (birds and mammals)(LN,HSK)

3.3.1. Data processing

Observations of cetaceans and seabirds are stored to the nearest time minute as a basis for creation of four working databases:
A line transect database covering all distances cruised during watch time for analyses of scale-dependence and comparison with continuous hydrographical and acoustic data;
A station database with samples of observations made in the proximity to stations as a basis for comparison with hydrographical and biological samples as well as acoustic data obtained at stations;
A database for analyses of correlations between acoustic data and observations of top predators at seamounts crossed;
A sightings database of cetacean observations holding records of group/pod size, radial distance and angle for calculation of detection functions.

1 - The line transect database holds details of densities (n/km^2) of each target species (group), geographical position (dGPS), ship speed (m/s), surface area covered by transect (km^2), weather (Baufort scale), temperature (ºC) at 8 m (from ship's salinograph), salinity at 8 m (from ship's salinograph), bottom depth (m) and slope (º) (from 18 kHz echosounder) and surface (m), sub-surface and mid-water current vectors (from ADCP) with a temporal resolution of one minute. The database also holds links to digital images in the MAR-ECO IMatch database. The database is transferred to a digital database in ArcGIS and EVS-PRO (shape file format) and Surfer (excel, ascii) for geo-statistical analysis and visualisation. Relative densities will be calculated by dividing observed numbers corrected for distance and weather bias by each area covered.

2 - The station database will be created by importing selected hydrographical and biological samples and aggregating transect observations made in the proximity to stations. The biological samples will include size (g) and depth aggregated densities (g/m^2) on copepods, euphausiids, shrimps, fish and cephalopods by major groups as well as aggregated acoustic data from the transect. Hydrographical data will include depth, temperature at 5m, 100m, 500m and 1000m, salinity at 5m, 100m, 500m and 1000m, thermocline depth, halocline depth and L-ADCP data.

3 - The database on linked acoustic and observational data will apply acoustic raw data files from the hull-mounted Simrad ER60 echosounder using five different transducers: 18, 38, 70, 120 and 200 kHz. The extensive vertical ranging 18 kHz transducer will be used for detailed bottom detection and defining total and average bottom depth as well as slope of selected seamounts were we have aggregations and hot spots of marine mammals. Possible prey species for sperm whales, pilot whales and beaked whales from the meso- and deep-water habitats (500-2000 m)

will be scrutinized and analysed in more detail by the 18 and 38 kHz transducers. Possible prey species for baleen whales and dolphin species from the shallow-water habitats (12-200 m) will be scrutinized and analysed in more detail by the high-resolution 120 and 200 kHz transducers.

4 - The sightings database will be used as a basis for estimating effective transect width (observation probability * transect width) and correction factors (1/observation probability) for distance and weather bias using detection functions for line transect distance data (Buckland et al. 1996).

Physical and biological data of the line transect database will be processed in ArcGIS version 8, Surfer version 8.0 and EVS-PRO version 7.6 for visualisation of observed and interpolated densities. Interpolation will be made by ordinary kriging using variograms, which also be used to determine overlapping spatial auto-correlations between data at various depths for at least three different regions (North, Charlie-Gibbs Fracture Zone (CGFZ), South). The results will be used to test hypotheses for potential physical habitat structures for different species of cetaceans and seabirds associated with the depth topography, horizontal flow gradients and water column structure. Potential habitats include areas with steep bottom relief, small-scale surface and sub-surface fronts, meso-scale fronts and water masses, up-welling associated with Taylor columns and pycnocline depth equivalent to diving depth of species. The geo-statistical analyses will also be used to derive total abundance estimates for the target species of cetaceans. Spatial habitat models will be used to extrapolate findings to the selected topographical and hydrographical structures by determining the correlation between species densities and distance to classified structures.

Trends in the concurrent biological and physical data from the station database will be determined by cluster and factor analyses followed by linear tests of relationships between target species of top predators, oceanographical features and potential prey. The analyses will be stratified vertically to take account of the diving capacity of the predator species in question. For Procellarian seabirds with extremely limited diving capacity, UVP data analyses from the upper 10 m will be included. Following this, estimates of top predator's consumption of key species (groups) of prey will be made as a basis for determining the ecological role of top predators in the different regions of the Mid-Atlantic Ridge (MAR).

The data from the 'seamounts' database will be used to determine marine mammal hot spots along the MAR. Acoustic, surface temperature, salinity and ADCP data will be analysed during selected crossings of seamounts and rises coinciding with concentrations of cetaceans and seabirds. Acoustic data analysis in relation to seamounts and hotspots will be concentrated on comparing possible prey densities and aggregations with our visual observations of marine mammals. Analyses comparing prey distribution and aggregations by depth layers before, during and after passage of seamounts will be explored. The filtered acoustic echograms and ADCP data will be exported with the two-dimensional hydrographical and sightings data to EVS-PRO or MatLab for production of advanced visualisation of identified fine-scale processes of potential importance.

Additional data collected are behavioural observations on feeding and interactions between cetaceans and seabirds as well as passive acoustic recordings of beaked whales at stations from a click detector attached to the Multinet.

Sighting data (marine mammals and seabirds) (LN, EO, HSK)

A total of 4712 km of line transect observations was made. We recorded 14 cetacean species and 24 seabird species (Table 2 and Table 3). Cetaceans were recorded along the entire range of the Mid Atlantic Ridge from Reykjanes Ridge south of Iceland to the Azores with notable areas of concentration in the Charlie Gibbs Fracture Zone (CGFZ), as well as in association with seamounts and rises. Seabirds were more widespread along the Ridge, although discrete increases in densities occurred near the frontal zone in the CGFZ. In the Labrador water mass of the northern part of the MAR Long-finned pilot whales (*Globicephela melas*), Atlantic white-sided dolphins (*Lagenorhynchus acutus* and white-beaked dolphins (*Lagenorhynchus albirostris)* were the dominant cetacean species, but sei whales (*Balaenoptera borealis),* fin whales (*Balaenoptera physalus)* and killer whales (*Orcinus orca)* were also observed. Seabird densities of the northern part of the Ridge were generally low with northern fulmar (*Fulmarus glacialis)* as the dominant species, and single observations concerning birds on late spring migration like Sabine's gull (*Larus sabinii*), long-tailed skua (*Stercorarius longicaudus*), arctic skua (*Stercorarius parasiticus),* pomarine skua (*Stercorarius pomarinus)* and arctic tern (*Sterna paradisaea*) as well as birds from breeding colonies on Iceland like northern gannet (*Sula bassana),* black-legged kittiwake (*Rissa tridactyla),* greater black-backed Gull (*Larus marinus),* lesser black-backed gull (*Larus fuscus),* great skua (*Stercorarius skua), c*ommon guillemot (*Uriia aalge*) and puffin (*Fratercula arctica*).

Large numbers of cetaceans and increased abundances of seabirds were associated with the transect observations in the frontal zone of the CGFZ, especially to the north and southwest of the fracture, coinciding with the zone of maximum surface temperature and salinity gradients. sei whales (*Balaenoptera borealis)* and sperm whales (*Physeter macrocephalus)* dominated the cetacean community, but humpback whales (*Megaptera noveangliae),* minke whales (*Balaenoptera acutorostrata)* and beaked whales (*Mesoplodon ssp)* were also observed..

Clicks of beaked whales were also recorded by a hydrophone at 1500-2500 m depth in the region. Both sei- and sperm whales showed highly patchy aggregations and were recorded feeding in the area, seemingly concentrated at or near seamounts or steep slopes in the bottom topography. South of CGFZ elevated densities of common dolphin (*Delphinus delphis)* were seen together with flocks of striped dolphin (*Stenella coeruleoalba)*. The seabird fauna of the CGFZ was generally dominated by the two large shearwaters great shearwater (*Puffinus gravis)* from the South Atlantic and Cory's shearwater (*Calonectris diomedea)* from the Azores/Cap Verde with single observations of other procellarians including the first Atlantic record of the Pacific Townsend's/Newell's shearwater (*Puffinus auricularis/newelli*). Townsend's shearwater breeds on the Pacific coast of Mexico, whereas Newell's Shearwater breeds on Hawaii, and is considered threatened throughout its range. Unfortunately, no photos were taken of the species.

Common dolphin was the most commonly observed species of cetacean along the southern part of the Ridge. Feeding fin- and blue whales (*Balaenoptera musculus)* were observed in relation to seamounts and rises.

In the warm water masses Cory's shearwater was the only widespread species of seabird, while British storm petrel (*Hydrobates pelagicus),* soft-plumaged petrel (*Pterodroma mollis)*, Wilson's storm-petrel (*Oceanites oceanicus)* and Madeira storm-petrel (*Oceanodroma castro)* occurred in low densities.

Table 2 Species of cetaceans, regional occurrence and numbers recorded along the G.O. Sars line transect. Dominant species marked with bold..

Species	Species name	Region	Number observed
Blue whale	**Balaenoptera musculus**	South	3
Fin whale	*Balaenoptera physalus*	Entire Ridge	14
Humpback whale	*Megaptera noveangliae*	CGFZ	3
Sei whale	*Balaenoptera borealis*	North, CGFZ	87
Minke whale	*Balaenoptera acutorostrata*	CGFZ	1
Sperm whale	*Physeter macrocephalus*	Entire Ridge	75
Beaked whale ssp.	*Mesoplodon ssp*	CGFZ	9
Long/Short-finned Pilot whale	*Globicephela melas/macrorhynchus*	Entire Ridge	326
Killer whale	*Orcinus orca*	North	5
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	North	103
White beaked dolphin	*Lagenorhynchus albirostris*	North	11
Common dolphin	***Delphinus delphis***	South	283
Striped dolphin	*Stenella coeruleoalba*	South	84

Table 3 Species of seabirds, regional occurrence and numbers recorded along the G.O. Sars line transect. Dominant species marked with bold.

Species	Species name	Region	Number observed
Northern Fulmar	***Fulmarus glacialis***	North, CGFZ	1009
Manx Shearwater	*Puffinus puffinus*	Entire Ridge	9
Townsend's/Newell's Shearwater	*Puffinus auricularis/newelli*	CGFZ	1
Sooty Shearwater	*Puffinus griseus*	Entire Ridge	2
Great Shearwater	*Puffinus gravis*	CGFZ	316
Cory's Shearwater	*Calonectris diomedea*	CGFZ, South	298
British Storm-petrel	*Hydrobates pelagicus*	South	5
Wilson Storm-petrel	*Oceanites oceanicus*	CGFZ, South	1
Madeira Storm-petrel	*Oceanodroma castro*	South	4
Soft-plumaged Petrel	*Pterodroma mollis*	South	1
Northern Gannet	*Sula bassana*	North	6
Black-legged Kittiwake	*Rissa tridactyla*	North	6
Great Black Backed Gull	*Larus marinus*	North	10
Lesser black-backed Gull	*Larus fuscus*	North	0
Sabine's Gull	*Larus sabinii*	North	1
Great Skua	*Stercorarius skua*	North	12
Long-tailed Skua	*Stercorarius longicaudus*	North	7
Arctic Skua	*Stercorarius parasiticus*	North	7
Pomarine Skua	*Stercorarius pomarinus*	North	1
Arctic Tern	*Sterna paradisaea*	Entire Ridge	7

Common Guillemot	***Uriia aalge***	North	1
Puffin	***Fratercula arctica***	North	8

The work of PN3 has to a large extent been carried out as planned, as the main activity; the visual observations could be carried out throughout the cruise. We experienced varied weather conditions, with mean wind speed of 9.9m/s and up to 8m wave height. For observation of cetaceans these conditions were sub-optimal, and we can assume that species without a visible blow, or without attraction to the vessel were not observed in a representative way. Except for the UVP, the cruise was carried out irrespective of time of day, and accordingly a reasonable proportion of the cruise time was available during the daylight hours. In these conditions seabird densities could be sampled with little or no bias. Cetacean observations were more affected by waves, especially observations of beaked whales, which require flat sea conditions. Thus, it is likely that our records of beaked whales reflect a considerable underestimate of the densities and distribution in the MAR.

Behavioural records of feeding predators were made throughout the cruise. However, due to time constraints we did not have the opportunity to carry out more detailed studies of predator-prey interactions by the use of the ship's sonar. Such studies are time consuming and they will require a more dedicated effort.

Satellite transmitters

We attached two of eight satellite transmitters to a humpback and a sperm whale, and attempted attachment to a sei whale and fin whale. So far neither of the transmitters have sent any signals indicating either that the transmitters have fallen off the animals, or that the attachment location is submerged too much to allow the transmitter to send signals to the ARGOS satellite. Sperm whales are known for their thick skin and dense blubber, and these biological factors may have prevented the transmitter from penetrating deep enough into the animal to secure it in the blubber, thereby falling out after a short time. So far the application of satellite transmitter has not succeeded, however, given the experience from similar attempts to put transmitters on large whales we were aware of the poor odds, and hope to be able to improve the devices and make new attempts in the near future. This is regarded as a priority for PN3, as satellite tracking may provide essential information to reveal whether the MAR functions not only as an important feeding area for large whales but also as a breeding area.

Table 4 Timetable for dataanlysis from PN3 project.

Time	Deliverable
End of Leg 1 (2004)	Four working databases established Cruise reports to funding agencies
Oct-Dec 2004	Abundance estimates – whales Abundance estimates – seabirds Geostatistical analysis – whales and seabirds "Hot-spot" – echogram studies – first draft UVP/Seabird/Multinet analysis finished Habitat models for whales and seabirds constructed
Jan-Mar 2005	Whale and sea-bird ecology analysis (by species) Analysis of hydrophone recordings – whales
April 2005	Presentation of results at MAR-ECO workshop

3.4. Acoustic back scattering data (JH)

3.4.1. Data collected

Acoustic data was continuously collected since leaving Bergen Harbour. A five-frequency (18 kHz, 38 kHz, 70 kHz, 120 kHz, 200 kHz), Simrad EK-60 echosounder has been synchronized with the ADCP and the Simrad EM-300 multibeam sonar. Pulse interval rate was set above 4 seconds to allow time for echoes to return from depth and to minimize noise interference from other acoustic instruments. Both raw and telegram data were logged to computer hard disk to facilitate analyses with a variety of post-processing software.

Prior to or at the conclusion of sampling at each super station, target strength data from individual animals within scattering layers were measured using a deep towbody equipped with a dual frequency (38 kHz, 120 kHz), EK-60 scientific echosounder. 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 m 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, the towbody was retrieved at a rate of 1 ms^{-1} until reaching the surface. Pulse repetition rate was set at 0.7 seconds. Pulse duration was set at 512 μs to increase the ability to resolve individual targets. Depth, pitch, and roll of the tow body were continuously monitored and recorded for the duration of each deployment. The towbody has a tendency to ride nose-up while being towed at depths greater than 500 m. Data dropouts occurred at random due to cable length.

The 18 kHz echosounder could easily "see" bottom 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.

We used normally net sampling to identify acoustic targets (see later chapter). In an effort to obtain visual confirmation of acoustic targets, the ROV Aglantha was used to inspect backscattering layers on its return from inspection of the first two acoustic lander deployments on June17th and June 22nd. Animals observed in video streams from the ROV did not match those caught in either the macrozooplankton or Åkra midwater trawls. The 18 kHz echograms showed disturbance and or avoidance of the ROV and cable during both descent to the acoustic landers and ascent to the surface. Disturbance was greater during ascent compared to that observed during descent. The ROV is not a viable tool to confirm the identity and relative density of acoustic targets.

In addition to the vessel data three moorings with Simrad EK 60 38 kHz echosunder were launched (Figure 1). They will sample the water column from about 900 m to the surface until being picked up during Leg 2. The mooring south of Charley Gibbs Fracture Zone will be redeployed to sample the water column over a period of about one year to reveal seasonal variation in the acoustic back scattering.

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3.4.2. Problems and assumptions

Using acoustic technique in an area with limited knowledge and information is challenging and demand well a defined approach with carefully identified assumptions and uncertainties. In our case we have paid particular attention to effects of *changing availability*, *layer boundaries, representative sampling to correctly identify species composition* and *acoustic target strength.*

Particularly in the southern part of the area the vertical migration to surface by night made a substantial portion of the biomass unavailable to the vessel echo sounders (transducer depth 8 m). This demand caution when analysing the density data but can also be exploited to distinguish the content of the various layers due to the difference in diel migration of the various animals.

One potential problem with the use of backscatter layers to define acoustic regions is the subjectivity of layer boundaries. Diel migration of whole or parts of layers to surface waters, the subsequent descent, and the resulting mixing of species may add a temporal component to layer compositions. To address the potential mixing of constituents within backscatter layers, the frequency-response (i.e. frequency-dependent backscatter) will be used within the software program KORONA to categorize each pixel and using a probability derived from discriminant function analysis, objectively define layer categories and boundaries. We are still unsure of the effect of diurnal migration on the frequency response, e.g. as a result of tilt angle change.

As mentioned previously the disturbance of backscattering layers due to the presence or avoidance of the ROV precluded its expected use in the optical identification of acoustic layer constituents. Similar avoidance behaviour also affects the efficiency of the other gears to a varying extent. Further, for the largest trawls mesh selection will be important but difficult to assess. The lag in the availability of catch composition and length frequency data delayed the ability to identify constituents within acoustic backscattering layers, and then to decide and implement the conversion of relative to absolute acoustic densities for biomass estimates. This was not a major impediment to the preliminary analyses, categorization, and scrutinizing of acoustic backscatter layer data. This task can easily be completed when the catch data is available.

An added challenge to this task is the lack of acoustic size to organism length conversion regression equations for many of the species encountered. Target strength to animal length conversions will have to be obtained from the literature for similar species, estimated using general equations, or modeled based on anatomical measurements. This will be compared to the on-station *in situ* measurements of TS.

3.4.3. Planned progress of work – analytical approach

The analytic approach for data analysis has been defined and preliminary analyses have been completed. Results of preliminary analyses are reported in section x.x.

Backscatter data from the hull mounted transducers will be analyzed 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, will be included in the analysis. Categorization of the pixels will be used to define layer boundaries and to proportion acoustic backscatter energy (i.e. area backscattering coefficient values) to species or species groups. This step requires matching the location of trawl hauls within acoustic records to determine which catches can be used to

characterize layers, layer species compositions, and species-specific length frequency data from appropriate samples.

The Bergen Echo Integrator (BEI) has been used to scrutinize the 18 kHz backscatter data from transects. Arbitrary layers and species codes have been used in this initial analysis. Layer boundaries and conversion of relative to absolute density or biomass will occur after trawl data and KORONA categorizations are available.

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

The paucity of information on species composition and acoustic characteristics of aquatic organisms within the mid-Atlantic ridge region limit the ability to conduct a traditional acoustic biomass survey. Since biological and acoustic information was limited we used backscatter patterns within the water column to guide our analytic approach. Our strategy was to quantify the acoustic structure and dynamics independent of biological sampling and then integrate acoustic characterizations using density and target strength observations with biological community composition and length frequency data to estimate biomass. This integrated ecosystem approach differs from a traditional acoustic survey in that species or species groups were not arbitrarily assigned to backscatter thresholds or water column regions at the onset of analysis.

A combination of technologies was used to provide a wealth of data types for an integrated analysis:

Daily echograms: We produced 18 kHz, 38 kHz, and 120 kHz echograms for each 24 hour period beginning at midnight UTC. These echograms were used to observe spatial and temporal patterns within a diel cycle. Inspection of the echograms revealed two consistent features: concentrations of backscatter in layers whose intensity depended on the frequency, and movement of whole or partial layers at night to surface water with subsequent stacking or mixing of layers at pre-dawn.

Target strength data: The deep towbody was deployed at the start or end of each superstation to collect target strength data at ranges shorter than those from the vessel mounted transducers. This geo-referenced data stream is matched to the vessel echogram to identify membership of individual target strengths with each layer.

Frequency response: Frequency-dependent scattering in the observed layers was used to characterize and potentially separate species assemblages within layers. A one half hour of test data was used as a test data set within Echoview to examine acoustic characteristics of each scattering layer.

Potential metrics that could be used to identify, characterize, and discriminate backscatter layers were examined. Sv frequency-differenced and TS frequency-differenced virtual echograms were produced for each combination of the five data channels. Variance among groups of three frequency data channels was also investigated as a summary metric. After initial analysis, all combinations of frequency pairs were used to produce virtual Sv differenced echograms for the test data set. Results of this analysis were compared to and used as a guide to form cluster categories within KORONA.

Identifying acoustic backscattering layers: Data on species identifications, community diversity, species-specific length frequency, and locations in the water column were used to 'convert' acoustic layers to biological layers. Once each layer has been characterized with its biological constituents, a numeric or biomass estimate can be calculated using the data.

Integrating results: Having translated acoustic to biological layers, the final step in the analysis is to compare biological distribution patterns to coincident environmental conditions. Potential physical variables include: temperature, salinity, fluid dynamics, light intensity, and weather conditions. Explicit temporal variables to be considered include time of day and lunar cycle.

Planned products/papers:

- Utilizing advanced technology to characterize an unknown pelagic ecosystem. A concept description.
- Characterisation of the pelagic nekton acoustics of the mid-Atlantic Ridge ecosystem – target strength distribution, relative densities, frequency response, vertical dynamics
- Spatial integration of pelagic nekton densities, patterns and dynamics in the mid-Atlantic Ridge region
- Distributions of marine mammals in relation to prey and bathymetry in the mid-Atlantic Ridge region
- Physical – biological coupling uncover large scale oceanographic phenomenon
- Temporal (diurnal and seasonal) variation in acoustic backscattering on MAR

3.5. Zooplankton and associated studies

Zooplankton was sampled by 8 gears, providing data of different size and depth resolution (Table X). In addition to these gears, acoustic recordings provided continuous data on large scale distribution pattern and the horizontal and vertical distributions in the upper 2000-3000 m.

Table 5. Gears providing data and samples of zooplankton.

Gear	Size class sampled	Type of sample
Multinet	0.2-2 mm	quantitative, depth stratified
UVP	>1 mm	quantitative, continuous vertical profile
Juday net	0.4-2 mm	non-quantitative, life samples
Net on Macrozoopl. trawl	0.8-2 mm	non-quantitative, integrated (0-3000m)
Macrozooplankton trawl	2-20 cm	quantitative, depth stratified
Åkra trawl		non-quantitative, depth stratified
Egersund trawl		non-quantitative

3.5.1. Mesozooplankton

The vertically towed Multinet (180 μm mesh size) was used in 9 or 5 (to save time during the latter part of the cruise) depth intervals from 2500 m depth to the surface (Table X). This net is assumed to capture mesoplankton (~0.2-2 mm) quantitatively. The same size class was partly covered (copepods >1 mm) by the Underwater Video Profiler (UVP) in the upper 1000 m. The UVP continuously store photographic images on a PC as it is lowered through the water column. These two gears complement each other, as the UVP gives much finer depth resolution than the Multinet, while the Multinet provides samples from much larger volumes. The sampling intervals for Multinet were set to be in accordance to the maximum rating of UVP (1000 m), in

order to make comparisons between the two datasets possible. A total of xx Mulinet profiles (providing xx samples) and 19 UVP profiles were obtained.

Mesozooplankton was also collected by a Juday net (375 µm mesh size) in the upper 100 m and with an "egg-net (750 µm) attached to the Macrozooplankton trawl (3000-0 m).

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Table 6. Sampling depth by zooplankton gear

Multinet (n=)	Multinet (n=)	UVP (n= 19)	Macrozooplankton trawl (MT) (n=)	Juday net (n=)	Net on MT (n=)
100-0	100-0	1000-0	200-0	100-10	0-(3000)-0
200-100	500-100		800-200		
500-200	1000-500		1500-800		
800-500	1500-1000		2300-1500		
1000-800	2500-1500		(3000)-2300		
1500-1000					
1900-1500					
2300-1900					
2500-2300					

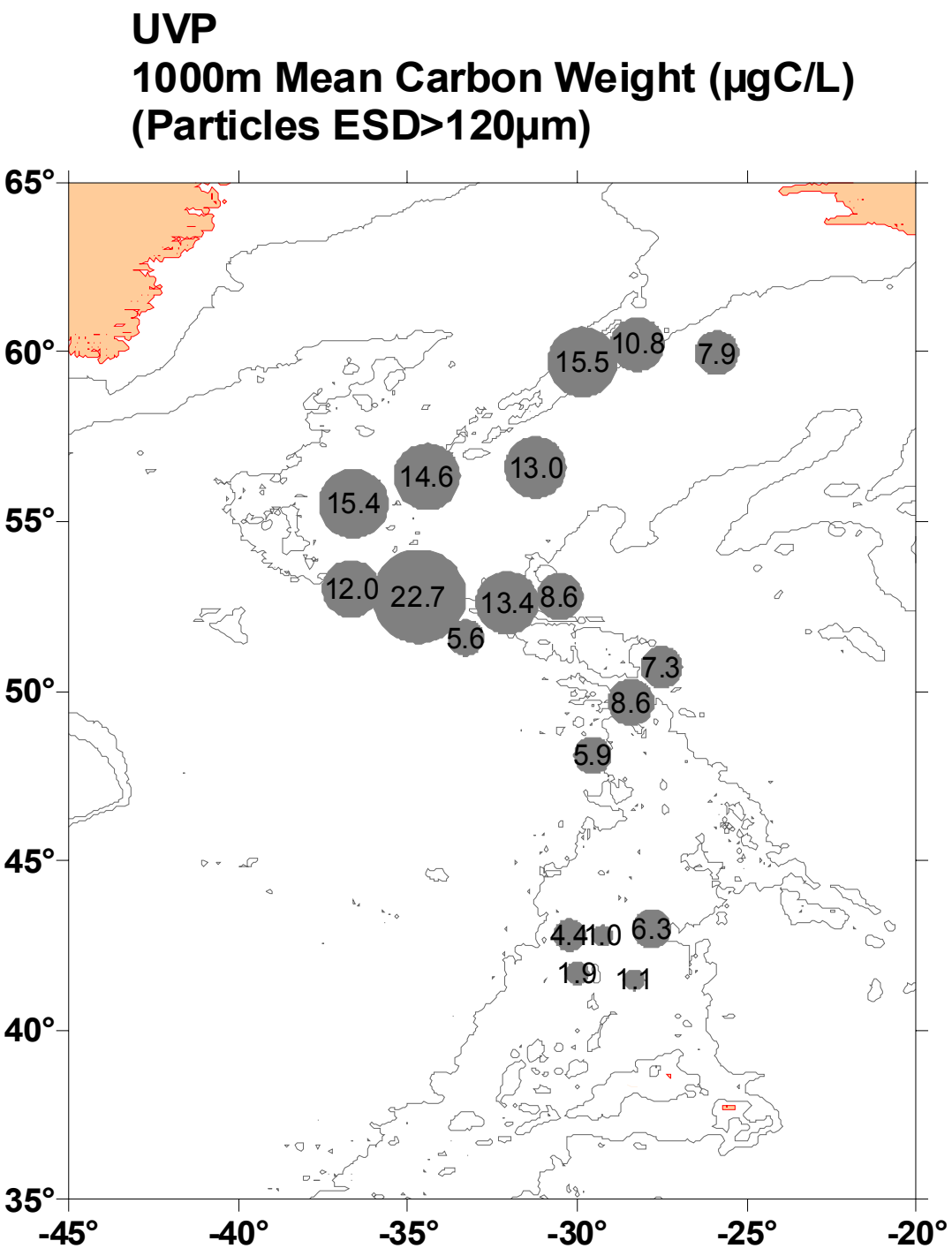
UVP (Marc Picheral)

The Underwater Videoprofiler (UVP) provides data on vertical distribution of particulate matter, CTD data, fluorescence, zooplankton above 5mm (ESD) and copepods above 1mm (ESD).

We have performed UVP 19 stations along the mid Atlantic ridge during Leg 1 of the cruise. Most of them were recorded during the night in order to avoid sun light perturbation on UVP images. All the profiles went down to 1000m (maximum UVP rating) except Superstation 12 due to the 930 depth of the place.

The exact position and time (UTC) of the UVPs are listed below. All the UVP data were treated immediately according to our standard procedures to give quasi real-time evaluation of the vertical distributions. Data from the UVP have been averaged (Carbon Weight) on the 1000m profile to provide an overall image of the Carbon content of the water column at each of the sampled station. UVP fluorometer results have also been averaged on the 100m first meters to provide the second image. More details about instrumentation and processing are given in

APPENDIX III.



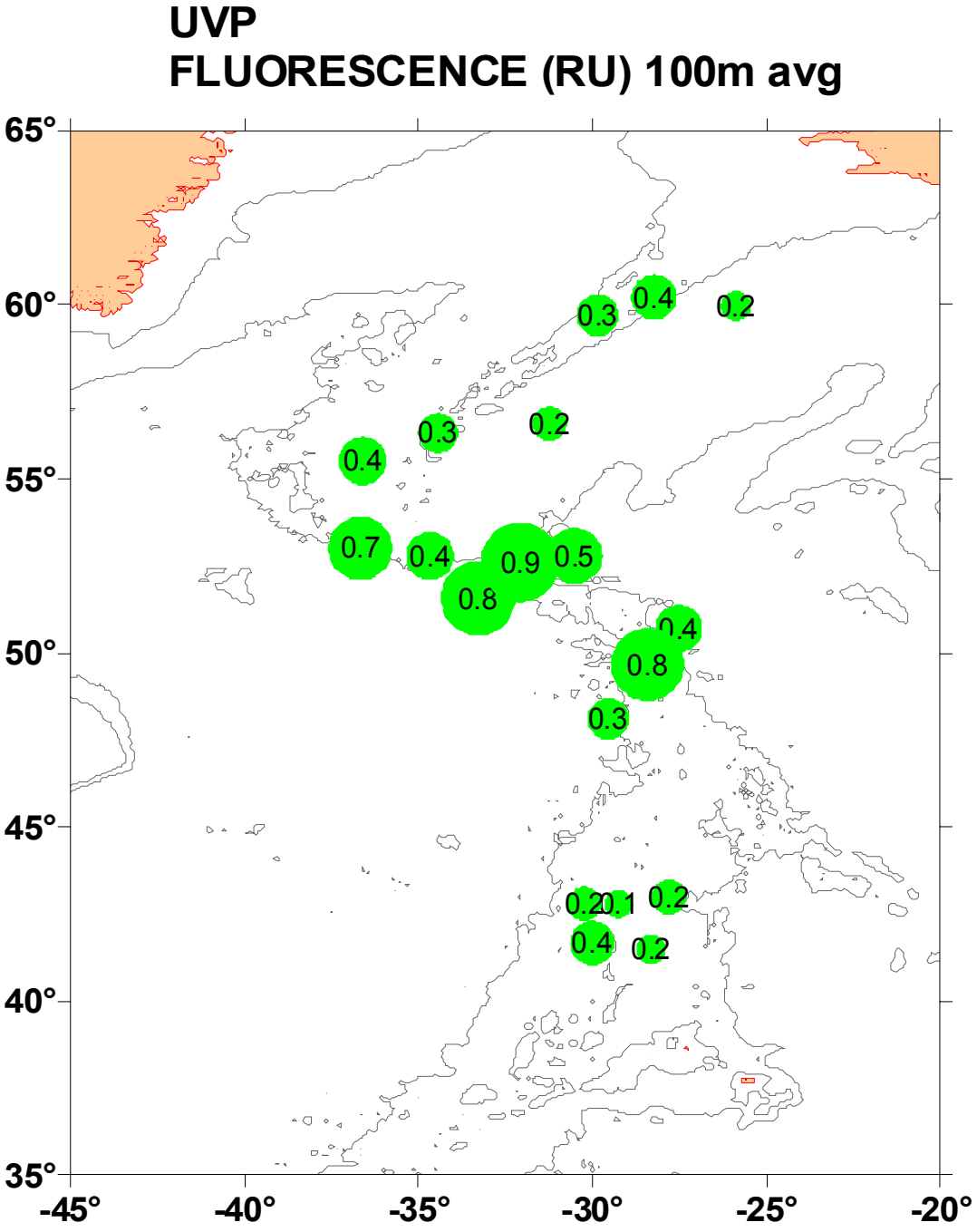


Table 7. UVP deployments

SuperStation	Lat	Long	Date UTC	Time UTC	SBE19 Number	Ofset (m)
2	59.58	25.53	20040610	54100	3	0
4	60.13	28.14	20040611	41400	5	0
5	59.42	29.51	20040611	180000	6	35
6	56.35	31.14	20040613	600	8	0
8	56.19	34.26	20040613	224700	9	0
10	55.31	36.36	20040614	201000	10	35
12	52.47	34.40	20040616	165000	11	75
14	53.00	36.40	20040618	10100	12	0

16	51.34	33.17	20040620	2800	13	0
18	52.36	32.04	20040620	222400	14	0
20	52.47	30.31	20040621	212800	15	29
22	50.42	27.31	20040623	14100	16	0
24	49.40	28.25	20040623	221500	17	0
26	48.06	29.33	20040625	23600	18	0
28	42.59	27.48	20040627	14000	19	0
30	42.47	29.15	20040628	20700	20	0
32	42.48	30.14	20040629	41200	21	0
34	41.40	30.00	20040630	34200	22	0
36	41.29	28.19	20040701	13700	23	0
36	41.29	28.19	20040701	20900	24	0

Multinet

The Multinet is equipped with five nets that are opened and closed on command from the ship. The volume of water filtered by the nets and their filtering efficiency, are measured with HydroBios flowmeters, on both inside and outside the net frame. The Multinet was towed vertically and the hauling speed was 40 m min^{-1}. The Multinet was towed at "long" stations. At Superstations 2, 4, 10, 12 and 14 the sampler was deployed two times, thereby obtaining samples from the depths of 2500-2300 m, 2300-1900 m, 1900-1500 m, 1500-1000 m, 1000-0 m (integrated sample; first haul), and 1000-800 m, 800-500 m, 500-200 m, 200-100 m, 100-0 m (second haul). On 17 June it was decided to deploy the Multinet only once at the remaining "long" stations in order to save time. The reduction meant that only 5 depth strata were sampled at Superstations 16, 20, 26, 28, 32 (2500-1500 m, 1500-1000 m, 1000-500 m, 500-100 m, 100-0 m).

All samples from the Multinet, except for the depth integrated sample (1000 – 0m), were preserved in 4% borax buffered formaldehyde for later species identification and enumeration. The material from the Multinet will be used in order to analyze latitudinal differences in abundance and composition, as well as vertical distribution of mesozooplankton.

The depth integrated samples (1000-0 m, first haul) were treated in the following way: Chaetognaths and Pteropods were removed and fixed for molecular analysis: Chaetognaths were fixed in acethone and Pteropods on ethanol. In addition, if possible, 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% ethanol for molecular analysis.

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 life animals. The net was lowered to a depth of 100 m and hauled up again with 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 life 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 were also sorted out from this sample. Rest of the sample was either put on 96% ethanol, 4% buffered formaldehyde or frozen.

Egg-net attached to the Macrozooplankton trawl
An "egg-net" (1m diameter, 750 μm mesh size) was attached to the Krill trawl during trawling (0–3000–0 m). This depth integrated sample were used for sorting out chaetognaths, pteropods, fish eggs and larvae. Chaetognaths were fixed on acethone, and pteropods on ethanol for molecular studies. The remaining sample was split in two parts: one half was fixed on 4% borax buffered formaldehyde and the other half on 96% ethanol. The samples are considered to be non-quantitative samples, but may provide valuable data on deepwater species.

3.5.2. Macrozooplankton
Larger zooplankton (like euphausiids, shrimps and mysids) were sampled by the Macrozooplankton trawl (Krill trawl, 3000 μm). This trawl was supplied with a multisampler cod-end, permitting sampling in 5 discrete depth intervals from 3000 m (bottom depth permitting) to the surface (Table X).

Samples of large sized macrozooplankton, such as large crustaceans and mysids, were also obtained from the Åkra trawl and Egersund trawl. However, due to size selectivity and large mesh size, these zooplankton samples are considered to be non-quantitative.

Crustaceans from the Macrozooplankton trawl, Åkra trawl and Egersund trawl were weighted and fixed in 4% borax buffered formaldehyde for later identification and enumeration. If catches were large, the crustaceans were split into two parts: one half was fixed in 4 % formaldehyde and the other half in 96% ethanol for molecular analysis.

Unidentified gelatinous zooplankton was photographed before fixation in 4% borax buffered formaldehyde. The prevailing jellyfish (*Periphylla periphylla* and *Atolla* sp) were counted, weighted, and then discarded. In some samples, individual umbrella diameters of these two

species were measured. Tissue samples of *Periphylla periphylla* and *Atolla* sp were frozen at – 80 C for molecular studies. More detailed studies of gelatinous zooplankton will be carried out at the Leg 2.

Total biomass of Crustaceans (g wet weight / m^2) is shown in Fig X. Small differences were found between stations on either side of the ridge. However, preliminary results indicate higher biomass of crustaceans at stations in the more southern stations (14 -) compared to the northern stations. Maximum crustacean biomass was found at station 14 in the frontal area of the Charlie Gibbs Fracture zone. This is in accordance with preliminary data from the UVP. The dominant crustaceans in the macrozooplankton were decapod shrimps (*Sergestidae, Pasiphaeidae* and *Oplophoridae*), euphausiids, and mysids (*Gnathophausia*). The relative amount of each group varied between stations, and a more detailed picture of the species composition and distribution will be available when samples have been analyzed.

Among Cnidarians, the two dominant species (by biomass) were *Periphylla periphylla* and *Atolla wyvillei.* The vertical distributions of both crustaceans and medusae differed between day and night with deeper distributions at night.

3.5.3. Molecular samples

Molecular samples on selected groups were collected from different gears, and fixed according to Table X. Molecular samples of medusae were taken as tissue samples, and frozen at –80°C. For all ethanol fixed samples, the preservative was replaced after one day to assure proper fixation. As the Multinet procedure was changed, mesozooplankton samples for molecular analysis were obtained from the plankton net ("egg-net", 750 μm mesh size) attached to the Krill trawl, sampling the entire water column covered by the trawl.

Table 8. Molecular zooplankton samples.

	Sampling gear							
Species/groups	Multinet	Juday net	Egg-net	Macrozooplankton trawl	Åkra trawl	Egersundtrawl	**Fixative**	**Destination**
Mixed mesozooplankton	X	X	X				96% ethanol	A. Bucklin
Chaetognats	X	X	X	X			Acethone	A.Pierrot-Bults
Pteropods	X	X	X	X			96% ethanol	A.Pierrot-Bults
Mysids				X	X	X	96% ethanol	Bergen Museum
Shrimps				X	X	X	96% ethanol	Bergen Museum

Euphausiids Medusae				X X	X X	X X	96% ethanol frozen –80C	A.Pierrot-Bults Aino Hosia, Bergen Museum

3.5.4. Fatty acids and stable isotopes (Astthor Gisalson and Eilif Gaard)

Samples for fatty acid analysis, and total lipids and stable isotopes analysis were collected at stations located north of the subpolar front (Superstations 2, 4, 8, 10, 12, 18, 20).

Samples for *fatty acids* were taken in the following manner: Small animals (*Calanus finmarchicus, Sergestes arcticus, Meganyctiphanes norvegica*) were picked out from the samples and put into a 2:1 solution of chloroform and methanol in small tubes (7-10ml) and frozen (-80°C). For *C. finmarchicus*, 10 animals were pooled, whereas for *S. arcticus* and *M. norvegica* 3 animals were pooled. Larger animals (*Mauroliccus mulleri, Bentosema glaciale*) were stored individually, either in C/M solution or frozen in plastic trays (-80°C). Usually 5 replicates were taken from each sample.

Total lipids and stable isotopes: Samples containing a mixture of several species was frozen in plastic trays (bulk samples) at -80°C. From these samples small animals (*Calanus finmarchicus, Sergestes arcticus, Meganyctiphanes norvegica*) will be picked out later in the laboratory for determination of total lipids and stable isotopes. Larger animals (*Mauroliccus mulleri, Bentosema glaciale*) were put individually in plastic bags and frozen (-80°C).

Table 9. Overview of samples taken for the analysis of fatty acid analysis, total lipids and stable isotopes

Species/group	Multinet	Juday Net	Macr. tr.	Åkra tr.
Calanus finmarchicus	X	X		
Sergestes arcticus			X	X
Meganyctiphanes norvegica	X			
Mauroliccus mulleri			X	X
Bentosema glaciale			X	X
Zooplankton, bulk sample	X	X		

3.5.5. Gut fluorescence and Calanus egg production (Astthor Gisalson and Eilif Gaard)

For gut fluorescence measurements, samples were taken from the life catch with a small net and frozen quickly (-20°C). In the laboratory on board, three to five replicates of 3-10 individuals per replicate were taken placed into 5 ml of 90% acetone overnight at 5°C in the dark. Extracts were then analysed before and after acidification with a Turner Designs Fluorometer. Conversion from fluorescence to chlorophyll values was found using dilution series made from standard chlorophyll *a* ampulles (from Danish Hydraulic Institute).

For egg production measurements, samples were taken from the life catch with a large pipette and transferred to Petri dishes where females in good condition were quickly sorted out (usually within 1 h after capture) using a stereomicroscope with cold fibre optic light. The females were then placed into 60 µm filtered seawater in incubation cylinders of plexiglass (~65 mm in diameter, ~180 mm in height) with a funnel at the bottom into which the eggs settled. A 330 µm net separated the cylinder from the funnel, which prevented the *Calanus* females from eating its own eggs. One female was added to each cylinder and usually 20 replicates were done per station. However, due to the paucity of females the experiments were run with fewer animals on some stations. The egg production chambers were incubated for 24 hours in the dark at ambient surface water temperatures. After incubation, the eggs were filtered onto a 60µm screen and counted immediately under a stereomicroscope.

Table 10. Overview of stations where egg production experiments and gut fluorescence measurements of *Calanus* were carried out.

Superstation	Egg production	Gut fluorescence
4	x	x
6	x	x
8	x	x
10	x	x
12	x	x
18	x	x
20	x	x
22	x	x
24		
26		
Total		

3.5.6. Studies on fish eggs (Anne Stene)

Fish eggs were observed at almost every station. Although the survival of eggs and larvae in the egg net was low, some of the surviving eggs were used for further developmental studies. All the larvae in the egg net, were however dead.

Egg type 1 was dominating the taws from station 8-26 and egg type 4 was most abundant at the southernmost stations.

STATION	Egg type 1	Egg type 2	Egg type 3	Egg type 4	LARVAE
10	9	0	0		
12	20	1	3		1
16	26	3	2		2
18	134	0	2		
20	22	2	2		
22	563*	5	2		2/8
24	29*	0	1		
26	150*	0	0		
28	4	0	1	36*	4

* early and late stages

Eggs stripped from ripe fishes and eggs from the plankton taws, were incubated at appropriate temperature for developmental studies. The eggs and larvae will be identified later according to photos, diameter, colour, chorion, oil globules and pigmentation.

There may be problems in identifying some of these eggs from existing literature. We will therefore make attempts to fertilise mature fishes artificially onboard to get a reliable identification of the eggs from plankton.

3.5.7. Planed progress of work

A preliminary plan for the analysis of samples has been made, with persons responsible for the analysis progress (Table X). It should be noted that the generated data will be available for all MAR-ECO partners.

Medusas in Multinet samples will be sorted out and identified during RV G.O. Sars Leg 2 by Aino Hosia (Univ. of Bergen). Remaining Multinet samples will be analysed by MRI (Astthor Gislason) in cooperation with Eilif Gaard (Faroese Fisheries Laboratory, Faroe Islands) and Tone Falkenhaug (IMR, Norway). Chaetognaths, fish eggs and fish larvae will be sorted out and sent to experts according to Table.

UVP: Unidentified targets will be checked after the cruise and compared to Multinet samples. Image identifications from the UVP has to be validated by net samples in collaboration with zooplankton experts. Particle and zooplankton abundances and vertical distributions have to be compared with acoustics from the ship.
The possibility for running the Multinet samples through the ZOOSCAN image analysis system at the Observatorie Oceanologique Villefranche (France), will be investigated by Marc Picheral.

Crustaceans from the Macrozooplankton trawl will provide material for a PhD study, if submitted application to the Norwegian Science Foundation is approved (Tone Falkenhaug (IMR), Stein Kaartvedt (UIO), Webjørn Melle (IMR)).

Taxonomic analysis of cryptic species in the Multinet samples and samples from the Macrozooplankton trawl, will be performed in cooperation with Russian colleagues.

Table 11. Preliminary plan for sample analysis.

Sample	Gear	Responsible
Continuous vertical video profile	UVP	Marc Picheral
Copepods etc.	Multinet	Astthor Gislason, Eilif Gaard
Chaetognaths	Multinet, agg-net,	Annelies Pierrot-Bults
Medusae	Multinet	Aino Hosia
Fish eggs and -larvae	Multinet, egg-net	Anne Stene
Medusae, siphonophors, salpa	Macrozooplanktontrawl	Aino Hosia, Fransesc Pages
Crustaceans	Macrozooplankton trawl	Stein Kaartvedt, Tone Falkenhaug
Molecular samples on copepods and euphausiids	Macrozooplankton trawl, Multinet	Ann Bucklin
Stable isotopes, fatty acids	Macrozooplankton trawl, Multinet	Astthor Gislason
Egg production, gut fluorescence	Juday net	Astthor Gislason, Eilif Gaard

3.6. Nekton *(UP, TS)*

- Data collected

- Problems and assumptions
- Planned progress of work

Cephalopods (UP and RY)

Data collected

Cephalopods were sampled with Krill-Trawl (17 hauls), Åkra-Trawl (15 hauls) and Egersund-Trawl (4 hauls). All specimens were directly sorted from the catch during sample processing in the ship`s lab, identified to the lowest possible taxon, and measured (dorsal mantle length in mm; weight in g). Then they were either preserved in 7% buffered formaline seawater solution or frozen at –20°C, always separated by species and catch. Additionally, tissue samples were taken of selected species and fixed in ethanol for genetic studies. All samples will be shipped to the Bergen Museum from where further studies on the material will be coordinated.

In total, 1021 specimens were obtained, belonging to 25 families, 35 genera and 44 species or types, respectively (see Table 4.6.1). Various species or types will need further inspection for clarification of a most precise taxonomic identification. First investigations of the data set clearly reveal a north to south gradient in cephalopod species diversity. There was a marked increase of species numbers from north to south coinciding with a change of the cephalopod community structure (see Table 4.6.2). Some species/genera showed clear geographical distribution patterns making them either a species confined to the stations north of the Charlie Gibbs Fracture Zone (for example *Gonatus* sp., see Fig. 4.6.1 left) or a typical inhabitant of the water masses in the southern box extending into the subtropical region (for example *Heteroteuthis dispar*, see Fig. 4.6.1 right). South of the polar frontal zone the increase in species number was most pronounced. If there will also be an east to west gradient or a difference in species composition of stations at the mid-Atlantic ridge compared to those off the ridge will need further inspection.

Nearly all species were photographed after capture; some of them still alive. We obtained several hundred of cephalopod images which will widely be used for updating information on cephalopod taxomony in the Tree of Life homepage. The photographs of freshly caught specimens of partly very rare families such as Cycloteuthidae, Chiroteuthidae, and Joubiniteuthidae will supply valuable information for further detailed taxonomic studies on these mostly unknown groups. Of particular interest in this context is the documentation of photophores that are arranged on the cephalopod body in species-specific patterns, thus forming an essential tool in identification of species from families such as Lycoteuthidae and Histioteuthidae.

Problems and assumptions

When sampling for rare species it might be of benefit to sample longer in discrete depths rather than performing oblique tows. That would strengthen the assumption that species are distributed and maybe concentrated along horizontal planes rather than dispersed vertically. A perfect pelagic net for sampling cephalopods more efficiently would be a larger Krill Trawl or an Åkra Trawl with no wings. Wings are good collectors but animals are badly damaged often making them useless for taxonomy and studies on feeding and reproduction.

Planned progress of work

In general, the present cephalopod collection is one of the most comprehensive ones ever made along the mid-Atlantic ridge. It will supply an enormous resource for further detailed studies on cephalopod biology, taxonomy, distribution, biogeography, as well as investigations related to feeding ecology, maturity and various aspects of cephalopod fisheries biology. The comprehensive data set which includes information on size and body mass of each individual collected will allow length-weight relationships of rare oceanic species. A more detailed analysis of the geographical distribution patterns and the cephalopod community structure will be a further major subject of the planned work. The stratified sampling of Krill Trawl and Åkra Trawl will also enable a study of the vertical distribution patterns of the cephalopods and their size ranges in various water depths. Further studies are planned to focus on ageing, feeding ecology, and specific issues in taxonomy of oceanic cephalopods.

It will be essential to perform further analysis of data in close collaboration with the working groups on physical oceanography, zooplankton, fish and marine mammals and seabirds. Only combined efforts of the different working groups will enable a new and valuable insight into the ecosystem structure along the mid-Atlantic ridge.

Table 12. Cephalopods sampled during the G.O. Sars cruise, June/July 2004; separated by different trawls.

Species/Type	Krill-Trawl	Åkra-Trawl	Egersund-Trawl	Total
Abraliopsis pfefferi	0	3	0	3
Ancistroteuthis lichtensteinii	3	17	1	21
Bathothauma lyromna	0	1	0	1
Bathyteuthis abyssicola	1	17	5	23
Bolitaena pygmaea	1	0	0	1
Brachioteuthis riisei	2	4	1	7
Chiroteuthis sp.	0	4	0	4
Chiroteuthis veranyi	0	1	0	1
Chtenopteryx sp.	3	9	2	14
Discoteuthis laciniosa	0	1	0	1
Galiteuthis armata	1	18	3	22
Gonatus steenstrupi	0	1	0	1
Gonatus sp.	250	116	36	402
Grimalditeuthis bonplandi	0	1	0	1
Haliphron atlanticus	1	3	0	4
Helicocranchia pfefferi	3	6	0	9
Heteroteuthis dispar	1	44	0	45
Histioteuthis bonnellii	0	4	11	15
Histioteuthis corona	1	4	0	5
Histioteuthis meleagroteuthis	0	3	0	3
Histioteuthis reversa	1	14	0	15
Japetella diaphana	2	2	0	4
Joubiniteuthis portieri	0	1	0	1
Lampadioteuthis megaleia	1	25	0	26
Leachia sp.	1	2	0	3
Mastigoteuthis hjorti	1	5	0	6
Mastigoteuthis magna	1	14	0	15
Mastigoteuthis sp.	3	38	54	95

Octopoteuthis danae	1	14	3	18
Octopoteuthis sp.	1	0	0	1
Ocythoe tuberculata	1	0	0	1
Onychoteuthis sp.	1	3	2	6
Pholidoteuthis boschmai	0	10	0	10
Planctoteuthis sp.	0	5	1	6
Promachoteuthis sp. nov.	0	1	0	1
Pterygioteuthis gemmata	1	3	0	4
Pyroteuthis margaritifera	7	41	0	48
Stauroteuthis syrtensis	2	17	32	51
Taonius pavo	0	17	2	19
Teuthoidea indet.	0	1	15	16
Teuthowenia megalops	16	40	17	73
Todarodes sagittatus	2	9	3	14
Vampyroteuthis infernalis	0	2	2	4
Vitreleledonella richardi	0	1	0	1
SUM	309	522	190	1021

Table 13. Cephalopod species and individual numbers, separated by target regions and sampling gear.

Station No.	Krill-Trawl	Åkra-Trawl	Egersund-Trawl
Northern stations:			
2	3/9	5/17	-
4	2/18	5/26	-
6	2/13	-	9/59
8	2/19	5/26	-
10	1/4	-	8/73
Central Box (Charlie Gibbs Fracture Zone Area):			
12	1/21	3/32	-
14	2/68	7/29	7/32
16	2/3	-	-
18	3/15	4/24	-
20	1/91	4/20	-
Transect to Southern Box:			
22	4/8	10/22	-
24	4/4	12/31	-
26	-	12/29	-
Southern Box:			
28	4/7	21/57	-
30	4/4	10/26	-
32	4/4	25/41	10/26
34	11/14	23/64	-
36	5/7	24/78	-
	No. Species/Ind.	No. Species/Ind.	No. Species/Ind.

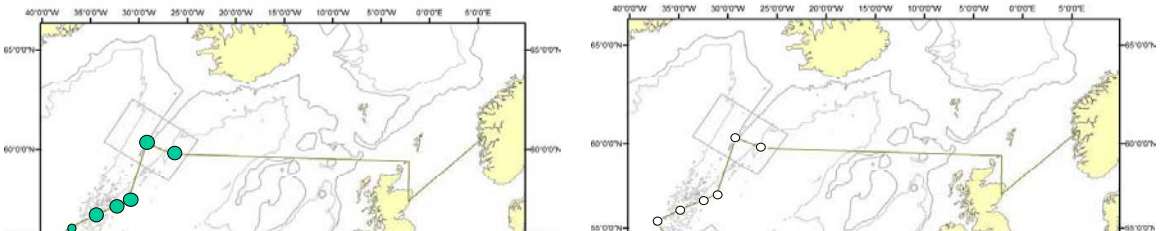


Figure 2. Distribution patterns of selected cephalopod taxa along the mid-Atlantic ridge.

3.7. Images and video (OAB)

- Data collected
- Problems and assumptions
- Planed progress of work

3.8. Can we make a comprehensive picture of the ecosystem?

- Comparison of gears – overall sizes, mesh sizes and rigging
- Representativity – species and size selection - mesh selection, avoidance and escape behavioure
- Contrast, similarities and complementary of the results from different gears
- Possible approaches and models for data merging

Describing an ecosystem includes describing its components at various organizational levels, the energy flows and interactions among those components, and the processes that govern spatial and temporal variation in energy flows and interactions among the components. This is a daunting task for a single cruise to tackle. Indeed, a single cruise is best suited for describing the components of an ecosystem, but has a limited utility in describing its dynamic, at least at time scales beyond few hours. On the other hand, second leg of the Mar-Eco cruise will give additional information on processes and so will the acoustic moorings, one of them hopefully collecting data over all seasons of the year. Further, our evaluation of the ecosystem will also include information from other Mar-Eco field efforts.

The biota along the mid-Atlantic ridge spans a huge range of sizes and is spatially structured. In order to gain a picture of the ecosystem components as comprehensive as possible, an array of complementary observation tools were used (Table 14. Typical performance of the observation tools as used during the first leg of the cruise.). In the one end of the spectrum are nets and trawls that allow a direct identification of the individuals but have a coarse spatial and temporal coverage, in the other end are the acoustic methods that allow a fine-scale spatial and temporal coverage but are constrained by the level of identification of observed targets.

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Table 14. Typical performance of the observation tools as used during the first leg of the cruise.

		Level of identification of targets	Spatial coverage	Temporal coverage	Depth resolution	Size of observable targets
Trawls and nets		Species	Point sampling	Point sampling	Coarse	~180 μm–100 cm, less for each single gear
Underwater video profiler		Order – phylum	Point sampling	Point sampling	Very fine	~60 μm–1 cm
Acoustics	vessel drop keel	Variable, from very coarse to species level under ideal conditions	Along the cruise track	Continuous	Fine	~10 mm–∞, the lower limit depending on density, frequency, and distance from the transducer
	towed body		Point sampling	Point sampling	Fine	
	lander		Point sampling	Continuous	Fine	
Underwater visual observations		Species – phylum	Point sampling	Point sampling	Very fine	~1 mm–1 m
Visual observations of mammals and		Species or genera	Along the cruise track	Continuous, subject to	n.a.	~1 dm–∞

birds			weather and daylight		

The observations carried out during the survey are in essence only “snapshots”, particularly when a single location is concerned. Landers are a notable exception: they complement all other tools by yielding data from a single location at high temporal resolution over longer periods of time. The landers deployed during this cruise will have operation times ranging from a couple of weeks to about one year.

Of the tools used routinely to observe sub-surface biota, only trawls and other nets regularly lead to species identification. Each net has different selection properties depending on the mesh size, opening and towing speed. Most obviously, there is selection with respect to size resulting from two independent escapement processes: relatively small individuals can escape or be squeezed through the meshes, and relatively large ones can behaviourally avoid nets by swimming away. The situation is complicated by the forenet with gradually decreasing meshes used in Åkra and Egersund trawls. In this part of the trawl, representing a greater part of the total opening of the trawl, selection is to a large extent determined by behaviour: the majority of the targets could swim through the net, but some of them try to avoid the approaching meshes and are herded to the codend. Because of the behavioural component, selection of a certain species cannot be known on the basis of size alone.

To the extent that size ranges selected by different nets overlap, it would in principle be possible to use one net as the reference, and calibrate the other nets against the reference net. Across-species calibration would also be possible, in as much the species can be assumed to have similar behaviour responses towards the nets. In both cases, care is needed to distinguish signal from noise (e.g., spatial heterogeneity). Whether such calibration could successfully be carried out for certain abundant species encountered during this survey remains to be seen, but will in any case be a worthwhile exercise.

Comprehensive picture of the ecosystem requires merging information from different observation tools in one way or another. Covariability of data from various observation tools that have similar spatial and temporal scopes can be explored with multivariate statistics such as principal component analysis. Merging observations from tools that have contrasting spatial and temporal scopes requires more carefully crafted approaches. Often it is possible to aggregate data such that data from different tools are brought to similar scales. Statistical models can then be used to calibrate observation tools against each other, and to seek for dependencies among the recorded variables. Ideally, statistical approaches can contribute to mechanistic understanding of processes underlying the observed patterns.

Another possibility is to use one data source to facilitate interpretation of another. This can have various degrees of formality. For example, merging trawl and acoustic data has traditionally been achieved in a somewhat informal fashion, letting the scientist to act as an expert when making the link between the two sets of data, but development of more formal approaches is well under way (see section 3.4). Acoustic stock assessments combine trawl and acoustic data also at more equal footing when acoustic densities are converted to biomass estimates (possible disaggregated by age and size).

The third category for merging data is in the context of process models (which could have a scope as large as the ecosystem). First, data are required to parameterise models. Second, data that were not used in parameterisation can be used to validate models.

Ultimately, our ability to describe the ecosystem along the mid-Atlantic ridge is limited by the observation coverage relative to the spatial and temporal variability of the system. With respect to spatial variability, we have been scratching the surface. With respect to temporal variability, the terrain is still almost uncharted.

4. Selected results and perspectives for future work

4.1. Examples

- Successful strategies
- Successful technology
- Successful interaction and integration of data from various sources
- Failures, lessons to learn

4.2. Scientific glimpses

- Large scale distribution patters
- New species
- We can "see" biological backscatters to 3000 m with vessel mounted acoustics
- ???

4 Selected results and perspectives for future work

4.1 Examples

The application of concurrent cetacean and seabird observations proved important in order to be able to outline the three-dimensional oceanographic processes in the different depth strata exploited by different predators. By comparing prey availability with densities of seabirds, which generally feed within the upper 5 m of the water column and densities of cetaceans with diving capacities from 50 m to 1500 m, we envisage that it will be possible to determine three-dimensional habitat segregation within the predator community in the MAR. Habitat segregation and resource partitioning among pelagic predators has not been described for a major oceanic region.

The use of a unified line-transect methodology for both cetaceans and seabirds was essential in order to be able to resolve fine-scale processes at seamounts as observed by the acoustic and hydrographic data. Sampling of distances to all animals along the transect also allowed us to calculate and compare densities of all predators, estimate realistic consumption rates and identify potential hot spots. The lack of knowledge on the ecological role and habitat use of cetaceans and seabirds outside shelf environments can to a large extent be explained by the application of variable recording methods during offshore whale and seabird surveys.

We attempted to use digital camera's (Nikon D70 with 70-200mm 2.8 IF-ED VR lens) to assist in species identification and this turned out to be a successful strategy, as the rate of unidentified species was significantly reduced. In many cases the digital technology made it possible to identify species recorded at large distances or during short periods of time. The introduction of detailed coding of observed behaviours of animals provided important information on feeding areas, interactions between cetaceans and seabirds and prey.

As observations of cetaceans and seabirds were the only biological data collected continuously on transects, integration with other continuously recorded data such as the acoustic and hydrographic data was very important to detect the variability of the pelagic ecosystem of the MAR. The application of advanced acoustics provided several indications of prey aggregations near seamounts related to concentrations of cetaceans and seabirds. We were able to initiate interpretations of these data with the acoustic experts of PN1 during the cruise. Through these discussions strategies for analysing our observational data with the acoustic data and the continuous recordings of flow velocities from the ADCP were sketched with the goal to identify key processes and oceanographical features at seamounts.

A fruitful co-operation was established with the colleagues of PN1 and Z1 responsible for processing data for potential prey for cetaceans and seabirds: calanoids, krill and cephalopods (*Gonatus ssp*). The co-operation will be extended to the analysis phase, during which species identification and estimates of the availability of target prey deduced from the acoustic data will be important input to analyses of the ecological role of top predators as well as input to analysing the pelagic ecosystem structure of the MAR.

Figure 3 Observations of target species of cetaceans aggregated around the G.O.Sars stations.

Figure 4 Observations of target species of seabirds aggregated around the G.O.Sars stations.

4.3. Can me make a comprehensive picture of the ecosystem?

- Comparison of gears – overall sizes, mesh sizes and rigging
- Representativity – species and size selection - mesh selection, avoidance and escape behavioure
- Contrast, similarities and complementary of the results from different gears
- Possible approaches and models for data merging

4.4. Art and science

Art and science are built on intellectual capabilities. Traditionally science has been dependent on art to illustrate and document findings and convey their message to the scientific community as well as to the public. The artistic taint on old scientific illustrations often stimulate beyond the hard fact and helps understanding and adds realism. In the computerized world this tradition has been lost and interaction seldom take place. From a philosophical point of view, however, innovative science and art cannot build on intellectual capabilities only. Indefinable abilities like imagination, intuitions and fantasy are often considered fundamental to innovation in both fields. Have science lost something along the road being now self-sustained with the help of computers? And from the other perspective, could an artist profit from better insight in the fantastic world accessible to the scientist? Uncovering, describing and understanding the unknown with all its beauty and brutality are of common interest and a driving force for both fields. We therefore decided to test the hypothesis: Close interaction between science and art is of great mutual benefit.

A wealth of sketches, watercolour paintings and notes has been produced throughout the cruise. The ocean surface, clouds, skies, sunset and sunrises are described under varying weather conditions. The work onboard is well documented but most stunning is the attempts to describe the underwater world. It is an overwhelming challenge to establish a perspective of the life 1000s of meter under the surface based on the disintegrating material coming to the surface, the recorded video sequences, and the explanations given by the scientists. Some of the pieces are completed but most raw materials for further study and work for months and years to come. In that respect the artist and the scientists have a common challenge.

From the artist's point of view the cruise has opened the opportunity to insight and understanding of a field of lifelong interest. The possibility to follow the scientists at work, watch the amazing shapes and forms of organisms appearing at surface, see how the catches are handled and systematically organised, has given impressions and impulses of great importance and stimulus to further development of my artistic expression through new pictures. My genuine interest and hope is that the marine life and processes seen from my point of view will be useful for the

scientists in their efforts to visualise the underwater world to the public. Further, I believe that the artistic expression of scientific results can stimulate beyond the hard facts of genus, species, cm and decibels and can potentially stimulate imagination, fantasy and curiosity. Under this perspective our experiment has been successful and may on a longer term be of great mutual benefit.

APPENDIX 1. Scientific crew on RV G.O. Sars. Mar-ECO 2004, Leg 1.

The crew list reflects the desire to assemble a multidisciplinary team of biologists and engineers with expertise on relevant aspects of taxonomy and ecology and relevant sampling methods, incl. hydroacoustics. In addition, marine mammal and bird experts, and a film crew recording footage for a MAR-ECO documentary are accommodated. Table 3 list the participants

	Name	**Country**	
1	Olav Rune Godø	Norway	PI, Biologist
2	Uwe Piatkowski	Germany	Biologist
3	Tracey Sutton	USA	Biologist
4	Filipe Porteiro	Portugal	Biologist
5	Odd Aksel Bergstad	Norway	Biologist
6	John Horne	USA	Biologist
7	Cairistiona Anderson	UK	Biologist
8	Marc Picheral	France	Biologist, techn.
9	Mikko Heino	Norway	Biologist
10	Leif Nøttestad	Norway	Biologist
11	Erik Olsen	Norway	Biologist
12	Henrik Skov	Denmark	Biologist
13	Richard Young	USA	Biologist
14	Stein Kaartvedt	Norway	Biologist
15	Annelies Pierrot-Bults	Nether-lands	Biologist
16	Eilif Gaard	Faroe Islands	Biologist
17	Ruben Patel	Norway	Engineer, acoustician
18	Tone Falkenhaug	Norway	Biologist
19	Astthor Gislasson	Iceland	Biologist
20	Anne Stene	Norway	Biologist
21	Henrik Søiland	Norway	Oceanographer
22	Jaime Alvarez	Norway	Technician
23	Martin Dahl	Norway	Technician
24	Hans Petter Knudsen	Norway	Technician
25	Terje Torkelsen	Norway	Technician
26	Jan Bryn	Norway	ROV Technician
27	Magnar Mjanger	Norway	Technician
28	Ørnulf Opdahl	Norway	Artist
29	Gry Molvær	Norway	TV-reporter
30	Øyvind Olsson	Norway	TV-photographer

APPENDIX II. Overview of the most important technologies available on RV G.O.Sars.

Platform	Instruments, sesors, and software
Vessel acoustics	
	EK60 echosounder –5 frequencies (18, 38, 70, 120,200 kHz)
	Multi-beam echosounderEM300 (EM1002)
	Sonar SP70
	Sonar SM2000
	Vessel mounted Acoustic Doppler current profiler (ADCP), 75 and 150 kHz
	ADCP on CTD
	Temperature, salinity, oxygen and fluorescence (surface sensors)
	Topas – parametric sonar
Towed systems	
	Deep towed body with two acoustic frequencies
ROVs	
	Aglanta ROV
Optics	
	Underwater Video Profilers
	Video camera in codend aquarium
Sampling equipment (for Leg1):	
	Big pelagic trawl (Egersund trawl) to be used for opportunistic sampling of particular targets located acoustically. Size: 90m x 180 m. Door spread 150 m
	Medium-sized pelagic trawl for routine use (Åkratrål) equipped with multisampler to sample 3 depth strata (3 cod-ends in one tow). Size: 20 x 35 m. Door spread 110m
	Multinet (for sampling mesozooplankton)
	Macrozooplankton trawl (for sampling large zoopl. and micronekton) equipped with multisampler to sample 5 depth strata (5 cod-ends in one tow) Size: 6 x 10 m Door spread
	Juday net mounted on the roof of the macrozooplankton trawl or hauled vertically from 100m to surface.
Trawl instrumentation	
	Scanmar Catch Control system – height, distance, trawl opening.
	Trawl sonar FS 20
	Trawl aquarium for collecting living animals equipped with camera.
Moorings	
	Oceanographic instruments
	Acoustic landers (Bergen system)
	Video lander (Oceanlab, Aberdeen University) – for deployment only
Software	
	ER60– echo integration and target analysis
	Korona– echo target analysis and categorisation
	Echoview – echo integration and target analysis
	OLEX – bathymetric mapping
	GNAV – bathymetric mapping

APPENDIX III. The Underwater Video Profiler UVP (MP) – Function and data processing

The UVP4 has been developed for the acquisition of large-particle (> 60 µm) and zooplankton abundance and size distribution data from 0 to 1000 m. Different models have been constructed since 1990 (Gorsky et al. 1992). It was designed to minimise the disturbance of the illuminated volume in order to reduce a possible disruption of imaged particles. It is autonomous and it has been be lowered to 1000m at each station on the hydrological steel cable of the GO SARS. The fourth digital model of the UVP used during MAR-ECO 2004 cruise is described here.
The UVP model 4 is a vertically lowered instrument mounted on a galvanized steel frame (1.1 x 0.9 x 1.25 m). The lighting is based on two 54W Chadwick Helmuth stroboscopes. Two mirrors spread the beams into a structured 8 cm thick slab. The strobes are synchronized with two full frame video cameras with 25 and 8 mm C-mount lenses and IR filters. The illuminated particles in a volume of respectively **1.25** and **10.5** liters are recorded simultaneously by the computer. The cameras are positioned perpendicular to the light slab and only illuminated particles in dark background are recorded. The short flash duration (pulse duration = 30 µs) allowed a 1m/s lowering speed without the deterioration of image quality.
Depth, temperature and conductivity data are acquired using a Seabird Seacat 19 CTD probe (S/N 1539) with fluorometer and nephelometer (both from Chelsea Instruments Ltd.). The system is powered by four 24V batteries and is piloted by a powerful computer. The data acquisition is time related and programmed prior to the immersion. The UVP is well adapted to count and measure fragile aggregates such as marine snow as well as delicate zooplankton.

The depth of the images is obtained with the SBE19 probe fixed in the main frame and geographical position by the ships instruments (mainly GPS).

Samples consist of computer video files and CTD data.

Processing of particles
The UVP has two important features:

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

Processing of images obtained by the UVP in the structured light beam is automated and made by the system during the recovery. The images are analysed and treated automatically by custom-made software. The objects in each image are detected and enumerated. The area and the other parameters of every individual object interesting (measuring above a pre-set size) are measured. Data are stored in an ASCII file and are combined with the associated CTD, fluorometer and nephelometer data (Seasoft Software) using a spreadsheet software. Vertical profiles are printed out onboard immediately after the recovery of the UVP.
The results of the calibrations indicate that the tested configuration can detect 60 µm-sized particles and can reliably measure particles larger than 120 µm in diameter. The metric surface as a function of the pixel surface for the 25 mm and 8 mm lens cameras can be expressed by the following equations:

Equations for cam0 : $S_{réelle} = 0{,}0024 \times (S_{pixels})^{1{,}4959}$
Equations for cam1 : $S_{réelle} = 0{,}0149 \times (S_{pixels})^{1{,}6128}$

The calibrations were carried out in a dark test tank filled with 3 m3 filtered (20 µm) sea water. The brightness measured in the test tank was similar to that in the aphotic layers. A calibration grid, placed at different depths of the light slab, was used to estimate the recorded water volume. The dimensions of the parallel light beam recorded by the cameras are :

Caméra 25 mm : 14.1 x 10.6 cm

Caméra 8 mm : 43.5 x 32.7 cm

The pixel/mm relationship was calibrated in a test tank by injection of biological particles (range 40 µm - 20 mm) measured prior to their use with a stereomicroscope (Gorsky et al., Estuarine, Coastal and Shelf Science).

Zooplankton processing

We used both Camera 0 and Camera 1 for Zooplankton identification.

Camera 0 targets measuring more than 1mm ESD have been visually identified above 200m to count large copepodlike bodies. The results are given as total numbers of copepods per 10m of profile (equivalent to 150L of seawater).

Camera 1 targets measuring more than 5 mm ESD and filtered for surface noise due to the sun or from non interesting large aggregates have also been manually identified and sorted in major groups: appendic euphaus largedecapod maedusa radiolarians chaetognathe largeaggregates fish thaliacae siphon ctenophore sphere mollusk shapeless otherzoo particle copepodlike diatommatslike. The results are given in total numbers of organisms per 10m of profile (equivalent to 1263 L).