Survey Report

The second leg of the AKES survey with R/V *"G.O. Sars"*, 19 February-28 March 2008 AKES-2

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27.05.08

1 INTRODUCTION

The vessel left Cape Town, South-Africa, 19 February 2008 to survey the southern ocean along two transects, to and from Astridryggen, including finer mapping around Bouvetøya and experimental work on krill (AKES). Samples were collected for MARBANK, GENETICS, FISH PATOGENES and the Brazilian fluoride project (BRAZIL). Bathymetry at Astridryggen was mapped acoustically. The cruise ended 28 March 2008, in Walvis Bay, Namibia. The participants are listed in Table 1.1.

AKES (**A**ntarctic **K**rill and **E**cosystem **S**tudies) is IMR's project to investigate target strength of krill (*Euphausia superba*) and mackerel ice fish (*Champsocephalus gunnari*), and the abundance of pelagic fish and squid in the Bouvetøy area. The main objectives are:

- to evaluate the links between the krill resources and distribution in the area and Bouvetøya based mammals and birds
- to study krill biology and ecology
- to establish TS (Target strength; the ability of an organism to reflect sound) for krill and ice fish
- to study aggregations of krill, fish and plankton relative to the hydrography
- to compare aggregations and abundance of krill and plankton relative to hydrography in Antarctica and Nordic Seas
- stomach contents and feeding behavior of krill and fish

The University of Oslo's krill project is included in the AKES project. The survey is carried out in close relation with CCAMLR (Convention on the Conservation of Antarctic Marine Living Resources). AKES is divided in two periods. This survey report covers the second period, AKES-2.

MARBANK. Samples for the Norwegian marine biobank have been collected during the survey.

GENETICS. Sustainable management of krill (*Euphausia superba*) resources in the Southern Ocean is dependent of detailed information of the population genetic structure of the species. The possibility that there are distinct genetic populations would affect both management strategies and conservation. Some of the earlier genetic studies (Fevolden & Schneppenheim 1989), based on allozyme variation, revealed little or no evidence for population structure. The more recently developed DNA techniques, such as mitochondrial and microsatellite DNA analyses, offer new and more powerful approaches to detect population structure in marine

species. Based on mitochondrial DNA studies, Zane et al. 1998 provided evidence for genetic subdivision of krill in the area. A similar situation has also been demonstrated for the northern krill *(Meganyctiphanes norvegica)*: some studies (Sundt & Fevolden) suggesting no genetic structure, while recent investigations (Papetti et al. 2005) with more sensitive DNA methods, demonstrated substantial sub structuring within the north Atlantic. The development of microsatellite DNA methods for krill investigations (Zane et al., 2002) are now providing "state of the art" approaches for detailed krill population investigations.
Samples of krill will be collected throughout the survey period. Two approaches will be used, including allozyme analyses to be carried out on board during the survey to ensure high quality samples and results; further high quality sampling of tissue for various DNA analyzed. These samples will be divided in two groups – one for permanent storage and one group that are used for high quality DNA extraction carried out during the survey period. The DNA analyses will be coordinated with similar ongoing work in other regions in the Antarctica. The same approach is suggested for sampling of important fish species, such as ice fish (*Champsocephalus gunnari*) where also some genetic methods have been developed (Kuhn & Gaffney 2006).

FISHPATHOGENS. The main goal is to establish baseline data on the distribution and abundance of some selected fish pathogens and bacteria communities in the study region which is one of the most "un touched" areas in the world, with emphasis on fish and zooplankton populations.

Both euphauciaceans and fish will be examined for pathogens. It is expected that both sampling, methods, extent and probably aims will have to be revised according to the actual infection patterns (i.e. for samples analysed at sea) and the working conditions met with.

BRAZIL. Will study how fluoride that is highly concentrated in the Antarctic ecosystem affects some enzymes related to the energy metabolism of fish, and how this metabolism is affected by salinity and pH fluctuations in the environment at a normal temperature for the Antarctic and at a higher temperature, mimicking global warming events. We will be focusing on the molecular evolutionary adaptation that occurred in these systems, and compare them with those of tropical fish from the Brazilian coast. This project will work on samples collected by AKES.

"ASTRIDRYGGEN" is a detailed bathymetric mapping of the Astridryggen close to Dronning Maud land. The survey grid for the mapping is not ready yet but the area is indicated in Figure 1.

2 SURVEY GRID

Cruise tracks and map of different types of stations worked during the survey are given in Figs. 2.1-2-4. The numbers of various stations taken are shown in Table 2.1.

3 HYDROGAPHY

3.1 Methods

3.1.1 CTD

The first CTD was occupied on 22th February and the last on 23 March. The CTD had one set of temperature and conductivity sensors. In addition, it was equipped with a Chelsea Aquatracker III fluorometer and a SeaBird oxygen sensor (SBE43). Water samples were collected at all stations for calibration of the conductivity sensors. Calibration will take place after water samples have been analyzed at IMR. The salinity presented in this report is not calibrated.

A Total of 74 CTD casts were taken, however 20 of these were shallow double casts taken for water sampling, and so a total of 54 CTD stations were occupied during the cruise (Fig. 2.1). The standard depths of the stations were 1500m. On the Vema seamount 20 CTD casts down to the bottom were occupied.

3.1.2 ADCP

A 75 kHz RDI Ocean Surveyor ADCP was operated along the whole cruise track on the second leg. The ADCP was run in the narrow band mode with 60 vertical bins each 16 m long. During most of the cruise high quality data were obtained down to 750-800 m. To minimize the interference with the fishing echo sounders, the ADCP was trigged from the Simrad EK60 echo sounder system on the ship. The navigation data was obtained from the ship's SeaPath navigation system. The RDI software WmDas was used for data acquisition and the 5 minute ensembles from the WmDas were post processed using the CODAS system (The CODAS software is available from the "Currents" group at University of Hawaii, SOEST : http://currents.soest.hawaii.edu)

3.1.3 Thermosalinograph

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 is located about 6 m below the sea surface, and there is a secondary temperature sensor mounted close to the intake. The system was stopped and cleaned at 27 Feb. 2007 at about 59^{o}N. These data will be compared with the corrected salinity data from the CTD-sonde when calibrations of these are performed. An overview of these data is shown in Figure 3.1.

3.1.4 Weather station aboard GO Sars.
Standard meteorological data are measured aboard the GO Sars using a weater station, Waisala – MILO weather station. Wind is observed at 30 m above sea level, and pressure is relative to the sea surface. An overview of these data is shown in Figure 3.2.

3.2 Results

The hydrographic data obtained during the AKES part 2 can be divided into two crossings of the major current systems in the southern ocean; 1) from Cape Town to about 67^{o}S along the 15^{o}E meridian (Fig. 3.1-4), and 2) a section from 66^{o}S to about 35^{o}N along the about the 7^{o}E meridian (Fig. 3.5-8). Both sections are similar in the main structure that is; a transition from warm water in the north to colder water associated with the Antarctic Circumpolar Current (ACC) that is bounded to the south by the underwater ridge that extend from Bouvet Island and eastwards. Southward of this ridge the water is about 0^{o}C, and with the Weddel Sea winter water as a relative temperature minimum at about 100-200 m depth. For both salinity and oxygen upwelling to the south of the ACC is evident. The fluorescence data show substantial variations but interpretation of these will not be attempted here.

The large scale currents include the eastward broad ACC extending from about 44-52 ^{o}S (Fig 3.9). Southward from here the main current are weaker. Regional blown ups are given for the Antarctic Polar Front (Fig. 3.10) and the eastern Weddel Sea (Fig.3.11).

As a supplement to the discrete CTD profiles data from the continuously running thermosalinograph (Fig. 3.12) and the meteorological weather station (Fig. 3.13) are shown.

4 TARGET STRENGTH MEASUERMENTS OF KRILL (*Euphausia superba*) AND SALPS

A total of 8 TS-probe stations were conducted. The TS-probe was operated at stations with krill, salps and fish. The data overview of observations are summarised in Table 4.1 and Figure 4.1.

5. CHEMICAL ANALYSES

Water samples for nutrient analyses (nitrate, phosphate and silicate) were collected at 36 stations (Fig. 2.1). Twenty mL water samples from 17 depths (1500, 1200, 1000, 800, 500, 400, 300, 200, 150, 125, 100, 75, 50, 30, 20, 10, 5 m) were collected, fixed with chloroform and kept at 4^{o}C until analysis on shore. Oxygen concentrations were measured vertically every meter from 0-1500 m using sensors on the CTD.

6. PHYTOPLANKTON

6.1 Aims

Almost all marine life in the Antarctic is based on phytoplankton production. One aim was to obtain information on the abundance and distribution of phytoplankton available as food for zooplankton, and its size and species composition. We also wanted to obtain further information on which environmental factors that determine phytoplankton abundance and composition in the region. Little is known about the biodiversity of pico-(0.2-2 mm) and nanoplankton (2-20 mm) in the Southern Ocean. Another aim was therefore to examine this diversity and abundances by advanced electron microscopy and molecular biological techniques.

6.2 Methods

Fluorescence data (*in vivo*, vertically and horizontally), water samples for chlorophyll *a* and phytoplankton analyses and net hauls were collected to obtain this information (Table 6.1, Figs. 2.1, 2.2). Algal cultures were started on board that later can be used for detailed studies of their morphology, genetics, biochemistry and physiology.

Chlorophyll a
In vivo fluorescence (a proxy for relative chlorophyll *a*) was measured vertically every meter from 0-1500 m using a sensor on the CTD. Another sensor on board the ship measured fluorescence horizontally and continuously during the cruise. For chlorophyll *a* analysis water samples (about 250 mL) were collected from 36 stations and, as a rule, from 10 depths (200, 150, 125, 100, 75, 50, 30, 20, 10, 5 m). Cells were collected on glass-fiber filters (0.45 □ m pore size) stored at -20^{o}C until analysis on shore. Water samples for size fractioned chlorophyll *a* analysis were collected from 19 stations and 4 depths (150, 100, 50, and 10 meters). One liter sample per depth was passed through a filtration system to fractionate cells into the size categories >60µm, <60 - >20 µm, <20 - >10 µm, <10 - > 1 µm. Filters were stored at -20^{o}C until analysis on shore.

Phytoplankton
Water samples (100 mL) for quantitative phytoplankton analysis were collected from 34 stations, as a rule, from 8 depths (150, 100, 75, 50, 30, 20, 10, 5 m) and fixed with neutral Lugol's solution (1.5% final concentration) (Fig. 2.1). The bottles are stored at room temperature in darkness until analysis on shore. Preliminary counts were performed of 9 samples using a Sedgwick-Rafter counting chamber. Material for nano- and pico-plankton analysis was collected, from most of the same stations and depths. Water was filtered through nylon gauze with mesh size 35 □ m to remove larger plankton organisms. Of this filtrate 250 mL was collected and fixed with Lugol's solution and glutaraldehyde (final concentration of 1% and 0.25%, resp.). The samples are kept at 4^{o}C in darkness until use. Nano- and picoplankton from 25 mL fixed samples were collected on polycarbonate filters (0.8 □ m pore size) for subsequent FE scanning electron microscopy analysis on shore (at the University of Oslo, UiO). Nano-and picoplankton will also be examined in the transmission electron microscopy on shore. From 13 stations total phytoplankton and nano-picoplankton (<35 □ m) were collected on polycarbonate filters for subsequent DNA analysis (clone libraries, hybridizations with oligonucleotide probes, DGGE, and if possible one Roche 454-DNA sequencing run) on shore (at UiO). The filters are kept at -80^{o}C. For qualitative phytoplankton analysis vertical net hauls (100-0 m depth, 10 □ m mesh size) were done. The samples were

divided in three and fixed with formalin, Lugol's solution and ethanol. The net-haul samples were examined under the light microscope on board. Ethanol-fixed samples are stored at 4 ^{o}C.

Cultures of total phytoplankton and of nano-picoplankton from 13 stations were started on board. Cell culture flasks (50 mL) were filled with 2/3 water samples and 1/3 of IMR ½ algal medium and kept at 4 ^{o}C in white continuous illumination. The cultures were transferred into new medium after about 3 weeks. Dilution series and culturing on agar to obtain mono-algal strains was also tested. Cultures were examined under the microscope and algae were photographed alive. The mixed cultures are kept on board to Bergen. Culturing work to establish mono-algal strains will be continued at the UiO.

6.3 Preliminary results from phytoplankton analyses

Vertical fluorescence measurements indicate that the phytoplankton was vertically distributed from the surface to about 150 m depth, with a fluorescence maximum usually between 80-20 m (Figs. 3.4 and 3.7). On the first N-S transect (st. 51-74), stations with relatively high abundances of phytoplankton (st. 53-57 and 72-76) appeared to be characterized by water masses with low stability and a deep mixed layer. This may suggest that the phytoplankton growth mainly was nutrient limited rather than limited by stability and light.

Preliminary cell counts from 6 selected stations indicated that small nano- and picoflagellates and monads (rounded cells without cell wall or flagella) as well as small diatoms dominated in numbers (Fig. 6.1). The most common diatom taxa were small forms of *Fragilariopsis, Chaetoceros*, *Dactyliosolen* and *Cylindrotheca*. The abundances of dinoflagellates (> 5 □ m) and ciliates appeared to be low at the stations examined. The nano-picoflagellates consisted of a.o. phototrophic or heterotrophic cryptophytes, heterokonts, haptophytes and choanoflagellates. Quantification of nano-picoflagellates to species level is lacking in this region and this will be searched for on shore.

Net haul samples from 7 stations (st. 63-77) were examined under the light microscope. At all stations diatoms clearly dominated. The most abundant taxa in net hauls were members of the diatom genera *Chaetoceros, Fragilariopsis, Proboscia, Rhizosolenia, Pseudo-nitzschia, Cylindrotheca* and *Corethron,* and the silicoflagellate *Dichtyoca speculum.* A preliminary species list is shown in Table 6.2. Most of the species appeared at all stations examined. Colonies of *Phaeocystis antarctica* were found at all stations examined except for the northernmost. (st. 63).

Pico- and nanoplankton (cell size 0.2-20 □ m), including flagellates from the algal divisions Cryptophyta, Haptophyta, Ochrophyta and Dinophyta and the protozoan group *Choanoflagellidea* were presents at all stations. Identification of most of these species requires electron microscopy.

7 ZOOPLANKTON

Methods

During Part 2 of the AKES expedition, sampling of krill and other zooplankton was undertaken at a total of 42 stations along predetermined transect lines (see Figures 2.2, 2.3 & 2.4). Five different sampling devices designed to target zooplankton organisms of varying size were used (Tables 7.1 & 7.2).

Juday, WP2 nets and MOCNESS were applied for mapping the horizontal mesozooplankton distributions along the cruise line in the uppermost part of the water column. Both nets are hauled vertically and have mesh-sizes of 90 and 180 µm, respectively. Hence, the Juday net catches smaller organisms such as copepod nauplii, which largely escape the WP2 net. The Juday net was hauled vertically from 100-0m. The WP-2 was hauled twice from 750-0 m and from 200-0 m. The WP-2 was used in bad weather instead of the MOCNESS.

The MOCNESS (Multiple Opening/Closing Net and Environmental Sensing System) was our standard mesozooplankton sampling system. The MOCNESS enables a detailed description of the vertical target distribution, and also provides more precise abundance estimates due to larger sampling volumes. The nets have an opening of 1 m^2 and can be remotely opened and closed. It is towed at approximately 1.5 knots with the shallowest net operating close to the surface while the deepest net was operated from 750 m in our study.

Larger organisms, like adult krill, can by locomotion avoid or escape from the relatively small nets mentioned above. To catch larger zooplankton we used a Krill trawl with a 38 m^2 mouth area, and with a Multisampler unit attached to the rear end. The Multisampler unit has five nets mounted on a frame, similar to the MOCNESS, and is also remotely controlled. The sampling-depths ranged from 750 – 0m, and the catches made with this trawl are regarded as quantitative. The volume of seawater filtered through the Krill trawl was calculated from flow data registered from an acoustic sensor attached at the mouth of the trawl. In order to test the validity of these values, additional flow-calculations were made on basis of the vessel movement as well as the horizontal component of wire shortening during the haul. The results from the two methods deviated within an acceptable range, indicating that filtered volumes registered by the acoustic sensor are adequate and applicable for concentration estimates. Furthermore, mass data from the various catches were vertically integrated to obtain species-specific estimates in terms of mass per unit area (representing the stratum 750-10m).

A conventional Macroplankton trawl was also used for catching krill. This was often the case when the aim was to verify the identity of acoustic scatterers. The Macroplankton trawl is a single-net trawl, with 7 mm stretched mesh-size in the cod-end. Gradually coarser meshes towards the front of the trawl make this trawl non-quantitative.

All trawl catches were sorted on board immediately after the catch was on deck. Specimens were identified, and body length and weight were obtained. Different specimens of

zooplankton from the Juday, MOCNESS, Krill trawl and the Macroplankton trawl were preserved on formalin, ethanol, or stored in a freezer at -80ºC for later analysis. Samples have also been collected for length-dry weight relationships along with individual mass measurements.

Results

From the 42 different sampling stations, 15 groups of organisms were identified to species and 38 groups were associated to the lowest taxonomic level possible (see Table 7.3).

The most prevalent zooplankton species in the 4 deepest nets of the Krill trawl (750-10m) were: *Euphausia superba*, *Salpa* sp., *Themisto* sp. and *Thysanoessa* sp. (Table 7.4, Fig 7.1 & 7.2). *E. superba* was mainly found in the most southern parts of the survey area. The horizontal and vertical distributions of this species, along with its size distributions, are presented in more detail in chapter 8 of the cruise report. *Salpa* sp. was most prevalent in the northern parts of the study area (Fig. 7.1). The vertical distribution of this genus showed no clear diurnal migratory pattern (Figs. 7.3 A & B). Along the transect, *T. gaudichaudii* was absent in the southern parts but rather evenly distributed when approaching closer to the sub-tropical convergence (Fig 7.2). No clear patterns regarding diel vertical distributions for this species were found in our data (Fig 7.4 A & B). *Thysanoessa* sp. was more or less evenly distributed throughout the whole survey area except for the most north-westerly stations (Fig. 7.2), and displayed no clear vertical diel patterns (Figs. 7.5 A & B). The horizontal distribution of the gelatinous zooplankton (Figs. 7.6 A & B) and *Euphausia triacantha* (Figs 7.7 A & B) has not yet been evaluated. The vertical distribution of gelatinous zooplankton showed no consistent diel migration patterns. *E. triacantha* was generally found deep in the water masses. During night, they occupied depths below 200 meter. During day, a bimodal distribution was observed, with a major part of the population occupying depths below 300 m and a minor part of the population residing between 0 and 200m. This indicates that a small part of the population undertake a reversed diurnal migration. An alternative explanation is that individuals in the uppermost 200 meter during night have been preyed upon.

SALPS

By Paola Lona Batta

During the AKES-2 research cruise, 3 Species of salps were found a long the cruise track (Table 7.5). *Salpa thompsoni* been the dominant one see the map below (MAP made by Øyvind). *Ihlea racovtizai* was found in the south portion of the transect and *Isais Zonaria* was found in the northern stations (Figure 7.8 and 7.9)

The salps were identify up to specie level under the dissecting scope, then the gut was removed to avoid any possible contamination from the prey's DNA. 492 individuals were

collected and dissected , 95% of this was frozen in liquid nitrogen the remaining 5% was fixed in 95% ethanol. These samples will be used for genetic analysis, which will be carried out at the Marine Science Department in the University of Connecticut.

The body length of Salps was measured from tip to tip instead of from oral to anal aperture (the latest been the more conventional way to measured body length). No significant difference was found between stations. (Fig 7.10)

Parasites were found inside 3 solitary forms of *S. thompsoni* under the dissecting scope, during the T-S probe stations pictures were taken and they showed 2 solitary form of *S. thompsoni* with the parasites inside. These parasites were fixed in ethanol for genetic analysis.

8 *EUPHAUSIA SUPERBA*

8.1 Acoustic data collection

Acoustic data for distribution or abundance estimation were collected with calibrated EK60 echo sounders systems at the acoustic frequencies 18, 38, 70, 120, 200 and 333 kHz at 1 ms pulse duration. The echo sounders were connected to transducers mounted on a protruding instrument keel with transducer faces 2.5 m below the hull, usually 9 m below the sea surface. Acoustic data for TS measurements were collected by means of the same hull-mounted echo sounder systems, but at 0.25 ms at all frequencies (except 18 kHz that was used at 0.5 ms). Other equipment was also used to measure TS (see TS section).

8.2 Acoustic data analysis

The acoustic data were scrutinized by 2 persons during the cruise, using LSSS (the Large Scale Survey System). The acoustic data were pre-processed prior to each scrutinizing session. The pre-processing involved spike-filtering (to remove unwanted acoustic temporal noise from e.g. trawl sensors during trawl operations), compensation for placement of transducers, compensation of total EK60-system delay, noise removal, automatic school detection, and automatic species identification. The main tool for identifying krill (*Euphausia superba*) was the frequency response. Fig. 8.1 shows a typical relative frequency response that represents krill. Except for salps that showed a similar frequency response, but did not occur in schools, the frequency response turned out to be a reliable criterion for the *Euphausia superba* schools.

8.3 Instantaneous growth rate experiment using the IGR E-Box

To measure growth rate of krill we collected 104 (or even more) live krill from the trawl and captivate it for 5 days. Single krill was kept in a plastic jar with small perforations. For each experiment 7 jars were placed in a tube, and together with 12 other tubes in a big tank. To

provide the animals with oxygen and water of the temperature, where they were caught (approximately 0°C), there was a water flow in the tank.
The krill were daily checked for moults and dead ones (Table 8.1).
Later we will measure the size difference between the uropod of the animal and the moult. We measure just the uropods because the moulting process tends to destroy parts of the moult. The uropod grows linearly to the body length.
We got krill in different parts of the cruise area, so it will be possible to compare the growth rates of different areas, age classes, size classes, nutritional conditions etc.

8.4 Distribution, abundance and biology

Horisontal distribution of *Euphausia superba* (krill) derived by the echo sounders is shown in Figs. 8.2. *E. superba* occurred in cold water, south of the Polar front at about 51ºS. Highest abundances were found in vicinity of the deep ocean ridges, Atlantic-Indian Ridge northeast of Bouvet Island and in the south near the Astridryggen. On a vertical scale along the two transects, southward along 15ºE and northwards along 7.5ºE, *E. superba* were almost exclusively observed above 120 m (Figs. 8.3, 8.4). Highest concentrations were observed between 52 and 54ºS and between 61 and 65ºS on the southward transect and around 65 and 53ºS on the northward transect. Abundances as obtained by acoustics were lower on the northward section than on the southward section. The reason for this may partly be the stronger wind and higher waves during surveying of the northward section. We observed schools of krill at the surface in most areas surveyed. These schools were not detected by the hull mounted echosounders which will both contribute to a lower absolute estimate of the krill and a misleading vertical distribution. We also had the highest krill catches at very shallow depths with our trawls.

In relation to water characteristics abundance of krill did not show an obvious relationship to the fluorescence, horizontally. However, the krill always prevailed in the upper 100 m with elevated fluorescence. The plankton and fish component was most abundant in the high salinity, temperature and low fluorescence part of the transects in the north (Figs. 8.3, 8.4).

The acoustic data showed that *E. superba* were mainly found above 150m, showing no diurnal vertical migration within this upper layer (Fig. 8.5). However, trawl catches of this species down to below 500 m show that a small part of the stock resides in deeper water (Fig. 8.6). We need to look better into the biological samples of the krill before we know if this is a particular part of the stock with respect to size, sex or other characteristics.

The area of lowest krill concentrations coincided with the upwelling of saline, deep Atlantic water in the middle of the sections, 52-59ºS, indicating that oceanographic features related to the upwelling of Atlantic water rather than topography (ocean ridges) may explain krill distribution.

E. superba body length (front of eye to tip of telson) suggested that the krill were largest in the south and north, and smaller in between (Figs. 8.7, 8.8). From all krill catches a sample of krill was preserved on formalin for staging and sex determination.

In many areas the krill possessed green stomachs. Frozen material (-80ºC) will be used for electron microscopy, genetic and fluorometric analyses of stomach content.

See also krill sections in chapter 15.

8.5 Biomass estimate of *Euphausia superba*

Using a krill TS-length relationship with density and sound speed properties of krill measured onboard (Chu and Wiebe) we made a preliminary attempt at a biomass estimate based on the acoustic data. We used scrutinized Sa values of 38 kHz per 5 nm and length distributions from the trawl hauls. The scattering model used to estimate the target strength (TS) of Antarctic krill is based on Distorted Wave Born Approximation (DWBA). The model takes into consideration the orientation and length distributions to provide a TS estimate reflecting the more realistic situation in the field (model input by Chu).

The required model parameters are:

Density contrast: $g = \frac{\rho_{krill}}{\rho_{water}}$, where ρ_{krill} and ρ_{water} are densities of krill and seawater, respectively. This value is chosen based on the ship board measurements during the cruise.

Sound speed contrast: $h = \frac{c_{krill}}{c_{water}}$, where c_{krill} and c_{water} are sound speed in krill body and seawater, respectively. This value is chosen based on the ship board measurements during the cruise.

Ratio of krill length to its cylindrical radius: L/a is chosen based on the actual measurements during the cruise.

Krill orientation distribution:

a. Gaussian or normal PDF: $N(\bar{\theta}, \sigma_{\theta})$
b. Uniform PDF: $1/\pi$

Length distribution: This is the PDF of the distribution of the length normalized by the measured mean length, and is assumed to follow a Gaussian or normal PDF: $N(1, \sigma_L)$.

Ratio of the radius of curvature to the length: ρ/L. From the photos taken by TS probe, the shape of krill is more straight than bent, so this value is set to to very high, i.e., 10.

Tapering order: α, this parameter is to control the rate of tapering toward the end of krill and is set to 10 in the model: $a_z = \sqrt{1-(2z/L)^{\alpha}}$, where z is the distance from the center of the krill body to position z, and a_z is the cylindrical radius at z.

Most of the modeling parameters are included in the legend of the Figs. 8.9-8.11.

To account for the measured reduction in TS with depth (measured in situ during the cruise, see own section) the estimate of biomass was increased by 6%. The biomass of *E. superba* in the area covered by the two sections, 302 000 nm^{-2}, was estimated at 14 mill tones (program used: BEAM).

9. FISH SPECIES IN THE SOUTHERN OCEAN

Background

The main focus for fish species on the AKES cruise was to determine the vertical and horizontal distribution of the species caught, and how the distribution of these fish were related to the underlying oceanography and the distribution of their predators and prey.

Trawling was mostly conducted using Krill trawl with Multisampler (13 hauls), while the Macro trawl (11 hauls) and Åkra trawl (2 hauls) were also used. When the nets had been recovered on deck, the samples were returned to the wet lab for sorting. Total catch weight were measured for each net. The species caught were determined to the lowest possible taxonomic level, depending on damage from the trawl (loss of scales, photophores and fin rays etc), the literature available and total species weight measured. Fish were keept cold after identification until standard length could be measured. If catches were large, subsamples were sorted and total weight determined from the subsample.

When fish were not used for other purposes, such as DNA work or parasitology, they were frozen in zip-lock bags for further analyses on land, especially considering stomach content determination.

Taxonomy on fish families and species

A total of 67 species from 25 families were caught during AKES leg 2 (Table 9.1). Fish catches were dominated by myctophids with the most abundant species being *Electrona antarctica*, *Gymnoscopelus braueri*, *Krefttichthys anderssoni* and *Protomyctophum bolini*. Species descriptions, pictures and length distributions of these most common species are

given (Figure 9.2). Descriptions and digital pictures of all species are given in a separate report entitled: ”Fiskearter samlet inn under AKES-toktet Sørishavet. Tokt 2008101 AKES”.

Major fish species description

Based on trawl catches of the different fish species caught in the South Atlantic Ocean and the Southern Ocean (Figure 9.1), we selected five species for presentation based on abundance and frequency in the Krill trawl with Multisampler.

***Electrona antarctica*:** probably the most common myctophid species occuring south of the Antarctic Polar Front (APF) (Gon and Heemstra 1990). It is a mesopelagic fish with Antarctic pattern, occuring in the upper 250 m during the day, and from 50 - 100 m during the night. Length-frequency distributions indicate a three-year life span (Rowedder 1979). *E. Antarctica* is a batch spawner, with peak spawning in autumn-winter (Lisovenko 1980). The diet of juveniles less than 60 mm standard length (SL) mainly consists of copepods (*Metridia gerlachei, Euchaeta antarctica, Calanus propinquus, Calanoides acutus*), while that of adults consists mostly of euphausiids (*Euphausia superba, E. frigida, Thysanoessa macrura*), but also polychaetes, chaetognaths, ostracods, amphipods (*Themisto gaudichaudii*), decapods, mollucs and juvenile fishes (Gon and Heemstra 1990). Adult fishes may consume a yearly ratio of 20 times their body weight.

Gymnoscopelus braueri: generally distributed between the coast of Antarctica and 33°S (south-western Atlantic Ocean sector), 46°S (Indian Ocean sector between 50 - 71°E), and about 46°S (Pacific Ocean sector off Chile) (Gon and Heemstra 1990). Vertical distribution is restricted to about 200 m depth during the night. *G. braueri* matures at about 114 mm SL (Gon and Heemstra 1990). The main prey has previously been identified as *Euphausia superba*, while copepods (*Euchaeta antarctica, Rhincalanus gigas*), amphipods (*Primno macropa, Themisto gaudichaidii*) and the euphausiid *Thysanoessa macrura* are also eaten (Williams 1985).

Krefftichthys anderssoni: occures throughout the Antarctic region, and also further north in meridional currents: to 32° – 33°S in the Peruvian Current and to 34°S in the Falkland Current (Gon and Heemstra 1990). Vertical distribution is mesopelagic confined in the upper 50 - 100 m during the night south of the APF, but deeper, 500 - 600m, north of the APF. It reaches maturity at about 54 mm SL (Gon and Heemstra 1990). The diet of *K. anderssoni* in the Indian sector is dominated by copepods (68% occurence: *Calanoides acutus, Calanus propinquus*), while small euphausiids (50%: Thysanoessa macrura furcilia /adults) and amphipods (Primno macropa, Hyperia sp.) are eaten to a smaller extent (Williams 1985). In the Atlantic Ocean sector the main prey species is *Euphausia superba* (68% of stomachs) (Rembiszewski et al. 1978).

Protomyctophum bolini: circumpolar distribution between the Antarctic Divergence and the northern boundary limits of the region, extending northwards to the STC zone (Gon and Heemstra 1990). It is mesopelagically distributed at about 600 - 750 m during the day and 350 – 450 m during the night. *P. bolini* reaches maturity at about 51 mm SL (Gon and Heemstra

1990). The main prey species have been found to include copepods and larval stages of krill, mainly calytopis and furcilia stages (Fishbase).

Bathylagus sp: We used Gon and Heemstra (1990) for the species identification. According to this book only two Bathylagus species were identified. We have later found that there are two other possible Bathylagus species: *B. niger* and *B. andriashevi* not included in Gon and Heemstra (1990). *B. niger* is found in the Antarctic area, *B. andriashevi* in the southeast Atlantic. Identification of Bathylagus was difficult using this book. *B. niger* may occure among the specimens identified as *B. antarcticus*.

Notolepis annulata
This species is known only from the western Atlantic Ocean, between 37°S and 72°S; probably circumpolar in Antarctic waters. Juveniles were captured at 45 m; adults from 550 to more than 2000 m. The dorsoventral extension of the lateral-line scales of *N. annulata* is a unique feature within the family. It has been interpreted as a species adaptation to detect fishes in krill swarms. *N. annulata* is polyphagous, feeding on krill and fishes.

Length distribution of major species
Accumulated length distribution for 8 fish species is shown in Figure 9.2.

Vertical distribution
Electrona antarctica were mainly distributed below 200 m during this survey, both day and night (Figures 9.3, 9.4). These results differ from the previous findings of Gon and Heemstra (1990), who found E. antarctica distributed in the surface layers during the night, and below 250 m during the day.
Vertical distribution of *Gymnoscopelus braueri* were generally below 200 m depth, independent of time of day, in accordance with the previous findings of Gon and Heemstra (1990) (Figures 9.5, 9.6). The highest abundances were found below 500 m. *Bathylagus tenuis* were only distributed below 200 m, mainly below 500 m (Figures 9.7, 9.8).

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10 SONAR OBSERVATIONS OF ANTARCTIC KRILL IN THE SOUTHERN OCEAN

We performed selected studies and recordings of Antarctic krill (*Euphausia superba*) with the Simrad MS 70 multibeam sonar onboard G.O.Sars in the Southern Ocean during 2 Leg of the AKES cruise. Sonar recordings were not performed continuously rather decided along the cruise track whether to store data or not, based on multi-frequency echosounder recordings and/or visible krill schools close to the surface. Sonar data were generally not stored during bad weather with strong winds and considerable wave heights, due to noise strongly influencing the quality of the sonar recordings. All sonar data were stored on an external hard drive. These data were replayed with Simrad software for quality check and for obtaining a general overview of the krill and fish recordings along the cruise track.
A large number of krill schools were predominantly distributed in the upper 10-25 m of the water column for part of the survey in the Southern Ocean (Figure 1). An important result from applying both multi-frequency echosounder and multi-beam sonar for krill distribution and abundance estimation is that krill were often aggregated within the surface dead-zone of the echosounder above the drop keel between 0-15 m depths. In short, this means that the abundance estimation based on echosounder recordings alone provide a gross underestimation of the true abundance of krill within the surveyed area. A combination of quantitative echosounder data and multibeam sonar data is required to obtain a more fully picture of the vertical and horizontal distribution and abundance of krill in the Southern Ocean.
One important analysis that needs to be done after the cruise is to compare echosounder values on krill in some selected areas with sonar detections of krill in exactly the same areas. The results from such a comparative analyses will tell us how representative the down-looking echosounder is for measuring krill in different areas and time of the day compared to the side-looking sonar. Factors such as vertical distribution of krill and their behaviour including potential avoidance behaviour towards the vessel, may significantly influence and bias the results. Sometimes when krill swarms/schools were visible at the surface as red patches of different diameter (~5-50 m), only the sonar detected these schools, whereas the echosounder due to the deep placement of the transducer (>10 m), did not observe these shallow distributed krill schools. In conclusion, the multibeam sonar has been an invaluable acoustic instrument to map Antarctic krill in order to better understand the vertical and horizontal distribution as well as their patchiness, especially when the krill is distributed in shallow schools mainly invisible for the echosounder.

11 MARINE MAMMALS IN THE SOUTHERN OCEAN

Marine mammal sightings were performed from the bridge onboard G.O.Sars along the cruise tracks by 1-3 observers during daylight hours from 20 February to 26 March 2008. This observation platform is about 13 m above sea level, and excellent for marine mammal observations. Digital filming and photos were taken on the bridge when possible for species identification, documentation of group size and general behaviour. Presence of seabirds and icebergs were noted alongside the sightings of marine mammals aimed at a broader ecological focus. Very seldom we changed predetermined course and speed in order to study whales up close. At oceanographical stations with CTD and biological trawling, we noted the presence and attraction of whales towards the vessel. Few whales seemed to avoid G.O.Sars during along the cruise track. On the contrary, humpback whales were seen on at least 5 occasions to be attracted to, and inspecting the vessel thereby remaining very close to G.O.Sars for considerable periods (hours). This behaviour was somewhat different than experienced in our own waters in the Northern Hemisphere with similar species.

We have so far documented eight different species, including sperm whale, minke whale, humpback whale and fin whale (see Table 11.1). The humpback whale has dominated so far with 41 sightings and minimum 103 animals (Figure 11.1). The group size has normally been between 2-4 individuals, sometimes large adults with a small calf. The humpback whale is a stout, thick-bodied whale weighing an average of 30,000 kg (up to 48,000 kg) and is approximately 14 m long (up to 18 m). The name humpback whale originates from the irregularities (humps) on their back. We have collected valuable fluke photos for individual identification that will be included and analysed in a large international database on humpbacks.

An interesting observation was the close association between drifting icebergs and small groups of humpback whales. Active plunge feeding at the surface was repeatedly observed within close proximity of icebergs. The krill are presumably attracted to drifting icebergs due to elevated phytoplankton concentrations as food for krill underneath and in near proximity of the icebergs. This in turn attracts humpbacks to the scene, since they have Antarctic krill on the top of their menu list. This would be very interesting study topic in more detail for the next Norwegian expedition to the Southern Ocean.

12 FISH PARASITES

The occurrence of fish parasites in a vide sense (virus, bacteria, fungi, protists and metazoans) in the Antarctic area is poorly known. A number of the larger crustacean, annelid and helminth parasites have been described during the recent decades, while both protists and other infectious agents are virtually unstudied.

Previous studies on Antarctic fish parasites has dealt with the Weddel Sea and areas off the Antarctic Peninsula, Drake Passage, South Orkneys, South Shetlands, Scotian Shelf and South Georgia area. In addition there are reports on fish parasites from Heard Island (Kerguelen) and off Adelie Land.
The areas off Queen Maud Land and around Bouvet Island have not been studied for fish parasites. The only records concern the Antarctic leech *Trulliobdella capitis* Brinkmann, 1947 from the icefish *Chaenocephalus aceratus* caught off Bouvet Island during the 'Norwegia' expedition 1927-8.
Since a primary AKES aim was to study aspects of the ecology of mackerel icefish around the Bouvet Island, this species and ecosystem was *a priori* selected for fish-health studies; the following aims were listed:

i) Occurrence of presumed cosmopolitan fish-pathogenic virus types in untouched seas.
ii) Occurrence of larval helminth parasites in fish from the Bouvet Island area, connected to the occurrence of homoeothermic (birds, fur seals, whales) final hosts
iii) Myxozoan parasites of *Champsocephalus gunnari*
iv) Haematozoa in *Champsocephalus gunnari*

In addition, *Euphausia superba* were collected for studies on microbiology by DGGE (IMR), and diet studies with DHPLC (BiO, University of Bergen, J.C. Nejstgaard).

Since only mesopelagic and bathypelagic fish were obtained during the first weeks of the cruise, sampling for aims i) and ii) was started from these. Samples for i) were restricted to the larger fish obtained. When the Bouvet Island shelf later was abandoned without fishing icefish, it became clear that the aims focusing on these had to be revised:

i) Fish-pathogenic viruses in meso- and bathypelagic fish
ii) Occurrence of larval helminth parasites in meso- and bathypelagic fish, of species maturing in homoeothermic (bird, seal, whale) final hosts. Establishment of trophic transmission pathways.
iii) Characteristics of parasite communities in Antarctic deep sea pelagic fish.

Table 12.1 gives an overview of the examined fish species, the parasites detected (preliminary ID) and the prey items identified.

i) Virus screening

Betanodavirus infections represent a major challenge in fish aquaculture World-wide. Numerous genotypes have been characterized, some apparently species or host-group specific, some showing a geographically restricted distribution. The virus is transmitted vertically (parents-gametes- zygote-larva-fry), which may be the 'normal' or 'natural' transmission mode, while in aquaculture horizontal transmission among juvenile fish lead to serious epizootics. The motivations for examining betanodavirus infections in Antarctic fish are:

Presence/absence? Is betanodavirus infections a widespread 'natural' situation or an anomaly related to human activities (aquaculture, breeding, introductions, stress). The southern ocean represents an area very far from human influence and may hence represent a good test.

Wild genotypes. Are any betanodavirus genotypes in the Antarctic 'regional' or related to host phylogeny?

Methods

Real-time rt-PCR with different assays detecting a broad spectrum of betanodavirus genotypes. Target tissue: brain. Virus from positive samples may be isolated in cell-culture, which will allow sequencing of the virus genome (RNAs-1 & 2) and genotyping.

ii) Trophic transmission pathways of larval helminth parasites

Several species or categories of Antarctic larval helminth parasites were detected (Table 12.2).

The identification of all these larval helminths requires sequence information (e.g. 18S rDNA).

The *Anisakis* sp., other Anisakinae gen. sp., Scolex pleruronectis A, *Diphyllobothrium* plerocercoids and Cercoid VII all became active in physiological saline at room temperature. It therefore seems likely that these represent species evolved to parasitize homeoterms. In the case of Scolex pleuronectis this is surprising, since the final hosts are poikilotherms. However, *Monorygma grimaldi* and *Phyllobothrium delphini* are tetraphyllideans adapted to accumulate in the blubber of cetaceans, and are likely acquired by the wales by feeding on squid and fish with larvae.

The most important group is the *Diphyllobothrium* sp. plerocercoid larvae. These occur in the stomach wall of a wide range of fish hosts. Some fish are heavily infected with small stomach-wall *Diphyllobothrium* larvae, which may be accumulated due to re-establihment of specimens from prey fish. An example is *Cynomacrurus piriei* (Macrouridae), which were relatively heavily infected by small plerocercoids (17-57 specimens per fish), all viable. A different case is *Melamphaes microps* (Melamphaidae), often infected but with most plerocercoids being degenerate or dead, and with no indication of parasite growth. This fish species likely represent a dead end to the parasites. *Electrona antarctica* (Myctophiidae) may be a key species in the life cycle of *Diphyllobothrium* sp., since many are infected and the fish is abundant. However degenerate specimens occur also in *E. antarctica*. Myctophiids may act as transport hosts, transmitting the parasite to predators such as the paralepidids. The largest *Diphyllobothrium* plerocercoids are met with in the paralepidid *Notolepis coatesi*, in which small larvae occur both in the stomach wall and ventrally in the girdle region of the belly musculature, while large specimens are confined to the dorsal hypaxial musculature. The latter, often visible externally, are apparently not encapsulated. The likely final hosts are marine mammals; both pinnipeds such as *Arctocephalus gazella* and *Mirounga leonina* and cetaceans are known to be infected with diphyllobothriid cestodes (At Bouvet Island, tapeworm strobilae are commonly seen hanging from the anus of the seals (Bjørn A. Krafft pers. com.)).

However, sequence information is needed to ensure conspecificity of the various *Diphyllobothrium* isolates, identify final hosts and ultimately suggest the transmission pathways of the worms.

iii) Characteristics of parasite communities in Antarctic deep sea pelagic fish

A total of 227 fish were screened for a broad spectrum of parasites, while more than 500 additional fish were screened for external macroscopic forms (copepods). The accurate identification of many of the parasites requires molecular tools. However, the patterns observed are unlikely to be significantly affected:

Four species of microparasites were detected, two coccidians (*Eimeria* spp.), a gastric flagellate (*Cryptobia* sp.) and a microsporidian infecting the kidney of *Notolepis coatesi*. While the life cycles of the actual species found are unknown, all these represent parasite types that are known to be directly transmitted between fish.

In the fully examined fish (N=227), 620 metazoan parasite individuals were collected. Of these, 99% were endoparasitic helminths and the rest mesoparasitic copepods. The copepods of the genera *Paeonocanthus* and cf. *Sarcotretes* where the only detected, but obviously less firmly attached types such as caligoids may have been lost in the trawl. *Paeonocanthus antarcticus* were only found on *Bathylagus tenuis*, and is likely specific to *Bathylagus* spp. *Sarcotretes* sp. was found on the unrelated *Bathylagus tenuis*, *Notolepis coatesi* and myctophiids (*Lampanyctus, Lampadena*) and in addition on *Hygophum hygomi* from warmer waters (Stn. 61). It is likely that two or more *Sarcotretes* spp. occur in this material.

Of the helminths, 93% were larval forms. However, in the present material all the adult helminths were represented by two hemiuroid trematode species exclusively infecting *Bathylagus tenuis*. Hence in the 186 fish examined from 25 other species, 100% of the helminths were larval forms. In fish caught in strictly Antarctic waters, 100% of these were cestode larvae. The few nematode larvae collected occurred in subantartic fish only (Stns 36, 56, 60), and similarly the ectoparasitic trematode *Copiatestes filiferus.* The latter was found attached to the eye of *Electrona carlsbergi* (Stn 60) as well as to the gill region of the krill *Nematocelos megalops* (Stn 36).

There was a tendency of increasing abundance of both *Diphyllobothrium* plerocercoids and *Scolex pleuronectis* with increasing fish size. The opposite was the case with the tetrabothriid larvae, mostly found in the small sized myctophiid *Krefftichthys anderssoni* and in small *Electrona antarctica*. As mentioned above (ii), most of the cestodes mature in homeotherms. In total, more than 88% of the cestode larvae are of types with homeotherm final hosts.

In conclusion, the open water fishes examined does not act as final hosts to gastrointestinal helminths. They act as transmitters of helminths to the major final host groups in the area, as evidenced from the present material these are marine mammals, birds and elasmobranchs. Monogenea were not detected, which is noteworthy since they have direct lifecycles. Trematoda are rare and Myxozoa absent, which is in accordance with these requiring benthic invertebrates in their lifecycles. One fish, *Bathylagus tenuis*, breaks this pattern, since it is final host to many of its parasites, homes few helminth larvae and prevalent microparasites.

It appears likely that many of the parasites infecting *B. tenuis* are specific to genus *Bathylagus*, but this needs verification.

13 GO SARS STUDIES OF THE MATERIAL PROPERTIES OF KRILL.

Peter H. Wiebe and Dezhang Chu

Introduction

Acoustic surveys of krill, fish, and other marine animals requires a fundamental understanding of how sound transmitted from a transducer mounted on the ship's hull is reflected back from a target organism as it goes about living at some subsurface depth below the sea surface. The intensity of the returned signal, or echo, can be measured quantitatively by the so called Target Strength (TS) of a given individual at a particular sound frequency, or a number of frequencies.

However, what determines an individual's target strength? Size and orientation are two components that are very important. In general, the larger the animal, the larger the target strength. An animal broad-side to the emitted sound will produce a larger echo than one angled obliquely. Equally important to the determination of target strength are what we call the "material properties" of the animal. These are its sound speed contrast (h), the ratio of the speed of sound through the animal's body to that through the surrounding seawater, and its density contrast (g), the ratio of the density in animal's body to that of the surrounding seawater. If the animal's sound speed contrast and density contrast were unity, there would be no echo. Fish are strong acoustic targets because they are large and usually have high sound speed and density contrast values. Zooplankton including krill, however, are much smaller and the material properties of their bodies are more nearly those of seawater. Thus most zooplankton are weak sound scatterers and to survey them requires high-resolution precisely-calibrated echo sounders that can detect very small acoustic targets. In addition, to interpret the scattering, commonly backscattering, from zooplankton and to discriminate krill from other animals in the water column, an understanding of their acoustic signatures i.e. the backscattering of sound at different frequencies, is required. One can obtain this information empirically by making in situ target strength measurements on krill (and other zooplankton) at different frequencies. Alternatively, with the appropriate mathematical model for how krill (and other zooplankton) backscatter sound and knowing their material properties, one can predict their frequency response. Both approaches are needed as checks one against the other.

Knowledge about zooplankton material properties, however, is scant primarily because of the difficulty of making such measurements on living zooplankton. On this AKES cruise, sound speed and density contrast measurements of krill and other zooplankton were made at a number of stations.

Method

The sound speed and density contrasts of zooplankton and some fish were measured with a specially designed device dubbed APOP ("Acoustic Properties Of zooPlankton" Chu and Wiebe, 2005). The system includes two components: the sound speed measuring apparatus and the density measuring apparatus.

<u>Sound Speed Contrast Measurement:</u>

APOP consists of two parallel sound tubes or chambers with a transmitting transducer at one end of the tube and a second receiving transducer at the other end (Figure 13.1A). Each acoustic chamber contains two identical broadband transducers with a center frequency around 500 kHz and a bandwidth of about 300 kHz. The two chambers are mounted next to each other on a frame that is suspended in an aluminum reservoir to keep the chambers surrounded by seawater. The sound speed chambers and reservoir are mounted in an aluminum pipe frame for deployment off the side of the ship for profiles down to 200 m (Figure 13.1B). A cable (~220 m) with electrical conductors connects the broadband transducers and the surface data acquisition system, which consists of a LeCroy 9310C Dual 400 MHz Osciilloscope, a Panametrics Pulser/Receiver Model 5800, and a Windows PC, equipped with an Analog to Digital data acquisition board (10 MHz acquisition rate), running a C-code acquisition program within a MATLAB workspace.

Both sound speed tubes have a central compartment in which animals can be placed and held alive for the duration of an experiment. During an experiment the travel time difference is measured for acoustic waves or sounds traveling directly from one acoustic transducer (the transmitter) to another transducer (the receiver) with and without animals in the acoustic path. If sound travels faster in animal bodies than in water, the travel time with animals present in the acoustic path will be shorter and vice versa. The standard procedure on this cruise was to do an initial set of measurements on the deck of the ship with both sound speed chambers empty after measuring the temperature of the seawater in the reservoir. Usually between 15 and 25 individuals of living krill, *Euphausia superba*, were then put into one of the sound speed chambers. After another set of measurements on the deck with the animals sealed in the chamber, the system was deployed over-the-side and sound speed measurements were made on both chambers at 20 m intervals down to 200 m and again on the way back to the surface to see what effect pressure had on their sound speed contrast (Figure 13.1B). The animals, still alive, were then removed from the sound speed chamber and held in seawater for the next step in the procedure.

The ratio of the sound speed in animals to that in seawater can be computed using the difference in travel times between the two tubes, Δt, (Chu *et al*, 2000a):

$$h = 1 + \frac{\Delta t}{\Phi_z t_D} \ , \tag{1}$$

where Φ_z is the volume fraction of animals in the animal compartment and the t_D is the travel time for acoustic wave propagating through the compartment (time of flight), which can be calculated by $t_D = D/c$, where *D* is the length dimension of the animal compartment and *c* is the sound speed in seawater determined from the temperature, salinity, and pressure measured with CTD. The uncertainty or potential error resulting from Eq. (1) can be estimated with

$$\left|\frac{\delta(\Delta h)}{\Delta h}\right| \le \left|\frac{\delta(\Delta t)}{\Delta t}\right| + \left|\frac{\delta\Phi_z}{\Phi_z}\right| + \left|\frac{\delta t_D}{t_D}\right| , \tag{2}$$

where $\Delta h = h - 1$ is the difference of the sound speed contrast from unity. The reason why we estimate $\frac{\delta(\Delta h)}{\Delta h}$ not $\frac{\delta(\Delta h)}{h}$ is the former quantity more directly reflects the error in predicting the target strength (TS) of the scattering objects. The estimated values for $\left|\delta(\Delta t)/\Delta t\right|$, $\left|\delta\Phi_z/\Phi_z\right|$, and $\left|\delta t_D/t_D\right|$ based on our measuring devices used in the cruise were 0.001%, 10%, and 2%, respectively. Hence the dominant source of

error was the uncertainty in total net volume of zooplankton in the animal compartment. The overall sound speed contrast uncertainty was estimated to be less than 15 % of Δh.

Density Contrast Measurement:

In order to determine the density and volume of animals, we used the "double density" method (Chu *et al.*, 2000b) which involves use of a special pre-weighed vessel. The animals were first placed in the weighing vessel that was a third filled with seawater (Figure 13.2). One thousand weight measurements of the vessel (w_1) were made with a precision electro-balance (Ohaus AP210) and the overall average used to get the precise weight of the vessel. While this was being done, the densities of the seawater (ρ_1) in which the acoustic measurements were performed and a quantity of distilled water (ρ_2) were measured in a densitometer (Anton Paar DMA 4500). After the first series of weight measurements, the vessel was filled to the top with distilled water. The top of the vessel has a very small opening with graduations that represent a fraction of a milliliter, so that the total volume (v_T) can be very accurately estimated. Then a second series of weight measurements (w_2) was made. Finally, the animals are separated from the "mixed" seawater/distilled water solution and the density of the mixed water (ρ_m) was measured. From these measurements, the volume and the density of the animals can be estimated using equations given in Chu and Wiebe, 2005. Additionally, the length of each individual was measured and their total volume was measured in a volumetric cylinder as a check. The volume estimate was used to estimate what fraction of the APOP animal experimental chamber volume was filled by the animals when the sound speed contrast measurements were made.

These steps can be mathematically described by the following equations:

$$\begin{cases} w_1 = (v_1 - v_z)\rho_1 + v_z\rho_z \\ w_2 = (v_T - v_z)\rho_m + v_z\rho_z \\ v_T = v_1 + v_2 \\ v_2 = (w_2 - w_1)/\rho_2 \end{cases}, \tag{3}$$

where ρ_z the average density of the animals and v_z the net volume of zooplankton. It should be pointed out that the weights, w_1 and w_2 are the net weights that have subtracted weight of the empty vessel or container whose weight has been pre-weighted regularly during the cruise. The solutions for v_z and ρ_z can be obtained by solving the above linear equations:

$$\begin{cases} v_z = v_T - \left(\dfrac{w_2 - w_1}{\rho_2}\right)\left(\dfrac{\rho_1 - \rho_2}{\rho_1 - \rho_m}\right) \\ \rho_z = \rho_m + \dfrac{w_2 - \rho_m v_T}{v_z} \end{cases}. \tag{4}$$

The uncertainties or potential errors resulting from the above equations can be estimated with:

$$\begin{aligned} |\delta v_z| \le |\delta v_T| &+ \left|\frac{\rho_1 - \rho_2}{\rho_1 - \rho_m}\right| \frac{|\delta w_2| + |\delta w_1|}{\rho_2} + \left|\frac{w_2 - w_1}{\rho_2}\right| \frac{|\delta\rho_1| + |\delta\rho_2|}{|\rho_1 - \rho_m|} \\ &+ \left|\frac{w_2 - w_1}{\rho_2}\frac{\rho_1 - \rho_2}{\rho_1 - \rho_m}\right| \frac{|\delta\rho_2|}{\rho_2} + \left|\frac{\rho_1 - \rho_2}{\rho_1 - \rho_m}\frac{w_2 - w_1}{\rho_2}\right| \frac{|\delta\rho_1| + |\delta\rho_m|}{|\rho_1 - \rho_m|}, \end{aligned} \tag{5}$$

$$|\delta\rho_z| \le |\delta\rho_m| + \frac{|\delta w_2| + |\delta\rho_m| v_T + |\delta v_T| \rho_m}{v_z} + \left| \frac{w_2 - \rho_m v_T}{v_z} \right| \frac{|\delta v_z|}{v_z}, \qquad (6)$$

where δv_T, δw_1, δw_2, $\delta\rho_1$, $\delta\rho_2$ and $\delta\rho_m$ are respective errors in measuring volume, weights, and densities. The estimated quantities for these measuring uncertainties were 0.01 cm^3 for δv_T, 20.0 mg for δw_1 and δw_2, 4×10^{-5} $g\,\mathrm{cm}^{-3}$ for $\delta\rho_1$ and $\delta\rho_2$, and 1.2×10^{-4} $g\,\mathrm{cm}^{-3}$ for $\delta\rho_m$. Using these numbers and the typical values for other parameters in (5) and (6), the quantity $|\delta\rho_z|$ was estimated to be less than 0.005 g cm^{-3}, which leads to $\delta g \le 0.005$ for the uncertainty in density contrast estimate since the density of seawater is always unity.

Calibration

To guarantee high quality material property measurements, calibrations for both sound speed and density sub-systems are required.

Sound Speed Measurement Calibration:

The acoustic calibration for the sound speed measurements was performed with both tubes being empty without any animals. The acoustic system was deployed to 200 m with the measurements taken in 20 m increments both going down to depth and returning to the surface. Ideally, the sound speed contrast should be zero if the two pairs of transducers associated with each tube are identical. However, realistically the two pairs of transducers are slightly different causing some measuring error. The average sound speed contrast estimate based on the difference of the travel times between the tubes was 1.0018 and the standard deviation was 0.0007 (Figure 13.3), which is much smaller than the error introduced by other factors described in the paragraph immediately following Eq. (2).

Density Measurement Calibration:

Due to the problem that one of the electric balances (Ohaus AP210) did not work at sea, the compensation method used in a previous Antarctic cruise (Chu and Wiebe, 2005) could not be used. Instead, we had to rely on a single balance. To obtain a reasonable accuracy, we took the average of 1000-weighings to obtain each weight measurement. A standard weight of 100-g was measured at least everyday with 5 sets of 1000-weiging averages to make sure the balance was working properly. The standard deviation of the means was basically less than 20 mg (only twice in the 20's and twice in the lower 30's). The measured weight distributions could be described by a Gaussian PDF reasonably well (Figure 13.4).

Another issue involved in the density measurements was the compensation of osmotic effect in which water would enter animal body by diffusion process during the part of the weighing procedure where distilled water was added to the weighing vessel. This uptake changed the density of the mixed water. To overcome this effect, we made time-series measurements to estimate the amount of water taken up by the animals using moribund and live animals with similar proportions of seawater, animals, and distilled water to those used in the density measurements. The measurements using 45 live animals and the curve with 4th order polynomial fit are presented in Figure 13.5. This curve was used to correct for the osmotic effect.

Results and Discussions

During the cruise, we have conducted 27 shipboard measurements with 16 of them being on Antarctic krill (*Euphausia superba* - Table 13.1) and the rest involving a variety of zooplankton and fish species (Table 13.2). Of the 16 measurements on krill, four included data from profiles, one to 55 m depth (Figure 13.6), one to 140 m (Figure 13.7), and two to 200 m (Figures 13.8 and 13.9).

It is important to note that almost all of the krill and amphipods were still alive after acoustic measurements, even after the profiling to 200-m deep and back, with a time span from about one and a half hours to a slightly over two hours. Most of the krill and amphipods also survived the density measurements, thus reducing the uncertainty of the material properties that might have existed had the individuals died during the procedure.

A number of observations include:

1. The overall levels of the measured density and sound speed contrasts (*g* and *h*) are higher than those measured by Chu and Wiebe (2005) in a previous Antarctic cruise between April and May 2002 around Marguerite Bay off the Western Antarctic Peninsula (WAP). On this cruise, we didn't find any size dependence of the *g* and *h*. The average length of the krill from Leg 2 of the AKES cruise is 39.9 mm and the corresponding averaged *g* and *h* values are 1.043 and 1.040. In contrast, for krill of 40 mm in length, the *g* and *h* values obtained from the 2002 Antarctic cruise (Chu and Wiebe, 2005) are 1.024 and 1.029, respectively. As a result, the predicted TS values using the DWBA scattering model with the *g* and *h* values from this cruise would be a little more than 4 dB higher than that using the *g* and *h* values from the 2005 cruise, an indication of TS strength variability possibly due to seasonal difference, geographic location difference, and/or other factors related to oceanographic, biological, as well as biochemical parameters. If such variability in sound speed and density contrast with season or locality is a general feature of krill populations, then it is important to assess this variability in the course of making krill stock size estimates based on high frequency acoustics data.

2. Three out of four sound speed measurements in profiling mode suggested that there was a noticeable decrease in *h* between the deck measurements and at 20 m depth. It is not clear what caused such a change since seawater water pumped directly from the ocean had been kept running through the APOP reservoir to maintain sea surface temperatures while the system was on deck.

3. The *g* and *h* values of salps (*Salpa thompsoni*), especially *g*, are very close to unity, indicating that salps are very weak scatterers. To our knowledge, this is the first time that the material properties of salps have been measured. These values are significantly lower than those assumed in David et al. (2001). Using the material properties of salps listed in Table 13.2, it was found that when they are in solitary mode, the TS is very low, less than -83 dB. However, when they are in aggregation mode, i.e. forming a chain up to a meter long or more, the resultant TS could be -65 dB or higher and the spectrum or frequency response is similar to that of the krill.

References:

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14 GENETIC CHARACTERIZATION OF ANTARCTIC KRILL POPULATIONS AND SELECTED FISH SPECIES

Responsible scientist: Knut E. Jørstad

Background and objectives

Sustainable management of krill (*Euphausia superba*) resources in the Southern Ocean is dependent of detailed information of the population genetic structure of the species. The possibility that there are distinct genetic populations would affect both management strategies and conservation. The results from some of the earlier genetic studies are, however, controversial, and different interpretations have been suggested. The development of various new DNA methods such as microsatellite and SNP analyses are now providing “state of the art” approaches for detailed krill population investigations.

Thus the objectives for the genetic studies were “c*onduct genetic analyses on important species such as Antarctic krill and commercial important fish species, including allozymes (carried out onboard) and sample collection for DNA studies.* Two approaches were planned, including protein (allozyme) analyses to be carried out on board during the survey to ensure high quality samples and results. The results from these analysed could be directly compared with similar analyses conducted earlier. Further, sampling of tissue for various DNA analyses to be analysed later in a molecular genetic laboratory.

Collection of krill samples from trawl stations

Samples of *Euphausia superba* were collected from various trawl hauls in both periods of the AKES survey. In the first period, about 100 specimens were taken from each of the different trawl stations in question. These krill (whole body) were spread on water resistant paper, put into a sealed plastic bag and stored as soon as possible in a deep freezer (-80 C). During this period 5 different samples were collected, for details see Table 14.1.

In the second period krill samples were collected from 9 trawl stations. In one case (T.st. 44; Table 14.1) a subsample (T. st. 44B) consisting of small specimens was selected in addition to the general

sample. In all, 10 samples (96 specimens from each station) were collected from the last AKES period. Thus the total krill samples collected for genetic analyses consisted of 15 samples, ranging from South Georgia to Bouvet island, supplemented with the region south to "Astrid-ridge" near Dronning Mauds Land on the Antarctic continent. The location of the various sampling stations are indicated in Figure 14.1, and the exact positions are given in Table 14.1.

Sampling of krill specimens

The frozen krill from AKES 1 were thawed on ice before individual sampling, while the fresh krill caught in the AKES 2 were processed as soon as possible after the trawling. During the actual sampling procedures all specimens and samples were kept on ice.

The total length of all the krill was measured and recorded. Then a small piece (about 2 g) of the abdominal muscle was taken and transferred to microtest plate (on ice) for protein (allozyme) analyses. The rest of the specimen or the part of the tail (large krill) was put in 2.5 ml tubes added 100 % ethanol. These samples to be used for DNA extractions and various DNA analyses.

Protein analyses on the boat

It was important to conduct the electrophoresis on in proteins (allozymes) variation based on fresh samples. This usually means high quality results of the protein analyses with high enzyme activities and sharp staining bands. Each individual sample of krill muscle was added 4-5 drops with destilled water and was sonicated (Kontes micro-ultrasonic cell disrupter) for a few seconds under cooling conditions (ice). Small pieces of filter paper (about 14X2 mm of size) were soaked in each sampling well and these filters were the applied to the electrophoretic gel.

The starch gels (histidine buffer pH=7.0) were prepared on a gyro-table and stayed in fridge for minimum one hour before used. The filter papers with solution soaked from each individual sample were mounted side by side of the fresh cut starch gel. The electrophoretic runs were conducted in a special apparatus designed for analyses on board research vessels at sea. The electrophoresis buffer was 0.4 M citrate pH=7.0, and each run was performed under constant current conditions, 100 – 120 mV for about 2 hours. After electrophoresis the 8 mm thick starch gel were sliced into 7 pieces of 1mm thin gels, where 5 of these (from the middle) were transferred to separate staining trays.

The samples from each trawl station was stained for 5 different proteins / allozymes including isocitrat dehydrogenase (IDH), maleate dehydrogenase (MDH), lactate dehydrogenase (LDH), phosphoglucose mutase (PGM) and glucosephosphate isomerase (GPI), using standard staining solutions. The staining was carried out at room temperature and the trays were kept on gyro-table during the staining period needed, usually 1 – 3 hours, depending on the enzyme in question. After the staining, the different 1 mm thin gels were washed out to get rid of remaining staining solution, and then dried for permanent storage using a slab gel dryer (model SE 1160; Hoefer Scientific Instuments, San Franscisco).

Enzyme banding patterns – preliminary results

All the different enzymes stained for produced strong banding under the conditions used. Normally the GPI gels produced readable bands after about 30 min, while some other enzyme loci were rather faint and needed several hours before they could be scored consistently.

IDH. Two different banding zones were seen on the gels. The fast moving strong banding zone was assumed to be product of one loci, designated IDH-2. In the krill collection analysed on the boat (see Table 14.2) this zone was largely monomorphic, but in some samples, rare slow moving and fast

moving bands were detected. These were designated *IDH-2*90* and *IDH-2*110*, respectively. The slow moving banding zone was product of the *IDH-1* locus, and needed prolonged staining time to be reliable scored. In most of the sample stations the locus was monomorphic, except in some cases where a rare slow moving allele (*IDH-2*95*) as well as a fast moving allele (*IDH-2*120)* were identified.

MDH. Two banding zones were found, – one (*MDH-2**) was moving very fast and was detected at the edge of the gel. Due to bad banding quality, no individual banding pattern could be detected. The slower moving zone, presumably controlled by the *MDH-1** locus, was strongly expressed. In most samples, however, the signal was only one single band suggesting that the locus was monomorphic. In some samples a slow moving (*MDH-1*80*) and a fast moving allele ((*MDH-1*120)* were detected.

PGM. For this enzyme only one strong banding pattern zone was found and 3 different alleles were detected in all samples. In addition to the most common allele (*PGM*100*), one slow moving (*PGM*70*) and one fast moving allele (*PGM*130*) were recorded.

GPI. Only one strong banding zone was found, and this locus was the most polymorphic enzyme of the group of enzymes tested. In all, 5 different alleles were detected, including two slow moving (*GPI*80* and *GPI*90*) and two fast moving alleles (*GPI*120* and *GPI*140*) in addition to the most common allele (*GPI*100*).

LDH. For this enzyme a more complicated banding pattern was detected, consisting of 5 different banding zones. By comparing the banding patterns of the typical variants, it was obvious that two different loci were represented, corresponding to the fastest and the slowest moving bands. The 3 intermediate banding zones represented different inter-loci combinations. Thus a variant banding in the fast moving band, designated *LDH-2**, was also detected in the inter-loci bandings. Similar situation was observed with regards to the slow moving zone, corresponding to the *LDH-1** locus. For the *LDH-1** locus 4 different alleles (*LDH-1*-170*; *LDH-1*100*, LDH-*1*150*, *LDH-1*200*) were found, while 3 alleles (*LDH-2*70*, *LDH-2*100*; *LDH-2*130*) were detected for the *LDH-2** locus.

Further work

Due to lack of sufficient staining buffer, only 13 of 15 sample collections (see Table 14.2) were analysed on the ship during the survey. Two samples have to be analysed by starch gel electrophoresis in the laboratory in Bergen. Based on the results obtained from the analyses conducted during the survey, some of the enzymes investigated provide important genetic variation that will be used in detailed inter sample comparisons. Most promising are the two LDH loci, PGM and GPI. After completion of the last analyses of the two remaining samples, detailed statistical analyses will be conducted, focused on comparisons between samples and geographic regions.

DNA will be extracted from the samples collected from the identical individuals already analysed for protein / allozyme variation. These extraction will be basic for conduction various DNA analyses, in particular microsatellites and SNPs. These samples will be important for establishing cooperation with other institutions and laboratories.

15 "EVOLUTION AND BIODIVERSITY IN THE ANTARCTIC: A RESPONSE OF LIFE TO CHANGE"

Leader: Dr Edith S E Fanta (UFPR, Brazil)

Participants: Dr Helena G Kawall (UNIANDRADE, Brazil)

Oc. Caroline V Cooke (FURG, Brazil)

Introduction

This Project is part of the EBA Program of SCAR and IPY, and shares the same name: "Evolution and Biodiversity in the Antarctic: a response of life to change". The main goal of the project is to study how fluoride, that is highly concentrated in the Antarctic ecosystem, is transported through the food chain and how it is processed, including the effects on some enzymes related to the energy metabolism of fish. The focus is to investigate the molecular evolutionary adaptation that occurred in these systems, and to compare them with those of tropical fish from the Brazilian coast.

A second objective of this research is to compare the activity of metabolic enzymes and biochemical components, in fish and in krill, obtained from regions with different environmental characteristics, and even belonging to different populations. A relation of the animal's metabolism and condition will be established with food availability.

There is also an interest in address the genotypic differences between species obtained in different locations around the Antarctic through sequencing of mitochondrial DNA (NADH dehydrogenase sub-unit 2) of fishes. Finally, our group is interested in collaboration with the CCAMLR survey of krill and fish, both in biological and acoustics studies, and also to collaborate with the Census of Antarctic Marine Life (CAML).

Krill

Krill (*Euphausia superba*) were collected using two nets: pelagic trawl and multisampler trawl. Groups of 100 to 150 individuals were separated from 11 stations and organisms analyzed in respect to size (AT= front of the eye to tip of the telson), krill colouration type (CCAMLR Krill Feeding Observations) and sex. Juveniles were identified as individuals without sexual secondary characteristics and correspond to stages I and II (sub-adults) of the CCAMLR stages of krill maturity. Mature females were identified by the presence of a developed thelicum, with or without spermatophore and mature males, the individual that presented a pethasma. Mature males and females correspond to stages III, IV and V according to CCAMLR Scientific Observers Manual (2007).

A total of 1274 *E. superba* was measured. The size distribution of all individuals is shown in Figure 15.1 and the mean length of all individuals analyzed is presented on Table 15.1. *E. superba* ranged from 21-63 mm, with an average size of 44.6 mm and a mode of 49 mm. They were similar in size to the organisms collected on the north-east side of South-Georgia on the first leg of the cruise. The sex and stage of maturity varied considerably along the two transects (North to South and South to North), but overall half of the animals encountered were juveniles and half adults, with a slightly higher number of females. Juveniles had a mean length of 40.2 mm, and males and females 49.3 and 48.1, respectively. A comparison of the size of individuals collected with the two sampling gears showed no differences between them.

The sizes of *E. superba* were similar to the overall mean on the North-South transect (stations 41-43 and 45) (Table 15.2) and the population was mainly comprised by juveniles (Figure 15.2). Further South (station 46) animals were slightly larger and it was observed an increase in the number of mature males and females. On the South-North transect, two stations, 47 and 49, presented the smallest animals studied, and in station 47 almost all animals were juveniles. Proceeding north, in the Bouvet Island area, except for a few individuals, krill were large adults with most of females presenting spermatophores attached to the thelicum. In this area, krill was associated with salps (*Salpa thompsoni*) and the euphausiid *Thysanoessa* sp. (mainly *T. macrura*). The northern most station (56) presented the largest animals studied and was comprised only by mature adults being the only station in which males occurred in larger numbers than females.

A group of 20 individuals of *E. superba* from each station was frozen for analyses of biochemical indicators. All the samples will be taken to the Federal University of Parana State, Curitiba/ Brazil where the analyses will be performed.

Fishes

Fishes were collected using the large pelagic Akratrawl, fishing in different depths between 1200m and surface, and the Multisampler trawl, which has 5 nets, each of them fishing in depths between 750 m and surface. A total of 83 fishes were selected for analysis of fluorite and metabolism (Table 15.3). Samples of tissues were extracted and immediately frozen in liquid nitrogen. For each specimen the following tissues were taken: muscle, liver, brain, gill, kidney, bone and skin. A total of 600 samples was collected.
The fluorite metabolism will be studied determining the levels of the fluorite and the activities of the enzymes arginase, enolase, succinate dehydrogenase, CYP450, EROD, CYP1, PFW within others. In order to determine the fish's condition and metabolism, the chemical composition (lipids, protein, carbohydrate and water) of muscle and liver will be determined as well as the activities of metabolic enzymes (LDH, CS, MDH and PK). Samples of muscle were collected for genetic analysis, from the 13 species, shown in Table 15.4.

Acoustics and TS Probe

The vessel "G.O.Sars" is equipped with the scientific multifrequency echosounder Simrad EK 60, with transducers operating in 6 frequencies: 18, 38, 70, 120, 200 and 300 kHz which continuously monitors the organisms in the water column. The acoustic data collected is processed and analyzed using the software LSSS (Large Scale Survey System), developed by the IMR. Also, several deployments of the TS PROBE were performed during the cruise with the objective of establishing the Target-Strength for the Antarctic Krill (*Euphausia superba*) and some of the associated organisms. These work was followed by our group.

Final Considerations

We believe the main objectives of our participation on the survey to the Southern Ocean were accomplished. We have collected a good number of samples and following the several projects developed onboard was an excellent opportunity to increase our personal knowledge and consequently the development of science in our Institutions in Brazil.

We hope to continue to collaborate with IMR and that Norwegians Scientists would be able to participate in of our research cruises in the South Atlantic and in the Antarctic.

We would like to thank the Institute of Marine Research for the opportunity, Dr Svein A Inversen for the invitation, Dr Melle Webjorn for the scientific planning, the captain Jon Hugo Johnsen and the crew of "G.O.Sars" for the outstanding work and all the colleagues that shared this experience with us.

16 BIRD SURVEY

(Eirik Grønningsæter, Feltbiologen Grønningsæter/NPI)

One bird observer from the Norwegian Polar Institute has been participating the Southern Ocean cruise, and the main objective of this work was to gather data to look at the correlation in distribution between birds and macro zooplankton (small scale distribution). However, the results presented in this report is mainly concerned about the larger scale distribution of the birds. Very few bird surveys have been conducted in the area visited by this cruise – especially the southern part of the study area (south of 54° south) is rarely visited by birders.

Most of the bird species observed on the cruise has just come into a post breeding mode. For some species, like the wandering albatross group, the breeding birds still have egg or chick in the nest during the cruise period. It is thus likely that many of the breeding birds is Southern Ocean is still fairly close to breeding colonies and this might influence both the numbers and the distribution of the species we encountered (since the birds still haven't had time to spread out as they do later in the year). For the smaller albatrosses (mollymawks), this was evident in that most of the individuals encountered were immature birds. The adults are still busy feeding their chick and thus not wander too far from the breeding colonies.

Methods

For the large scale distribution of the birds (the work presented here), the method used is by using binoculars and observing all birds seen from the ship's bridge area. Both birds following behind the ship and birds just migrating by are included in the material. Rough estimates of the total number of the different bird species seen are noted every day.

The method used for the small scale distribution part of the survey, is a modified version of the method that has long been used in pelagic bird surveys in the north east Atlantic. Instead of recording the birds continuously along the transect lines (like in the north), a sum of the birds seen each 10 minute period was conducted at this survey. The birds were observed from the bridge area of the ship. Only birds within 300m from the ship in a sector of 90° out to the side and to the ship's bow (0°), was included in the 10 minutes periods. Additionally, every 10^{th} minute, there was a point count of all the birds seen within a 300m radius in a 360° sector around the ship. Since a lot of birds are attracted to the ship when it is in a station mode (for instance trawling), only birds recorded when sailing between stations are included in the small scale distribution material.

Working this way, the material represented in this report is a result of 362 hours of observation time and is covering the area south of the Aghulas- and Benguela current systems (South Atlantic drift current).

The taxonomy of seabirds has, especially since the early 1990s when sophisticated molecular and mitochondrial DNA analysing methods became both popular and common science, been a subject of great dispute. The number of albatross species in the world is for instance shifting between 13 and 22,

depending on a conservative or liberal approach to the subject. For the work conducted on this survey, I have chosen to follow the recommendations in taxonomy of tubenoses published in "Onley, D. & Scofield, P. 2007; *Albatrosses, Petrels and Shearwaters of the world*, Christopher Helm imprint of A&C Black publishers Ltd."

Results & Discussion

Generally speaking, one can say that current fronts and shelf edges are areas where birds congregate. In this study, this was especially obvious sailing southwards when we crossed the shelf edge on 20 February south of Cape of Good hope. The numbers of birds dropped drastically the next day until about 16:00 UCT, when we crossed into the South Atlantic drift current. Between 14:00 UCT and 17:00 UCT the temperature dropped from 18 degrees Celsius to 10 degrees Celsius. Most of the birds recorded 21 February were observed after coming into the colder water. On the way north, we probably crossed an eddie of the Benguela current in the morning of 19th March when the sea temperature increased from 11,6 degrees Celsius to 16,7 degrees Celsius in just 2 hours (09:00 – 11:00 UCT). All these areas produced good species diversity and a high numbers of birds (see table 16.1 and table 16.2).

Many of the species encountered during the cruise is conducting extensive migration during a year – some going distances equal to several times around the globe. This is most evident in the difference in distribution of the species between seasons. It is thus important to remember that when reading these results (especially table 16.1 & 16.2), they only give an instant picture of a species distribution. For instance is the cape petrel (*Daption capense*), which we only recorded far south in the study area, common north to the African continent during the Austral winter. To get a broader understanding of the large scale bird distribution in the study area, it is thus necessary to do more surveys both at different time of the year and through several years.

Southwards vs northward transect

On the southwards transect, some species were recorded much further south than they were on the northwards transect. On the northwards transect, there was an opposite effect. Meaning that some species apparently had a more northerly distribution, than on the southwards transect. This might be coincidental, or due to the fact that we crossed the different latitudes at different time of the season (2 weeks is a long time for a migrating bird). There is also a good possibility that this is a ship effect. Many birds, and most of the species recorded on this cruise is associating ships with a possibility for food, and hence can follow ships for longer or shorter distances (ship followers). This means that they sometimes can drift out of their normally preferred distribution area because of a vessel that look interesting is passing by.

An obvious difference between the two transects was that while grey petrel (*Procellaria cinerea*) was fairly numerous on parts of the southward transect, it was basically absent on the way north. The opposite can be said for both southern fulmar (*Fulmarus glacialoides*) and cape petrel. The reason for the absent of grey petrel on the northwards transect is not understood, while the difference for the two latter species probably is due to the fact that Bouvet are well known breeding grounds for the species.

Bouvet Island

The time spent in the Bouvet area was 10 March to midday 13 March. Approaching the island, naturally produced an increase in observations of many of the breeding birds there compared to elsewhere. This was especially evident for Southern fulmar and the tiny Black-bellied storm petrel. The southern giant petrel (*Macronectes giganteus*), which isn't actually breeding on the island but using it as a foraging area when feeding on carcasses of seals and penguins also made a notable increase in numbers in the area around the island. The diving-petrels is known for not wandering far from the breeding sites. Even though not encountered in large numbers, diving petrels were recorded on latitudes comparable with the Bouvet island both on the southward and the northward transect. This suggests that that diving-petrels (Common diving- petrel? see species comment) breed on the Bouvet island. Diving-petrels are previously not recorded breeding on Bouvet as far as the author knows.

Birds and acoustic data

Even though no data is analysed yet, I briefly mention that it is believed that whenever there were observed large number of birds there were also much macro zooplankton to be seen on the ship's acoustic equipment (own observations). However, this does not apply the other way around. A number of times there were much macro zooplankton to been seen on the acoustics without many birds present. This is probably due to that birds simply can't be everywhere.

Icebergs seem to form some sort of micro ecosystems, and every time we sailed in areas with large icebergs present the number of birds increased. This was especially evident for the prion species and blue petrel (*Halobaena caerulea*). The amount macro zooplankton shown by acoustic equipment also increased in these areas.

Identification

Identifying seabirds can be challenging. Even when the observation is extremely good, it might be impossible to identify the bird down to species level. For some species, like the immature mollymawks, the wandering albatross group and not the least the prions this affect the accuracy of the data. Most of the published literature states the impossibility of having a positive id of these birds in the field.

Species comments

Wandering albatross – According to the taxonomy used, this species group consists of four species (Snowy-, Tristan-, Amsterdam- and New Zealand albatross) and is extremely difficult (the literature says impossible) to identify to species level in the field. However, it is believed that most birds recorded as wandering albatross in this survey actually is the snowy albatross (*Diomoeda exulans*). The snowy albatross has the nearest (to our study area) and largest breeding colony in the world at Prins Edward Island. As this species is an extreme shipfollower, it is difficult to know the exact number of birds involved in the dataset. For instance, through photo identification, one bird followed our vessel for 3,5 days.

Prion species – Prions are notoriously difficult, if not impossible to identify in the field. It is believed that most of the prions recorded as *prion sp.* observed in the southern part of the study area actually is antarctic prion (*Pachyptila desolata*). Three prions landed on deck

during dark hours in these areas and they all belonged to this species (confirmed by bill measurements). In the Bouvet area, two prions landed on deck and they proved to be the slender-billed prion (*Pachyptila belcheri*).

Diving petrel – Four species in the Southern Ocean, but only two of them is known to occur in the study area. The only certain way to tell these species apart is by bill measurements. Through field observation it is thought that most of the diving petrels observed is common diving-petrel (*Pelecanoides urinatrix*). This was supported by a bird that landed on the deck, and where morphological measurements proved it to be a common diving-petrel. The alternative species is south georgia diving-petrel (*Pelecanoides georgicus*).

Acknowledgements
Stuart Murray, an independent birder, made important observational contribution throughout the survey for this study. Additionally, he did his own study on the different plumage stages and the moult pattern in the wandering albatross group. Methodology for this work was primarily the use of digital photo identification.

17 PUBLIC OUTREACH, FILMING AND PHOTOS

Digital filming taken onboard G.O.Sars during AKES LEG 2

Digital filming with Sony A1E CMOS HDV and HDR-HC7 cameras has been performed from Cape Town in South Africa, via the South Atlantic Ocean and the Southern Ocean, to Walvis Bay in Namibia. Altogether 11 hours of digital HDV videotapes were recorded from 19 February until 27 March 2008 onboard the Norwegian research vessel G.O.Sars (Table 17.1). The video tapes have been registered at the website of Snøball Film http://www.snoball.no/ in relation to the International Polar Year (IPY) and the Norwegian Research Council (NRC):
http://www.snoballkino.com/polaryear/pages/review.php
A more detailed content list for each HDV tape has been written and added to the specific tape number. Raw editing of the tapes has been done accordingly. Some video-footages have preliminary been used in the web-based cruise diary:
(http://www.imr.no/antarctic/criuse_diary).
The HDV tapes will be sent to Snøball Film. Tollbugt. 8b, N-0152 Oslo, Norway after arriving at the Institute of Marine Research in Bergen, Norway.

Digital photos taken onboard G.O.Sars during AKES LEG 2

Several thousand digital pictures have been taken by different photographers onboard G.O.Sars from 19 February to 27 March 2008. Many of them have been stored on a common server onboard the vessel and copied over to external discs and DVD's for general distribution and used for different purposes, including the national and international press. Many pictures have been used daily for the cruise diaries available in English at http://www.imr.no/antarctic/criuse_diary and Norwegian at http://www.imr.no/antarktis/toktdagbok

Cruise diaries written onboard G.O.Sars during AKES LEG 2

About 15 different cruise diaries have been written by different authors in English http://www.imr.no/antarctic/criuse_diary and 20 cruise diaries written in Norwegian http://www.imr.no/antarktis/toktdagbok onboard G.O.Sars during 2 LEG of the AKES expedition for general Public Outreach work at the Institute of Marine Research. This work together with cruise diaries written at LEG 1 of the AKES expedition may lead to writing a popular science book from this 3 months Antarctic expedition in the South Atlantic Ocean and Southern Ocean.

TABLES

Table 1.1. List of participants during the G.O. Sars survey 19 February to 27 March 2008.

Name	*Task*	
Haugland Terje	Instr	IMR
Steinsland Asgeir	Instr	IMR
Pedersen Ronald	Acoustics	IMR
Nøttestad Leif	Fish	IMR
Røttingen Jostein	Fish	IMR
Tangen Øyvind	Fish	IMR
Langøy Herdis	Fish	IMR
Melle Webjørn	Krill	IMR
Bagøien Espen	Krill	IMR
Krafft Bjørn	Krill	IMR
Årnes Cecilie Broms	Krill	IMR
Wiebe Peter	Krill	guest
Chu Dezhang	Krill	guest
Lona Paola Batta	Salps/krill	guest
Hoelter Anna	Krill	UoB
Torgrimsby Tonie Leonora	Krill	UoB
Edvardsen Bente	Phytoplankton	UoO
Grønningsæter Eirik	Bird	NPI
Murray Stuart	Bird	guest
Skagseth Øystein	Hydrography	IMR
Ostrowski Marek	Hydrography	IMR
Karlsbakk Egil	Patogenes	IMR
Jørstad Knut	Genetics	IMR
Kawall Helena	Brazil	guest
Cooke Carolina	Brazil	guest

Table 2.1. Station activities and numbers executed during the AKES expedition leg 2, 2008.

Station	**N**
CTD	74
Nutrients/phytoplankton	48
Phytoplankton net hauls	20
Juday net haul	15
Mocness	7
WP2	10
Krill trawl with multinett	13
Macroplankton trawl	13
Åkra trawl	2
APOP profiles	4
TS-probe profiles	8

Sum	**214**

Table 4.1. TS-Probe Data Log 2008001

Date	Time UTC	Ship	Cruise#	Bottom Depth (m)	Measure Depth (m)	Reference Target (type)	Station Number	GPT-1 Freq. (kHz)	GPT-2 Freq. (kHz)	GPT-3 Freq. (kHz)	Trawl Station	Comments
11.03.	16:34:27	G.O.Sars	2008001		30	Wc38.1	1	38	120	200	52	S 54 33.43 E 004 54.17
11.03.	17:12:12	G.O.Sars	2008001		20	Wc38.1	1	38	120	200	52	Krill near surface
12.03.	19:35:10	G.O.Sars	2008001		10	Wc38.1	2	38	120	200	53	S 54 35.15 E 004 58.02
12.03.	19:39:00	G.O.Sars	2008001		20	Wc38.1	2	38	120	200	53	Krill near surface
12.03.	19:56:00	G.O.Sars	2008001		20	Wc38.1	2	38	120	200	53	File range 50 to 25 meter
12.03.	19:59:00	G.O.Sars	2008001		12	Wc38.1	2	38	120	200	53	
12.03.	20:15:00	G.O.Sars	2008001		20	Wc38.1	2	38	120	200	53	
12.03.	20:41:42	G.O.Sars	2008001		20	Wc38.1	2	38	120	200	53	Stop
12.03.	23:19:19	G.O.Sars	2008101		20-50	Wc38.1	3	38	120	200	53	S 54 35.15 E 004 58.02
13.03.	02:18:51	G.O.Sars	2008101		20-50	Wc38.1	3	38	120	200	53	Stop
13.03.	17:17:12	G.O.Sars	2008101		19	Wc38.1	4	38	120	200	54 - 55	S 53 45.06 E 007 30.14
13.03.	18:46:15	G.O.Sars	2008101		19	Wc38.1	4	38	120	200	54 - 55	Stop
14.03.	11:40:01	G.O.Sars	2008101		22	Wc38.1	5	38	120	200	56	S 52 31.50 E 007 31.47
14.03.	13:06	G.O.Sars	2008101		22	Wc38.1	5	38	120	200	56	Stop Logging Camera Focus=3 m
17.03.	10:57:23	G.O.Sars	2008101		78	Wc38.1	6	38	120	200	59	S 45 07.96 E 007 39.70
17.03.		G.O.Sars	2008101		78	Wc38.1	6	38	120	200	59	Stop Camera Focus=3 m
17.03.	11:16	G.O.Sars	2008101		362	Wc38.1	6	38	120	200	59	Start
17.03.	11:42	G.O.Sars	2008101		362	Wc38.1	6	38	120	200	59	Stop
17.03.	11:48	G.O.Sars	2008101		520-528	Wc38.1	6	38	120	200	59	Start
17.03.	11:59	G.O.Sars	2008101		520-528	Wc38.1	6	38	120	200	59	Stop
17.03.	12:07	G.O.Sars	2008101		702	Wc38.1	6	38	120	200	59	Start
17.03.	12:19	G.O.Sars	2008101		702	Wc38.1	6	38	120	200	59	Stop

17.03.	12:19	G.O.Sars	2008101		721-1200	Wc38.1	6	38	120	200	59	Start Transport
17.03.	12:35	G.O.Sars	2008101		721-1200	Wc38.1	6	38	120	200	59	Stop Transport
17.03.	12:36	G.O.Sars	2008101		1205	Wc38.1	6	38	120	200	59	Start
17.03.	12:56	G.O.Sars	2008101		1205	Wc38.1	6	38	120	200	59	Stop
17.03.	12:57	G.O.Sars	2008101		1205-0	Wc38.1	6	38	120	200	59	Start Transport
17.03.	13:38:46	G.O.Sars	2008101		1205-0	Wc38.1	6	38	120	200	59	Stop Transport
17.03	17:17:21	G.O.Sars	2008101		0-100	Wc38.1	7	38	120	200	59	S 45 00.28 E 007 40.11
17.03	17:19	G.O.Sars	2008101		0-100	Wc38.1	7	38	120	200	59	Stop Transport
17.03	17:19	G.O.Sars	2008101		100	Wc38.1	7	38	120	200	59	Start
17.03	20:59	G.O.Sars	2008101		100	Wc38.1	7	38	120	200	59	Stop
17.03	21:00	G.O.Sars	2008101		100-360	Wc38.1	7	38	120	200	59	Start Transport
17.03	21:04	G.O.Sars	2008101		100-360	Wc38.1	7	38	120	200	59	Stop Transport
17.03	21:04	G.O.Sars	2008101		360	Wc38.1	7	38	120	200	59	Start
17.03	21:27	G.O.Sars	2008101		360	Wc38.1	7	38	120	200	59	Stop
17.03	21:27	G.O.Sars	2008101		360:420	Wc38.1	7	38	120	200	59	Start Transport
17.03	21:30	G.O.Sars	2008101		360:420	Wc38.1	7	38	120	200	59	Stop Transport
17.03	21:30	G.O.Sars	2008101		420	Wc38.1	7	38	120	200	59	Start
17.03	21:40	G.O.Sars	2008101		420	Wc38.1	7	38	120	200	59	Stop
17.03	21:40	G.O.Sars	2008101		420-520	Wc38.1	7	38	120	200	59	Start Transport
17.03	21:44	G.O.Sars	2008101		420-520	Wc38.1	7	38	120	200	59	Stop Transport
17.03	21:44	G.O.Sars	2008101		520	Wc38.1	7	38	120	200	59	Start
17.03	22:03	G.O.Sars	2008101		520	Wc38.1	7	38	120	200	59	Stop
17.03	22:03	G.O.Sars	2008101		520-22	Wc38.1	7	38	120	200	59	Start Transport
17.03	22:20	G.O.Sars	2008101		520-22	Wc38.1	7	38	120	200	59	Stop Transport
17.03	22:20	G.O.Sars	2008101		22	Wc38.1	7	38	120	200	59	Start
17.03	22:28	G.O.Sars	2008101		22	Wc38.1	7	38	120	200	59	Stop
23.03	09:20	G.O.Sars	2008101	110	86	-	8	38	120	200		S 31 37.33 E 008 17.95

Table 6.1. Number of stations and samples collected during leg 3.

Number of	Nutrient	Chloroph. *a*	Chl. *a* fract.	Phytoplankton	Phytoplankton net hauls
Stations	36	36	19	34	17
Samples	497	308	280 (4x70)	230	17

Number of	Plankton < 35 □ m	Plankton for DNA-analysis	Filters for electron microscopy	Cultures (mixed)
Stations	20	13	20	13
Samples	130	66	139	26

Table 6.2. Preliminary list of taxa observed south of latitude 45°00 00 S.

Ochrophyta
Bacillariophyceae
Asteromphalus hookeri
Asteromphalus parvulus
Corethron criophilum
Chaetoceros atlanticus
Chaetoceros concavicornis
Chaetoceros criophilus
Chaetoceros dichaeta
Chaetoceros flexuosus
Chaetoceros spp. (incl. solitary)
Coscinodiscus spp.
Cylindrotheca closterium
Dactyliosolen antarcticus
Dactyliosolen cf. *blavyanus*
Dactyliosolen cf. *tenuijunctus*
Fragilariopsis kerguelensis
Fragilariopsis cf. *cylindrus*
Fragilariopsis cf. *pseudonana*
Fragilariopsis spp.
Guinardia cylindrus
Leptocylindrus mediterraneus
Plagiotropus gaussii
Navicula spp.
Nitzschia spp.
Pseudo-nitzschia spp.
Proboscia truncata
Proboscia inermis
Rhizosolenia antennata f. *semispina*
Rhizosolenia antennata f. *antennata*
Rhizosolenia imbricata
Thalassiosira spp.
Thalassiothrix antarctica
Trichotoxon reinboldii

Dictyochophyceae
Dictyocha speculum
Dinophyta
Amphidinium sp.
cf. *Diplopsalis* sp.
Gymnodinium spp.
Gyrodinium sp.
Protoperidinium sp.
Cryptophyta
Cryptophyta spp.
Haptophyta
Phaeocystis antarctica
Chrysochromulina sp.
cf. *Emiliania huxleyi*
Choanoflagellidea
Parvicorbicula cf. *socialis*
Calliacantha sp.

Table 7.1. Station numbers, dates and overview of sampling gear for mesozooplankton.

Station no.	Date in 2008	Juday (90µm)	WP2 (180 µm)	MOCNESS (180 µm)
56	23.Feb.	X		X
59	24.Feb.	X		X
63	26.Feb.	X	X	
66	27.Feb.	X	X	X
69	28.Feb.	X		X
72	29.Feb.		X	
73	1.March		X	
74	2.March		X	
75	4.March	X		X
77	6. &7.March	X	X	
80	8.March	X	X	
83	9.March	X	X	
88	13.March	X		
89	13.March	X	X	
92	14.March	X		X
95	15.March	X	X	
98	17.March	X		
100	18.March	X		X
Sum		15	10	7

Table 7.2. Station numbers, dates and overview of macrozooplankton sampling gear.

Station no.	**Date in 2008**	**Krilltrawl**	**Macroplankton trawl**
36	22.Feb	X	
37	24.Feb	X	
38	25.Feb	X	
39	25.Feb		X
40	26.Feb		X
41	27.Feb	X	
42	28.Feb	X	
43	28.Feb		X
44	01.March		X
45	02.March		X
46	05.March	X	
47	07.March	X	
48	07.March	X	
49	08.March		X
51	11.March		X
52	11.March		X
53	12.March	X	
54	13.March		X
55	13.March		X
56	14.March	X	
57	15.March		X
59	17.March	X	
60	18.March	X	
61	20.March	X	
Sum		**13**	**13**

Table 7. 3. Zooplankton species found during the AKES expedition, Leg 2.

Species list	
Amphipoda	Nematoscelis sp
Atolla sp	Ostracoda
Cephalopoda	Parandalia sp
Chaetognatha	Parandania boecki
Copepoda	Parandania gigantea
Ctenophora	Parandania sp
Cyllopus sp	Pegohyperia princeps
Cyphocaris anonyx	Periphylla sp
Cyphocaris richardi	Phronima sp
Cyphocaris sp	Polychaeta
Decapoda	Primno macropa
Euchaeta sp	Primno sp
Euphausia crystallorophias	Sagitta sp
Euphausia frigida	Salpa sp
Euphausia sp	Schypozoa
Euphausia superba	Scina sp
Euphausia triacantha	Siphonophora sp
Euphausiacea sp	Stygiomedusa gigantea
Eurythenes sp	Stygiomedusa sp
Gammaridae	Tecatia sp
Gastropoda	Themisto gaudichaudii
Gymnosomata sp	Themisto sp
Hyperiidae	Thysanoessa macrura
Lanceola sp	Thysanoessa sp
Lasis zonaria	Tomopteris sp
Limacina	Vibilia antarctica
	Vibilia sp

Table 7.4. Estimated abundance of selected zooplankton groups given in terms of unit surface area. Only abundances within the stratum 750-10m are included in these calculations.

Station	Species	Latitude	Longitude	Year	Month	Day	Weight g m^{-2}
41	Euphausia_superba	58.77517	17.98533	2008	2	27	2.254
42	Euphausia_superba	60.97733	15.13367	2008	2	28	0.015
46	Euphausia_superba	65.79950	13.38183	2008	3	5	54.668
47	Euphausia_superba	59.97667	7.46633	2008	3	7	9.425
48	Euphausia_superba	58.34934	7.50700	2008	3	7	59.438
53	Euphausia_superba	54.58050	4.92300	2008	3	12	2.430
56	Euphausia_superba	52.50483	7.52450	2008	3	14	0.106
36	Salpa_sp	45.02500	14.99600	2008	2	22	1.750
38	Salpa_sp	52.54483	14.99250	2008	2	25	23.963
41	Salpa_sp	58.77517	17.98533	2008	2	27	0.389
53	Salpa_sp	54.58050	4.92300	2008	3	12	2.046
56	Salpa_sp	52.50483	7.52450	2008	3	14	26.505
59	Salpa_sp	45.11017	7.66183	2008	3	17	0.022
60	Salpa_sp	43.34500	8.35083	2003	3	18	0.007
37	Themisto_gaudichaudii	50.03883	15.02233	2008	2	24	2.718
38	Themisto_gaudichaudii	52.54483	14.99250	2008	2	25	0.008
53	Themisto_gaudichaudii	54.58050	4.92300	2008	3	12	0.000
56	Themisto_gaudichaudii	52.50483	7.52450	2008	3	14	0.207
59	Themisto_gaudichaudii	45.11017	7.66183	2008	3	17	0.028
60	Themisto_gaudichaudii	43.34500	8.35083	2003	3	18	0.084
36	Thysanoessa_sp	45.02500	14.99600	2008	2	22	0.008
37	Thysanoessa_sp	50.03883	15.02233	2008	2	24	0.021
38	Thysanoessa_sp	52.54483	14.99250	2008	2	25	0.260
41	Thysanoessa_sp	58.77517	17.98533	2008	2	27	1.018
42	Thysanoessa_sp	60.97733	15.13367	2008	2	28	0.193
46	Thysanoessa_sp	65.79950	13.38183	2008	3	5	0.179
47	Thysanoessa_sp	59.97667	7.46633	2008	3	7	0.402
53	Thysanoessa_sp	54.58050	4.92300	2008	3	12	0.015
56	Thysanoessa_sp	52.50483	7.52450	2008	3	14	0.112

Table 7.5. Specie distribution along the different stations

	S. thompsoni	I. racovitza	Isais zonari
sta 37	5	0	0
sta 38	19	0	0
sta 39	7	0	0
sta 41	8	9	0
sta 42	4	2	0
sta 46	8	0	0
sta 47	0	15	0
sta 51	85	0	0
sta 52	13	0	0
sta 53	40	0	0
sta 54	39	0	0
89-750	39	0	0
sta 55	52	2	0
sta 56	54	0	0
sta 57	23	0	0
sta 59	0	0	28

Table 8.1. IGR experiments

gear	net	# individuals	temperature	Start date	End date	# moulted	# dead	# finished	molts p-value	dead p-value	
Krilltrawl	5	208	0	27.02.08	03.03.08	33	21	154	0.158653846	0.100961538	the light was turned on during night & the tubes fell out -> no flow
Krilltrawl	5	103	0	28.02.08	04.03.08	13	2	88	0.126213592	0.019417476	
Macroplanktontrawl	-	103	0	29.02.08	05.03.08	11	8	84	0.106796117	0.077669903	
Macroplanktontrawl	-	208	0	01.03.08	06.03.08	30	8	174	0.144230769	0.038461538	
Krilltrawl	2B	208	0	05.03.08	10.03.08	45	55	108	0.216346154	0.264423077	the tube fell out on the 2nd day, so the flow was interrupted
		12	0	07.03.08	12.03.08	1	1	10	0.083333333	0.083333333	storm, so just 4 times checked
		210	0	07.03.08	12.03.08	44	7	159	0.20952381	0.033333333	storm, so just 4 times checked
Macroplanktontrawl	-	104	0	08.03.08	13.03.08	12	14	78	0.115384615	0.134615385	storm, so just 4 times checked
		69	0	11.03.08	16.03.08	2	21	46	0.028985507	0.304347826	
		136	0	13.03.08	18.03.08	18	18	100	0.132352941	0.132352941	
		1361				209	155	1001			
						0.153563556	0.113886848	0.735488611			

Table 9.1. Fish families and species encountered during the AKES cruise

Family	Species	Short family
Alepocephalidae	Alepocephalus sp	alepoceph sp
Anotopteridae	Anotopterus pharao	anapt pharao
Apogonidae	Apogonidae	apogonidae
Astronesthidae	Astronesthes sp	astronest sp
Bathydraconidae		Bathydraconidae
Bathylagidae	Bathylagus antarcticus	bathl antarc
Bathylagidae	Bathylagus sp	bathl sp
Bathylagidae	Bathylagus tenuis	bathl tenuis
Centrolophidae	Icichthys australis	icich austra
Channichthyidae		Channichthyidae
Channichthyidae	Chaenocephalus aceratus	chaen acerat
Channichthyidae	Champsocephalus gunnari	champ gunnar
Channichthyidae	Dacodraco hunteri	dacod hunter
Channichthyidae	Pseudochaenichthys georgianus	pseud georgi
Chauliodontidae	Chauliodus sp	chauliodu sp
Chiasmodontidae	Chiasmodon bolangeri	chias bolang
Chiasmodontidae	Chiasmodon niger	chias niger
Gempylidae	Paradiplospinus gracilis	parad gracil
Gigantactinidae	Gigantactinidae	gigantactini
Gonostomatidae	Cyclothone sp	cyclothon sp
Liparididae	Paraliapris sp	paral sp
Macrouridae	Cynomacrurus piriei	cynom piriei
Macrouridae	Macrouridae	macro sp
Melamphaidae	Sio nordenskjöldii	sio nordensk
Melamphaidae	Melamphaes microps	melam microp
Melanonidae	Melanonus gracilis	melan gracil
Microstomatidae	Nansenia antarctica	nanse antarc
Microstomatidae	Microstomatidae	microstom sp
Myctophidae	Maurlolicus inventiones	maurl invent
Myctophidae		Myctophidae
Myctophidae	Diaphus hudsoni	diaph hudson
Myctophidae	Electrona antarctica	elect antarc
Myctophidae	Electrona carlsbergi	elect carlsb
Myctophidae	Electrona paucirastra	elect paucir
Myctophidae	Electrona subaspera	elect subasp
Myctophidae	Protomyctophum andriashevi	proto andria
Myctophidae	Gymnoscopelus bolini	gymno bolini
Myctophidae	Gymnoscopelus braueri	gymno brauer
Myctophidae	Gymnoscopelus fraseri	gymno fraser
Myctophidae	Gymnoscopelus hintonoides	gymno hinton
Myctophidae	Gymnoscopelus microlampas	gymno microl
Myctophidae	Gymnoscopelus nicholsi	gymno nichol
Myctophidae	Gymnoscopelus opisthopterus	gymno opisth

Myctophidae	Gymnoscopelus piabilis	gymno piabil
Myctophidae	Hintonia candens	hinto canden
Myctophidae	Krefftichthys anderssoni	kreff anders
Myctophidae	Lampanyctus achirus	lampa achiru
Myctophidae	Lampanyctus ater	lampa ater
Myctophidae	Lampanyctus australis	lampa austra
Myctophidae	Lampanyctus intricarius	lampa intric
Myctophidae	Lampanyctus macdonaldi	lampa macdon
Myctophidae	Lampanyctus sp	lampa sp
Myctophidae	Protomyctophum bolini	proto bolini
Myctophidae	Protomyctophum choriodon	proto chorio
Myctophidae	Protomyctophum gemmatum	proto gemmat
Myctophidae	Protomyctophum normani	proto norman
Myctophidae	Protomyctophum parallelum	proto parall
Myctophidae	Protomyctophum tenisoni	proto teniso
Myctophidae	Symbolophorus boops	symbo boops
Myctophidae	Symbolophorus borus	symbo borus
Nemichthyidae	Nemichthys scolopaceus	nemic scolop
Nototheniidae	Lepidonotothen larseni	lepid larsen
Nototheniidae	Lepidonotothen squamifrons	lepid squami
Nototheniidae	Trematomus eulepidotus	trema eulepi
Oneirodidae	Oneirodes notius	oneir notius
Paralepididae	Magnisudis sp	Magnisudi sp
Paralepididae	Notolepis annulata	notol annula
Paralepididae	Notolepis coatsi	notol coatsi
Paralepididae	Notolepis sp	notol sp
Phosichthyidae	Phosichthys argenteus	phosi argent
Scopelarchidae	Benthalbella elongata	benth elonga
Scopelarchidae	Benthalbella macropinna	benth macrop
Sternoptychidae	Argyropelecus hemigymnus	argyr hemigy
Stomiidae		Stomiidae
Stomiidae	Borostomias antarcticus	boros antarc
Stomiidae	Borostomias antarcticus	boros anarct
Stomiidae	Idiacanthus atlanticus	idiac atlant
Stomiidae	Stomias boa boa	stomi boa
Stomiidae	Stomias gracilis	stomi gracil
Zoarcidae	Lycenchelys sp	lycen sp
Zoarcidae	Lycodichthys sp	lycod sp
Zoarcidae	Zoarcidae	Zoarcidae

Table 11.1. Overview of marine mammal sightings along the cruise track onboard G.O.Sars in the Southern Ocean.

Species	# Observations	# Animals (Best estimate)	# Animals (Max estimate)
Humpback whale	41	103	129
Fin whale	4	4	7
Minke whale	3	3	3
Baleen whale	6	16	20
Sperm whale	7	7	7
Dusky dolphins	2	60	90
Dolphin species	1	30	50
Fur seal	1	1	1

Table 12.1. Overview of the examined fish species, the parasites detected (preliminary ID) and the prey items identified. N=sample size, Vir=sampled for virus screening, Para=Screened for parasites. #

Family	**N examined**		**Parasites detected**	**Stomach contents**
Species	Vir	Para		
Platytroctidae				
gen. sp.	0	1	Raphidascarinae gen. sp. *Anisakis* sp.	hyperiids
Scopelarchidae				
Benthalbella macropinna	0	2	Ichthyosporea?	empty
Stomiidae				
Stomias gracilis	3	2	Scolex A § Scolex B §	Transparent medusa (from trawl?)
Astronesthidae				
Borostomias antarcticus	1	1	Scolex C §	*Salpa*
Phosichthyidae				
Phosichthys argenteus	3	2	*Anisakis* sp. Anisakinae gen. sp.	Myctophiids, *Themisto*, krill
Microstomatidae				
Nansenia antarctica	0	1	Ichthyosporea?	*Euchaeta*, small amphipods
Bathylagidae				
Bathylagus tenuis	11	46	*Cryptobia* sp. *Eimeria* sp. A *Lecithophyllum* sp. *Lecithochirium* sp. Scolex A § Plerocercoid 'arrow' *Paeonocanthus antarcticensis* *Sarcotretes* sp.	Mainly cnidaria and salps, also hyperiids, small krill, other small amphipods, ostracods, *Euchaeta* and smaller copepods, tomopterids
Myctophiidae				
Electrona antarctica	0	52	*Diphyllobothrium* plerocercoids Scolex A § Cercoid VII	Krill (incl. adult *Euphausia superba*), hyperiids and other amphipods, Chaetognatha, copepoda, small fish
Electrona carlsbergi	0	4	*Copiatestes filiferus* Scolex A §	-
Lampadena speculigera	0	1	*Sarcotretes* sp.	-
Lampanyctus achirus	20	1	*Eimeria* sp. *Sarcotretes* sp.	-
Lampanyctus intricarius	3	0		
Gymnoscopelus spp.*	16	5	*Eimeria* sp.	-
Protomyctophum bolini	0	3	-	-

	Krefftichthys anderssoni	0	59	Cercoid VII trypanorhynch metacestode	Small salps, small krill (*Thysanoessa macrura*), small hyperiids, copepods, fish eggs
Gonostomatidae					
	Cyclothone spp.	0	10	-	-
Paralepididae					
	Notolepis coatesi	0	21	Microsporidia indet. *Diphyllobothrium* sp. plerocercoids Trypanorhyncha (?) indet. metacestoda Scolex A § *Sarcotretes* sp.	Krill (*Euphausia superba, Thysanoessa macrura*), also Chaetognatha
Anotopteridae					
	Anotopterus pharao	0	1	*Diphyllobothrium* sp. plerocercoids	Fish remains
Macrouridae					
	Cynomacrurus piriei	0	3	Ichthyosporea? Coccidia Scolex A § *Diphyllobothrium* sp. plerocercoids	Fish, copepods, chaetognaths
Melanonidae					
	Melanonus gracilis	1	1	Scolex A §	Hyperiids, *Euchaeta*, Crustacea indet.
Melamphaidae					
	Melamphaes microps	10	6	Scolex A § Trypanorhynch pl. *Diphyllobothrium* sp. plerocercoids	Mainly krill, also *Euchaeta*, *Metridia*, small amphipoda, Chaetognatha
	Sio nordenskioldi	3	10	*Eimeria* spp. B, C	Small hyperiids, Cnidaria (nematocysts)
Epigonidae					
	Rosenblattia robusta	1	1	Scolex A §	Chaetognatha
Gempylidae					
	Paradiplospinus antarcticus	3	4	Ichthyosporea? Scolex A § Scolex C § Cercoid VII *Anisakis* sp.	Small Myctophiidae
	Sum	77	227		

**Gymnoscopelus nicholsi* (4), *G. braueri* (1), *G. hintonoides* (16, virus)

§ Scolex A = Scolex pleuronectis with two loculi (sensu Olsson 1867), Scolex B = Scolex pleuronectis with one elongate loculus, Scolex C=Scolex pleuronectis with one loculus and a large wing like bothridium. # in addition, two *Champsocephalus gunnari* from AKES part 1 was sampled for both virus and parasites; 7 additional parasite species were found.

Table 12.2. The following species or categories of Antarctic larval helminth parasites were detected:

Major group **Order**	**Genus/Type**	**Typical final hosts**
Nematoda		
	Anisakis sp.	Whales
Cestoda		
Trypanorhynchidea		
	Unidentified types, only one with developed scolex.	Elasmobranchs
Tetraphyllidea		
	'Scolex pleuronectis' (4 types)	Elasmobranchs
Tetrabothriidea		
	Cercoid VII of Wojciechowska (1993)	aquatic birds
Diphyllobothriidea		
	Diphyllobothrium sp. plerocercoids	Marine mammals, aquatic birds

Table 13.1. Summary of shipboard sound speed and density contrast measurements of Antarctic krill (*Euphausia superba*). Data items with asterisks signs are the values measured on board the vessel and in profile mode. The superscripts "a" and "b" correspond to single and multiple cod-end pelagic trawls, respectively.

No.	No. anim.	L (mm)	L/a	Date	Time	Trawl #	Lat (deg)	Lon (deg)	Temp (^{o}C)	Sal (ppt)	V_z (cm^3)	*g*	*h*
1	19	47.3	-	26.2.08	1615	40 [a]	56.80 S	15.05 E	0.9	34.12	13.28	1.035	1.062
2	16	46.3	-	27.2.08	1224	41 [b]	58.85 S	15.00 E	0.4	33.89	11.52	1.038	1.048
3	15	45.8	-	28.2.08	1022	42 [b]	61.03 S	15.16 E	0.5	33.84	9.83	1.064	1.047
4	15	47.6	-	2.3.08	1307	73 [a]	67.12 S	07.95 E	0.9	34.00	11.31	1.056	1.031
5	15	38.4	-	5.3.08	0830	46 [b]	65.80 S	13.38 E	0.5	34.00	11.50	1.050	1.039
6	15	47.4	-	5.3.08	1435	46 [b]	65.80 S	13.38 E	0.5	34.00	12.14	1.050	1.037
7	15	46.4	15.1	5.3.08	1844	46 [b]	65.80 S	13.38 E	-0.2	33.98	10.96	1.057	1.036
8	15	48.0	16.2	6.3.08	1332	46 [b]	65.80 S	13.38 E	1.0	33.84	11.46	1.060	1.038
9	15	40.7	19.4	7.3.08	0850	47 [b]	59.98 S	07.47 E	1.5	33.94	8.66	1.031	1.044
10	21	38.5	22.8	7.3.08	1530	47 [b]	59.98 S	07.47 E	1.5	34.04	8.09	1.042	1.030
11	29	39.3	24.4	7.3.08	2045	48 [b]	58.35 S	07.51 E	1.0	34.12	10.94	1.031	1.035
12	28	40.3	20.8	8.3.08	1931	49 [a]	57.49 S	07.49 E	1.0	34.21	11.63	1.033	1.036
13*	15	52.6	17.3	11.3.08	1756	52 [a]	54.57 S	04.92 E	1.5	34.05	14.20	1.043	1.036
14*	15	49.7	17.7	12.3.08	2300	87 [b]	54.58 S	04.92 E	1.5	34.04	12.50	1.047	1.031
15*	16	49.8	22.0	13.3.08	1524	54 [a]	54.58 S	04.98 E	1.2	34.06	12.64	1.035	1.039
16*	11	48.3	17.4	14.3.08	1318	54 [a]	54.58 S	04.98 E	2.0	33.80	8.18	1.032	1.049

Table 13.2. Summary of shipboard sound speed and density contrast measurements of species other than *Euphausia superba*. The superscripts "a" and "b" correspond to single and multiple cod-end pelagic trawls, respectively.

No.	Species	No. anim.	L (mm)	Date	Time	Trawl #	Lat (deg)	Lon (deg)	Temp (^{o}C)	Sal (ppt)	V_z (cm^3)	*g*	*h*
1	*Themosto gaudicaudi*	30	13.7	22.2.08	2050	36 [a]	45.00 S	15.00 E	10.0	23.67	3.97	1.032	1.011
2	*Parandania boecki*	27	21.6	24.2.08	0940	37 [a]	50.10 S	15.00E	9.1	33.98	15.94	1.018	-
3	*Salpa thompsoni*	15	45.5	12.3.08	1831	53 [a]	54.58 S	4.16 E	1.5	34.04	15.55	1.000	1.013
4	*Salpa thompsoni*	11	48.0	13.3.08	1158	54 [b]	54.58 S	4.98 E	1.5	34.10	22.24	1.001	1.006
5	*Salpa thompsoni*	12	58.0	13.3.08	1316	54 [b]	54.58 S	4.98 E	1.0	34.11	24.07	1.009	1.009
6	*Salpa thompsoni*	15	43.6	15.3.08	1444	57 [b]	49.98 S	7.53 E	4.0	33.68	12.12	1.003	1.017
7	*Themosto gaudicaudi*	51	22.0	17.3.08	2030	59 [a]	45.06 S	7.66 E	9.0	33.77	5.12	1.002	1.040
8	Squid	1	34.0	20.3.08	0824	61 [a]	37.54 S	9.20 E	19.0	35.76	5.68	0.979	1.012
9	Eel larvae (leptocephalus)	10	171.9	20.3.08	0841	61 [a]	37.54 S	9.20 E	19.0	35.76	20.38	0.995	1.007
10	*Notoscopelus resplendens*	6	62.0	20.3.08	1057	61 [a]	37.54 S	9.20 E	19.0	35.78	11.46	1.035	1.033
11	*Hygophum hygomli*	5	54.8	20.3.08	1112	61 [a]	37.54 S	9.20 E	19.0	35.78	11.77	1.036	1.029

Table 14.1 Collection of samples of Antarctic krill, *Euphausia superba,* during the research period. Samples from trawl stations no. 1 - 5 were collected on AKES 1, while the rest of the samples (6 - 14) were collected on the second period AKES 2.

				Positions	
Sample no	Trawl Station.	Date	No. krill		
1	3	19.01.2008	96	53 52,6 S	36 21,0 W
2	19	29.01.2008	96	56 16,9 S	08 42,5 W
3	24	31.02.2008	96	58 45,5 S	00 02,2 W
4	25	01.02.2006	96	58 12,4 S	00 03,2 W
5	32	03.02.2008	96	54 16,4 S	00 03,7 W
6	41	27.02.2008	96	58 49,0 S	15 00,0 E
7	44	01.03.2008	96	65 35,8 S	18 28,4 E
8	44	01.03.2008	96	65 35,8 S	18 28,4 E
9	46	05.03.2008	96	65 47,7 S	13 22,9 E
10	47	07.03.2008	96	59 58,6 S	07 27,9 E
11	48	07.03.2008	96	58 20,7 S	07 30,4 E
12	49	08.03.2008	96	57 39,5 S	07 29,6 E
13	52	11.03.2008	96	54 34,2 S	04 55,4 E
14	54	13.03.2008	96	54 34,8 S	04 58,8 E
15	56	14.03.2008	96	52 30,3 S	07 31,5 E

Table 14.2 Total number of samples collected for allozyme analyses and DNA investigations during the AKES surveys in the Antarctic, January to March 2008. The samples analysed for allozyme variation on board the research vessel G.O. Sars during the second survey period are also indicated (X).

Sample no	Trawl Station.	Protein samples	Protein analyses performed on boat	Samples for DNA analyses	DNA analyses
1	3	96	X	96	
2	19	96	X	96	
3	24	96	X	96	
4	25	96	X	96	
5	32	96	X	96	
6	41	96	X	96	
7	44	96	X	96	
8	44	96	X	96	
9	46	96	X	96	
10	47	96	X	96	
11	48	96		96	
12	49	96		96	
13	52	96	X	96	
14	54	96	X	96	
15	56	96	X	96	
		Totally 1440		Totally 1440	

Table 15.1 – Mean length of *E. superba* from all stations.

Number of individuals	1274
Minimum	21,0
Maximum	63,0
Median	46,0
Mode	49,0
Mean	44,6
Standard deviation	6,8

Table 15.2: Mean length of *Euphausia superba* at different location in the Atlantic-Indian sector of the Southern Ocean (Min= minimum size; Max= maximum size).

Station (date)	**Position**	**Mean (± sd)**	**Min**	**Max**	**% Juv.**	**% Fem.**	**% Male**	**Number of individuals**
41 (27/02)	58º 48.81S, 15 º 00.18E	45,2 (± 4,9)	34	57	83,2	15,8	1,1	95
42 (28/02)	61º 02.01S, 15º 09.60 E	44,1 (± 4,1)	33	57	75,5	20,8	3,8	106
43 (29/02)	63º 59.25 S, 15º 31.04 E	44,2 (± 6,8)	27	53	61,6	21,2	17,2	99
45 (02/03)	67º 06.97 S, 7º 57.20 E	44,9 (± 4,3)	31	54	61,4	21,8	16,8	101
46	65º 47.55 S,	46,8 (± 3,5)	33	54	55,4	22,3	22,3	130

(05/03)	13º 33.11 E							
47 (07/03)	59º 55.53 S, 7º 24.98 E	35,5 (± 4,9)	21	49	96,7	3,3	0,0	150
49 (08/03)	57º 29.30 S, 7º 29.17 E	37,1 (± 5,0)	21	50	64,0	20,7	15,3	150
52 (11/03)	54º 34.17 S, 4º 55.40 E	49,9 (± 3,4)	35	60	9,0	28,0	63,0	100
53 (12/03)	54º 34.10 S, 4º 49.49 E	47,1 (± 3.2)	38	55	10,0	47,0	43,0	100
54 (13/03)	54º 34.25 S, 5º 00.78 E	47,9 (± 3,1)	38	55	2,1	51,4	46,5	144
56 (14/03)	52º 26.79 S, 7º 34.16 E	54,0 (± 2,9)	47	63	0,0	22,0	77,8	99

Table 15.3: Fishes collected for fluorite and metabolism analysis.

Family	**Species**	**Number of specimens**
Bathylagidae	*Bathylagus tenuis*	17
Myctophidae	*Electrona antarctica*	17
	Gymnoscopelus braueri	5
	Gymnoscopelus nicholsi	4
	Gymnoscopelus opisthopterus	13
	Krefftichthys anderssoni	16

Table 15.4: Species collected for genetic analysis.

Family	**Species**
Bathylagidae	*Bathylagus tenuis*
Myctophidae	*Electrona antarctica*
	Electrona carlsbergi
	Gymnoscopelus bolini
	Gymnoscopelus braueri
	Gymnoscopelus nicholsi
	Protomyctophum bolini
	Protomyctophum normani
Paralepididae	*Notolepis annulata*
Gempylidae	*Paradiplospinus gracilis*
Stomiidae	*Stomias gracilis*

Table 17.1. Overview of number of HDV tapes recorded during the 2 LEG of the AKES cruise

Tape number	Date	Raw-editing
1	18-20 February 2008	Yes
2	21-22 February 2008	Yes
3	23-27 February 2008	Yes
4	28 Feb.- 1 March 2008	Yes
5	2-4 March 2008	Yes
6	5-7 March 2008	Yes
7	8-10 March 2008	Yes
8	11-12 March 2008	Yes
9	13-15 March 2008	Yes
10	16-23 March 2008	Yes
11	24-27 March 2008	Yes

Table 16.1. Birds along the southward transect

Species	Scientific name	Ship follower	Feb 19. CPT harbour _5hrs south	Feb.20 S36*35 E17*09 - S38*44 E16*46	Feb.21 S40*46 E15*39 - 42*48 E15*32	Feb.22 S44*48 E15*03 - S45*38 E15*01	Feb.23 S47*35 E15*00 - S49*07 E15*00	Feb.24 S50*14 E15*03 - S52*04 E14*59	Feb.25 S53*13 E15*00 - S54*44 E15*01	Feb.26 S54*33 E15*01 - S57*29 E15*00	Feb.27 S58*44 E14*58 - S60*11 E15*00	Feb.28 S61*13 ES15*10 - S63*12 E15*23	Feb.29 S64*46 E15*17 - S64*29 E16*55	Mar.1 S65*36 E18*28 - S65*47 E14*13	Mar.2 S66*53 E10*32 - S66*53 E08*11	Mar.3 S66*45 E10*29 - S65*36 E11*40	Mar.4 S64*33 E09*23 - S65*25 E12*17
Wandering albatross	Diomedea sp.	yes			3	5	13	4	4	5	3					1	1
Tristan albatross	Diomedea dabbenena	yes					1										
Shy albatross	Thalassarche cauta	yes	100	8	3	6											
Black-browed albatross	Thalassarche melanophrys	yes	10	3	2				1								5
Atlantic yellow-nosed albatross	Thalassarche chlorohynchos	yes			2												
Indian yellow-nosed albatross	Thalassarche carteri	yes			2												
Grey headed albatross	Thalassarche chrysostoma	no					1	1	1	1							3
Black-browed/Grey headed albatross	Thalassarche sp.	x			11	25											
Atlantic/Yellow-nosed albatross sp	Thalassarche sp.	yes		4	10												
Light-mantled albatross	Phoebetria palpebrata	yes						1		1	2	5	37	10	6	4	7
Sooty albatross	Phoebetria fusca	no			2	1					1						
Northern Giant petrel	Macronectes halli	yes				6				6			2				
Southern Giant petrel	Macronectes giganteus	yes								3		3				1	
Southern fulmar	Fulmarus glacialoides	yes									3		2	2	6	5	4
Cape petrel	Daption capense	yes										1		3	4		1

Antarctic petrel	Thalassoica antarctica	no													9	11	1
Lesser/Greater snow petrel	Pagodroma sp.	no														1	1
Great-winged petrel	Ptrerodroma macroptera	yes		60	25	25	10	2	5								
Kerguelen petrel	Lugensa brevirostris	no							40	12	15	6		4	25	20	80
			Feb.19	Feb.20	Feb.21	Feb.22	Feb.23	Feb.24	Feb.25	Feb.26	Feb.27	Feb.28	Feb.29	Mar.1	Mar.2	Mar.3	Mar.4
Soft-plumaged petrel	Pterodroma mollis	no			17	70	150	100									
White-headed petrel	Pterodroma lessoni	no					1	15	3	10	20						
Antarctic prion	Pachyptila desolata	yes						4		25	15	35					10
Fulmar prion	Pachyptila crassirostris	yes						4	4	5							
Prion sp.	Pachyptila sp.	no			13	4	7	500	50	55	380	300	1100	200	10	5	
Blue petrel	Halobaena caerulea	no									1	600	300	1500	200	100	500
Spectacled petrel	Procellaria conspicillata	yes		1	3												
White-chinned petrel	Procellaria aequinoctialis	yes	500	40	23	100	25	5	10	5	5	15	12	10		1	3
Grey petrel	Procellaria cinerea	no				2	50										
Great shearwater	Puffinus gravis	yes	60	10	1	3	2	6	2								
Cory's shearwater	Calonectris diomedea	no	200	30	25												
Sooty shearwater	Puffinus griseus	yes	10	1		3	2	15				10	10	30			6
Subantarctic little shearwater	Puffinus elegans	no				2	6										
Common diving-petrel	Pelecanoides urinatrix	no						1									
Diving petrel sp.	Pelecanoides sp.	no						15									
Wilson's storm petrel	Oceanites oceanicus	yes					1							3	10	1	
Leach's storm petrel	Oceanodroma leucurhoa	no		20													
White-bellied storm petrel	Fregatta grallaria	no		2													
Black-bellied storm petrel	Fregatta tropica	no				8	8	25	25	6	4						
African jackass penguin	Spheniscus demersus	no	15														
Cape gannet	Morus capensis		3														
Cape cormorant	Phalacrocorax capenis		6														
Swift tern	Sterna bergii	no	1														
Sandwich tern	Sterna sandvicensis	no	1*														
Antarctic tern	Sterna vittata	no															1

Cape gull	Larus vetula		5															
Subantarctic skua	Catharacta antarctica	yes	3	3	2	1				1								
Pomarine skua	Stercorarius pomarinus	no																
Long-tailed skua	Stercorarius longicaudus	no	1															

Table 16.2. Birds along the northward transect

Species	Scientific name	Ship follower	Mar. 5 S65*44 E13*31 - S63*52 E12*55	Mar.6 S62*08 E10*16 - S60*34 E08*34	Mar.7 S59*56 E07*25 - S58*27 E07*30	Mar.8 S57*29 E07*29 - S56*40 E07'29	Mar.9 S54*59 E07*29 - S54*57 E05*38	Mar.10 S54*29 E04*16 - S54*30 E03*38	Mar.11 S54*30 E08*38 - S54*33 E04*52	Mar.12 S54*30 E04*52 - S54*33 E04*49	Mar.13 S54*34 E05*01 - S53*45 E07*30	Mar.14 S52*51 E07*29 - S51*57 E07*32	Mar.15 S50*08 E07*31 - S49*35 E07*40	Mar.16 S48*03 E08*11 - S46*26 E08*14	Mar.17 S45*07 E07*39 - S45*00 E07*40	Mar.18 S43*51 E08*11 - S43*08 E08*25	Mar.19 S41*22 E09*28 - S39*34 E09*27	Mar.20 S37*31 E09*12 - S35*32 E08*55
Wandering albatross	Diomedea sp.	yes	2	3	2	5	8	5	6	3	5	6	3	2	11	2	2	
Tristan albatross	Diomedea dabbenena	yes															1	1
Northern Royal albatross	Diomedea sanfordi	yes													1			
Shy albatross	Thalassarche cauta	yes													20	10	25	1
Black-browed albatross	Thalassarche melanophrys	yes	6	6	5		2	5	3	2	2			8	40	25	40	
Atlantic yellow-nosed albatross	Thalassarche chlorohynchos	yes																3
Indian yellow-nosed albatross	Thalassarche carteri	yes															1	
Grey headed albatross	Thalassarche chrysostoma	no	4	4	3	2	2	2		3	2	5			5			
Black-browed/Grey headed albatross	Thalassarche sp.	x																5
Light-mantled albatross	Phoebetria palpebrata	yes	9	10	15	5	4	15	6	4	4	6	3					
Sooty albatross	Phoebetria fusca	no				1		3	1	1		4	2	11	3	3	2	
Northern Giant petrel	Macronectes halli	yes					1					1						

Southern Giant petrel	Macronectes giganteus	yes				4		3	70		3	3			2			
Giant petrel sp.	Macronectes sp.	yes						2										
Southern fulmar	Fulmarus glacialoides	yes		2	1	35	40	200	500	50	300	40						
Cape petrel	Daption capense	yes	8	1	1		2			2	3	2						
Antarctic petrel	Thalassoica antarctica	no	4															
Great-winged petrel	Ptrerodroma macroptera	yes					2							20	10	5	25	1
Kerguelen petrel	Lugensa brevirostris	no	40	20	50	50	50		40	35	150	40	15					
			Mar.5	Mar.6	Mar.7	Mar.8	Mar.9	Mar.10	Mar.11	Mar.12	Mar.13	Mar.14	Mar.15	Mar.16	Mar.17	Mar.18	Mar.19	Mar.20
Soft-plumaged petrel	Pterodroma mollis	no				6	100	40	25	30	30	25	15	200	15	20	10	
White-headed petrel	Pterodroma lessoni	no			25	20	15	15	10	1	10	3						
Antarctic prion	Pachyptila desolata	yes	500	100	500		5											
Slender-billed prion	Pachyptila belcheri	yes					10				1			1		1	5	
Fulmar prion	Pachyptila crassirostris	yes					2		1		2	5	1	2				
Prion sp.	Pachyptila sp.	no				10	200	15	10	5	40	20	3	40	10	20	140	
Blue petrel	Halobaena caerulea	no	1500	500	200	3												
Spectacled petrel	Procellaria conspicillata	yes													1		1	1
White-chinned petrel	Procellaria aequinoctialis	yes	2	4	4	5	15	40	15	2	4	6	4	10	25	15	80	20
Grey petrel	Procellaria cinerea	no											1	10	1		2	
Great shearwater	Puffinus gravis	yes				1			15	25	40	50			25	30	10	8
Sooty shearwater	Puffinus griseus	yes	100	25	2	16						40			10	10		
Subantarctic little shearwater	Puffinus elegans	no									1			15	6	10	10	
Common diving-petrel	Pelecanoides urinatrix	no								1								
Diving petrel sp.	Pelecanoides sp.	no									3	1						
Wilson's storm petrel	Oceanites oceanicus	yes												1	10	10	15	
White-bellied storm petrel	Fregatta grallaria	no													1	1		
Black-bellied storm petrel	Fregatta tropica	no	1		1	2	2	30	80	25	100	30	1	2	8	1		
King penguin	Aptenodytes patagonicus	no									1							
African jackass penguin	Spheniscus demersus	no																
Chinstrap penguin	Spheniscus antarctica	no						3*		2			1*					
Arctic tern	Sterna paraisaea	no					1											

Arctic/common tern	Sterna sp.	no																	
Kelp gull	Larus dominicanus	yes							2										
Subantarctic skua	Catharacta antarctica	yes							15						3			1	
Arctic skua	Stercorarius parasiticus	no															1		

FIGURES

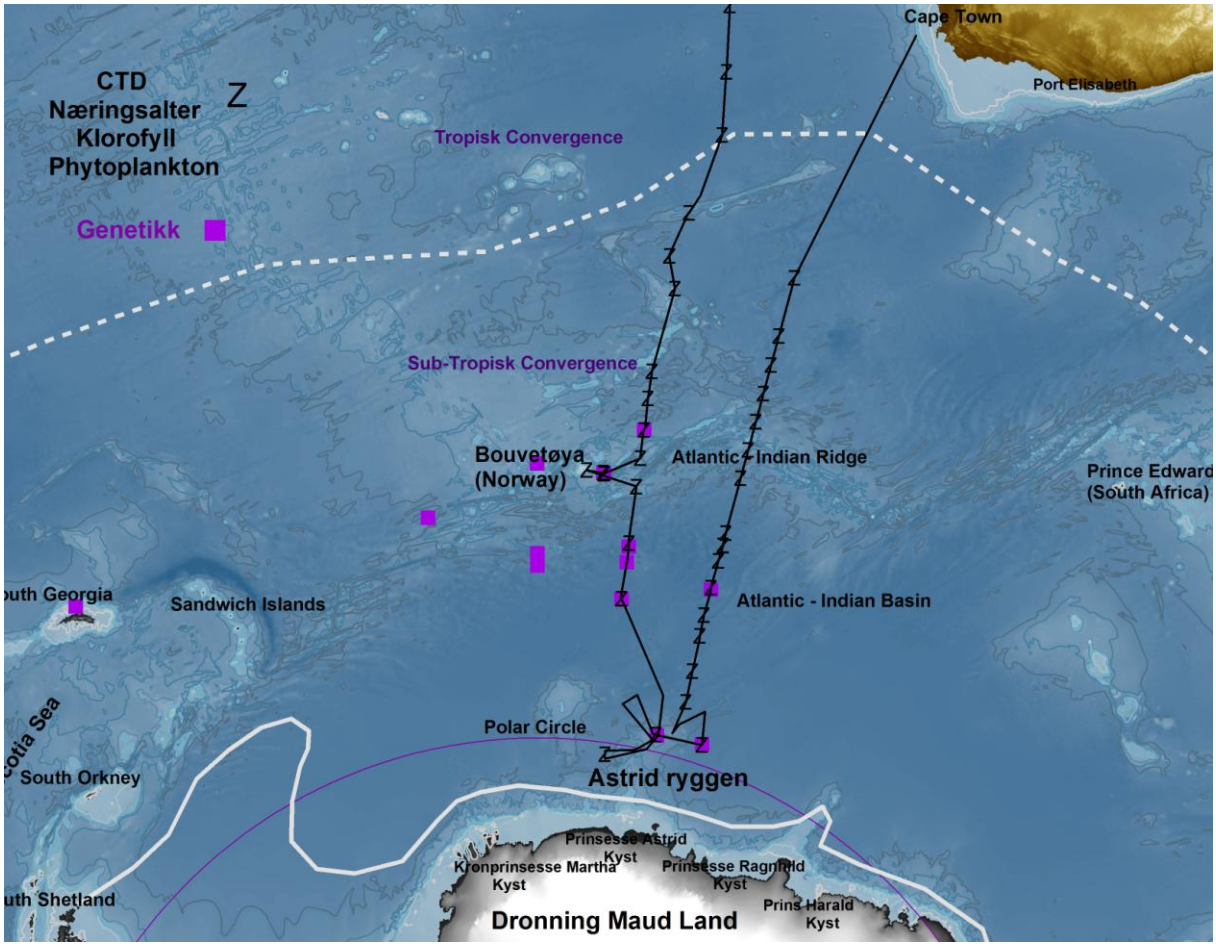


Figure 2. 1. Cruise route with sampling positions of CTD, nutrients, chlorophyll *a* and genetics.

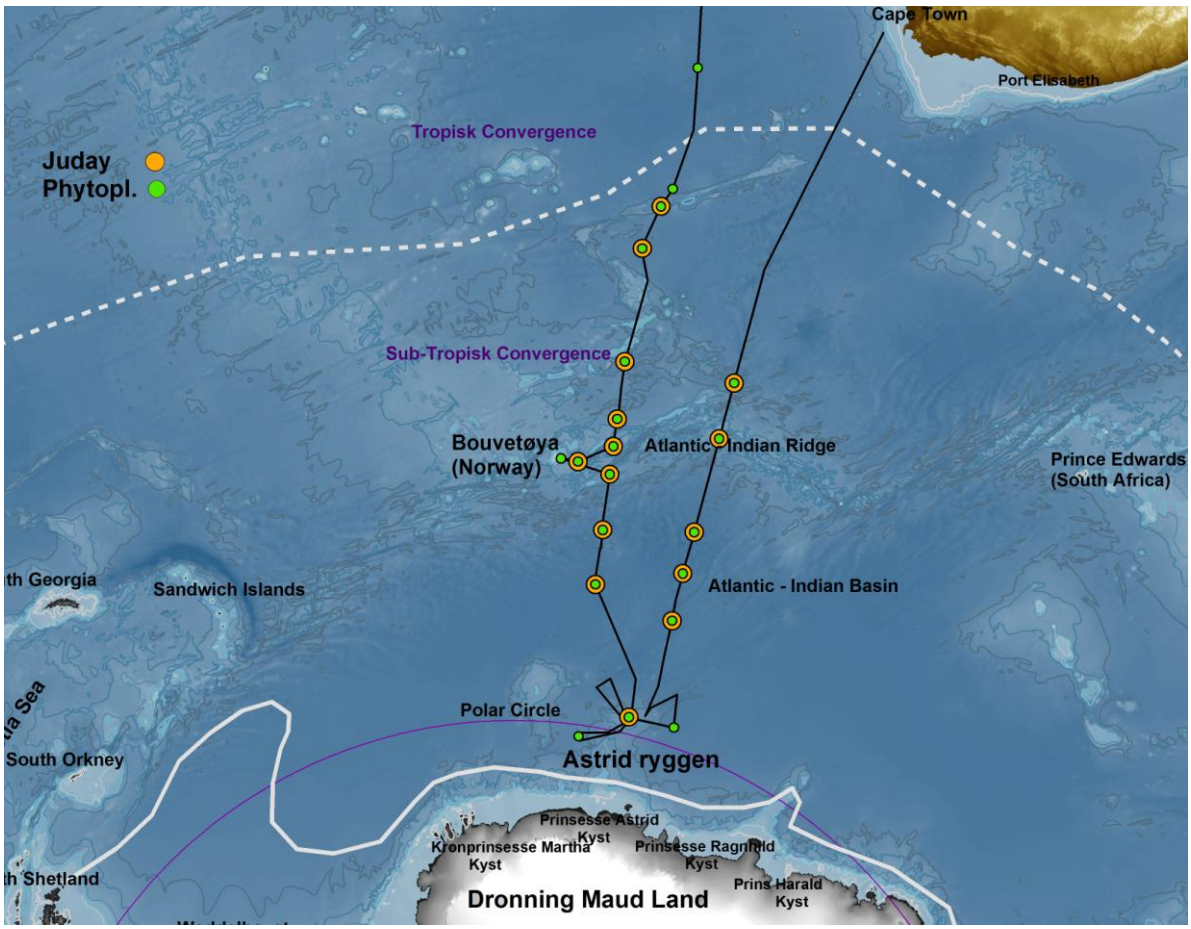


Figure 2. 2. Sampling positions of phytoplankton and Juday nets.

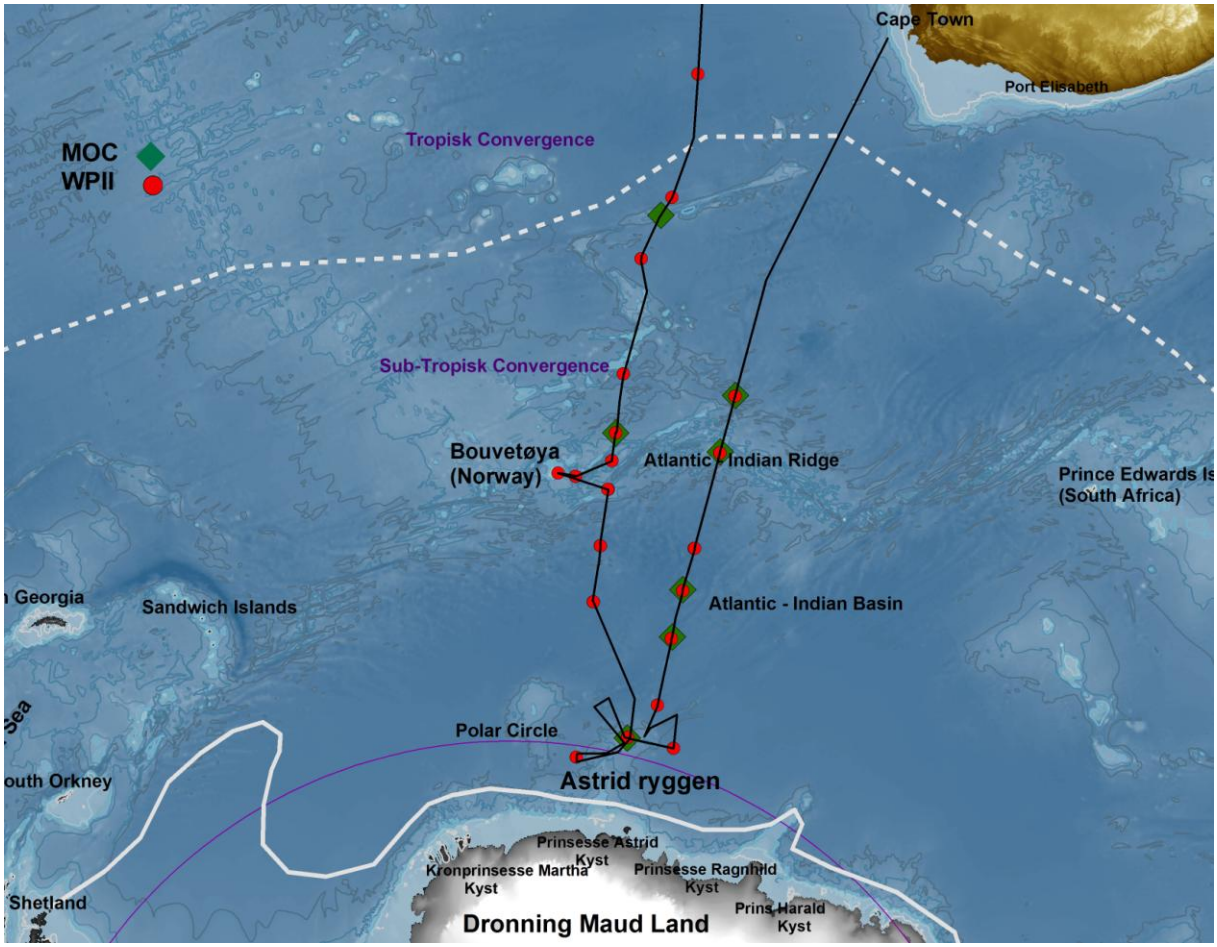


Figure 2.3. Sampling positions for mesozooplankton using MOCNESS and WP2 net.

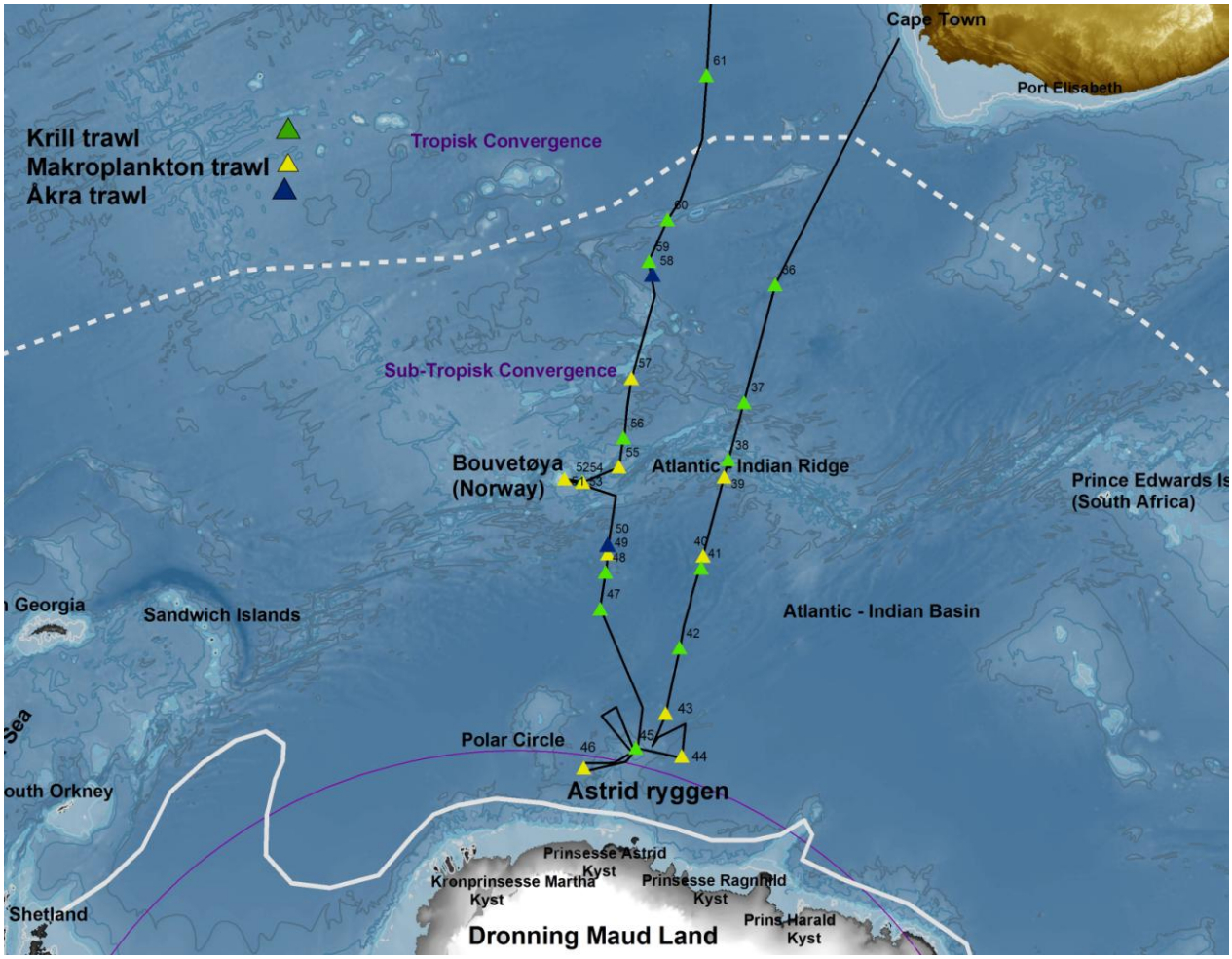


Figure 2.4. Positions for Krilltrawls, Makroplanktontrawls and Åkratrawls.

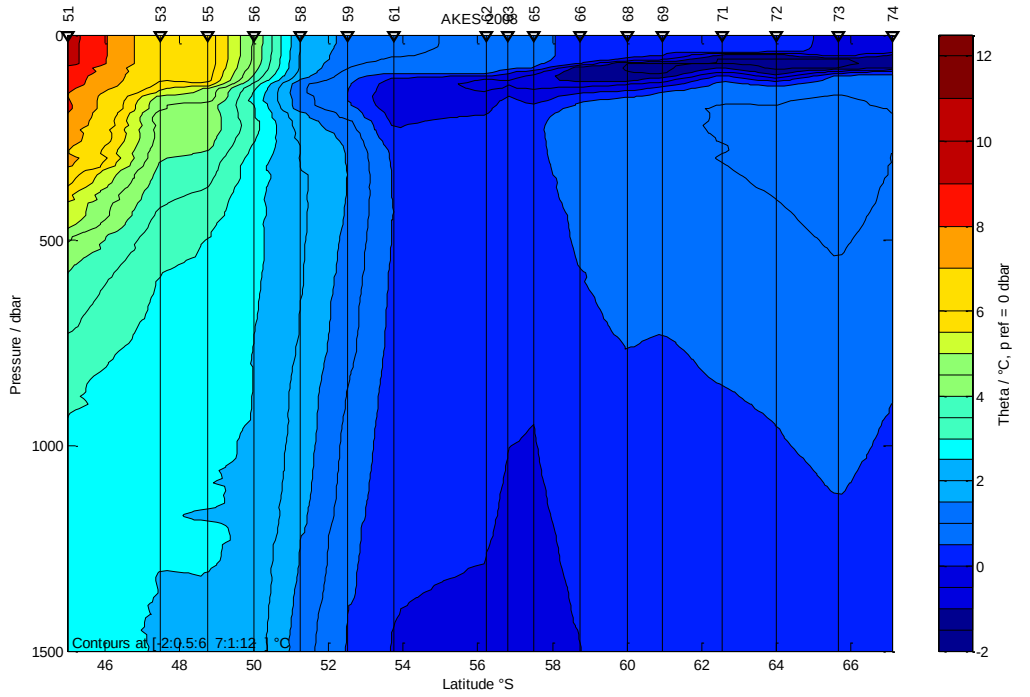


Figure 3.1 Section from north to south along the 15°E meridian showing potential temperature relative to the surface (sigma-□̃.

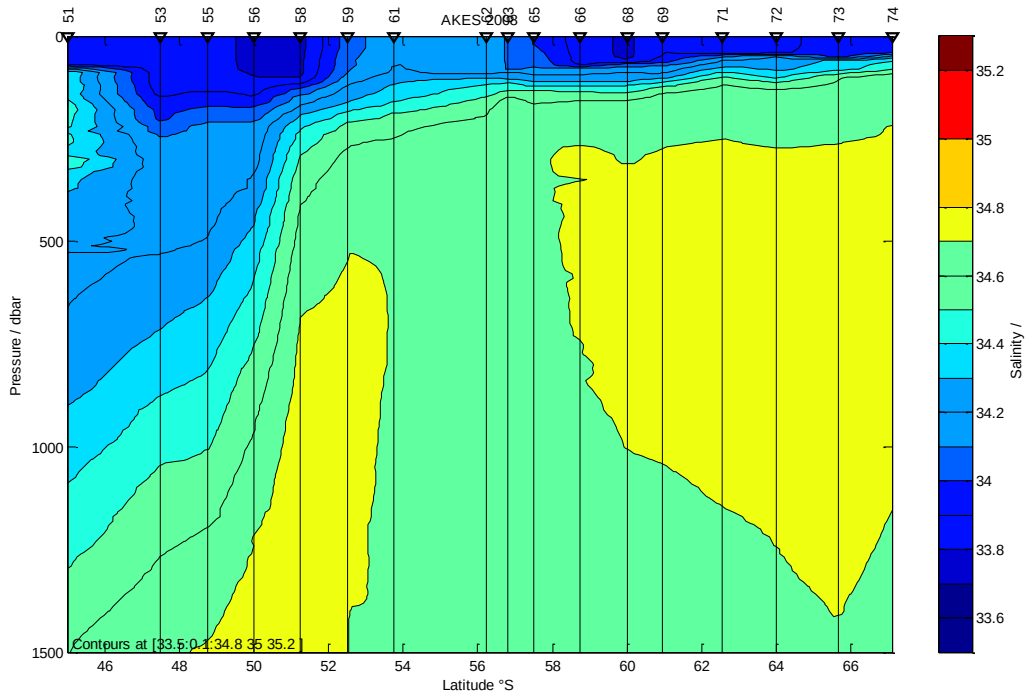


Figure 3.2 Section from north to south along the 15°E meridian showing salinitỹ

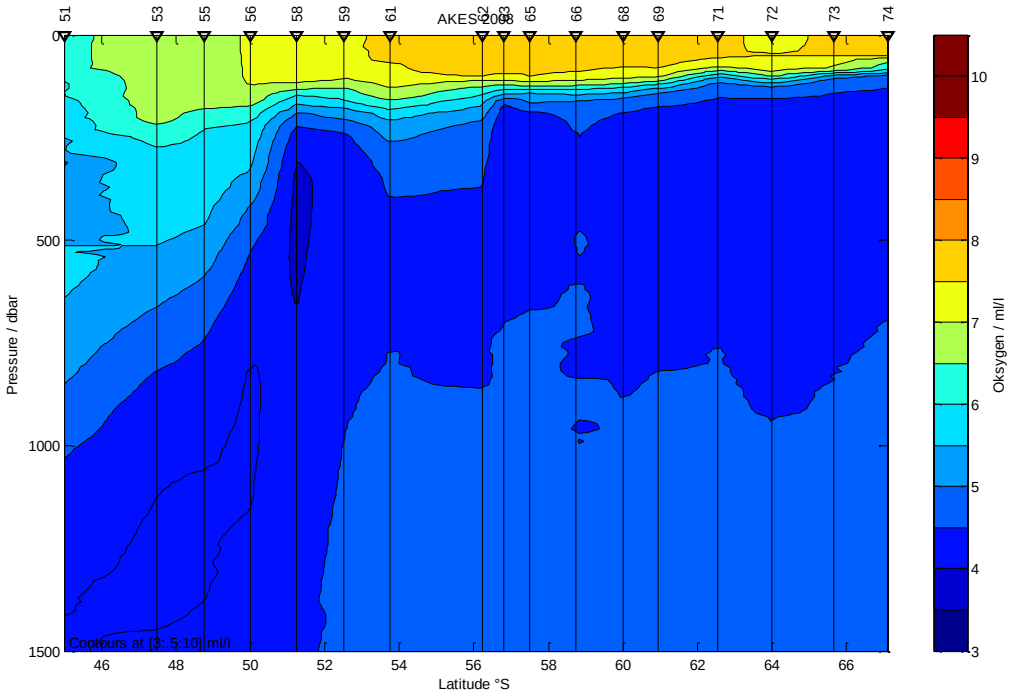


Figure 3.3 Section from north to south along the 15°E meridian showing oxygen

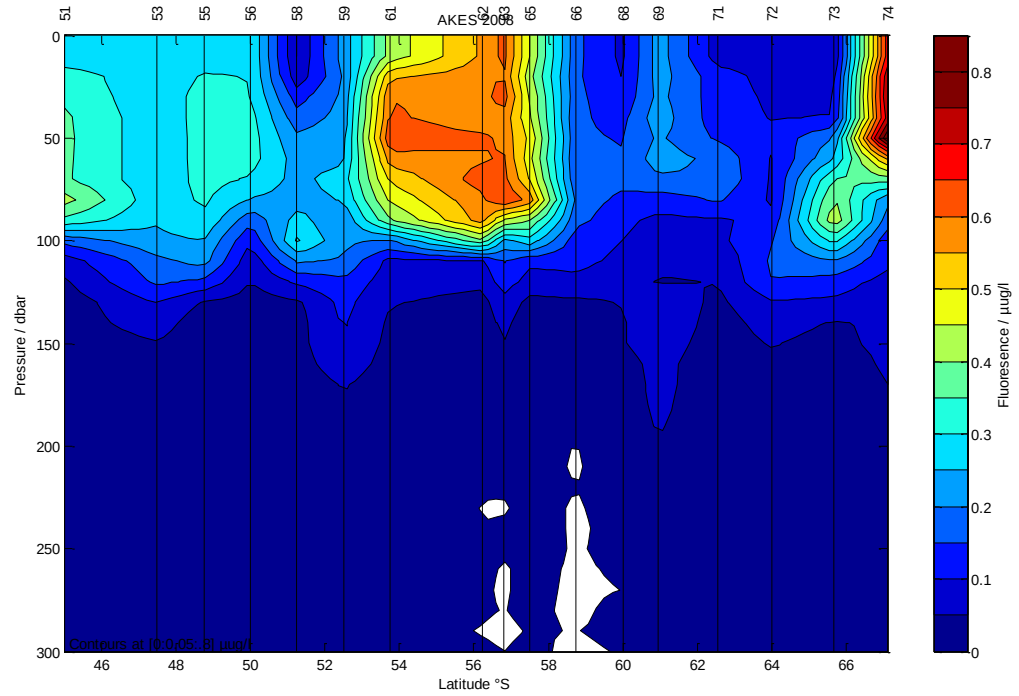


Figure 3.4 Section from north to south along the 15°E meridian showing fluorescence of the upper 300 m.

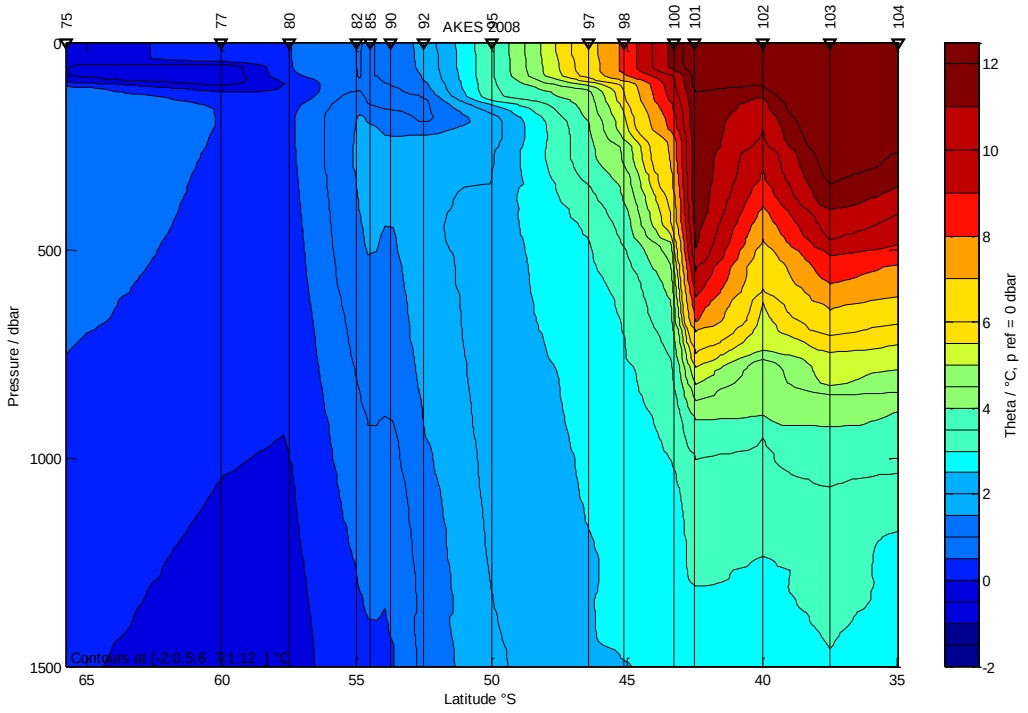


Figure 3.5 Section from north to south along the 7°E meridian showing potential temperature relative to the surface (sigma-□̃.

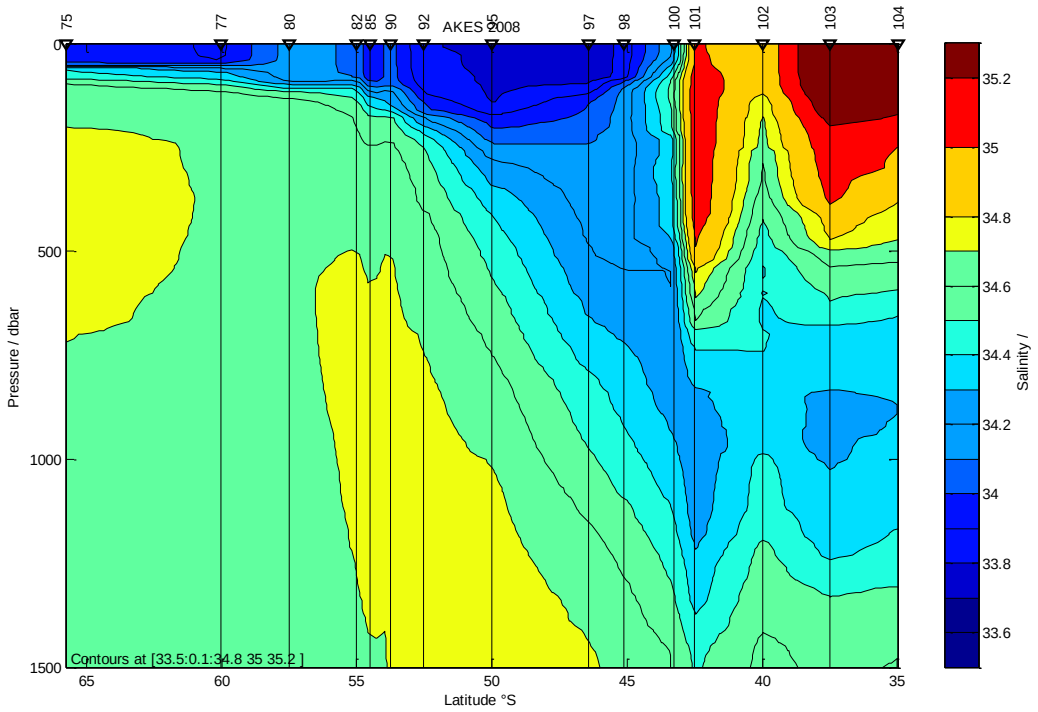


Figure 3.6 Section from north to south along the 7°E meridian showing salinitỹ

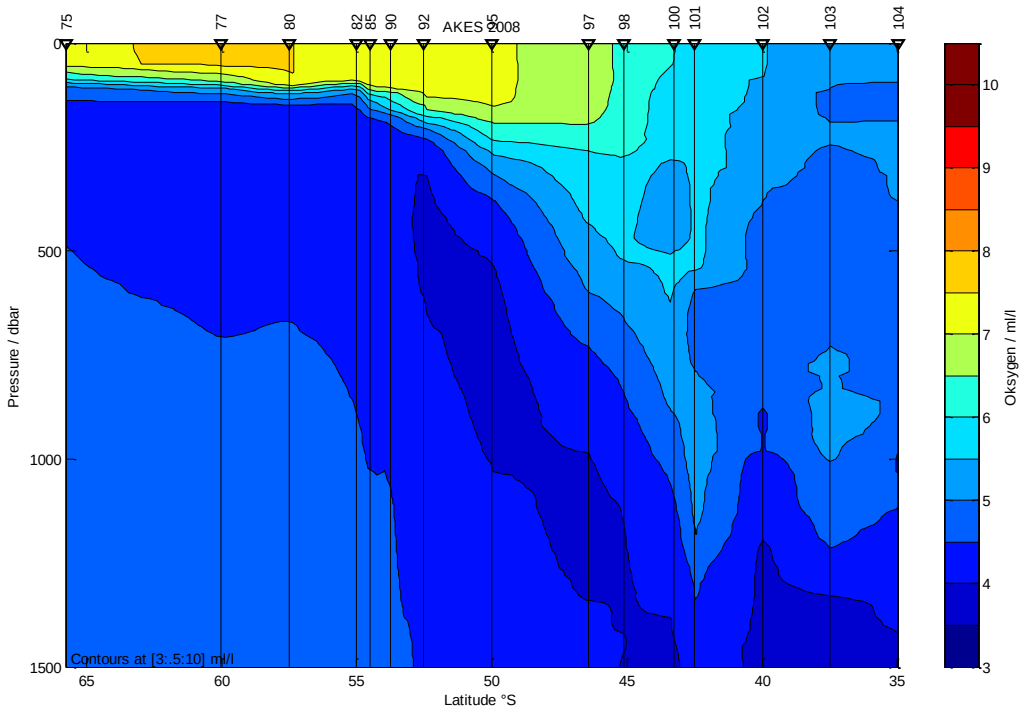


Figure 3.7 Section from north to south along the 7°E meridian showing oxygen

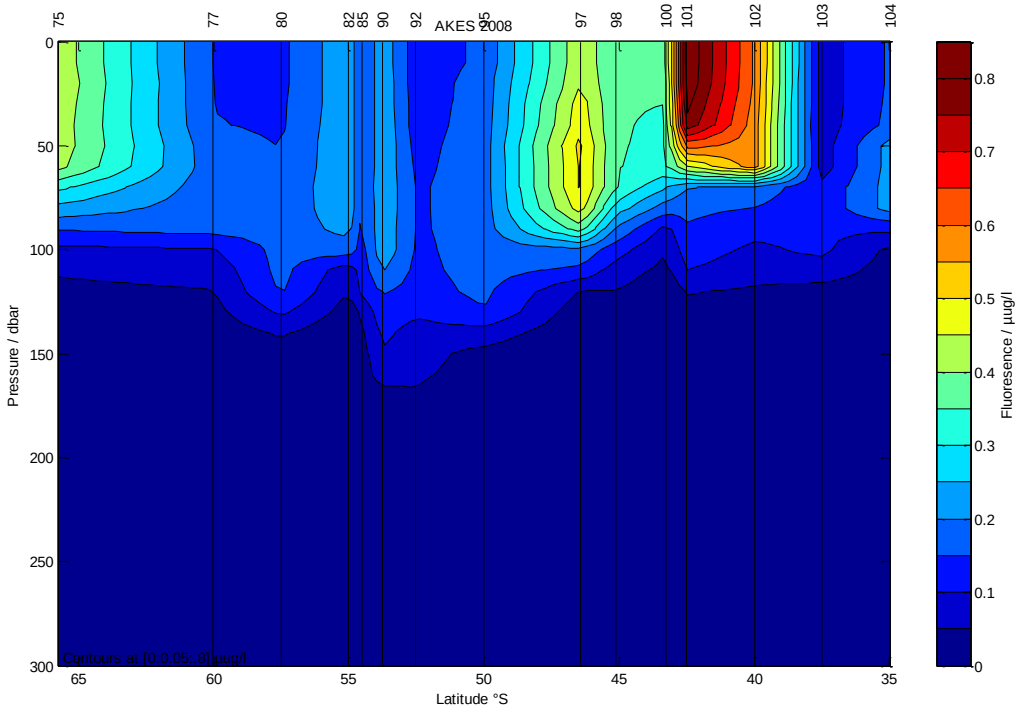


Figure 3.8 Section from north to south along the 7°E meridian showing fluorescence of the upper 300 m.

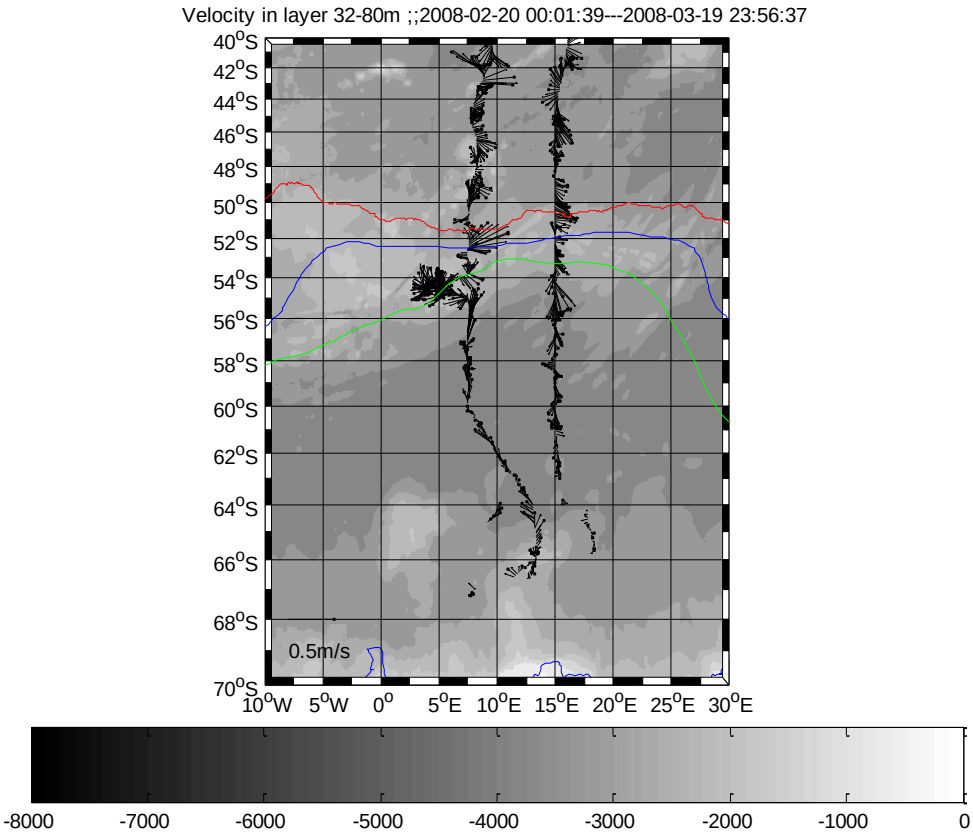


Figure 3.9 Large-scale overview of horizontal currents from the shipboard ADCP- 75kHz.

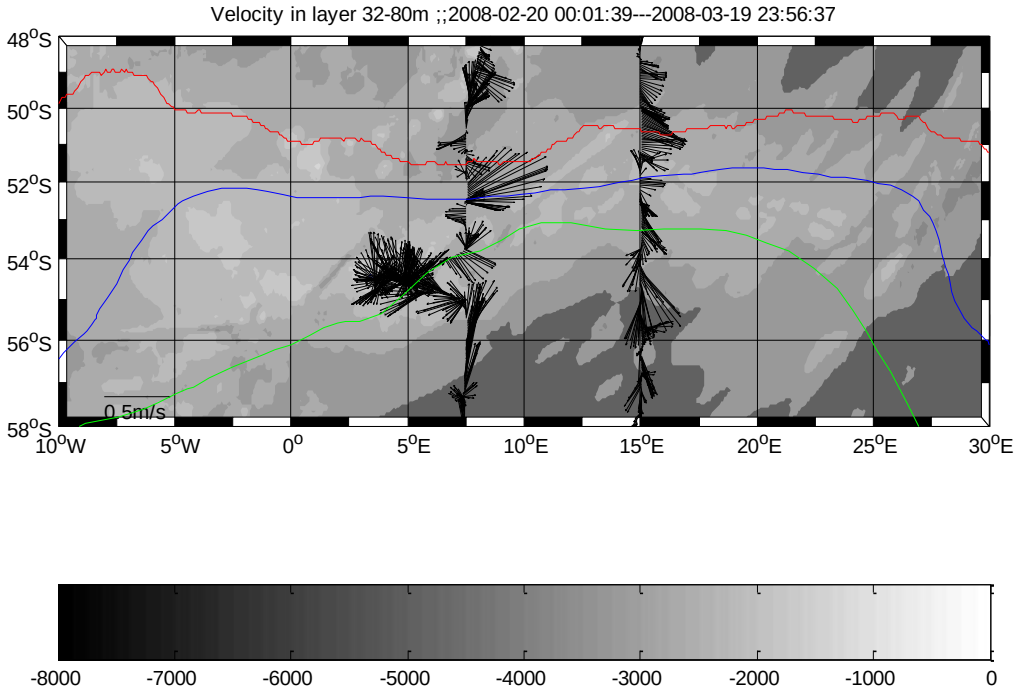


Figure 3.10 Blow up of the horizontal currents in the main frontal region from the shipboard ADCP- 75kHz.

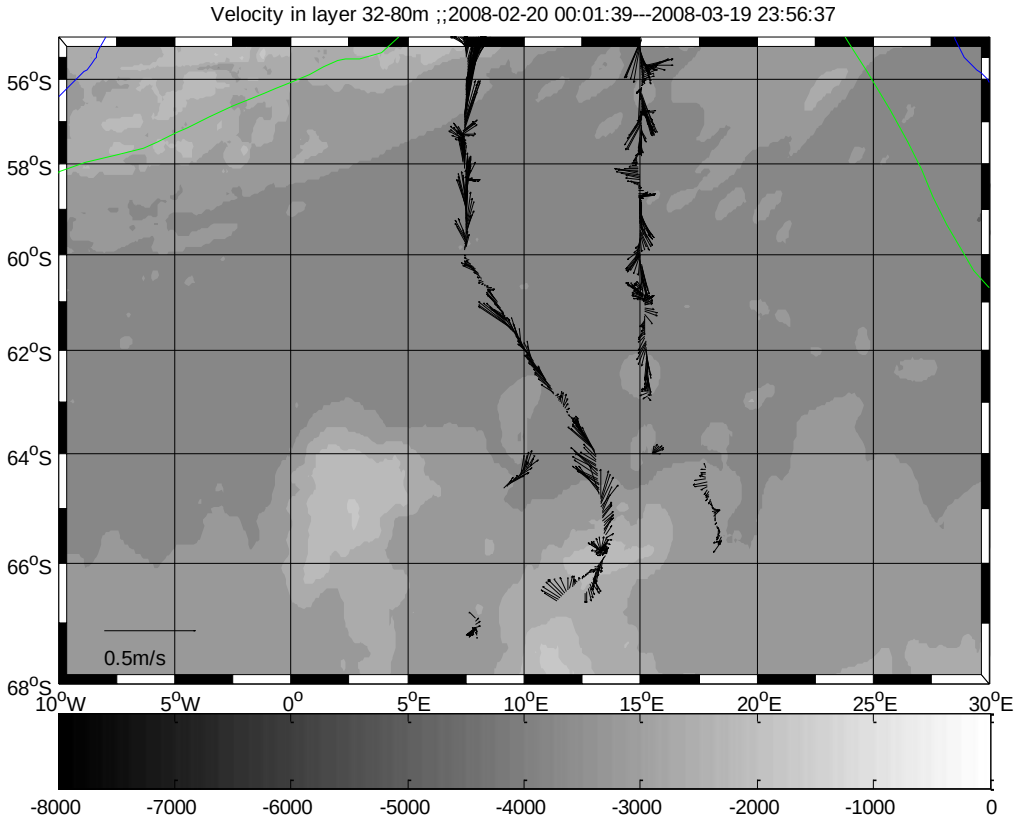


Figure 3.11 The horizontal currents in the southern region from the shipboard ADCP- 75kHz.

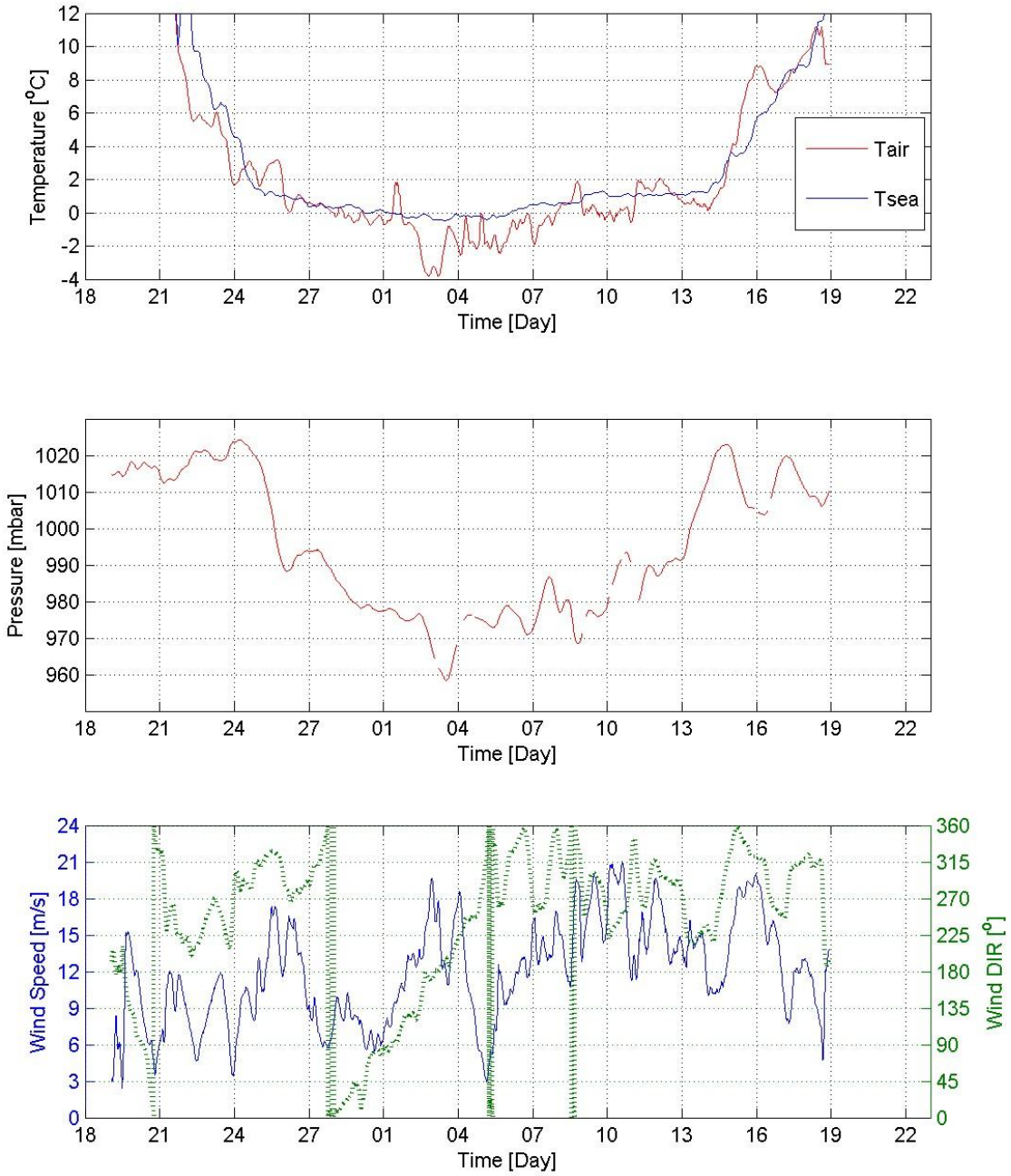


Figure 3.12 Meteorological measurements from the GO Sars during the Akes cruise from 18th Feb - 19th March 2008.

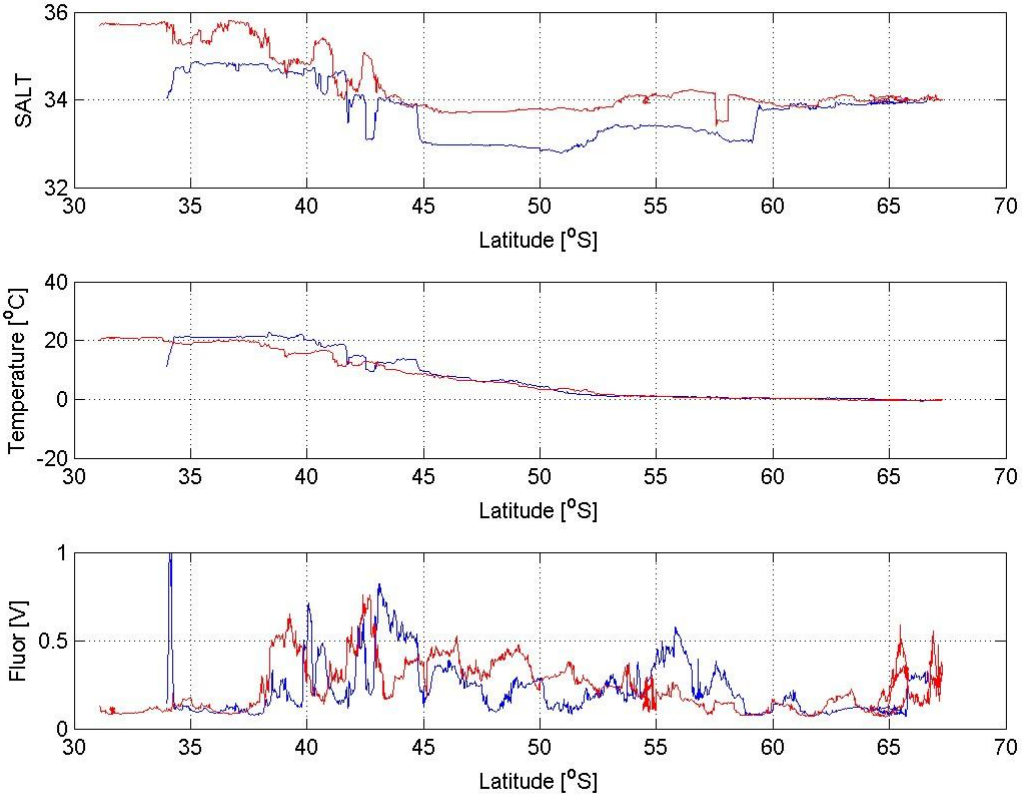
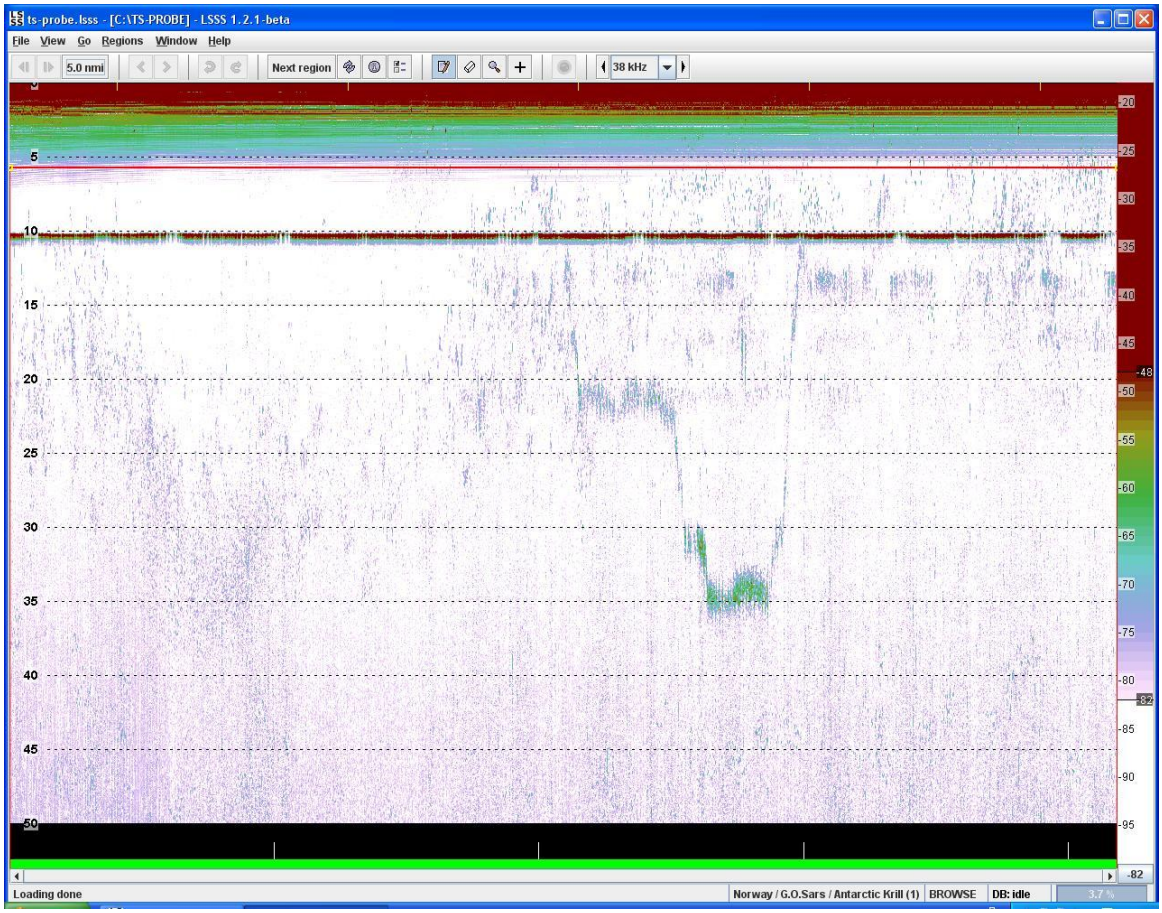


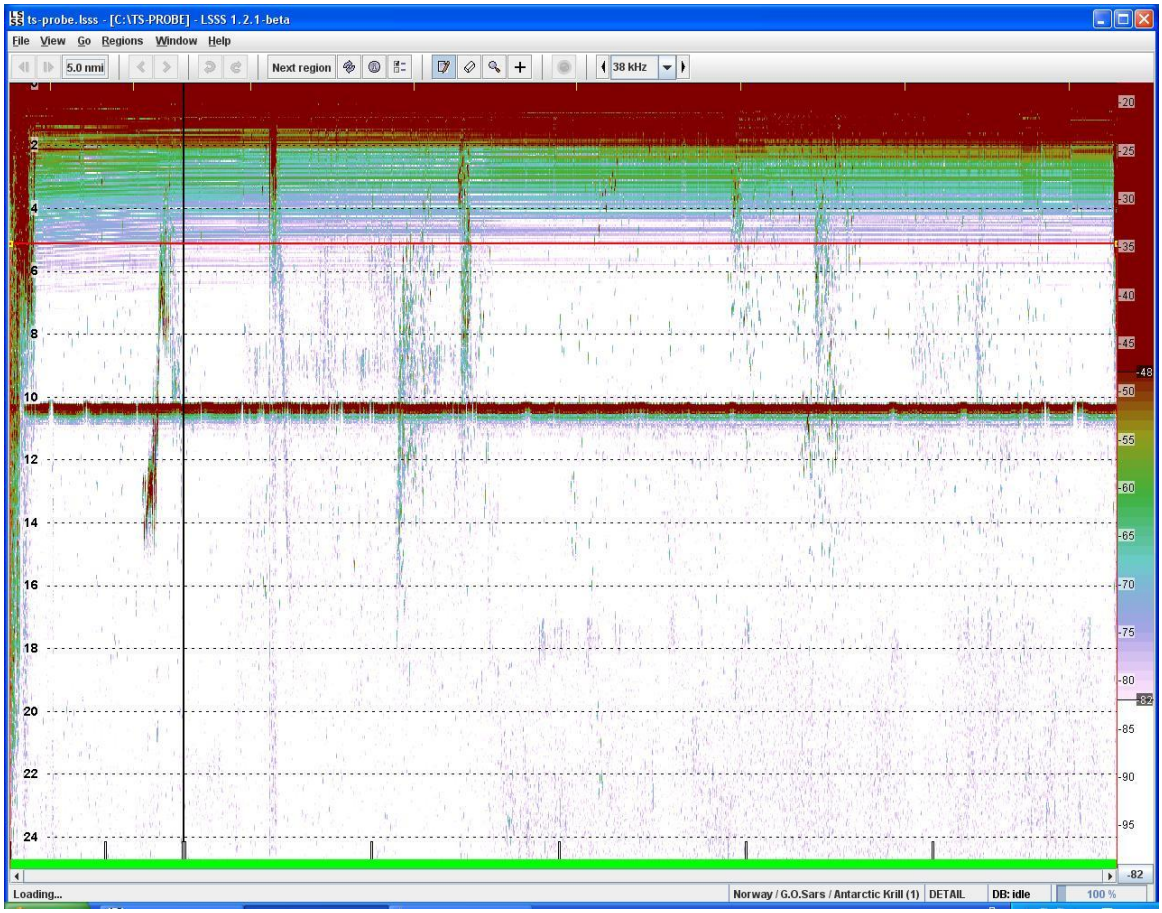
Figure 3.13 Data from the GO Sars thermosalinograph showing a) salinity b) temperature, and c) fluorescence. Blue show data from the section toward south, and red denotes data from the section toward north. Note that for salinity there was an offset in the data at the southward section, probably due to accumulation of biological species in the salinity sensor. The system was stopped and cleaned at 27 Feb. 2007 at 59°N. These data will be compared with the corrected salinity data from the CTD-profiles when calibrations of these are performed.

TS Probe:



Station 1 - 11.03.08
During daylight. Only Salps. Several good pictures on both cameras.

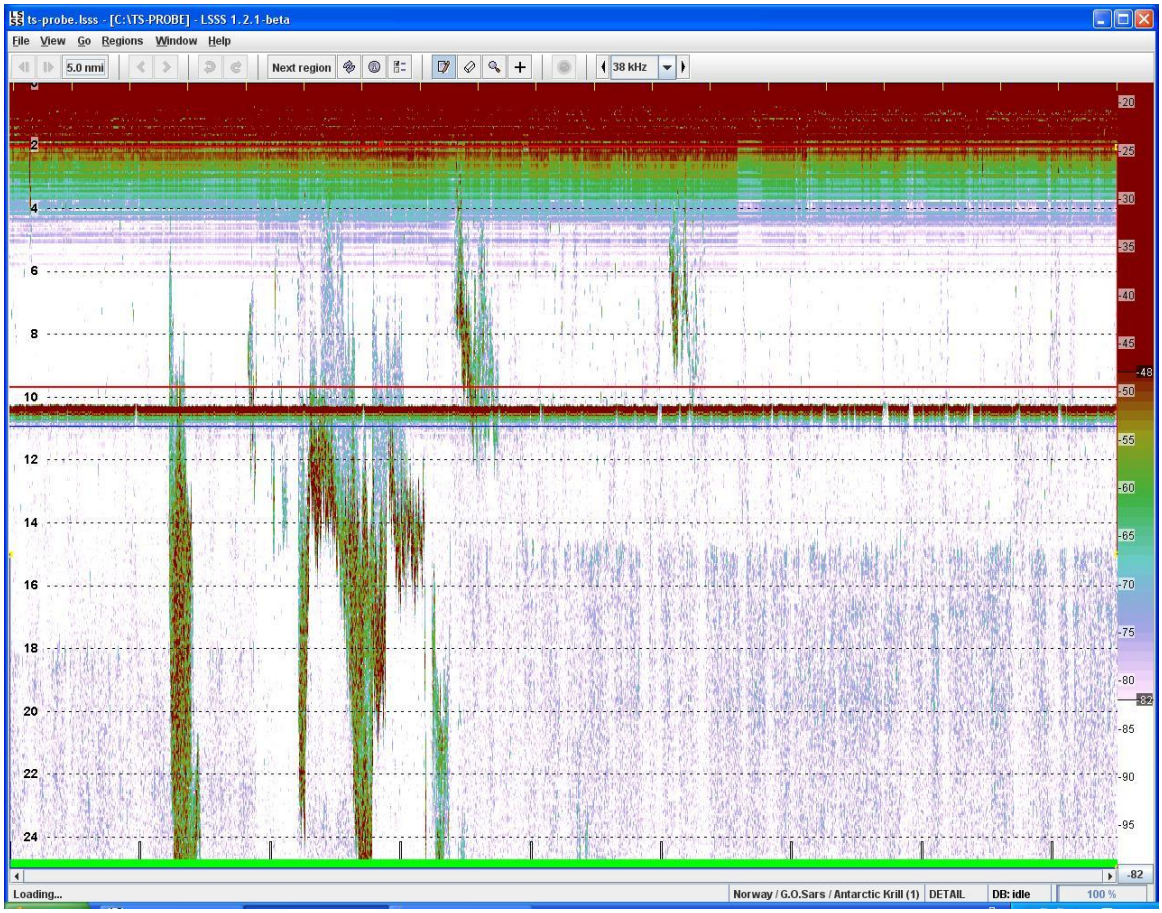
Figure 4.1. TS- Probe Data Sampling Stations Report



Station 2 - 12.03.08

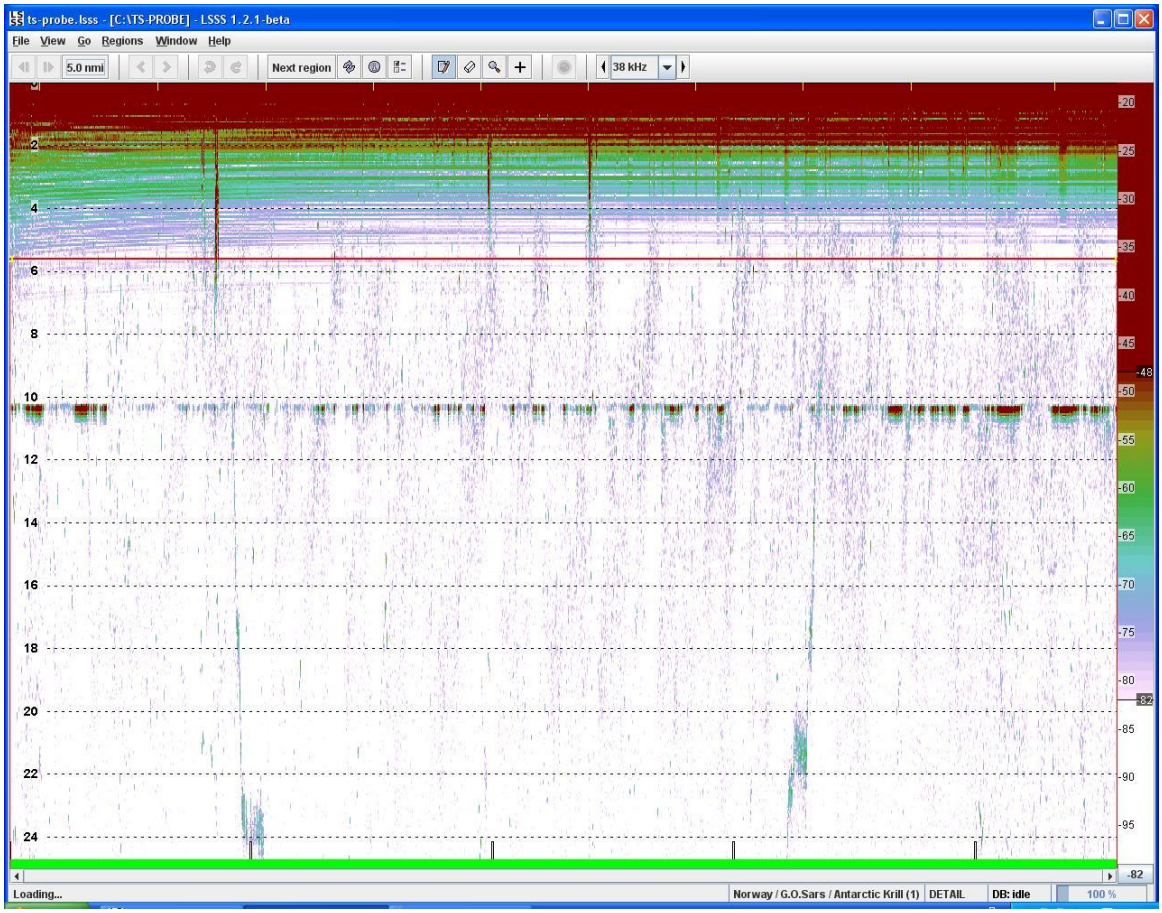
After darkness. Dense Krill schools. Some Salps. Good pictures.

Figure 4.1. Continued



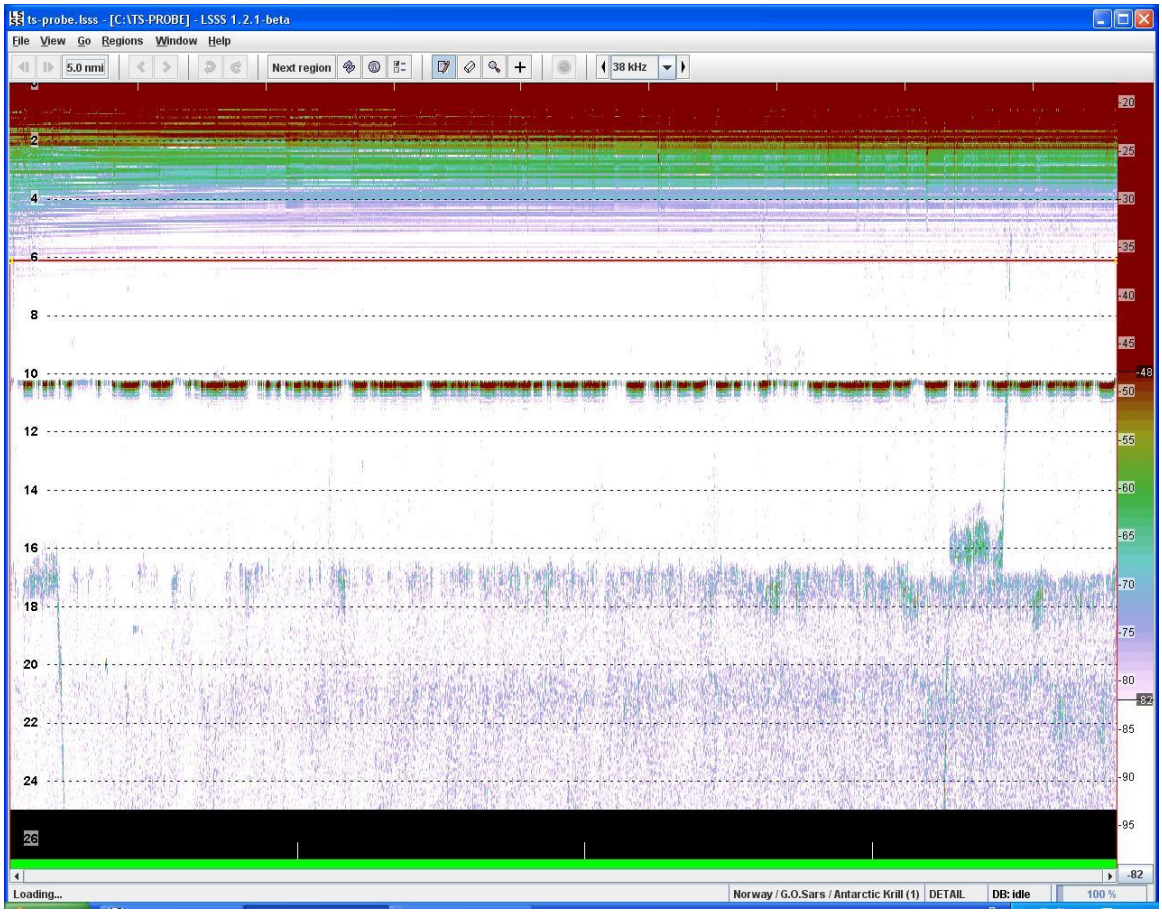
Station 3 - 12.03.08
During night. Dense and scattered Krill schools. Some Salps and Jellyfish. Some good pictures. Problem with flash. Probably too short time between the shootings for the flash-battery to recharge.

Figure 4.1. Continued



Station 4 - 13.03.08
From daylight to darkness. Only Salps. Many splendid Salp pictures.
Flash worked better this time.

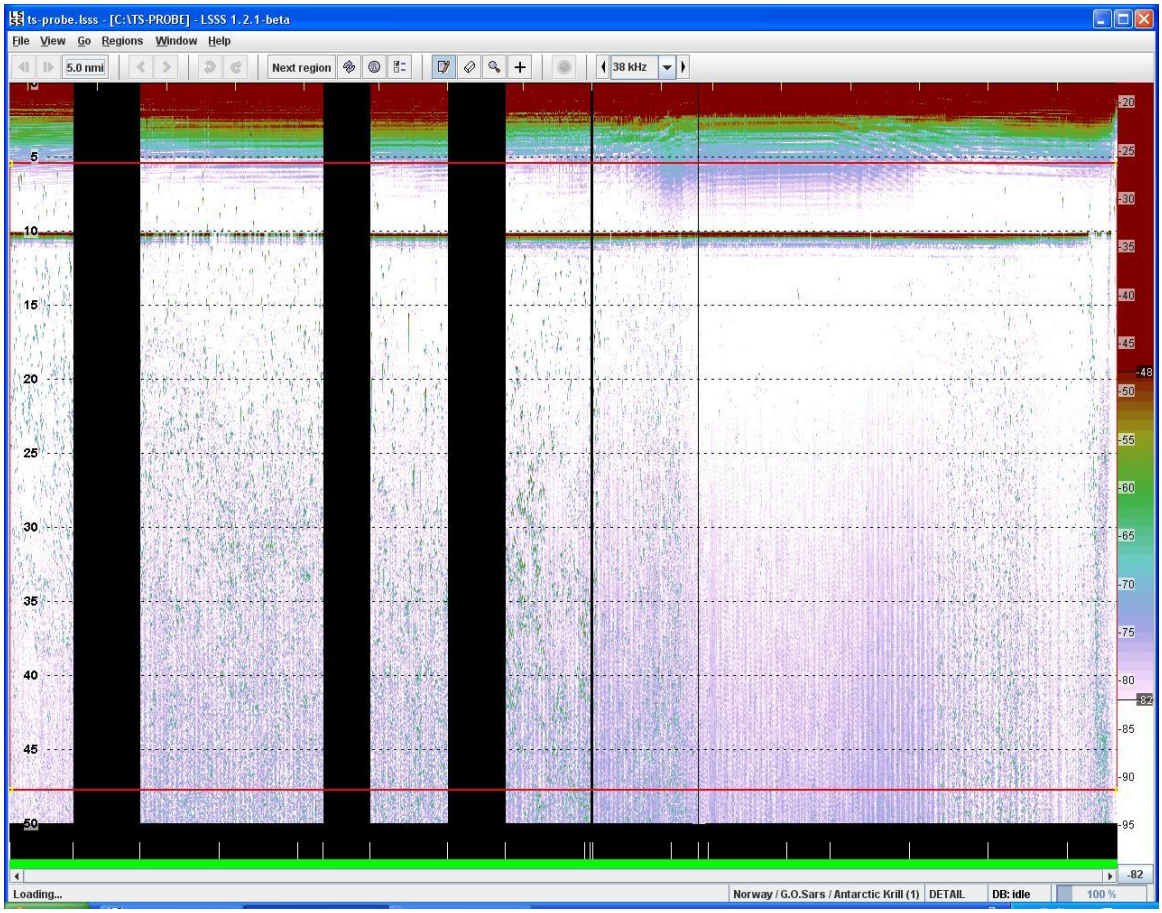
Figure 4.1. Continued



Station 5 - 14.03.08

Daytime. No good registrations either on echosounder nor cameras.

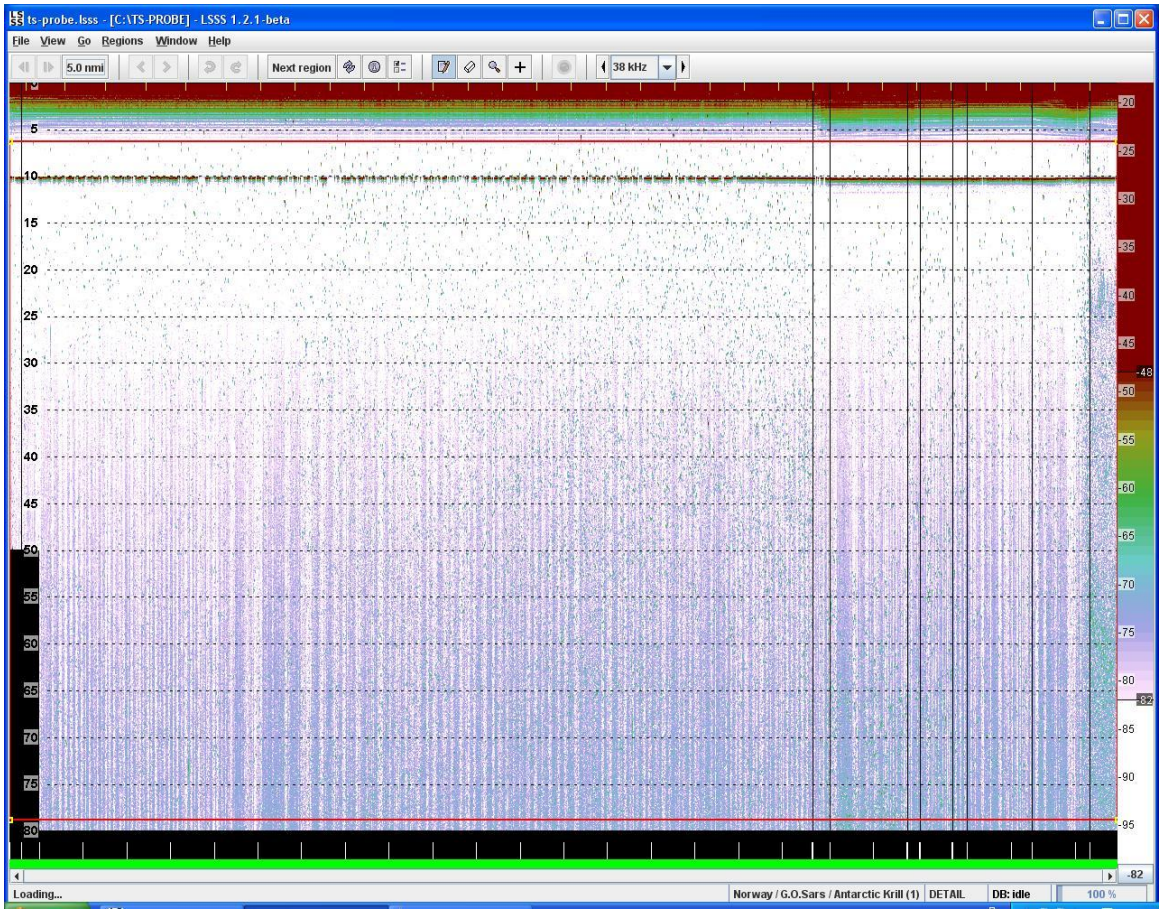
Figure 4.1. Continued



Station 6 - 17.03.08

Daytime. TS-Probe down to 1200 meters. New record ! Nothing on the pictures.

Figure 4.1. Continued



Station 7 - 17.03.08
From daylight to darkness. Many pictures, but nothing on them.
Flash problems again.

Station 8 - 23.03.08
Daylight. At Vema Seamount. Few pictures, some of them with unknown
fish species, probably Mackerel family. Good echosounder registrations.

More details of each station can be found in: TS-PROBE-DATA-LOG-2008001.DOC

Figure 4.1. Continued

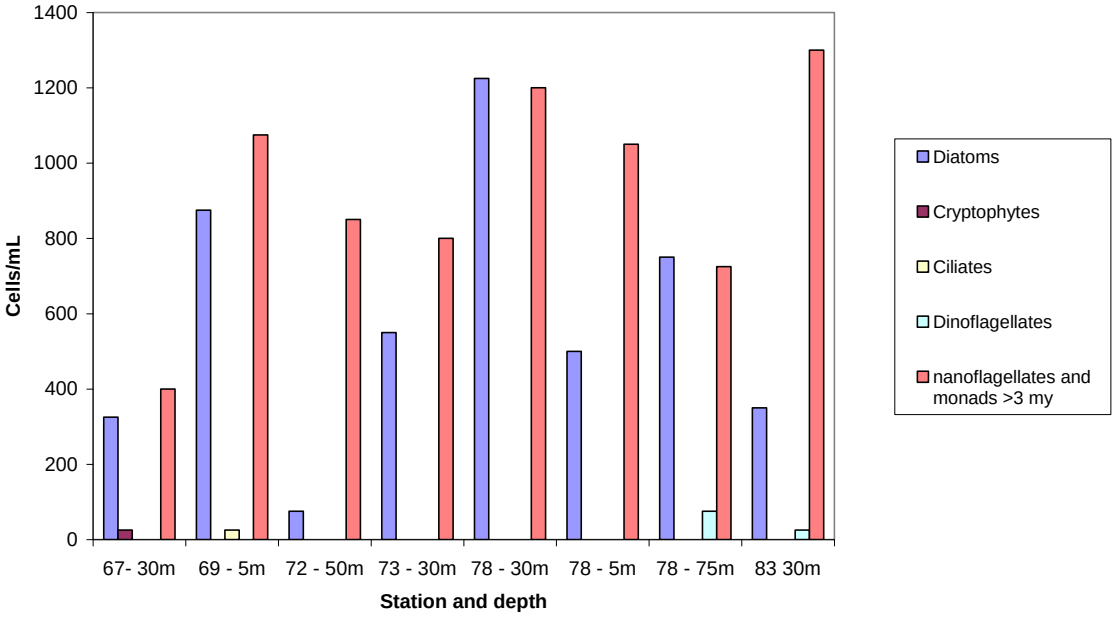


Figure 6.1. Preliminary phytoplankton abundances at a selection of stations and depths by cell counts in a small subsample.

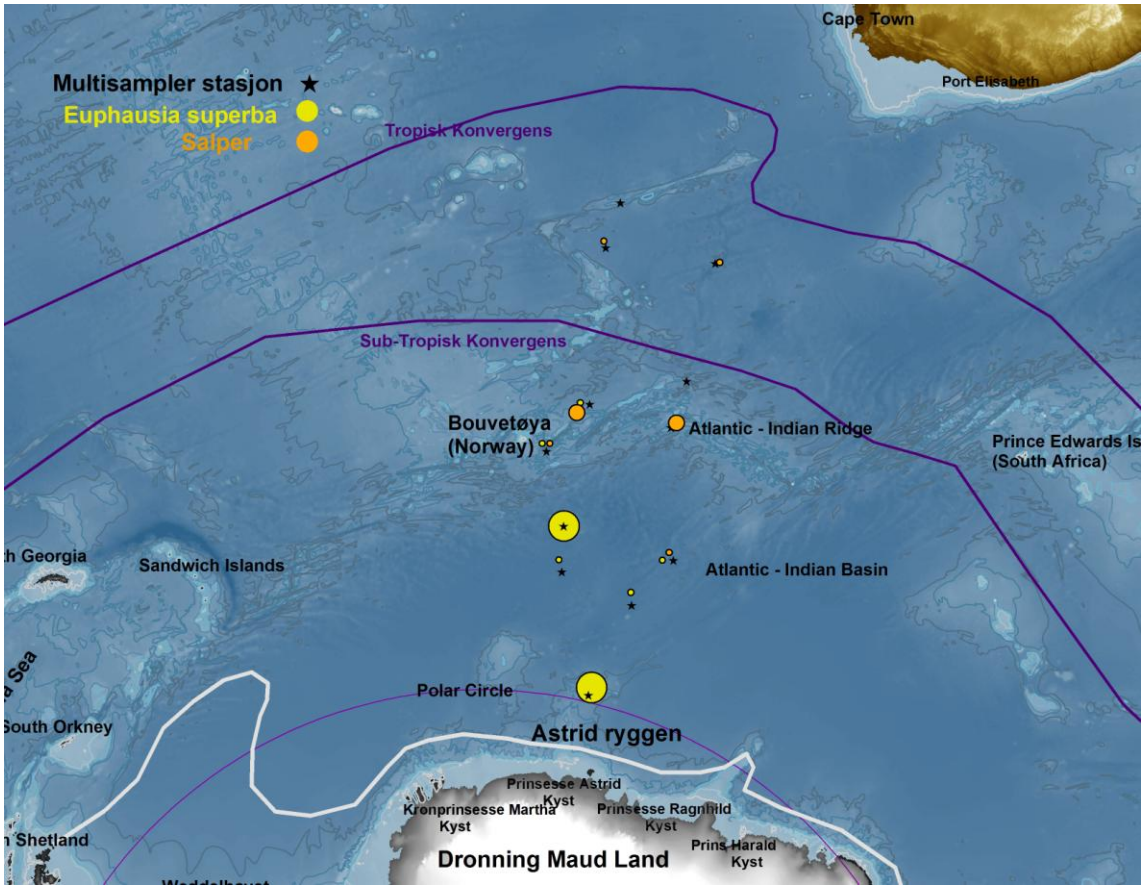


Figure 7.1. Estimated abundances of *Euphausia superba* and salps . Circle-size indicates abundance per square meter surface (within 750 -10 m depth). The sizegroups are divided into 6 categories: 0-10 g, 10-20, …, 50-60 g m^{-2}. Note that only the two extreme size-classes are represented in the figure. For more detailed information see Table 4.

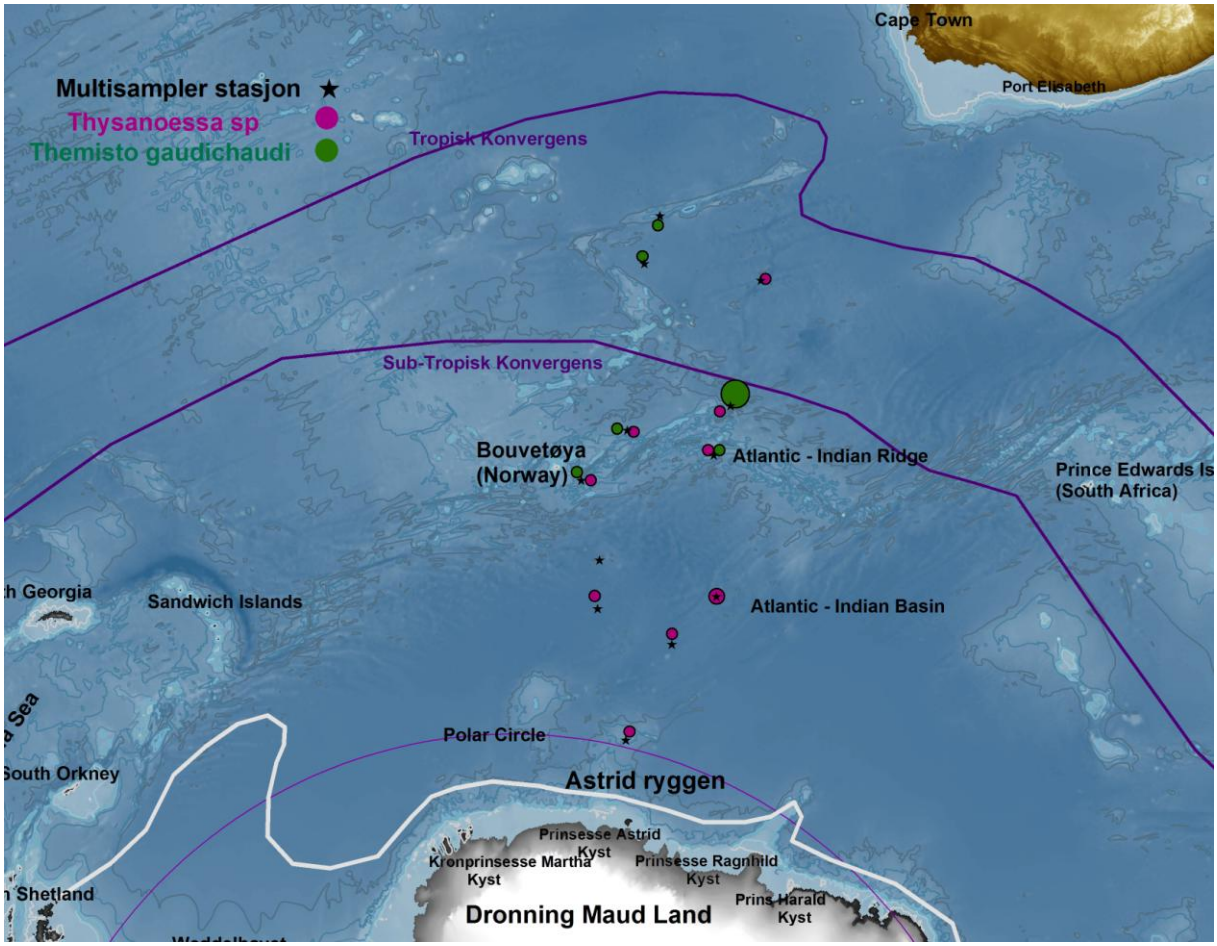


Figure 7.2. Estimated abundances of *Thysanoessa* sp. and *Themisto gaudichaudii* . Circle-size indicates abundance per square meter surface (within 750 -10 m depth). The sizes are divided into 3 categories, 0-1, 1-2, and 2-3 g m^{-2}. For more detailed information see Table 4.

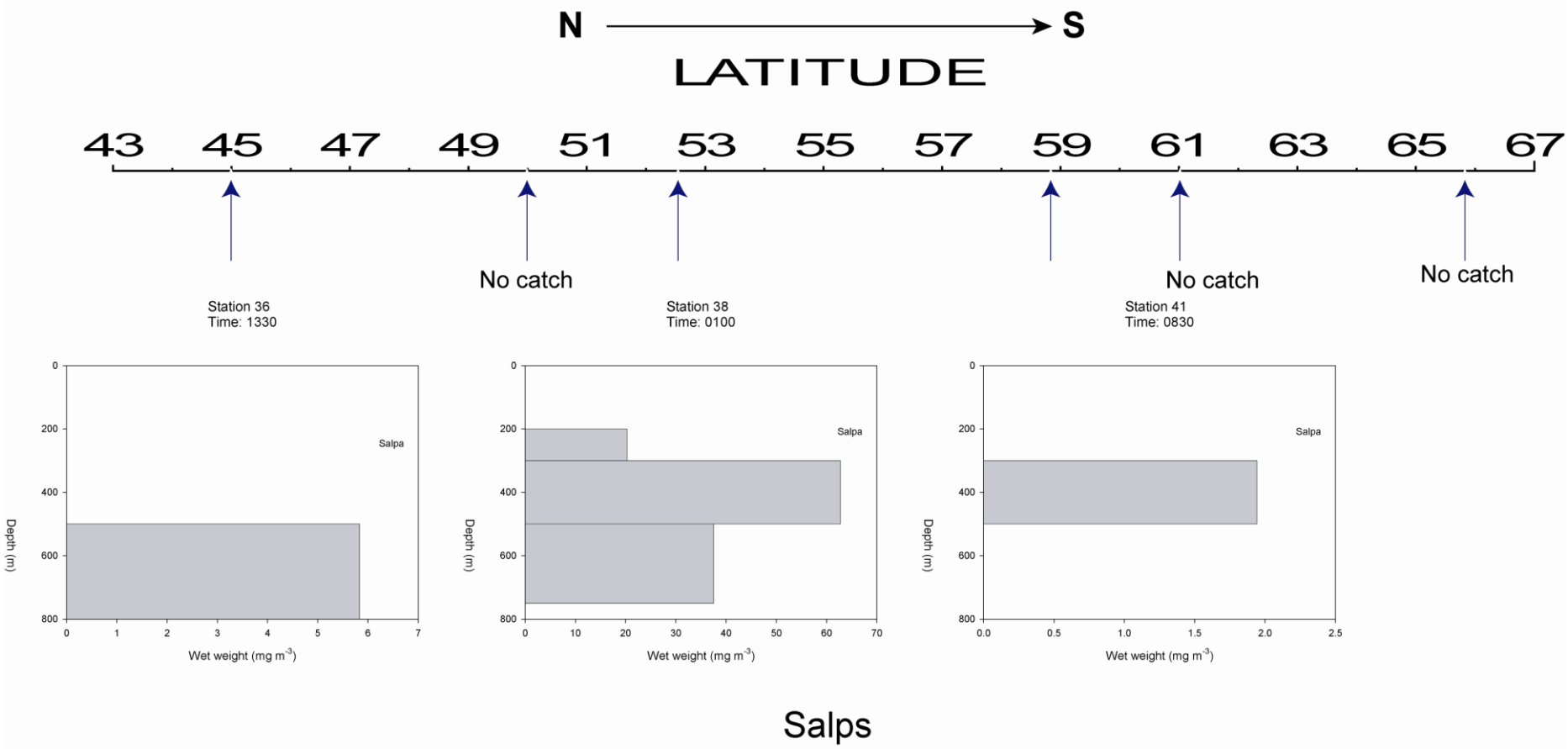


Figure 7.3 A. Vertical distribution of salps based on Krill trawl catches with Multisampler. Southward transect at 15° E.

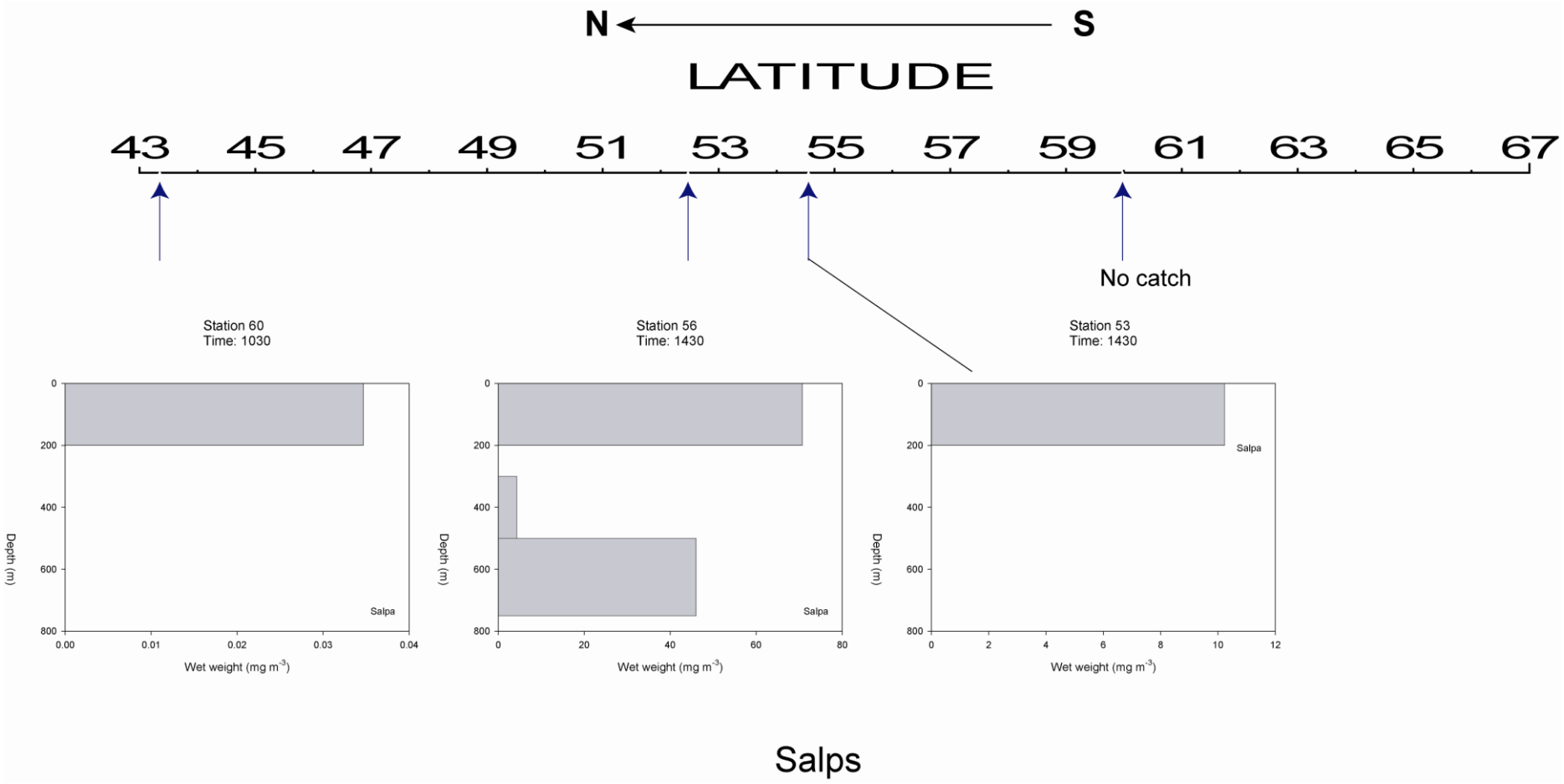


Figure 7.3 B. Vertical distribution of salps based on Krill trawl catches with Multisampler. Northward transect at 7° 30´ E.

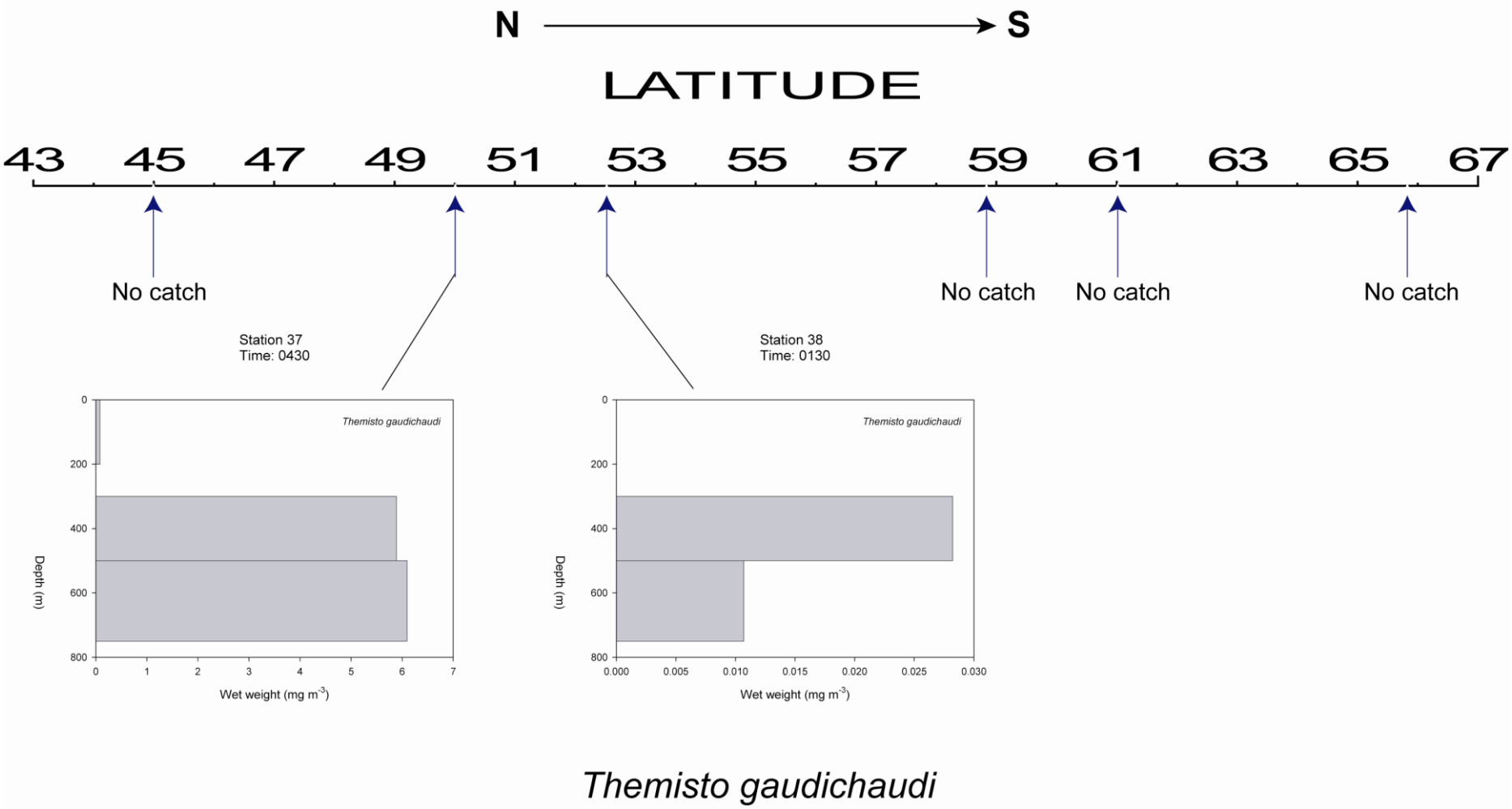


Figure 7.4 A. Vertical distribution of *Themisto gaudichaudii* based on Krill trawl catches with Multisampler. Southward transect at 15° E.

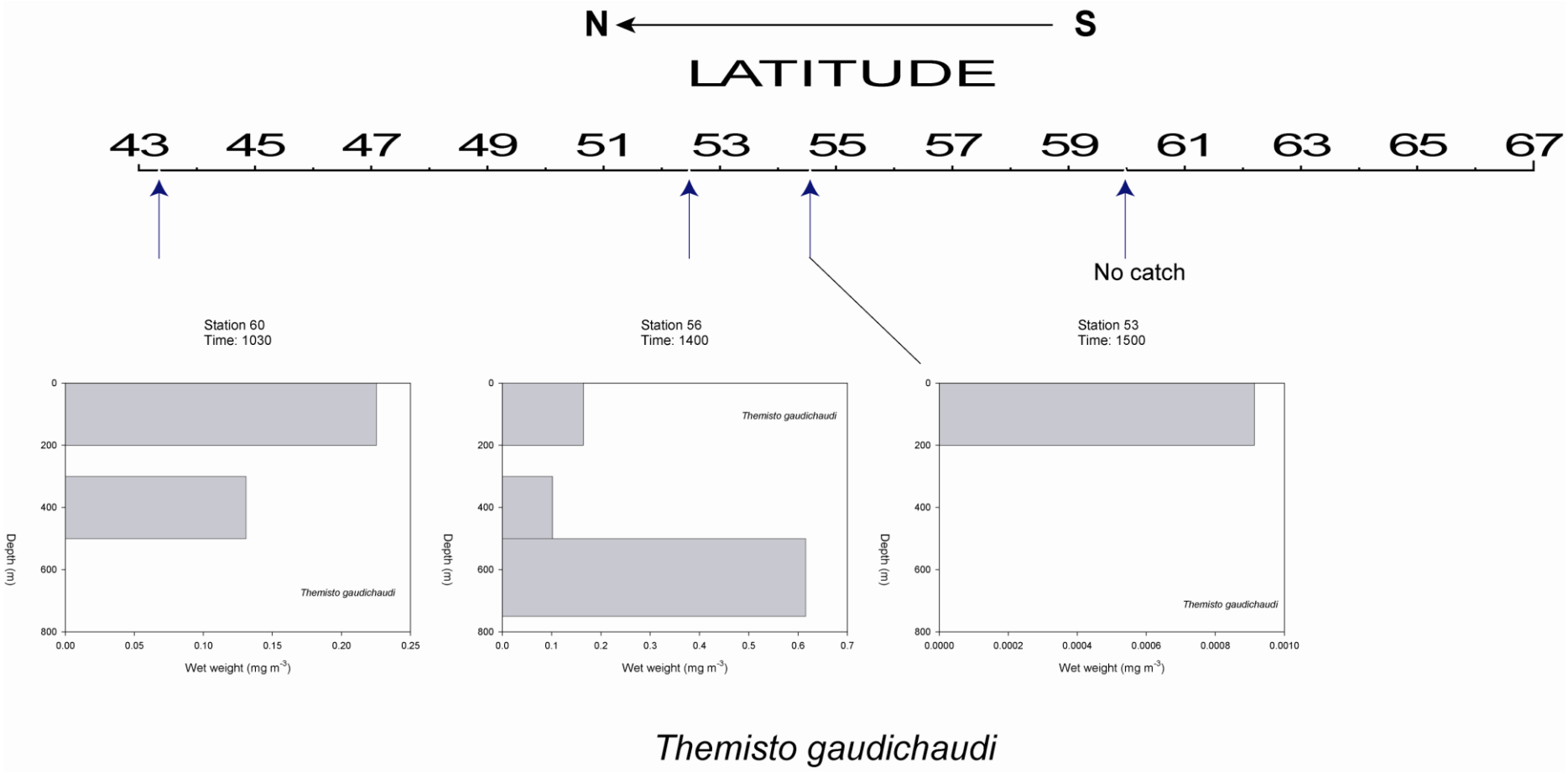
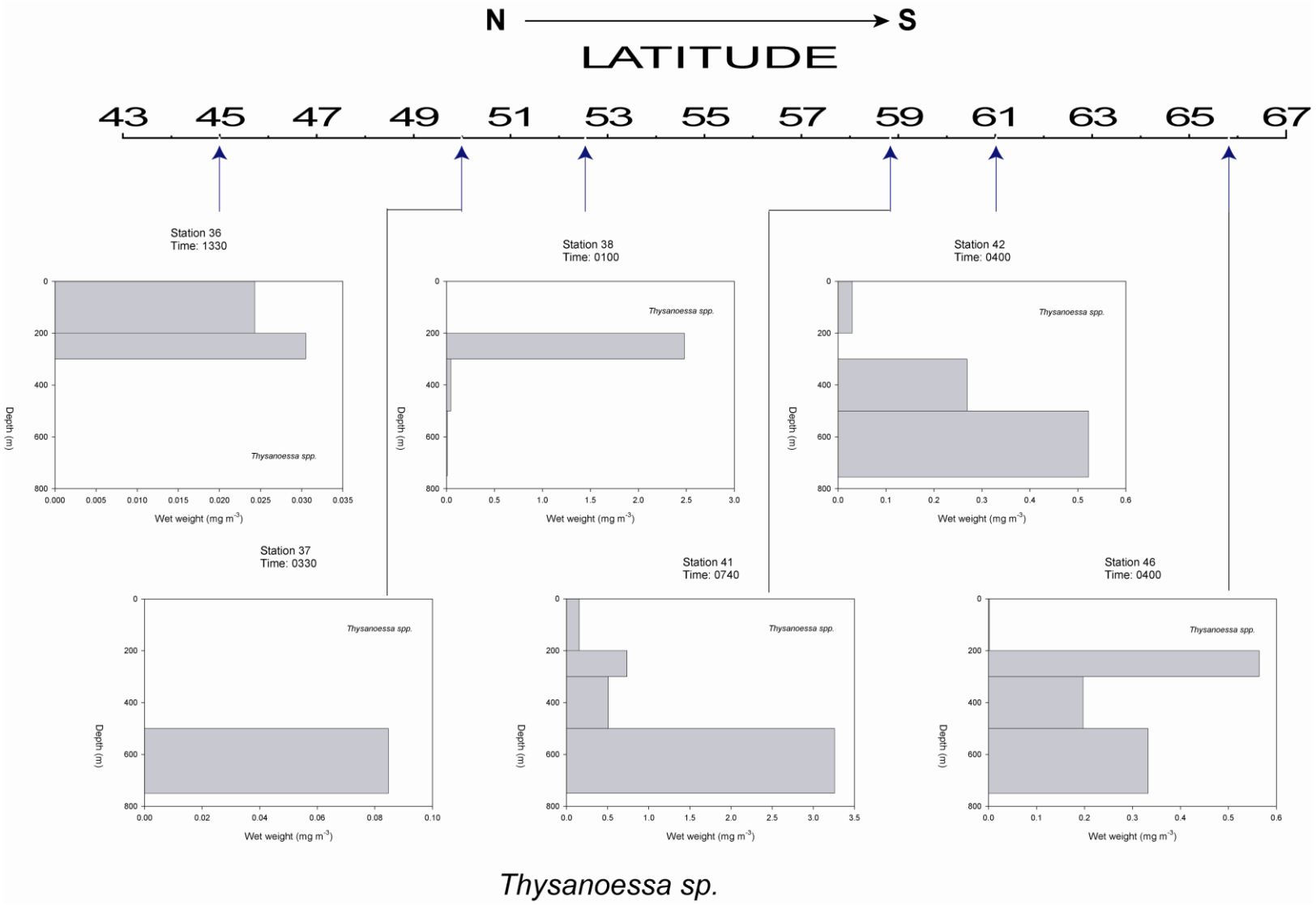


Figure 7.4 B. Vertical distribution of *Themisto gaudichaudii* based on Krill trawl catches with Multisampler. Northward transect at 7° 30´ E.



Thysanoessa sp.

Figure 7.5 A. Vertical distribution of *Thysanoessa spp.* based on Krill trawl catches with Multisampler. Southward transect at 15° E.

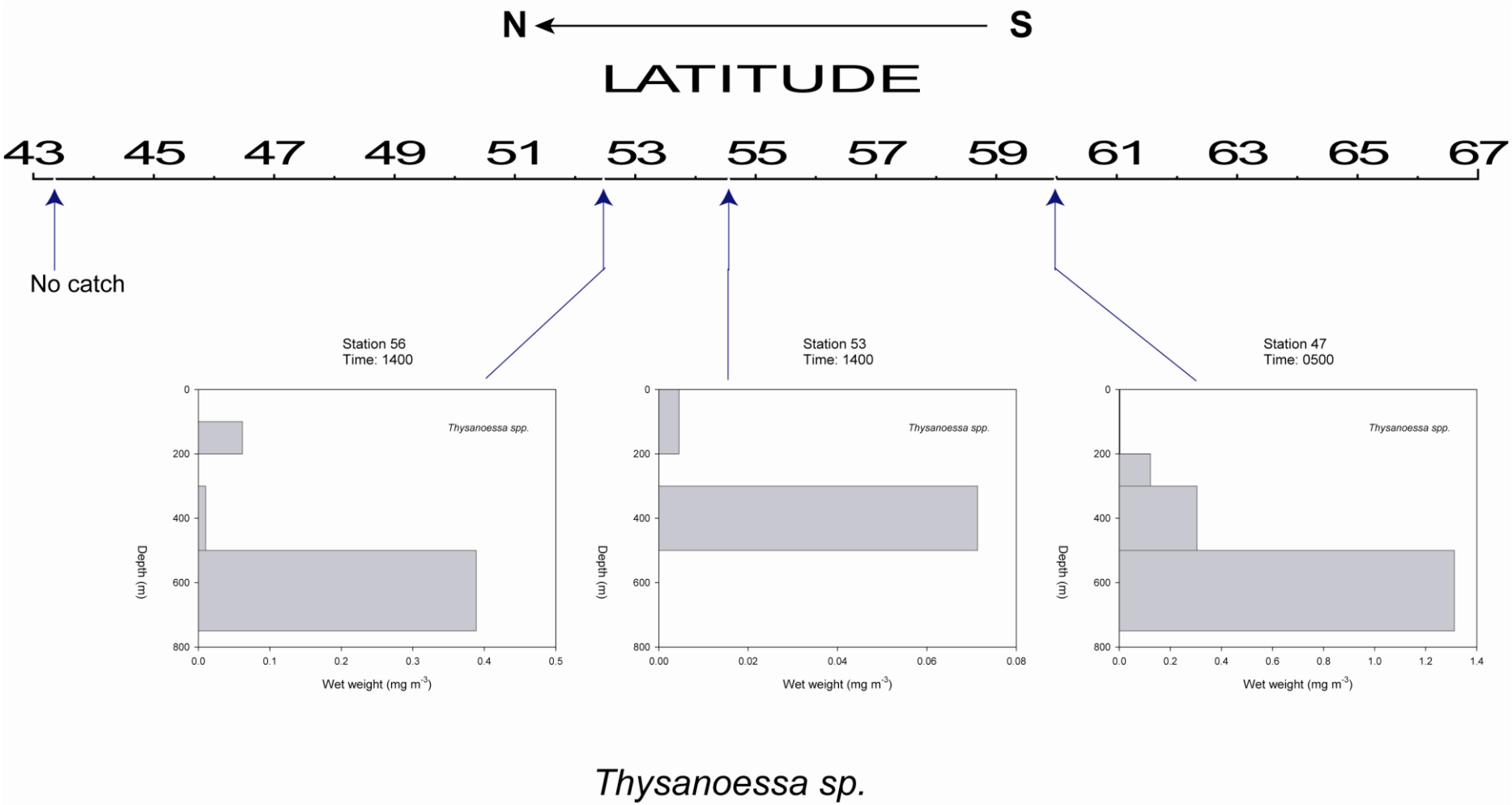


Figure 7.5 B. Vertical distribution of *Thysanoessa spp.* based on Krill trawl catches with Multisampler. Northward transect at 7° 30´ E.

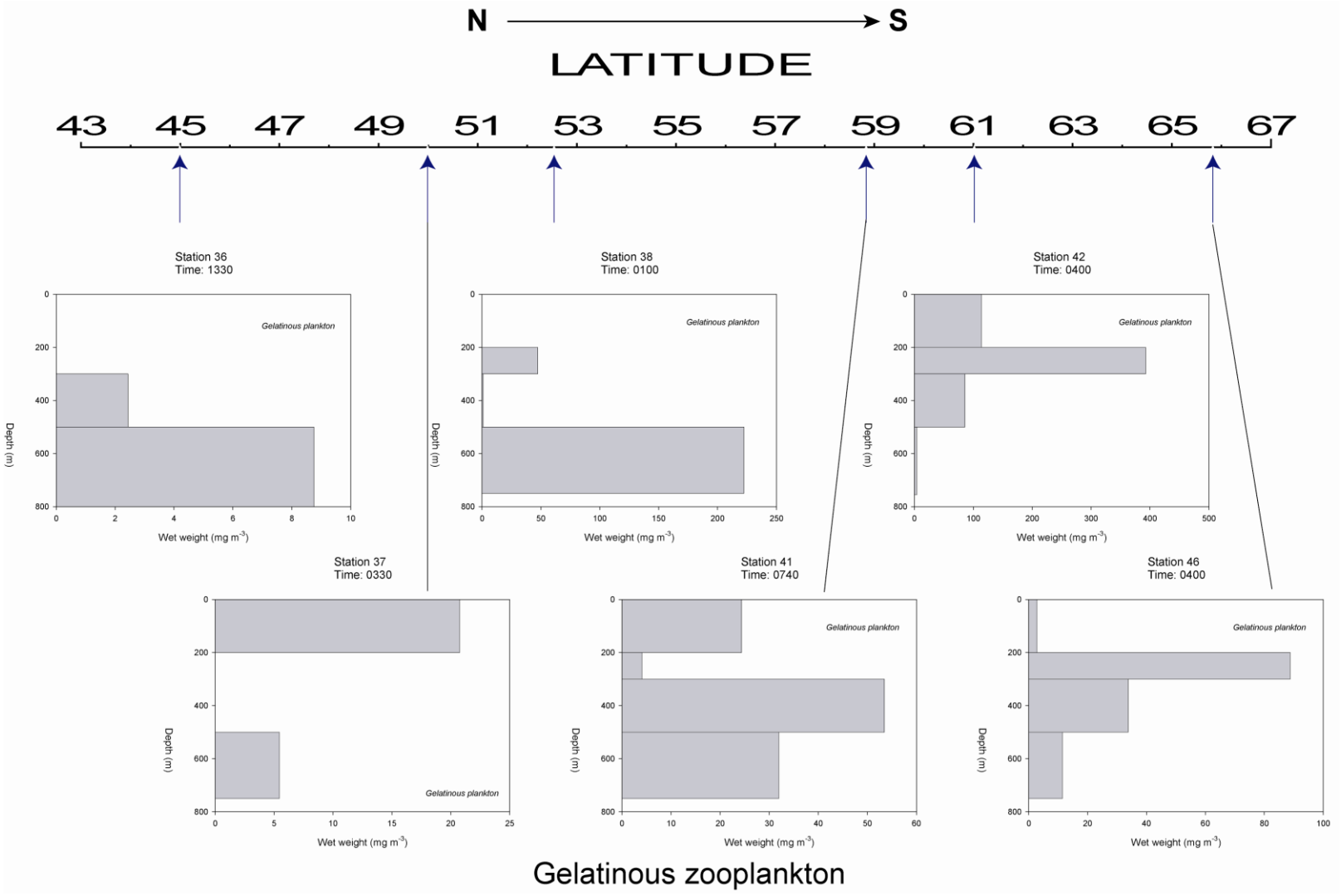


Figure 7.6 A. Vertical distribution of gelatinous zooplankton based on Krill trawl catches with Multisampler. Southward transect at 15° E.

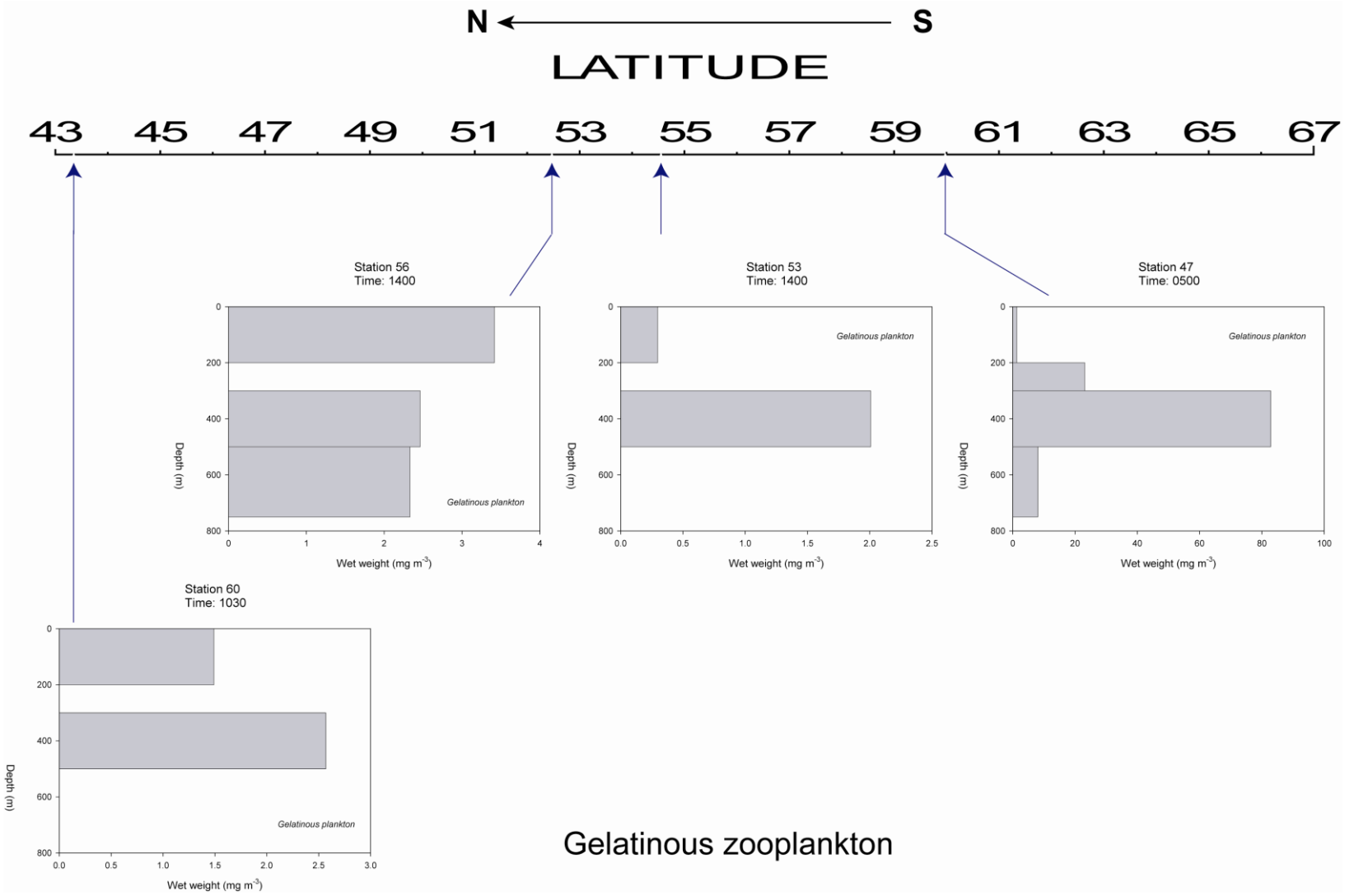


Figure 7.6 B. Vertical distribution of gelatinous zooplankton based on Krill trawl catches with Multisampler. Northward transect at 7° 30´ E.

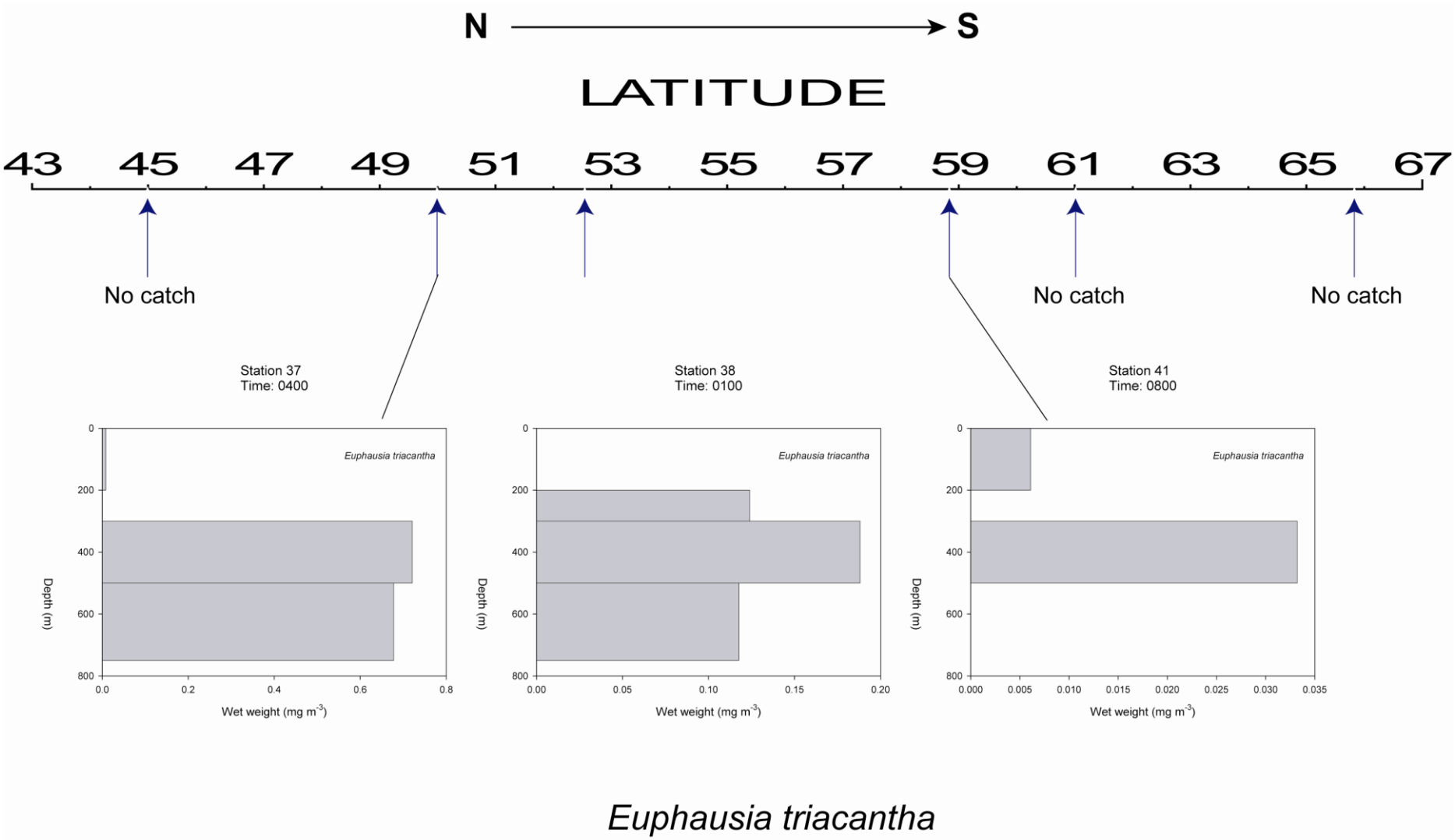


Figure 7.7 A. Vertical distribution of *Euphausia triacantha* based on Krill trawl catches with Multisampler. Southward transect at 15° E.

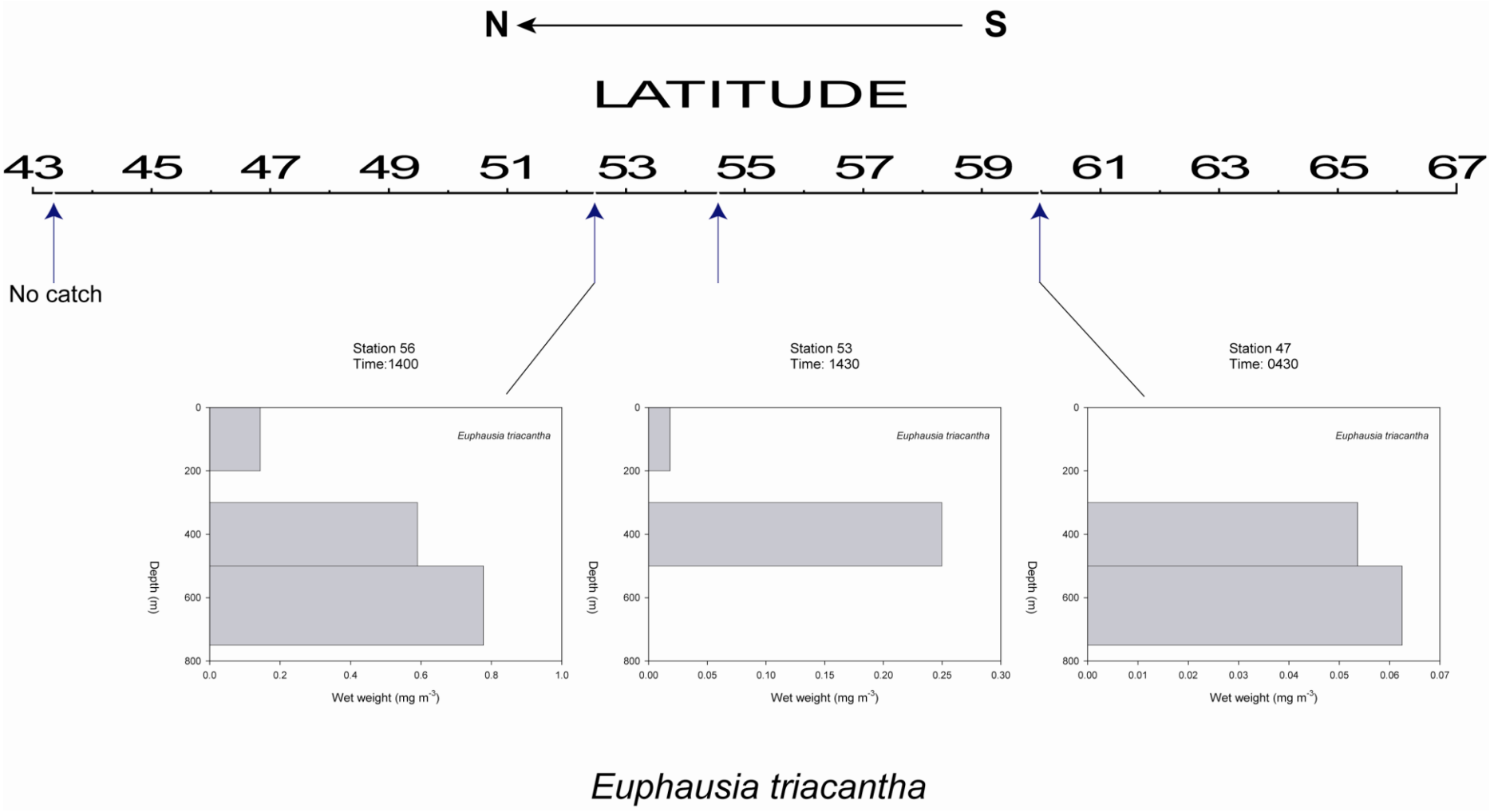


Figure 7.7 B. Vertical distribution of *Euphausia triacantha* based on Krill trawl catches with Multisampler. Northward transect at 7° 30´ E.

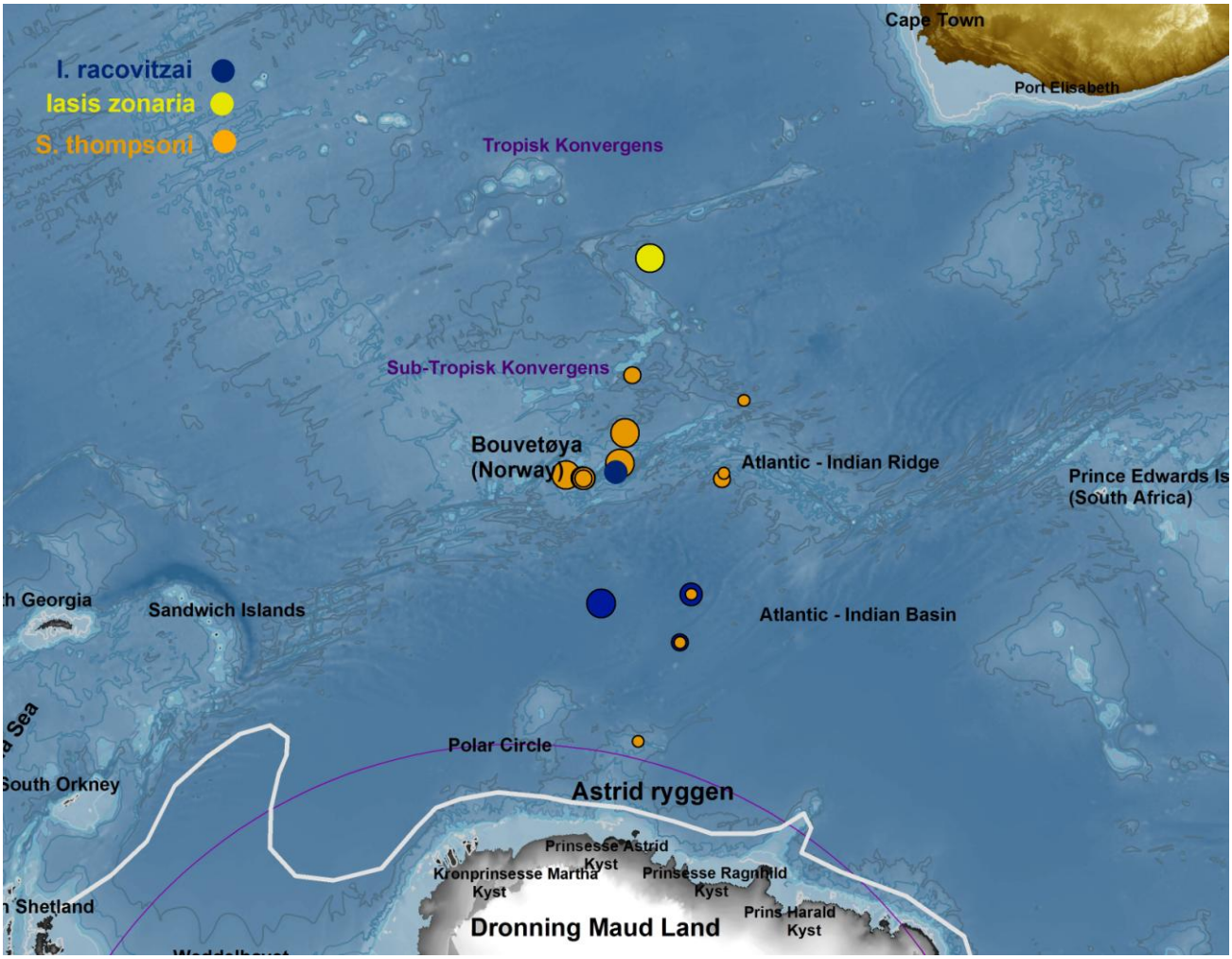


Figure7.8. Species distribution map for salps collected during AKES-2

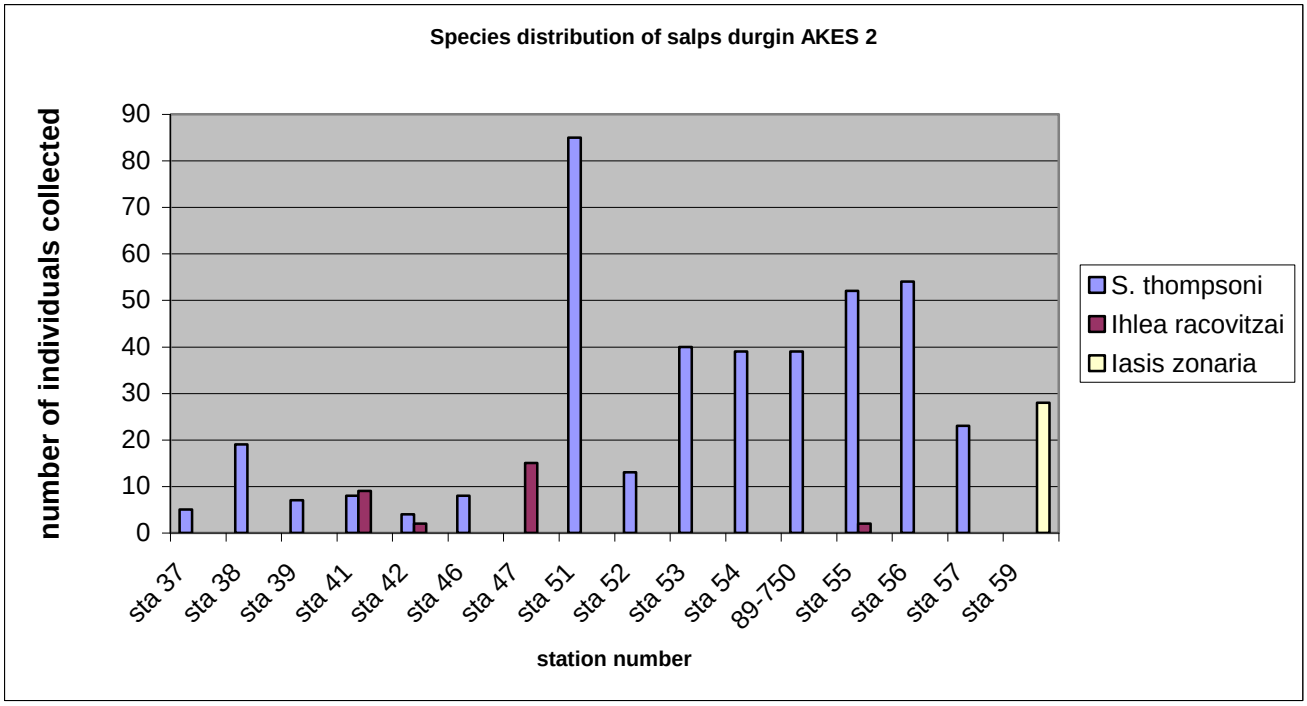


Figure 7.9. Representation of the number of individuals collected during the AKES 2 cruise.

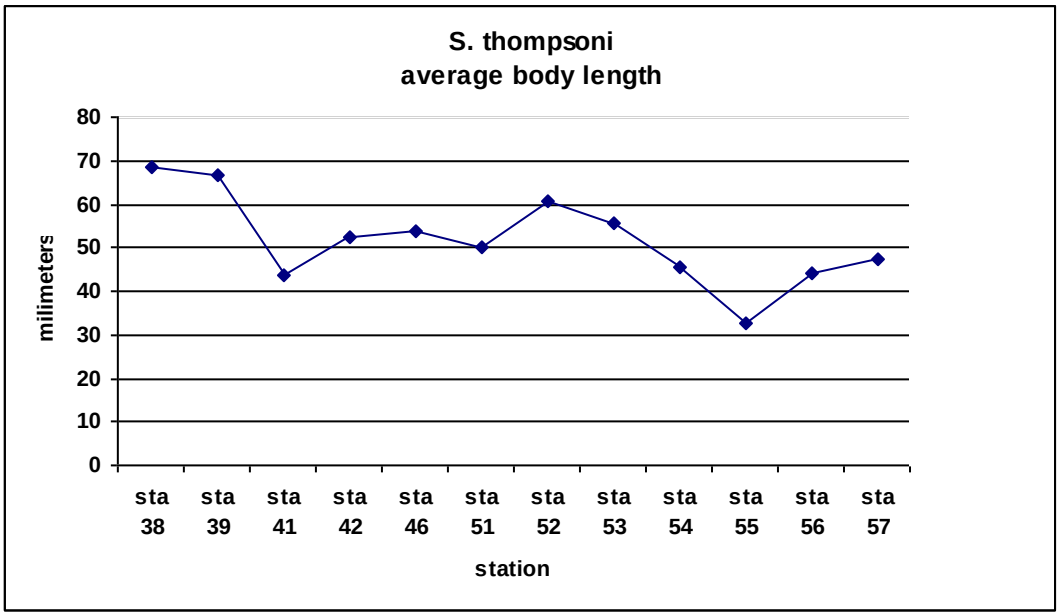


Figure 7.10. Average body length of S. thompsoni.

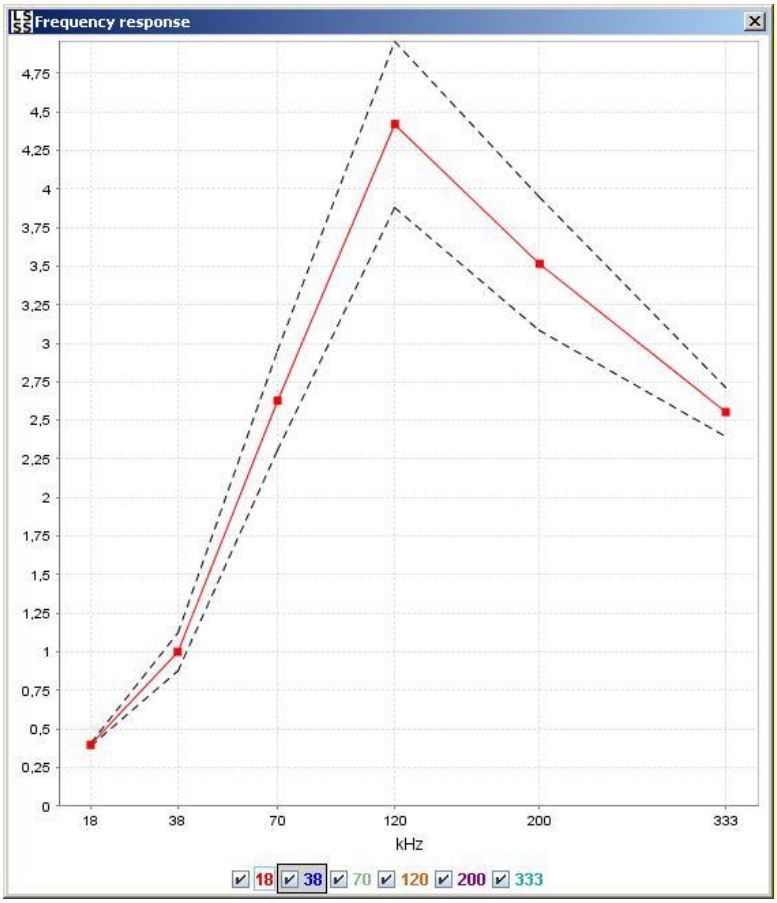


Figure 8.1. Frequency response of krill.

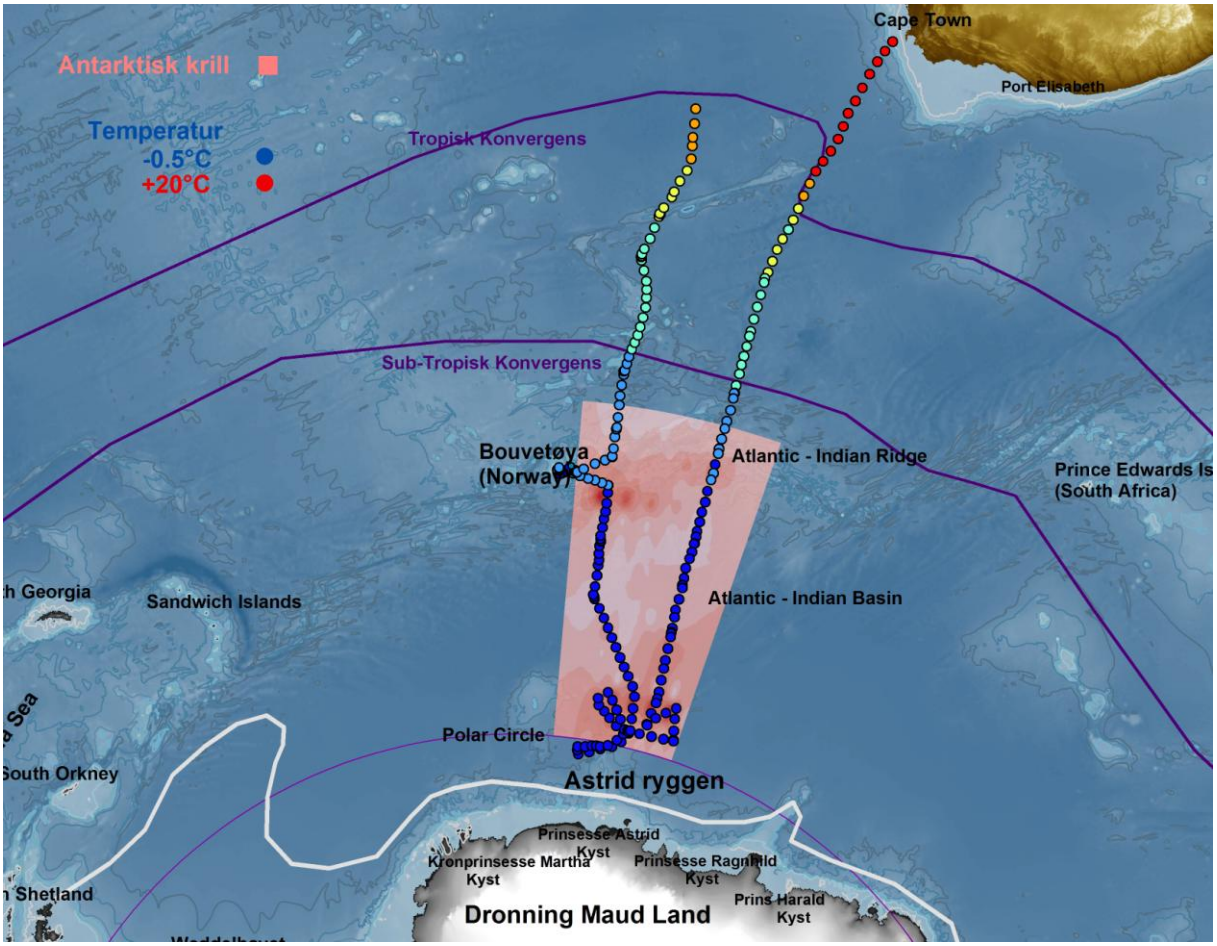
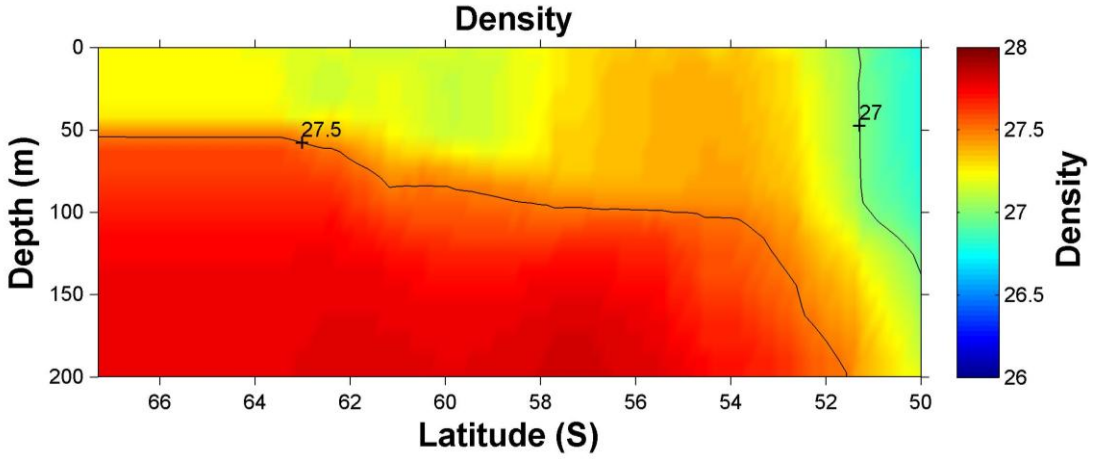


Figure 8.2. Horisontal distribution of *Euphausia superba* from acoustic recordings.


Density
Depth (m)
Latitude (S)
Density
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27
0
50
100
150
200
66
64
62
60
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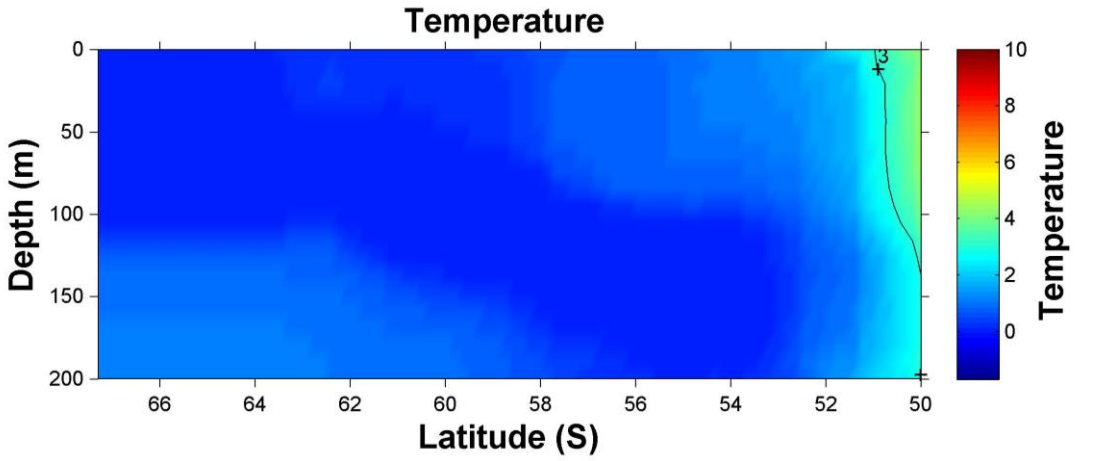
54
52
50
28
27.5
27
26.5
26


Temperature
Depth (m)
Latitude (S)
Temperature
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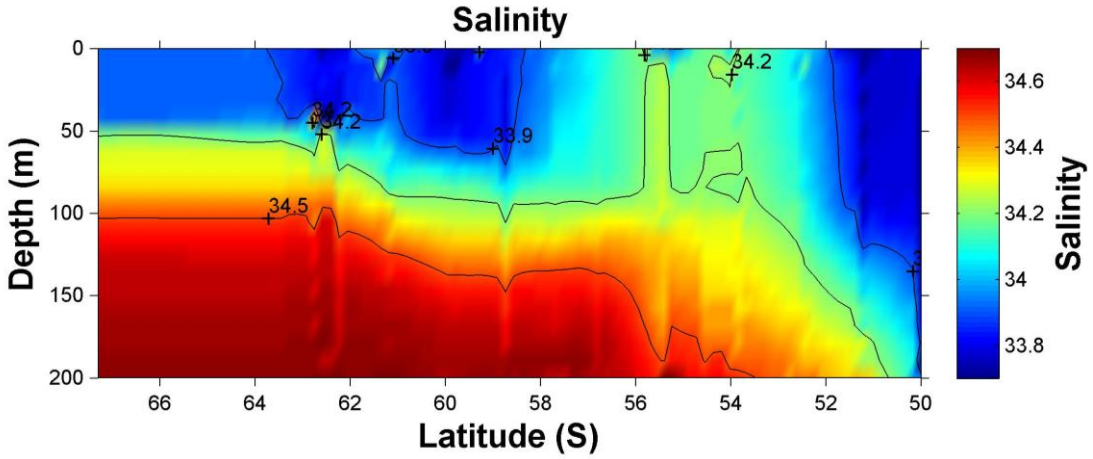
50
100
150
200
66
64
62
60
58
56
54
52
50
10
8
6
4
2
0


Salinity
Depth (m)
Latitude (S)
Salinity
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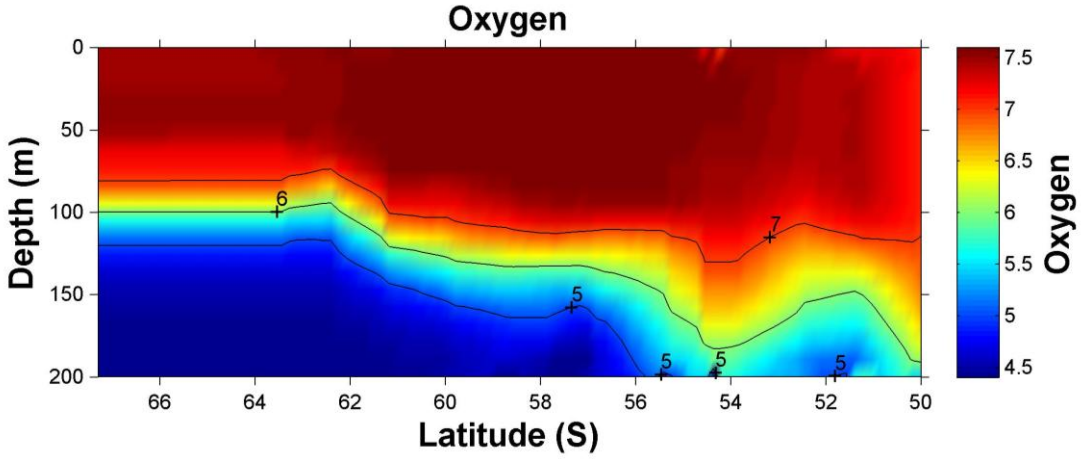
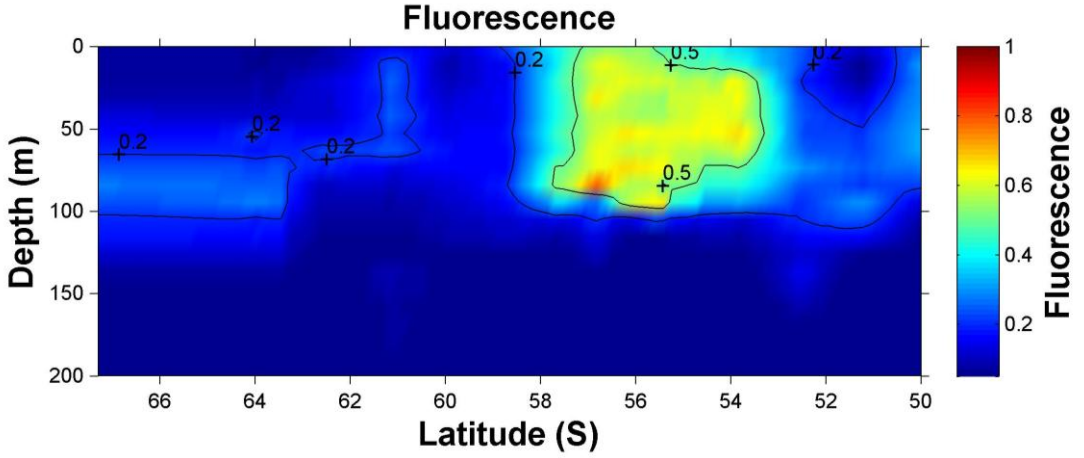
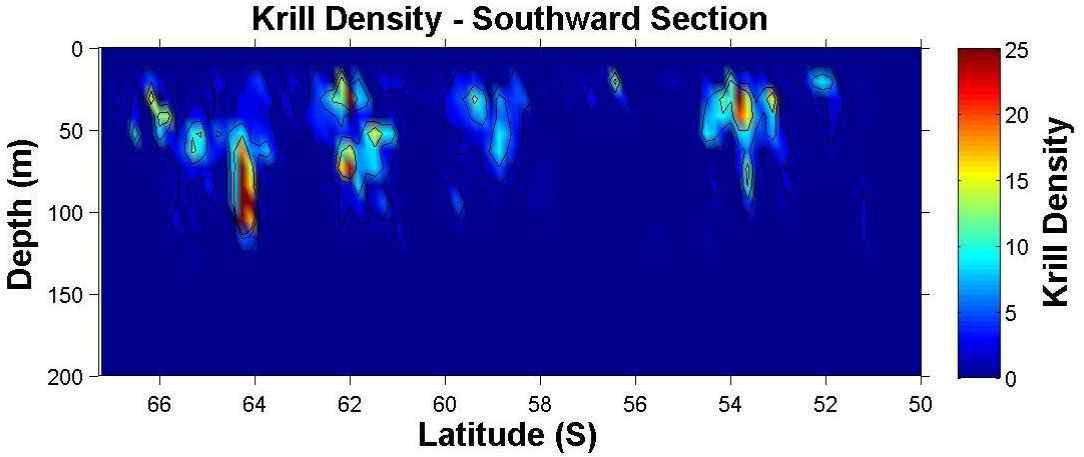
34.2
34.2
33.9
34.5
0
50
100
150
200
66
64
62
60
58
56
54
52
50
34.6
34.4
34.2
34
33.8


Oxygen
Depth (m)
Latitude (S)
Oxygen
0
50
100
150
200
66
64
62
60
58
56
54
52
50
7.5
7
6.5
6
5.5
5
4.5
6
7
5
5
5
5


Fluorescence
Depth (m)
Latitude (S)
Fluorescence
0
50
100
150
200
66
64
62
60
58
56
54
52
50
1
0.8
0.6
0.4
0.2
0.2
0.2
0.2
0.2
0.5
0.5


Krill Density - Southward Section
Depth (m)
Latitude (S)
Krill Density
0
50
100
150
200
66
64
62
60
58
56
54
52
50
25
20
15
10
5
0

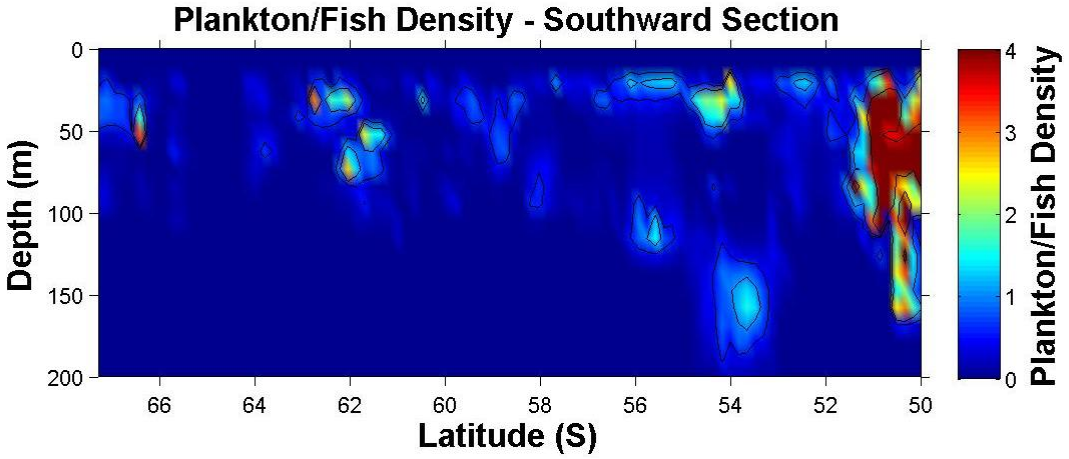
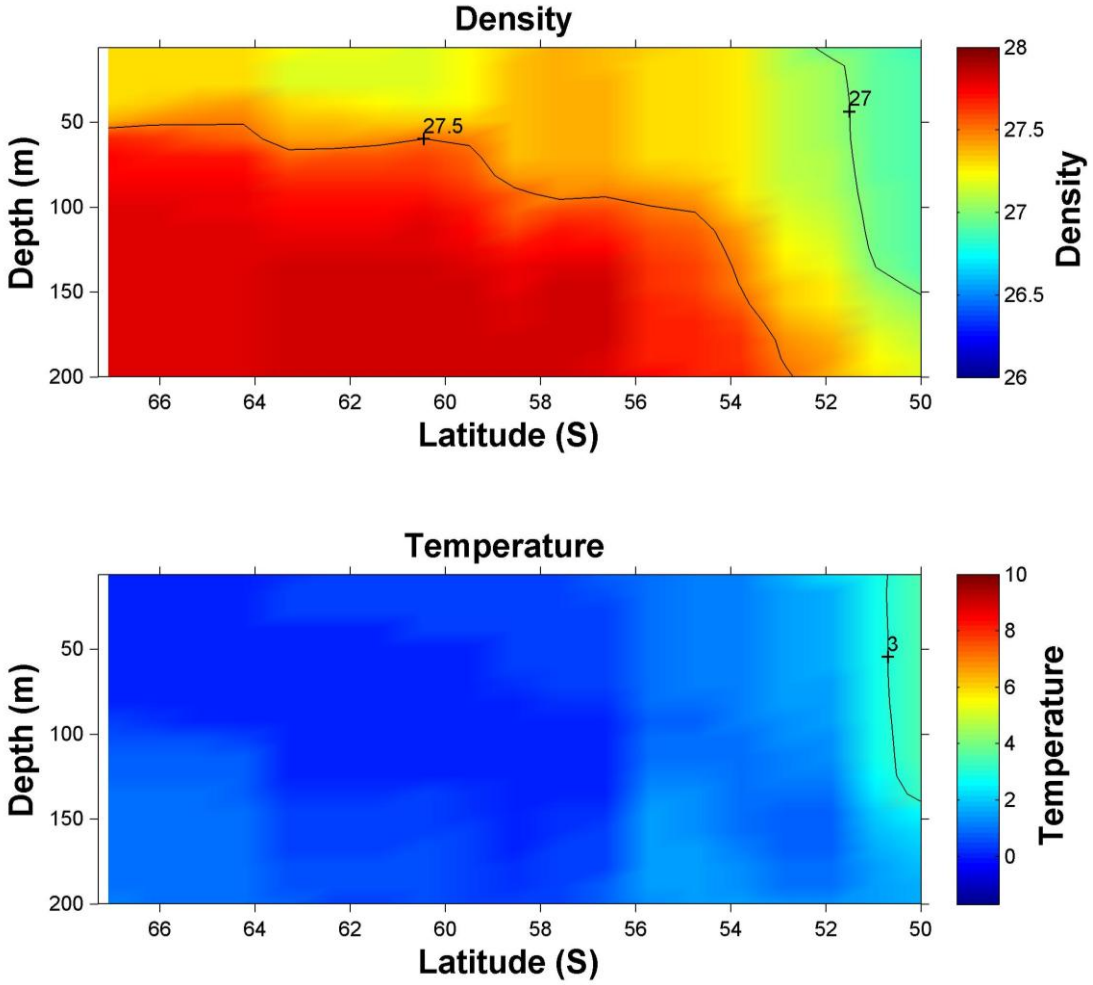
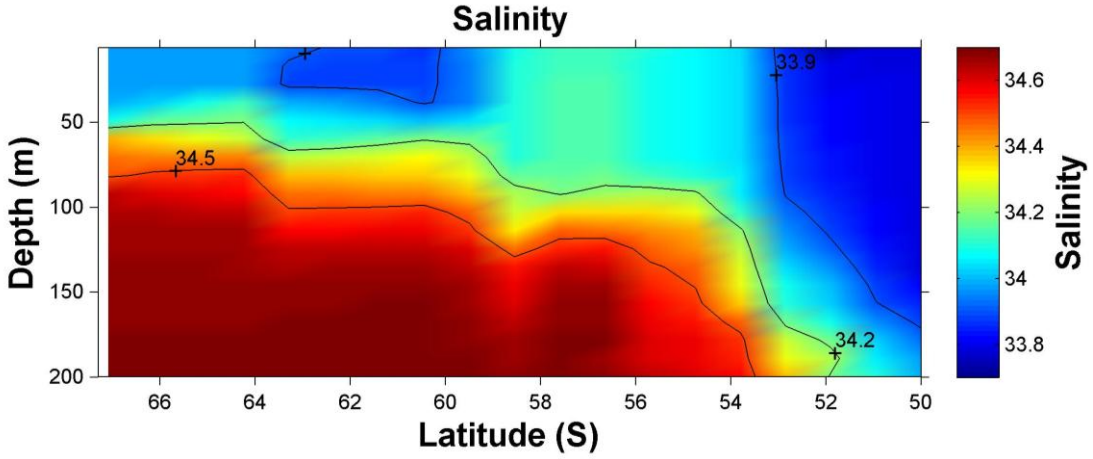
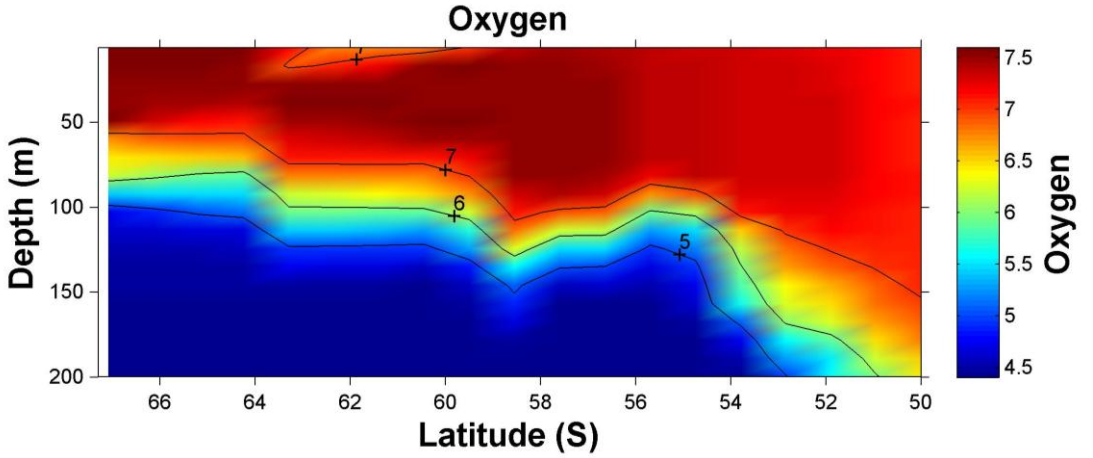
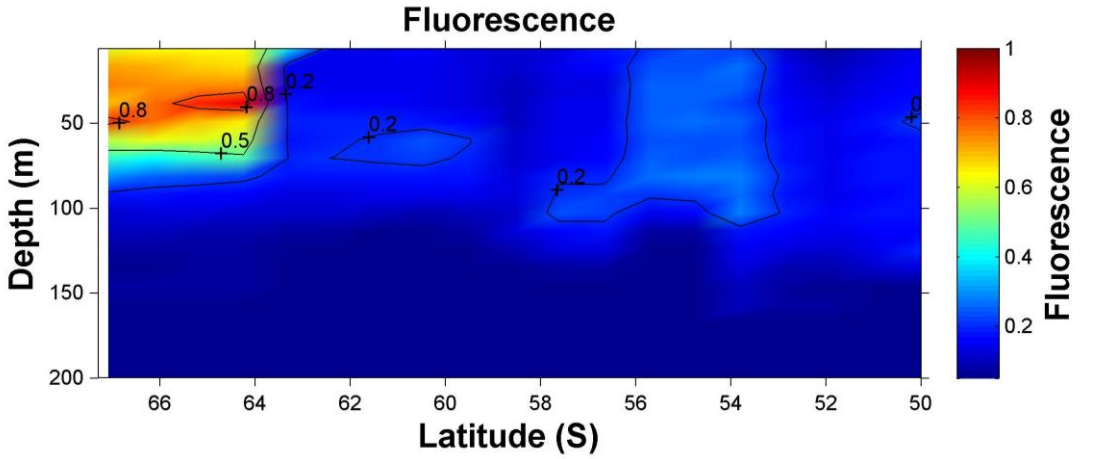


Figure 8.3. Density, temperature, salinity, oxygen, fluorescence, krill (*E. superba*) and fish/plankton distribution along southward transect at 15ºE (Kriging and plotting: Peter Wiebe).




Salinity
Depth (m)
50
100
150
200
66
64
62
60
58
56
54
52
50
Latitude (S)
34.5
33.9
34.2
34.6
34.4
34.2
34
33.8
Salinity


Oxygen
Depth (m)
50
100
150
200
66
64
62
60
58
56
54
52
50
Latitude (S)
7
6
5
7.5
7
6.5
6
5.5
5
4.5
Oxygen


Fluorescence
Depth (m)
50
100
150
200
66
64
62
60
58
56
54
52
50
Latitude (S)
0.8
0.8
0.2
0.5
0.2
0.2
1
0.8
0.6
0.4
0.2
Fluorescence

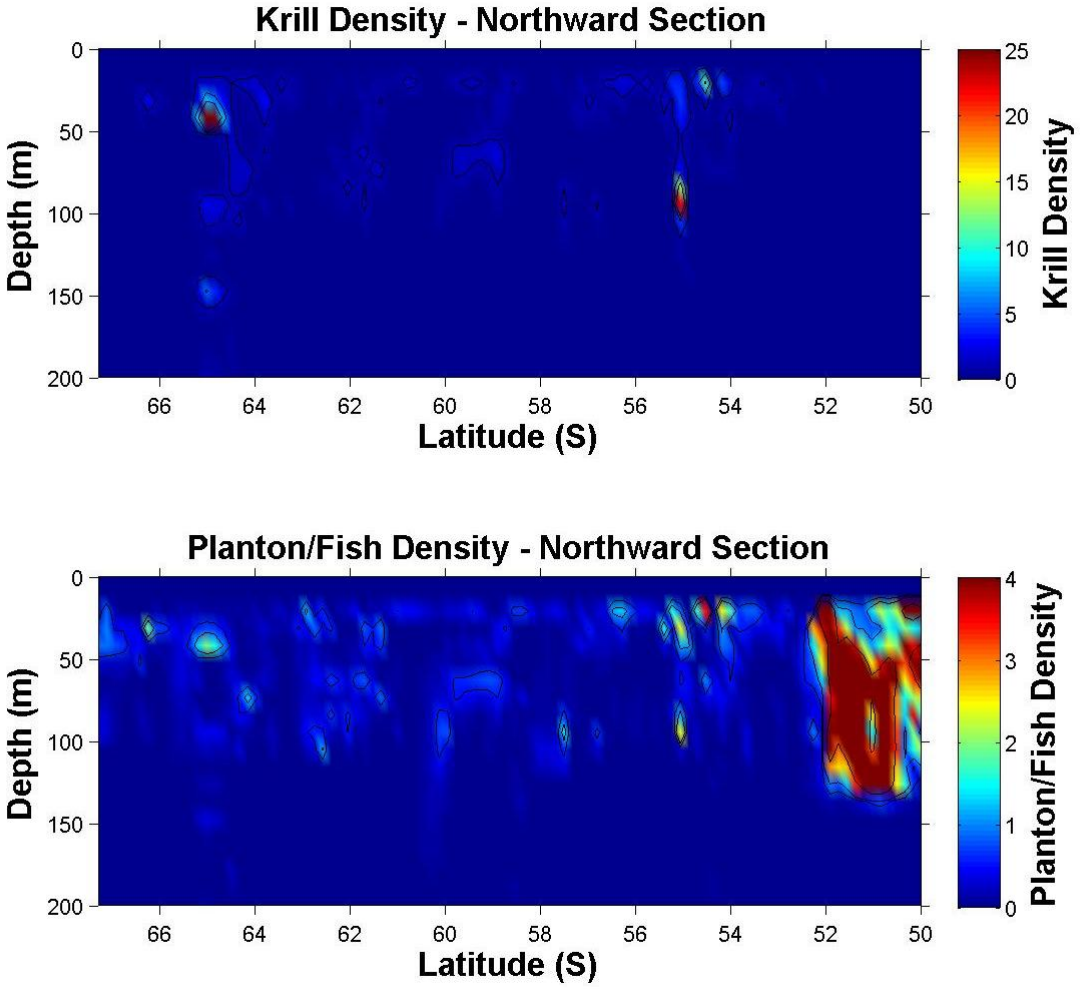


Figure 8.4. Density, temperature, salinity, oxygen, fluorescence, krill (*E. superba*) and fish/plankton distribution along northward transect at 7.5ºE (Kriging and plotting: Peter Wiebe).

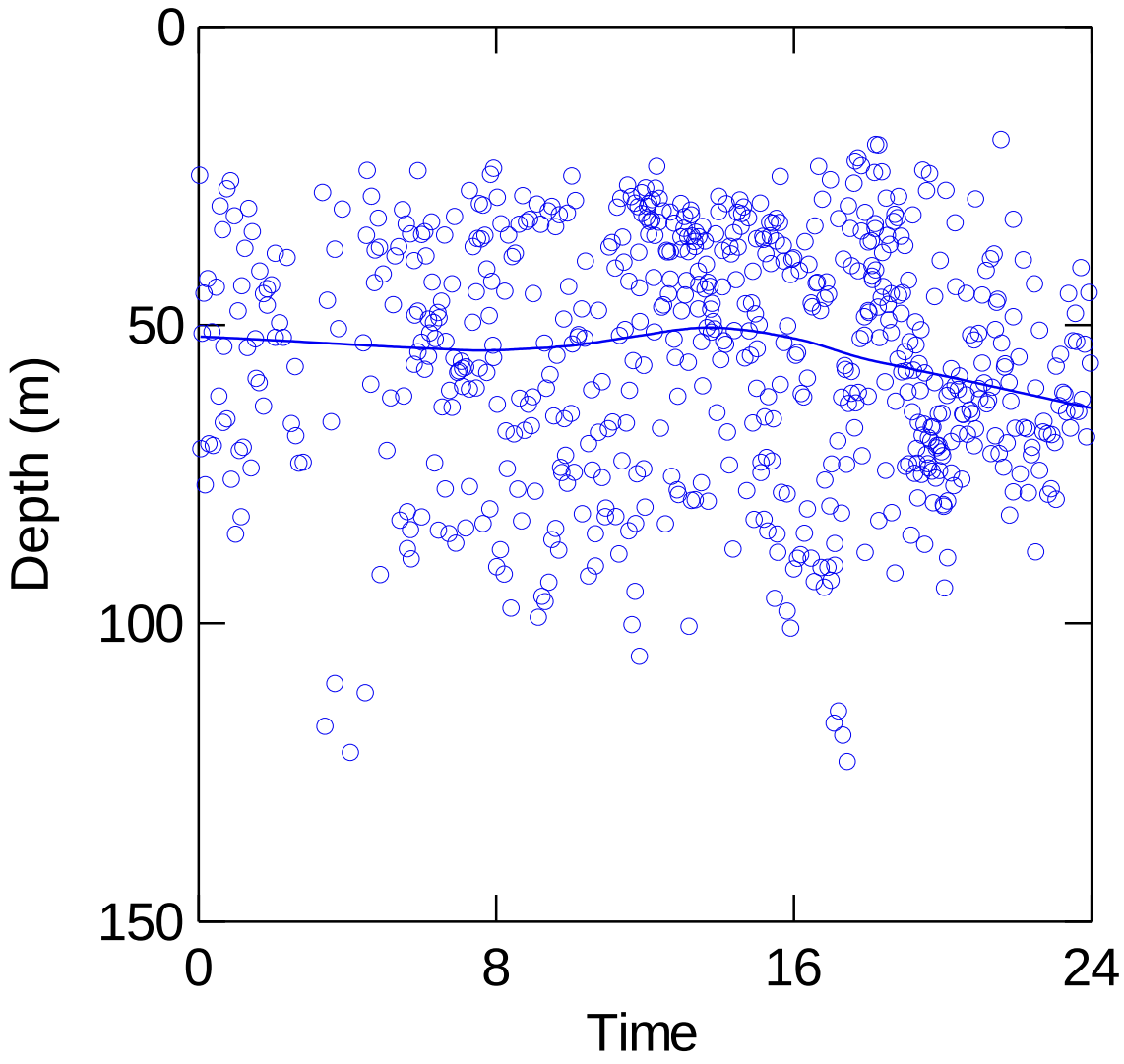


Figure 8.5. Weighted mean depth of krill vs. time of the day from acoustic measurements.

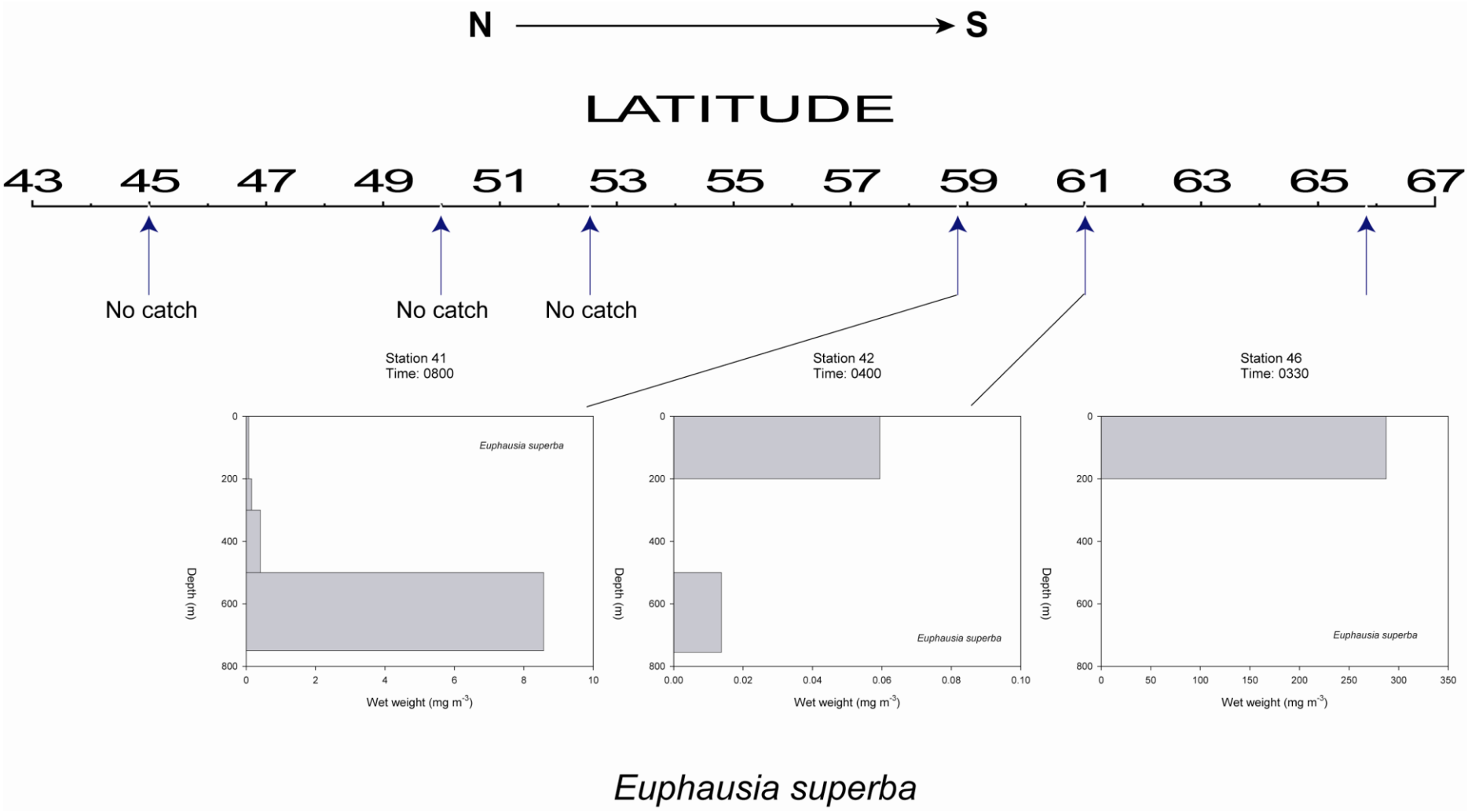


Figure 8.6a. Vertical distribution of *Euphausia superba* based on Krill trawl catches with Multisampler. Southward transect at 15° E.

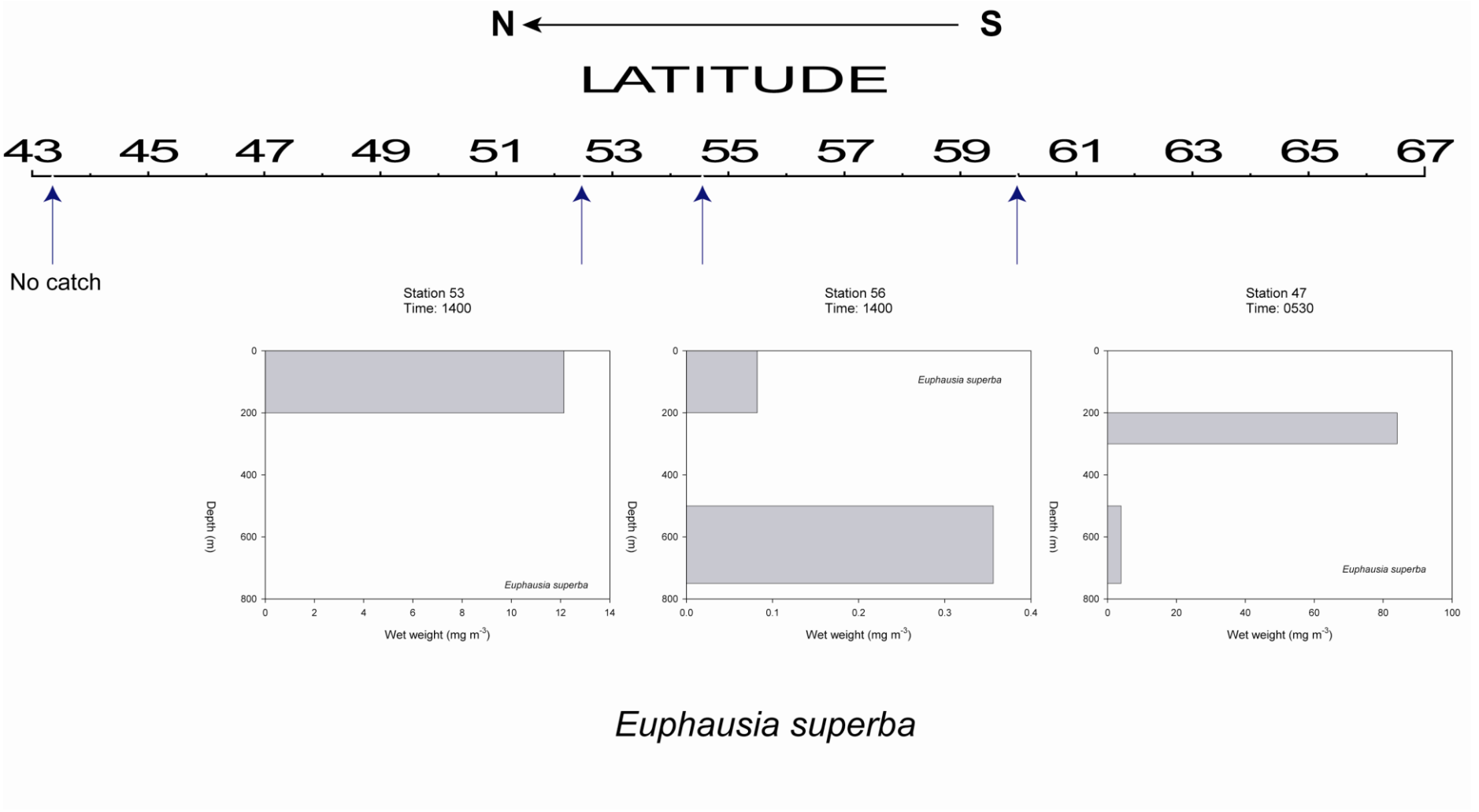


Figure 8.6b. Vertical distribution of *Euphausia superba* based on Krill trawl catches with Multisampler. Northward transect at 7° 30´ E.

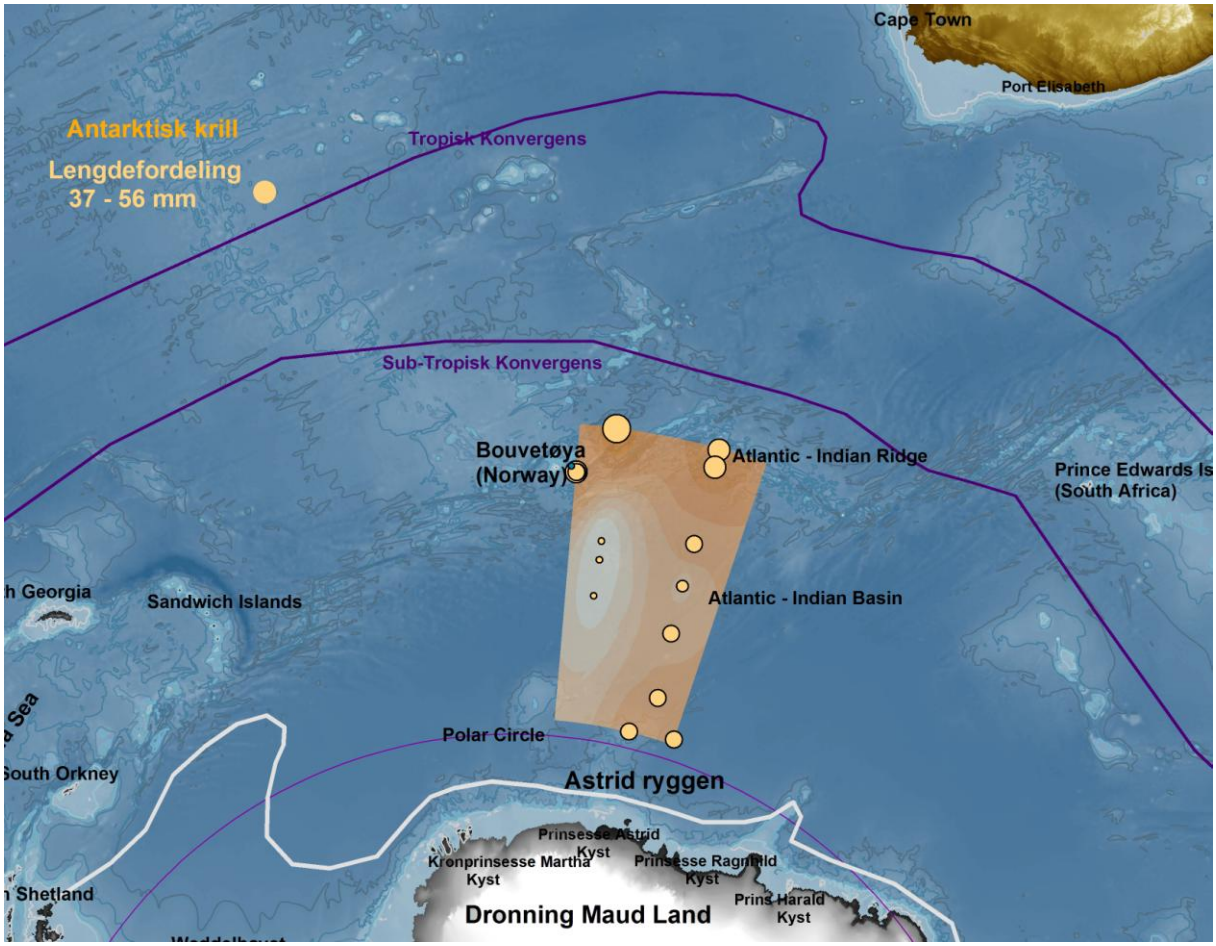


Figure 8.7. Horisontal distribution of average lengths per trawl station of *Euphausia superba*.

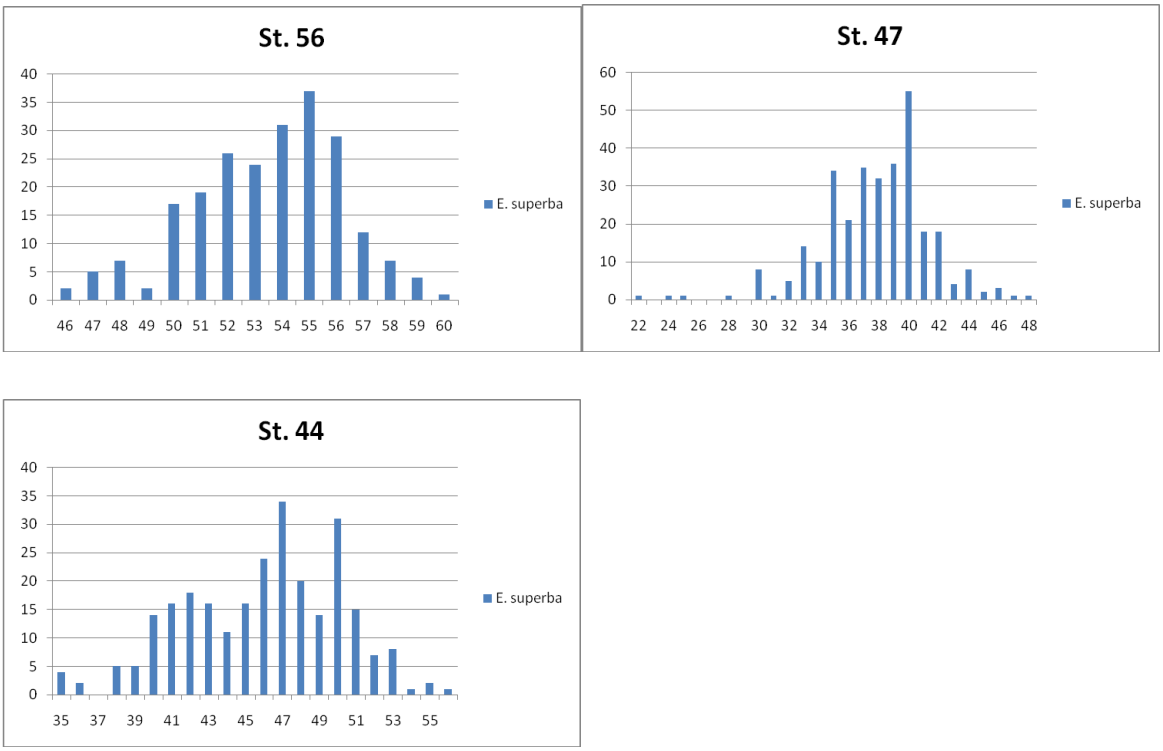


Figure 8.8. Length distribution of Euphausia superba at a northern (56), intermediate (47) and southern (46) station.

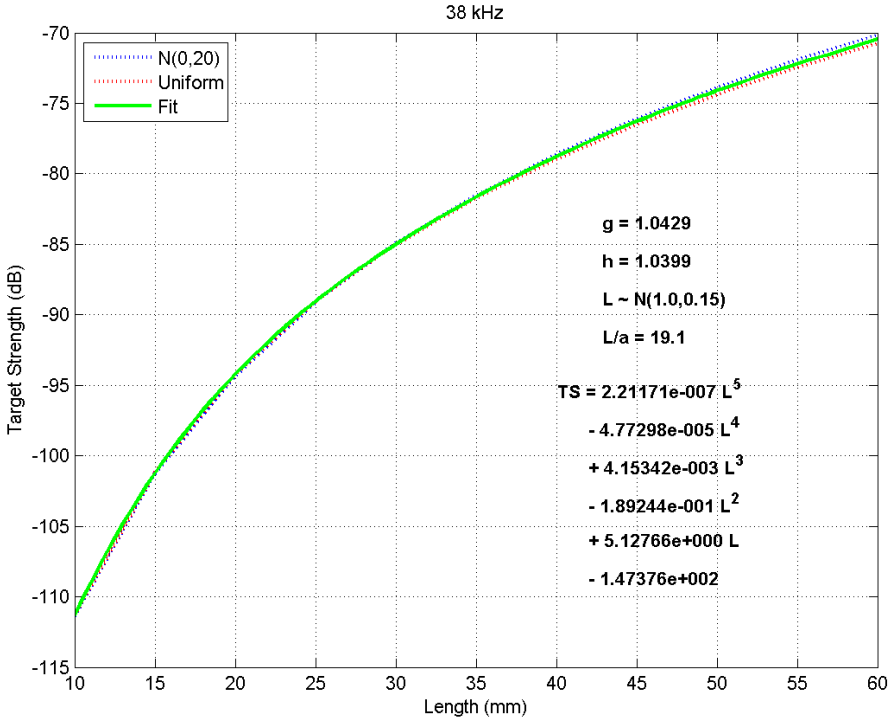


Figure 8.9. Target strength versus length for 38 kHz.

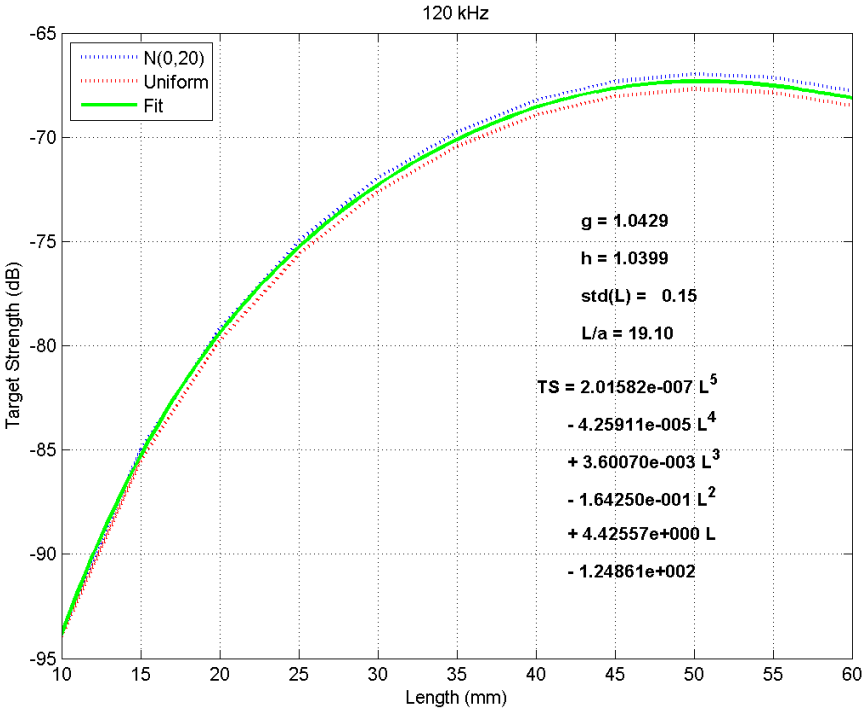


Figure 8.10. Target strength versus length for 120 kHz.

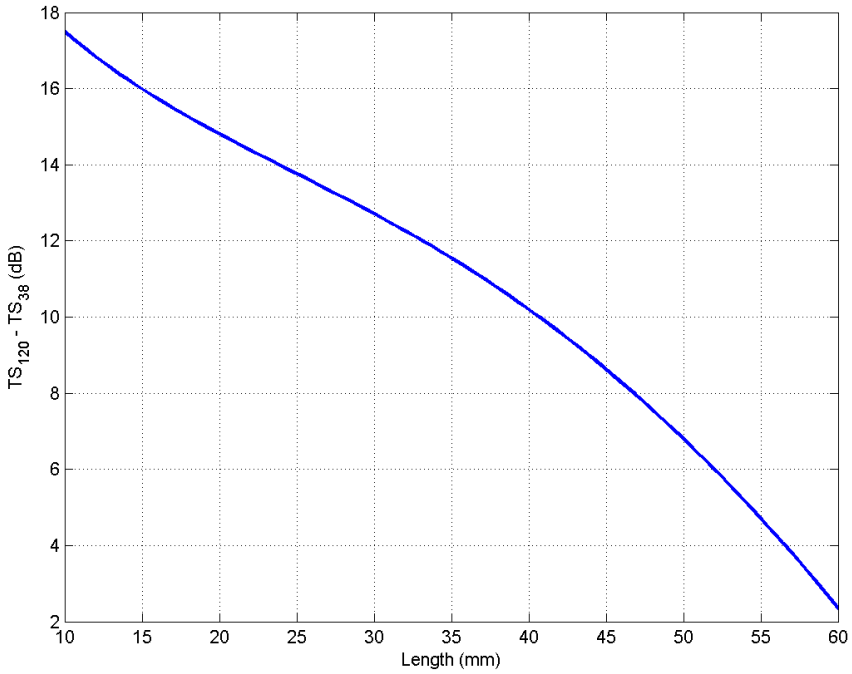


Figure 8.11. Target strength difference, $TS_{120} - TS_{38}$, as a function of length.

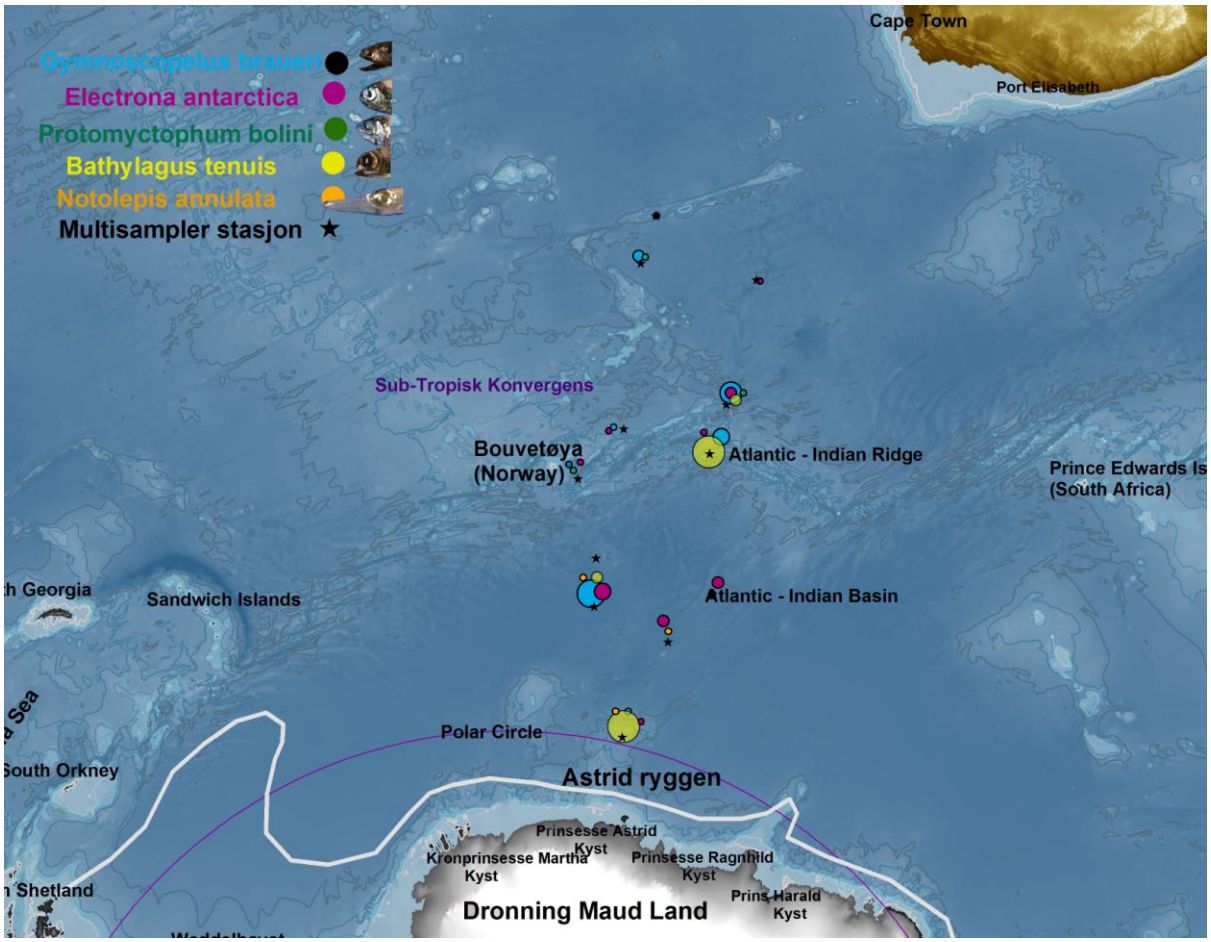


Figure 9.1. Horizontal distribution of major fish species caught by Krill trawl with Multisampler.

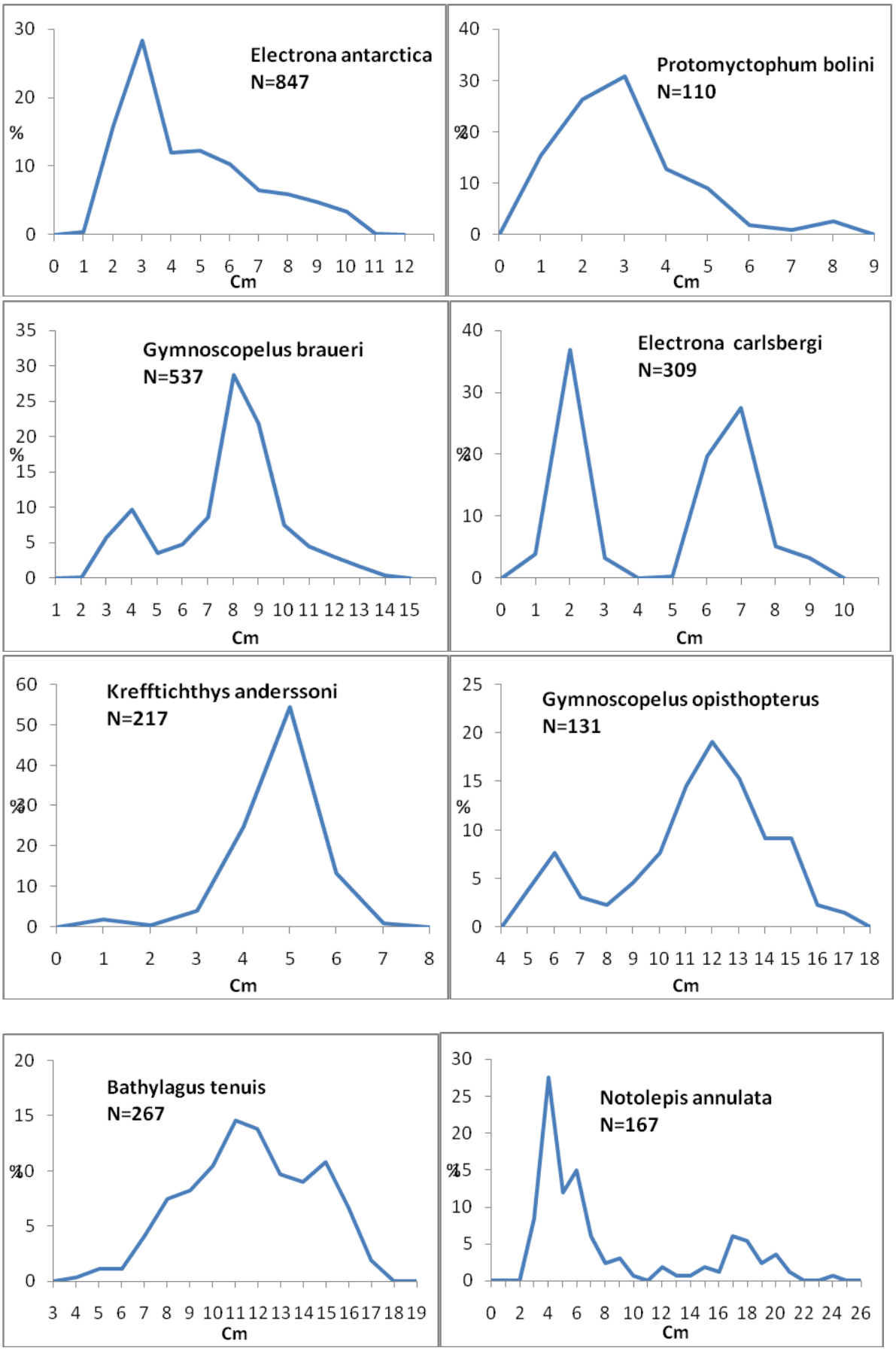


Figure 9.2. Length distribution (cm) for our major species groups during the survey

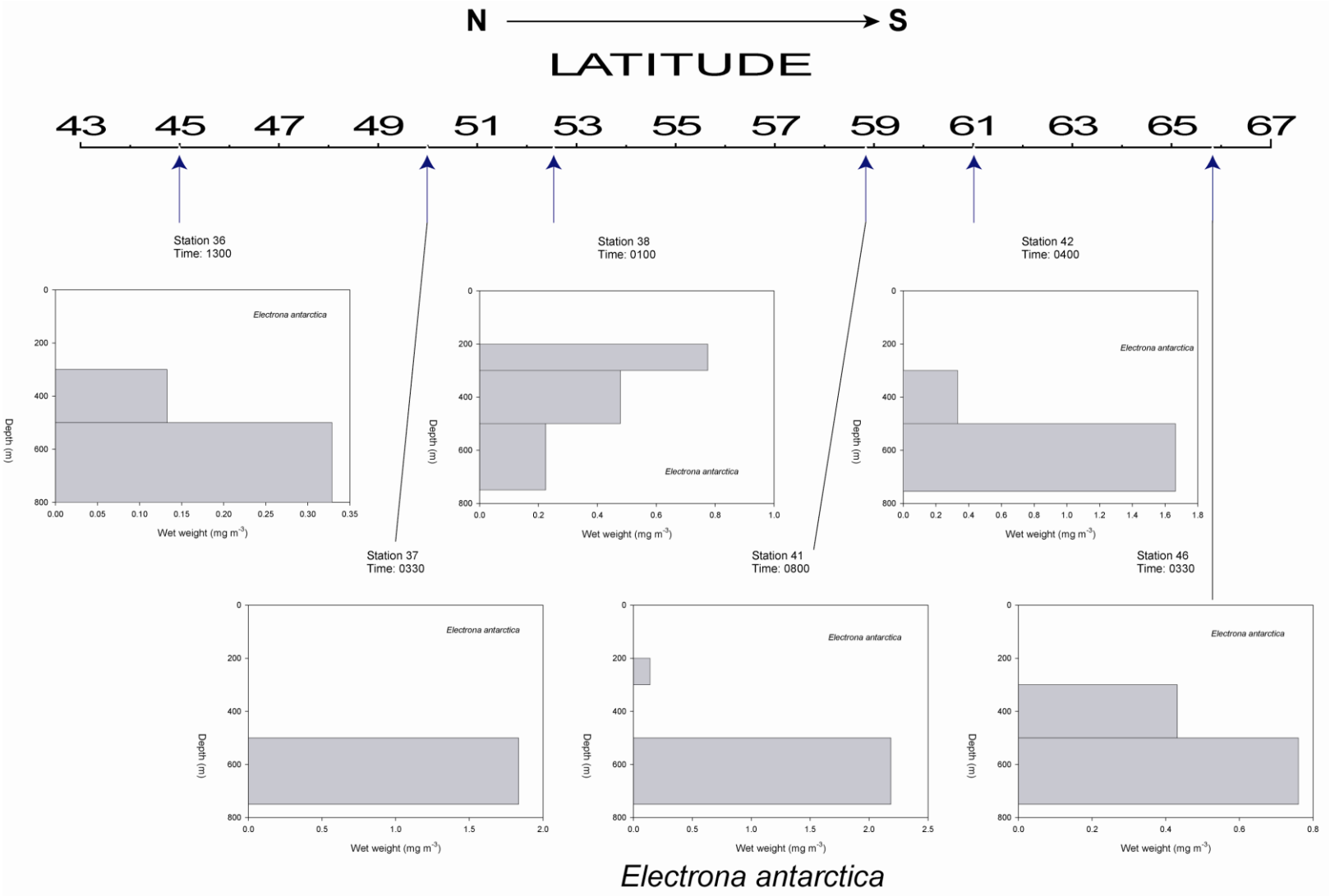


Figure 9.3. Vertical distribution of *Electrona antarctica* based on Krill trawl catches with Multisampler. Southward transect at 15° E.

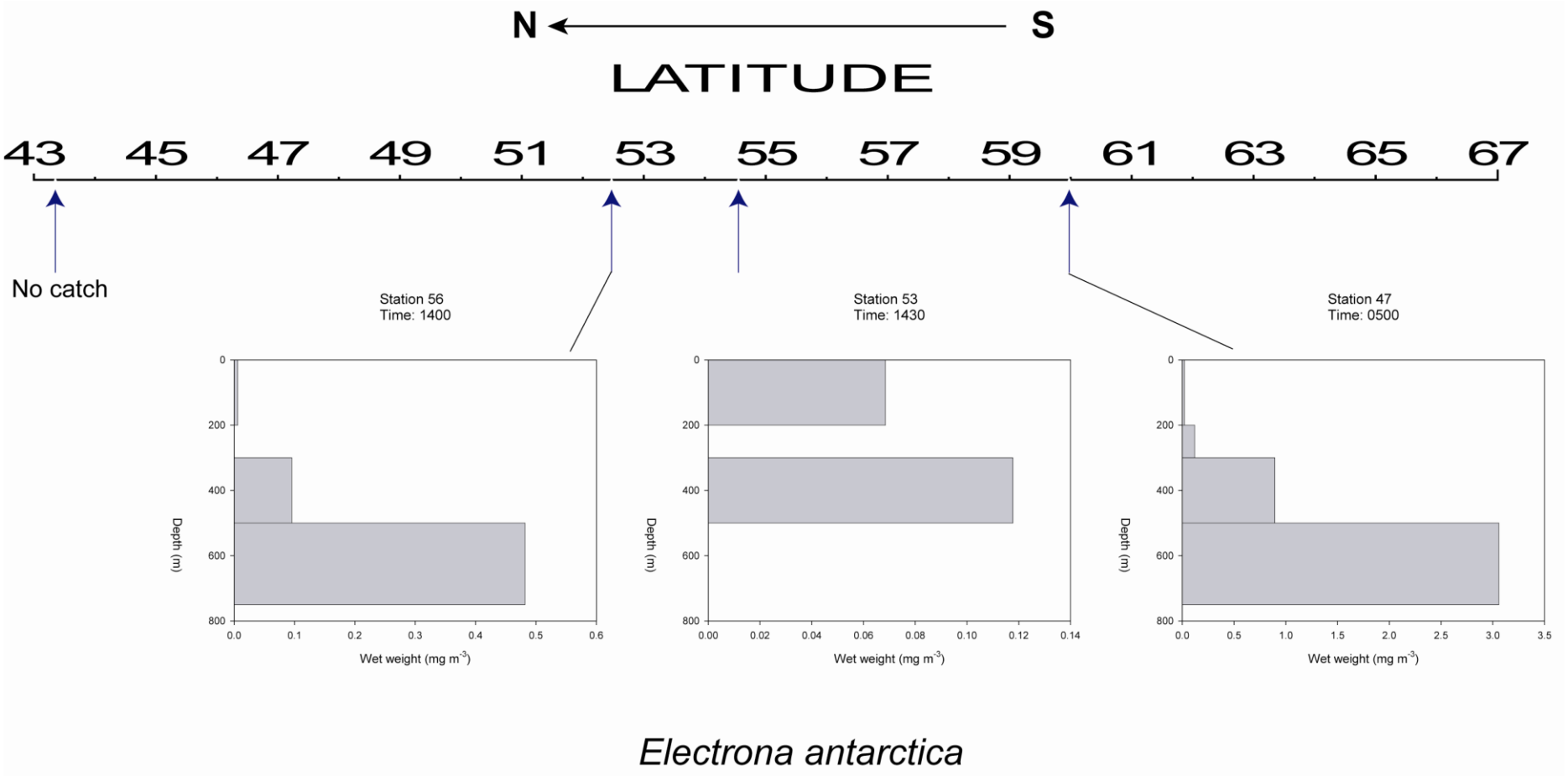


Figure 9.4. Vertical distribution of *Electrona antarctica* based on Krill trawl catches with Multisampler. Northward transect at 7° 30´ E.

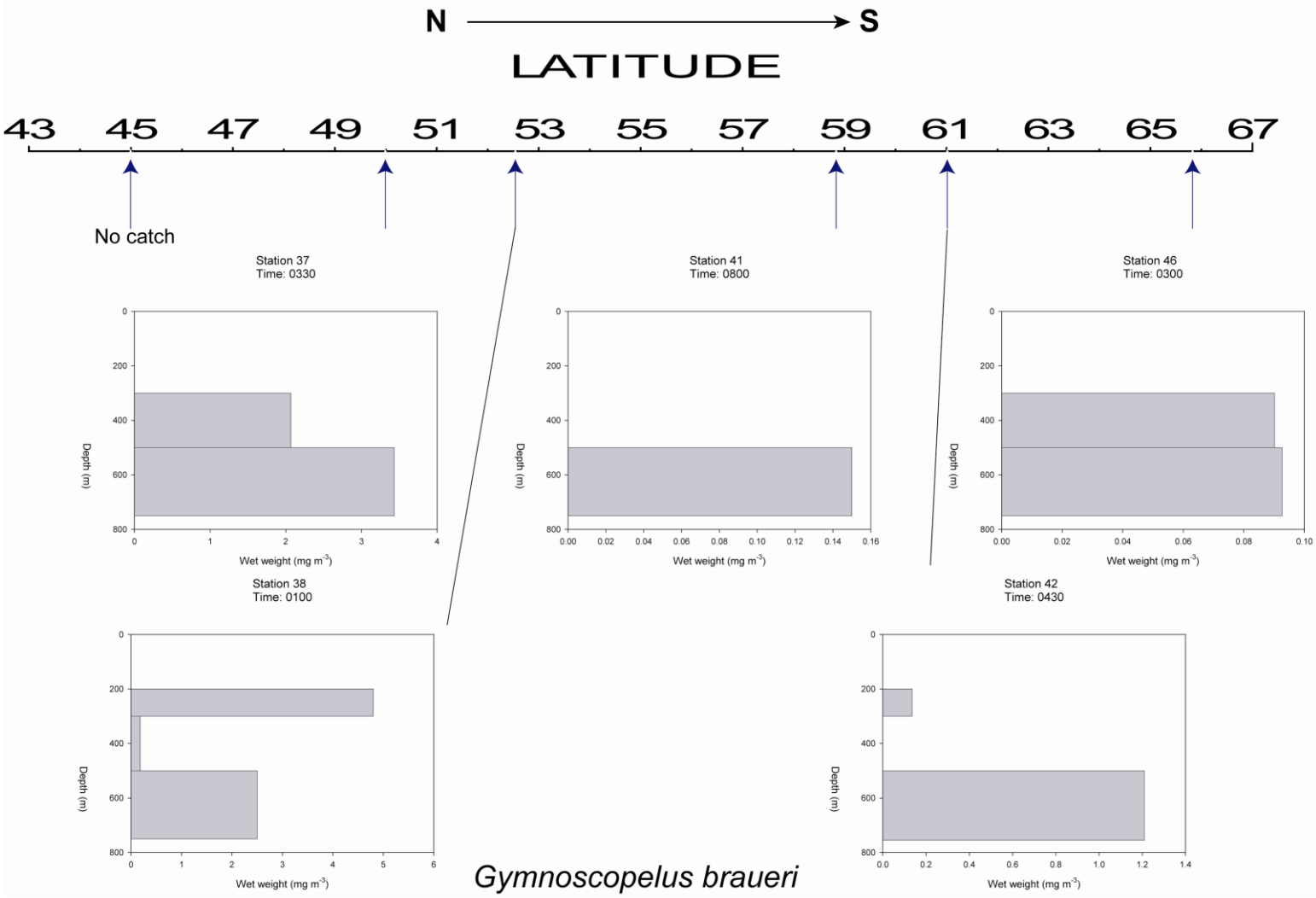


Figure 9.5. Vertical distribution of *Gymnoscopelus braueri* based on Krill trawl catches with Multisampler. Southward transect at 15° E.

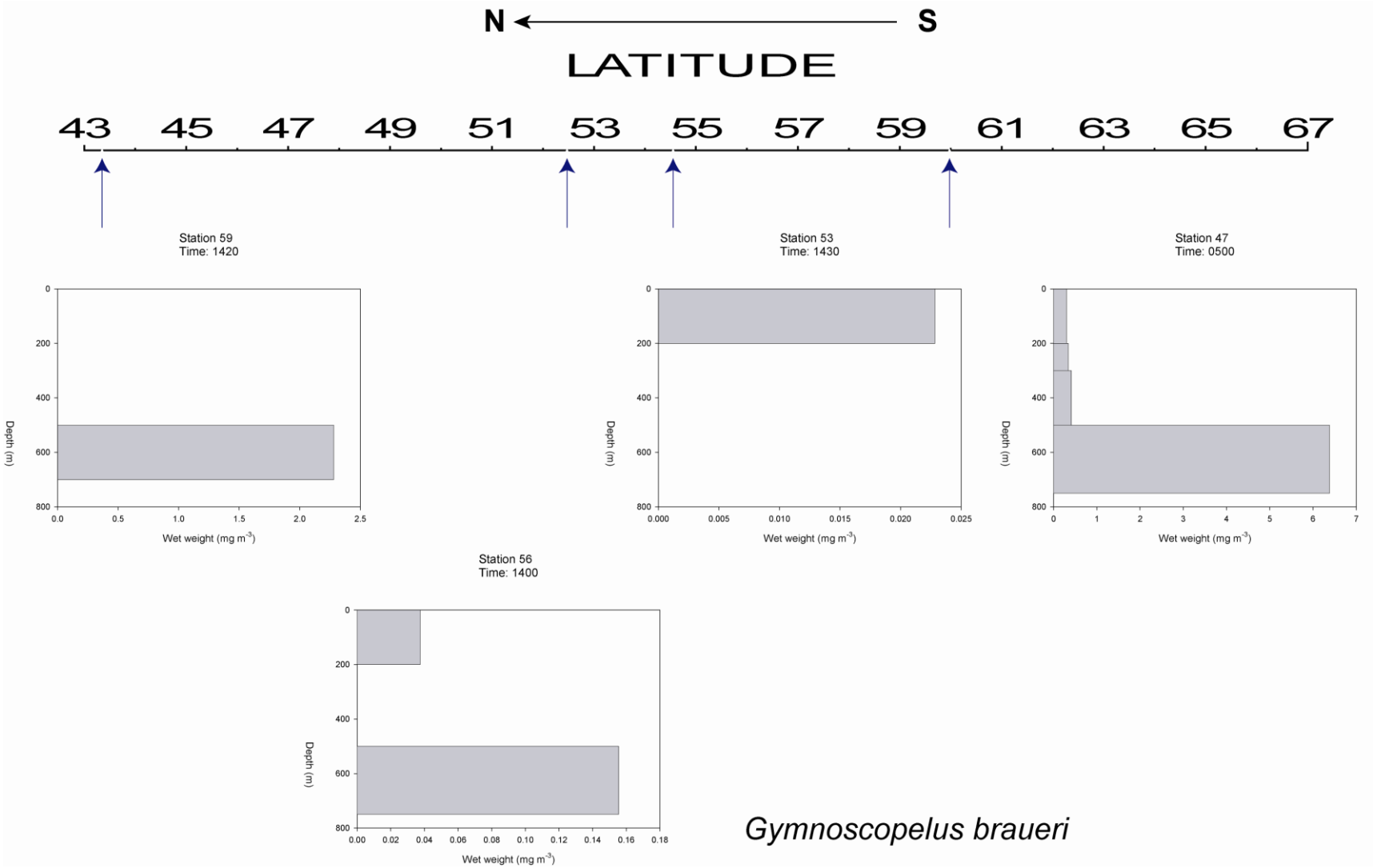


Figure 9.6. Vertical distribution of *Gymnoscopelus braueri* based on Krill trawl catches with Multisampler. Northward transect at 7° 30´ E.

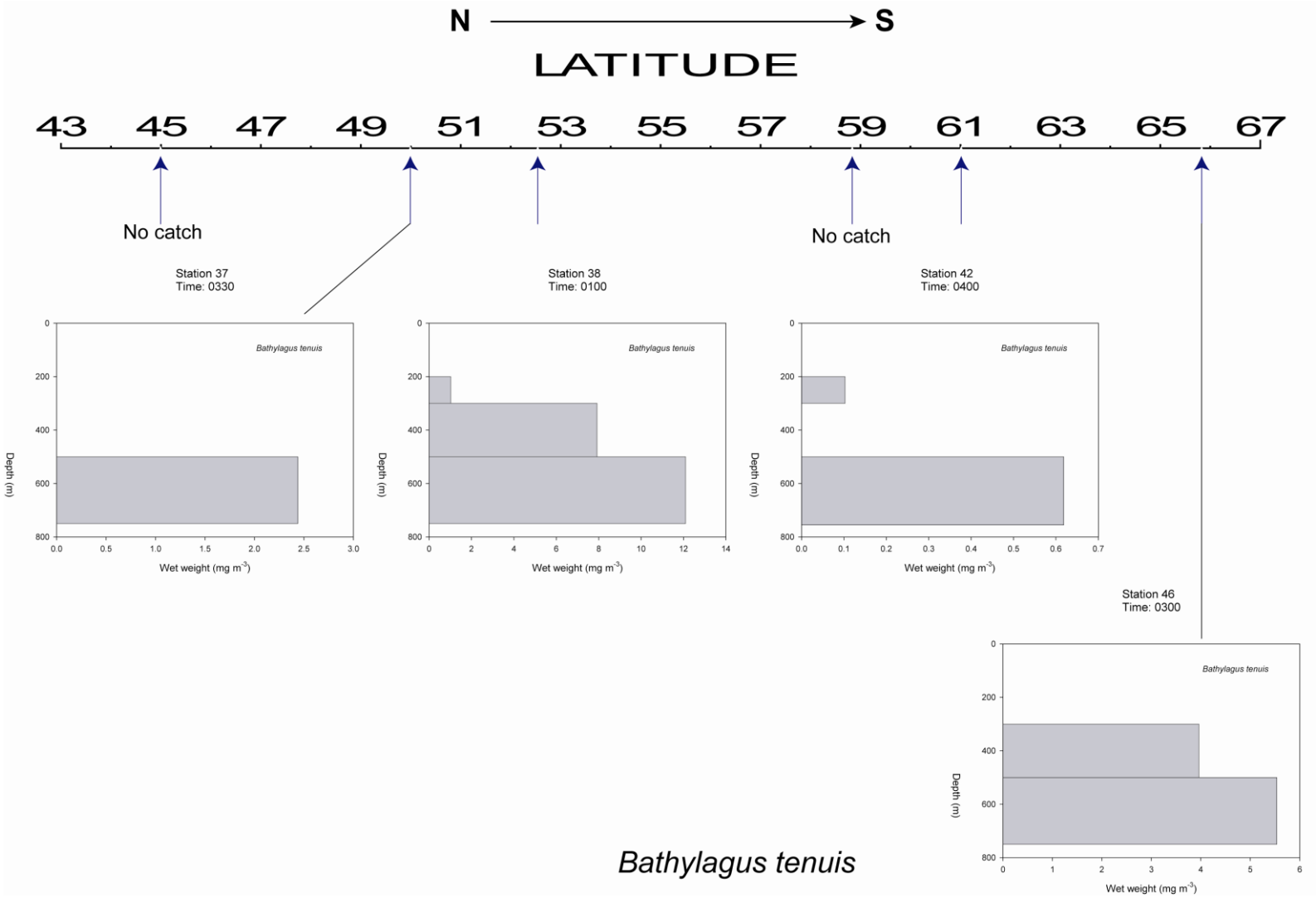


Figure 9.7. Vertical distribution of *Bathylagis tenuis* based on Krill trawl catches with Multisampler. Southward transect at 15° E.

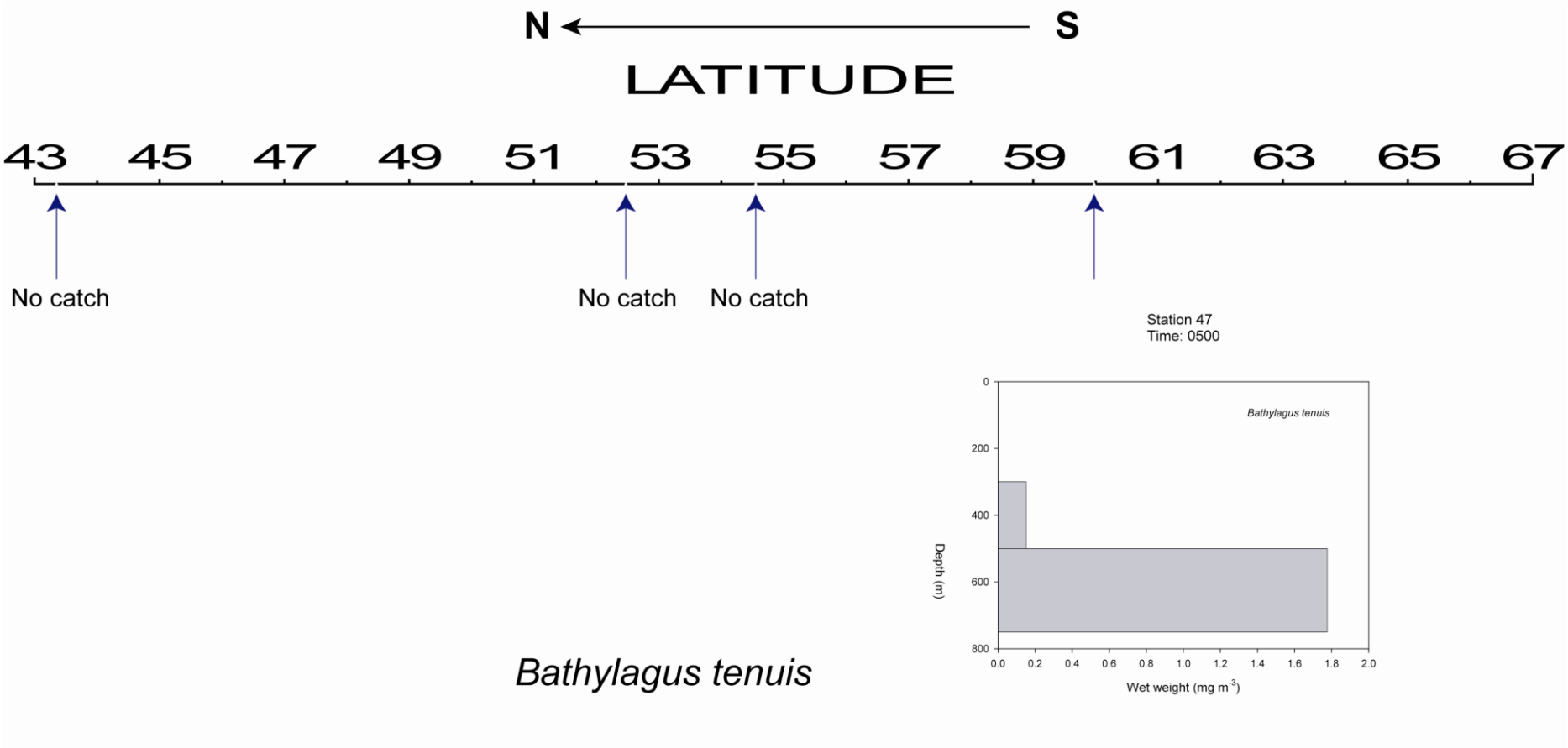


Figure 9.8. Vertical distribution of *Bathylagis tenuis* based on Krill trawl catches with Multisampler. Northward transect at 7° 30´ E.

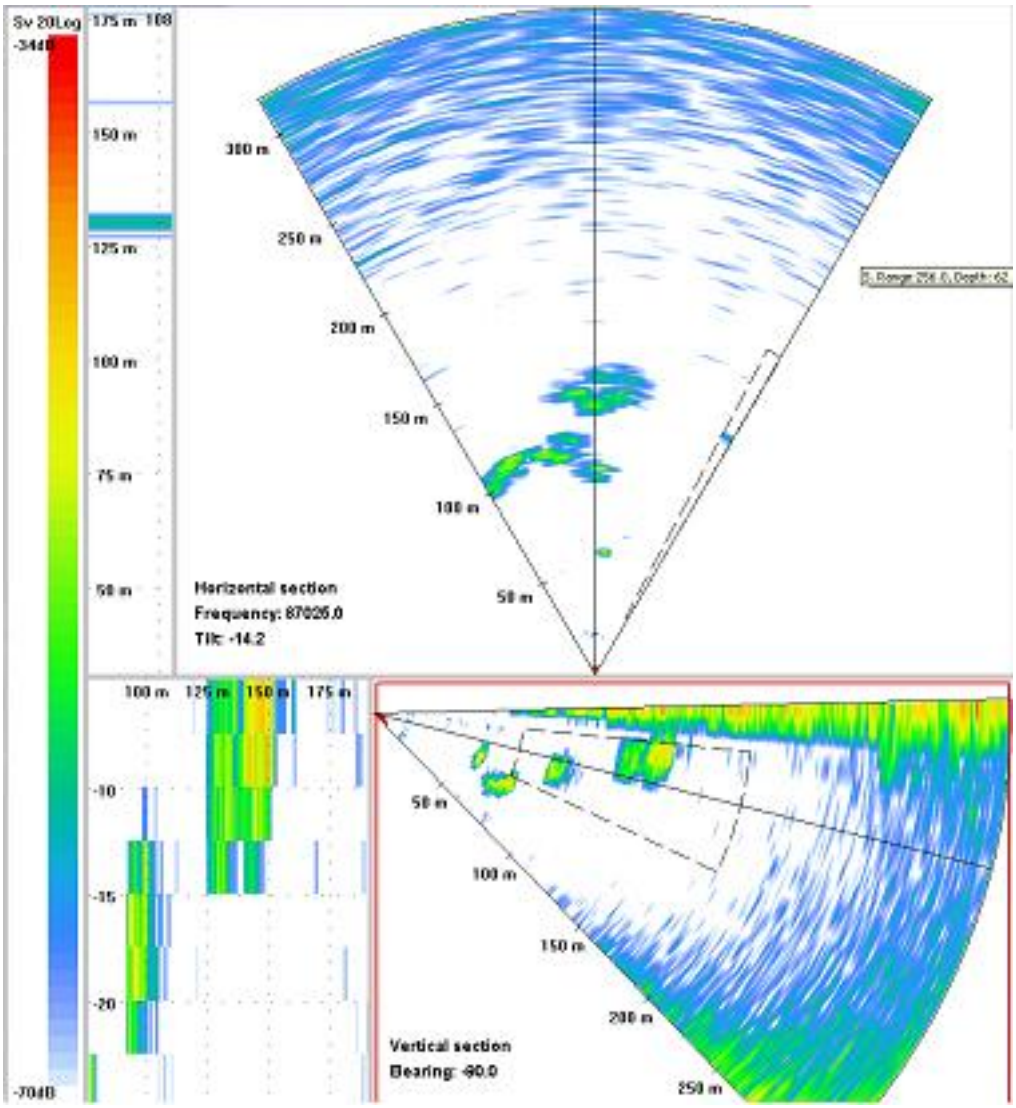


Figure 10.1. Sonar screendump 29.02.08 (64º31 S, 017°50 E) produced from Simrad MS 70 multibeam sonar. The picture is showing krill schools of various dimensions and densities within 150 m from the port side of the vessel and distributed shallower than 22 m depth.

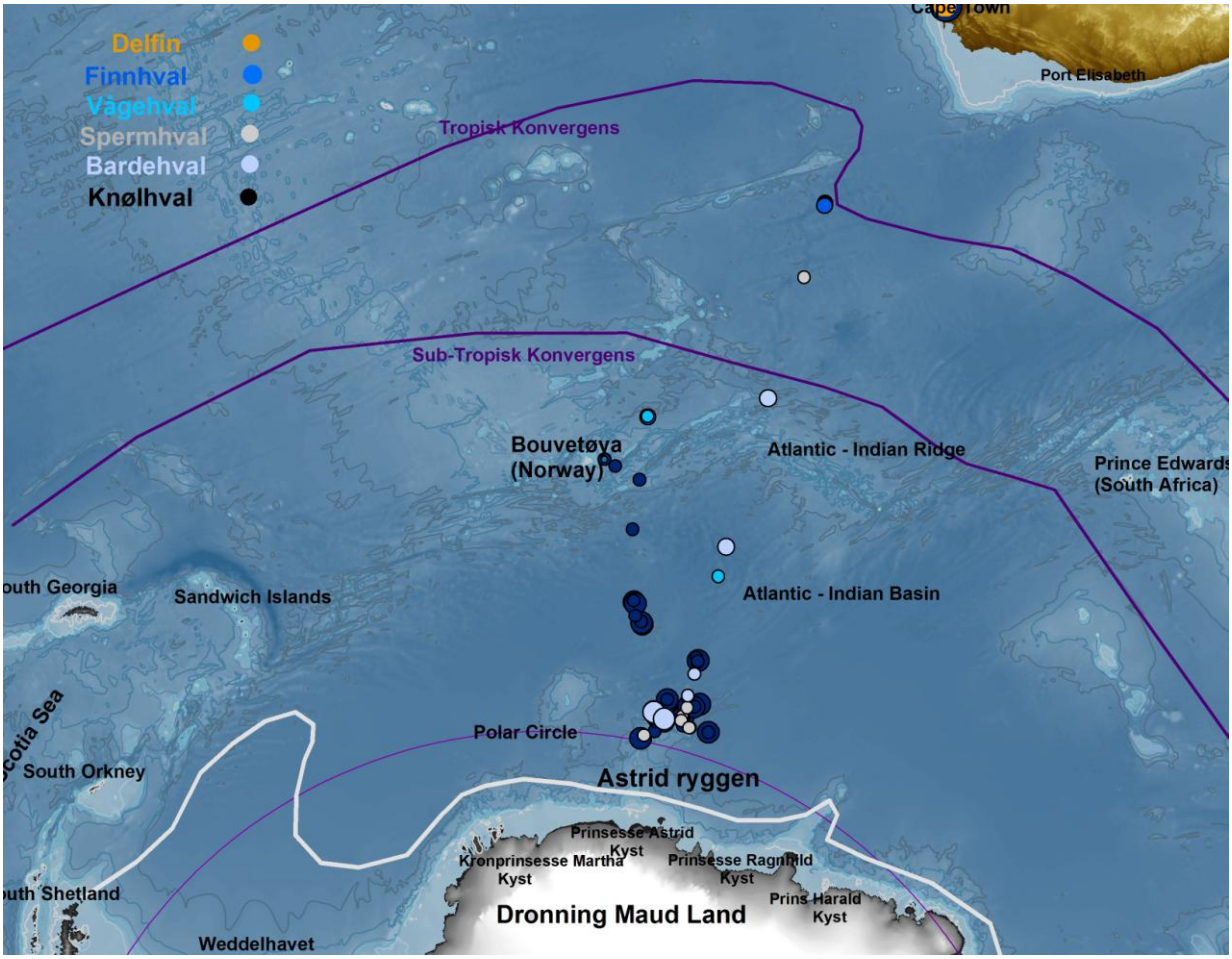


Figure 11.1. Distribution of different marine mammal species along the cruise track from Cape Town to the Astrid Ridge.

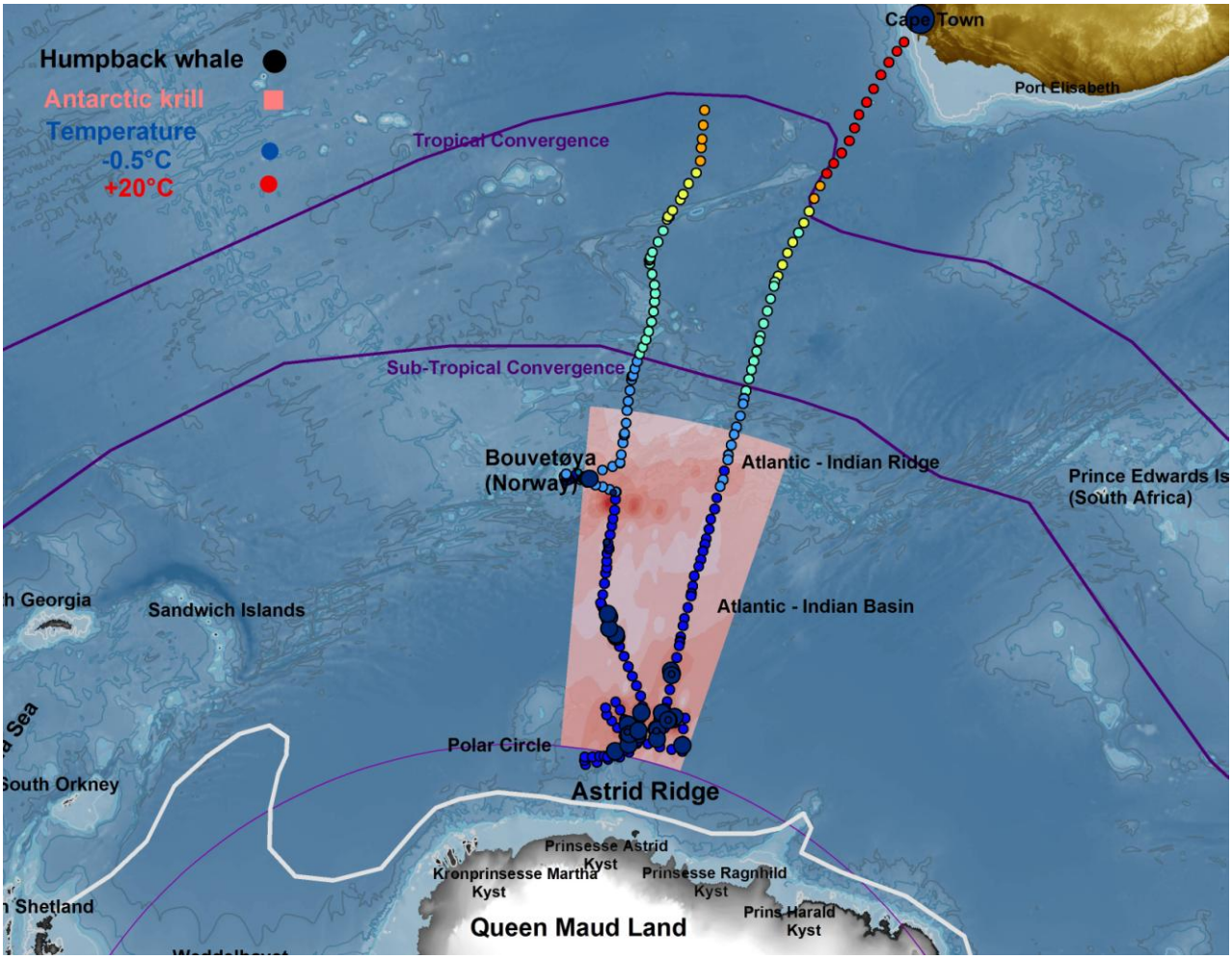


Figure 11.2. Map of humpback whale sightings, krill distribution and surface temperatures along the cruise tracks from Cape Town to the Astrid-Ridge close to Dronning Maud Land on the Antarctic continent, and northwards to Bouvet Island and beyond. Illustration: Øyvind Tangen.

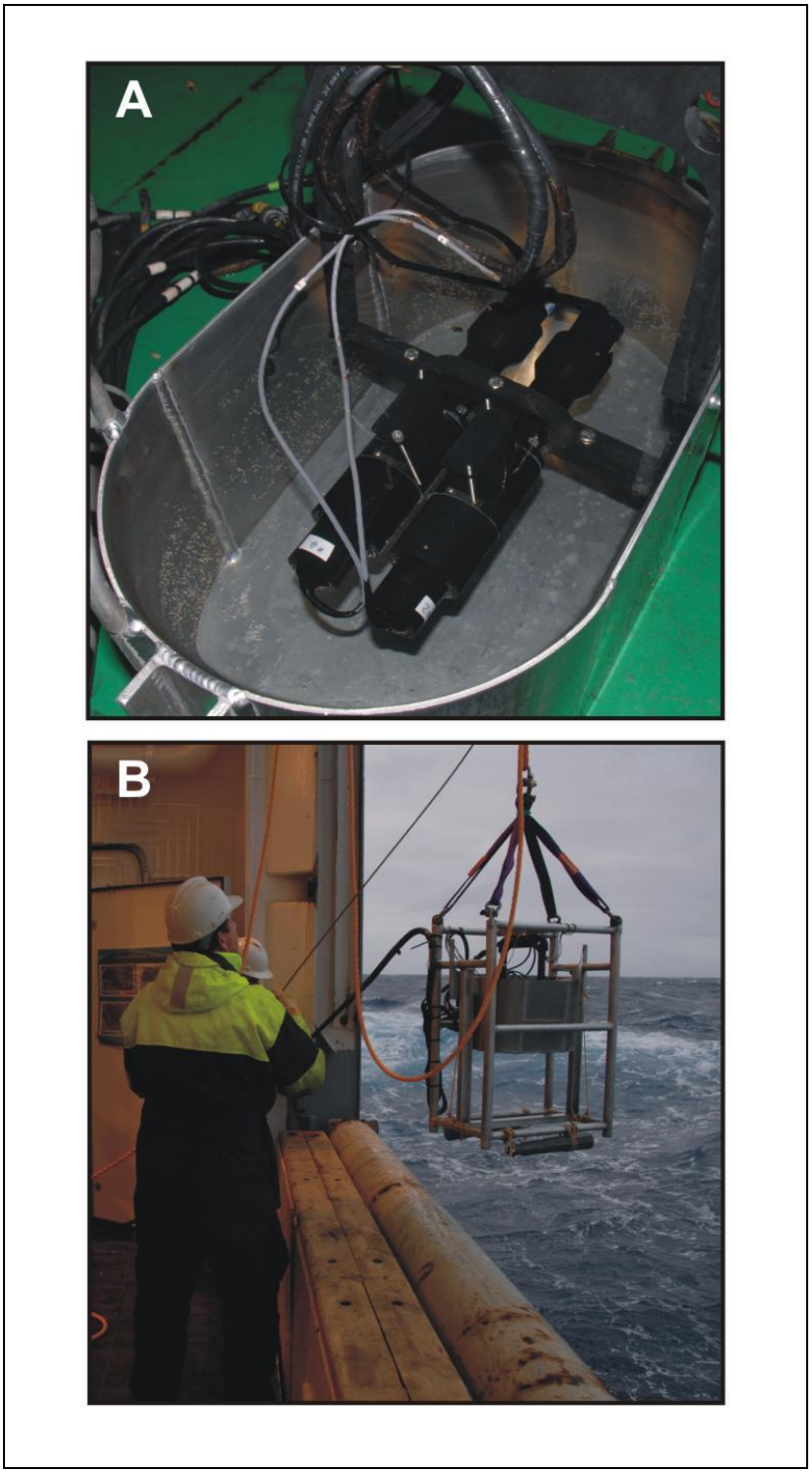


Figure 13.1. A) The two sound speed tubes side by side in the aluminum reservoir filled with seawater. At one end of each tube is a transmitting transducer and at the other end is a receiving transducer. In the middle of each tube is a compartment in which krill and other animals can be placed so that they are in the path of the transmitted sound. Normally one chamber is kept empty to serve as a control. B) APOP with live krill being deployed for a 200 m profile cast to measure their sound speed contrast as a function of depth. Note the aluminum reservoir within the pipe framework that the sound speed chambers are contained in.

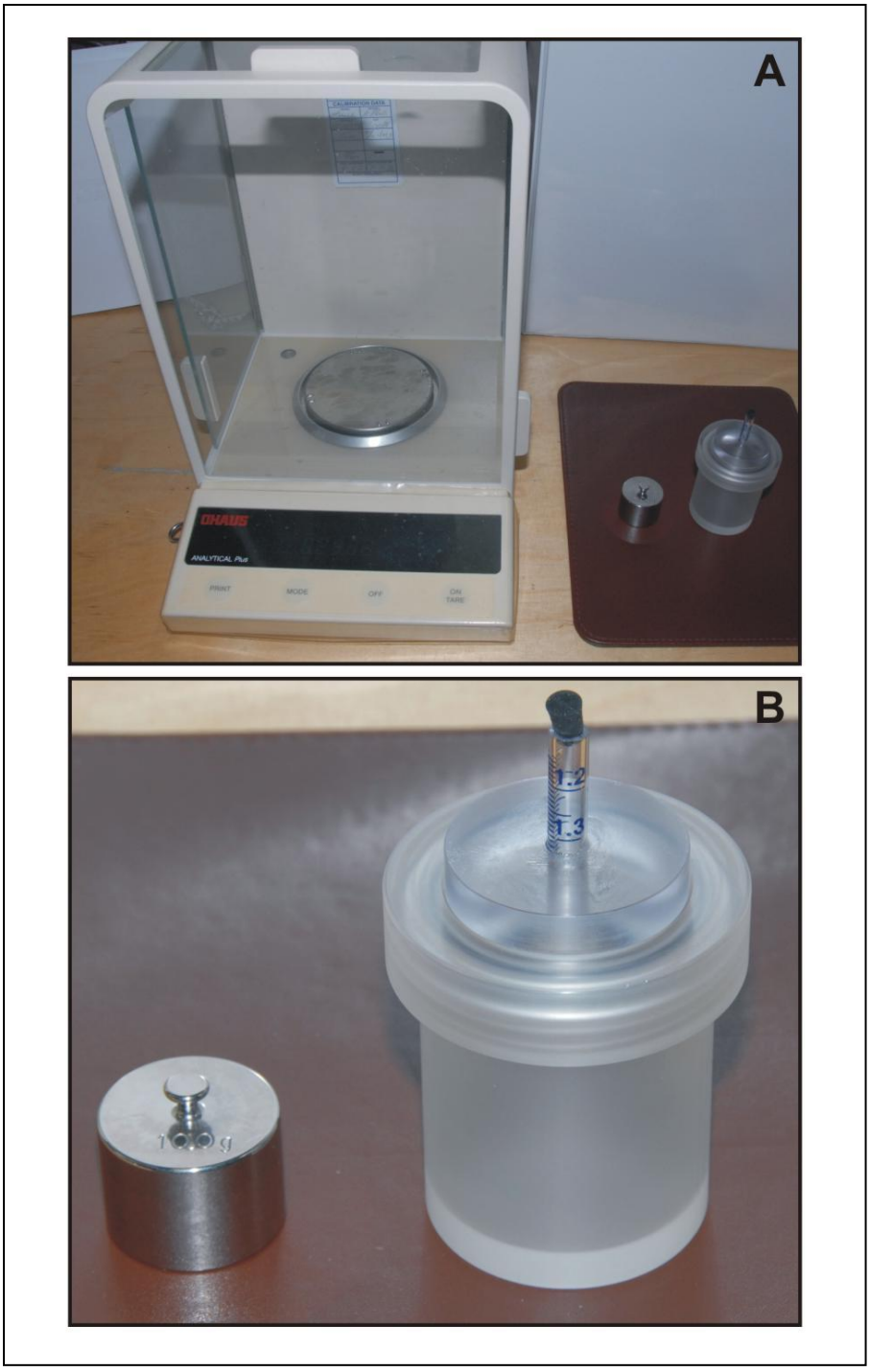


Figure 13.2. A) Ohaus electro-balance, standard 100 g weight, and the weighing vessel used in the "dual density" method measurements on the GO SARS AKES cruise in February/March 2008. B) Close-up of the weight and weighing vessel showing the high volume resolution markings at the top of the vessel.

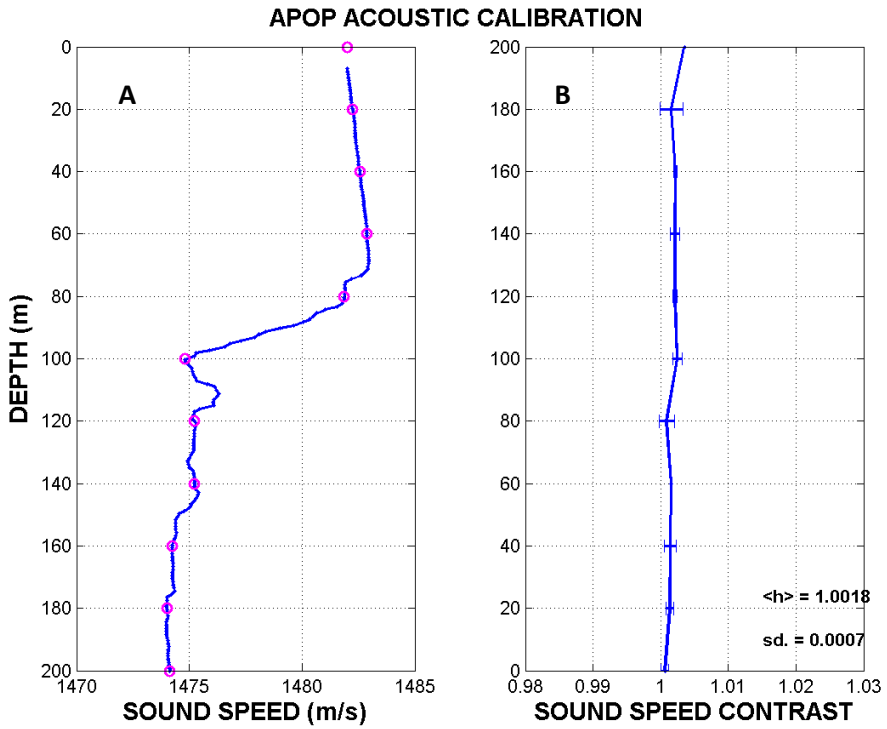


Figure 13.3. A) The water column sound speed based on temperature and salinity and B) the APOP sound speed contrast calibration profile conducted on 17 March 2008.

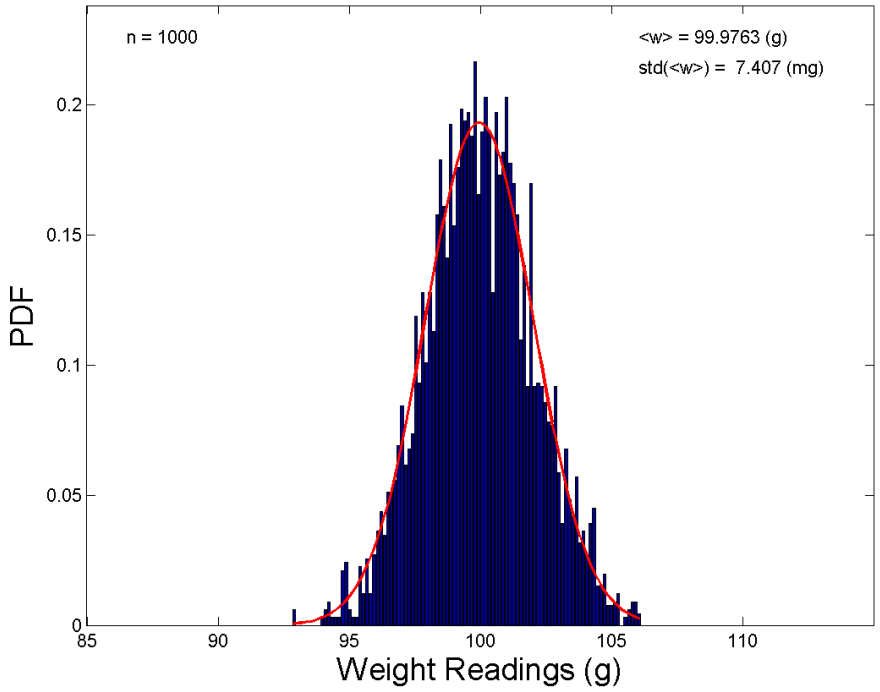


Figure 13.4. The PDF and a Gaussian PDF fit (red) of 1000 weight measurements of an 100-g standard weight. There are 5 runs with each including 1000 weighing values. The mean and the standard deviation of the 5 runs are given in the legend.

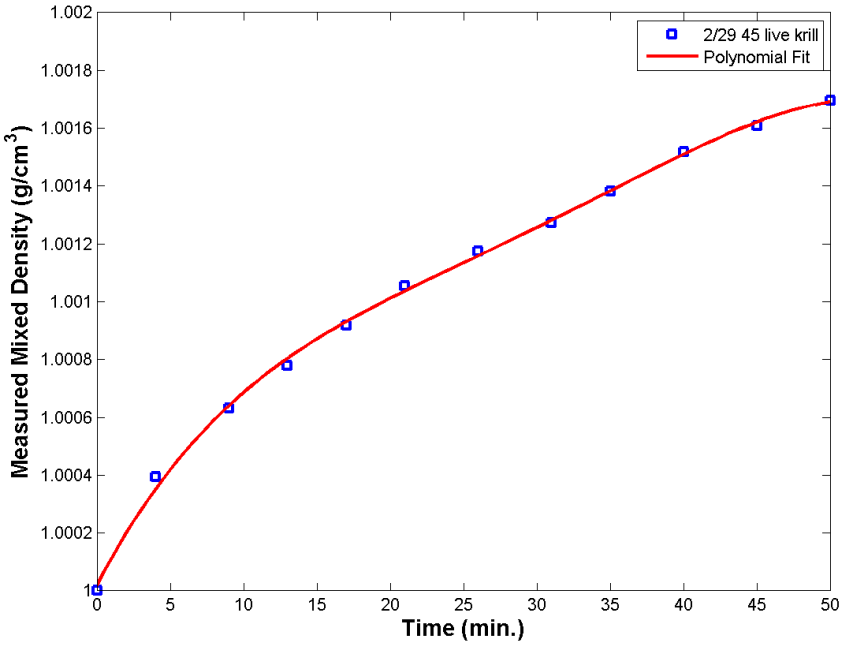


Figure 13.5. Measured osmotic effect of live krill.

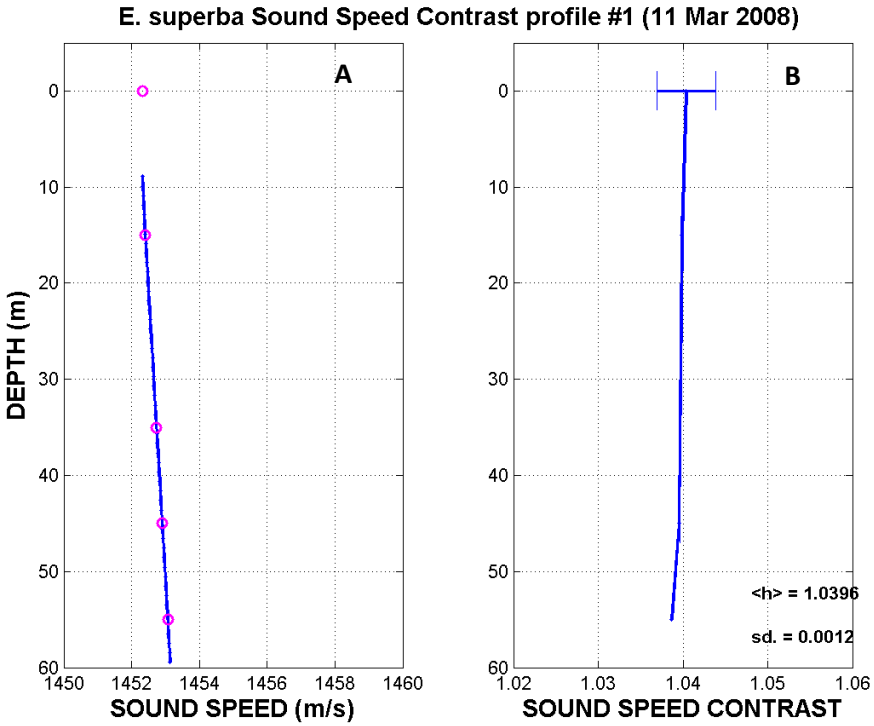


Figure 13.6. A) The water column sound speed based on temperature and salinity and B) the sound speed contrast of Antarctic krill (*E. superba*) measured on 11 March 2008.

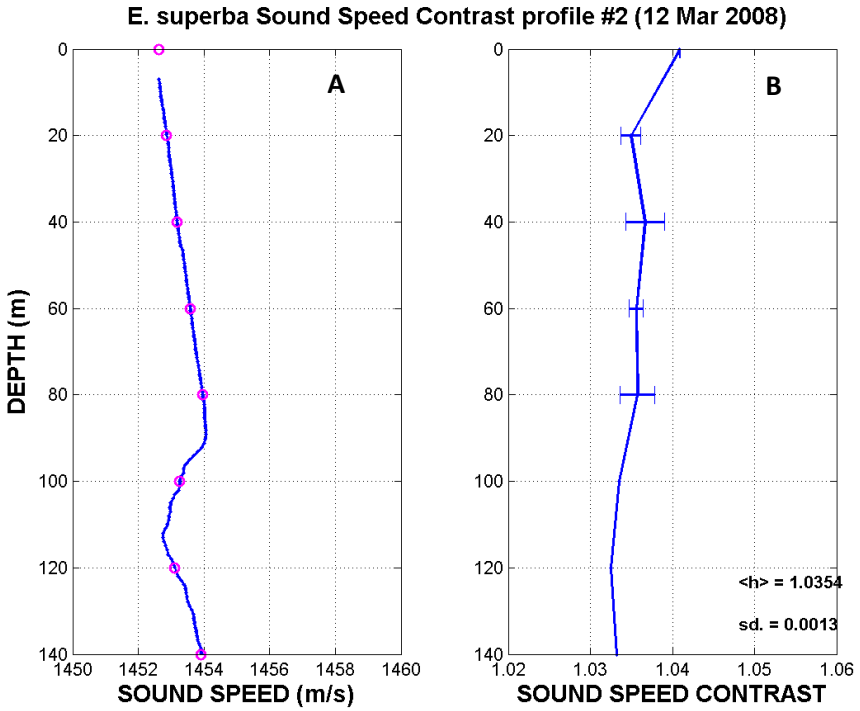


Figure 13.7. A) The water column sound speed based on temperature and salinity and B) the sound speed contrast of Antarctic krill (*E. superba*) measured on 12 March 2008.

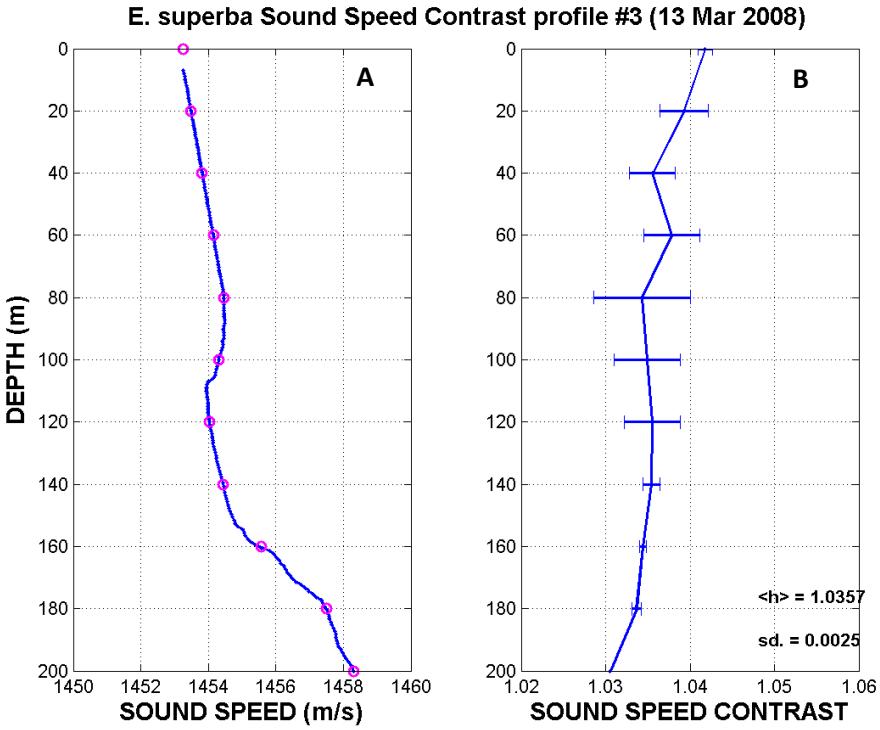


Figure 13.8. A) The water column sound speed based on temperature and salinity and B) the sound speed contrast of Antarctic krill (*E. superba*) measured on 14 March 2008.

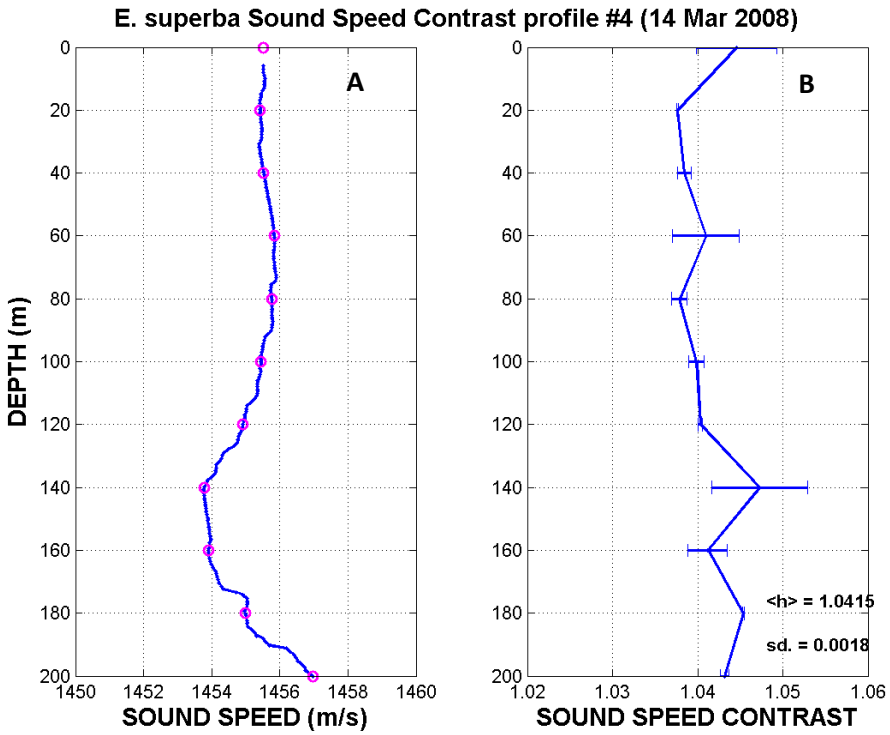


Figure 13.9. A) The water column sound speed based on temperature and salinity and B) the sound speed contrast of Antarctic krill (*E. superba*) measured on 14 March 2008.

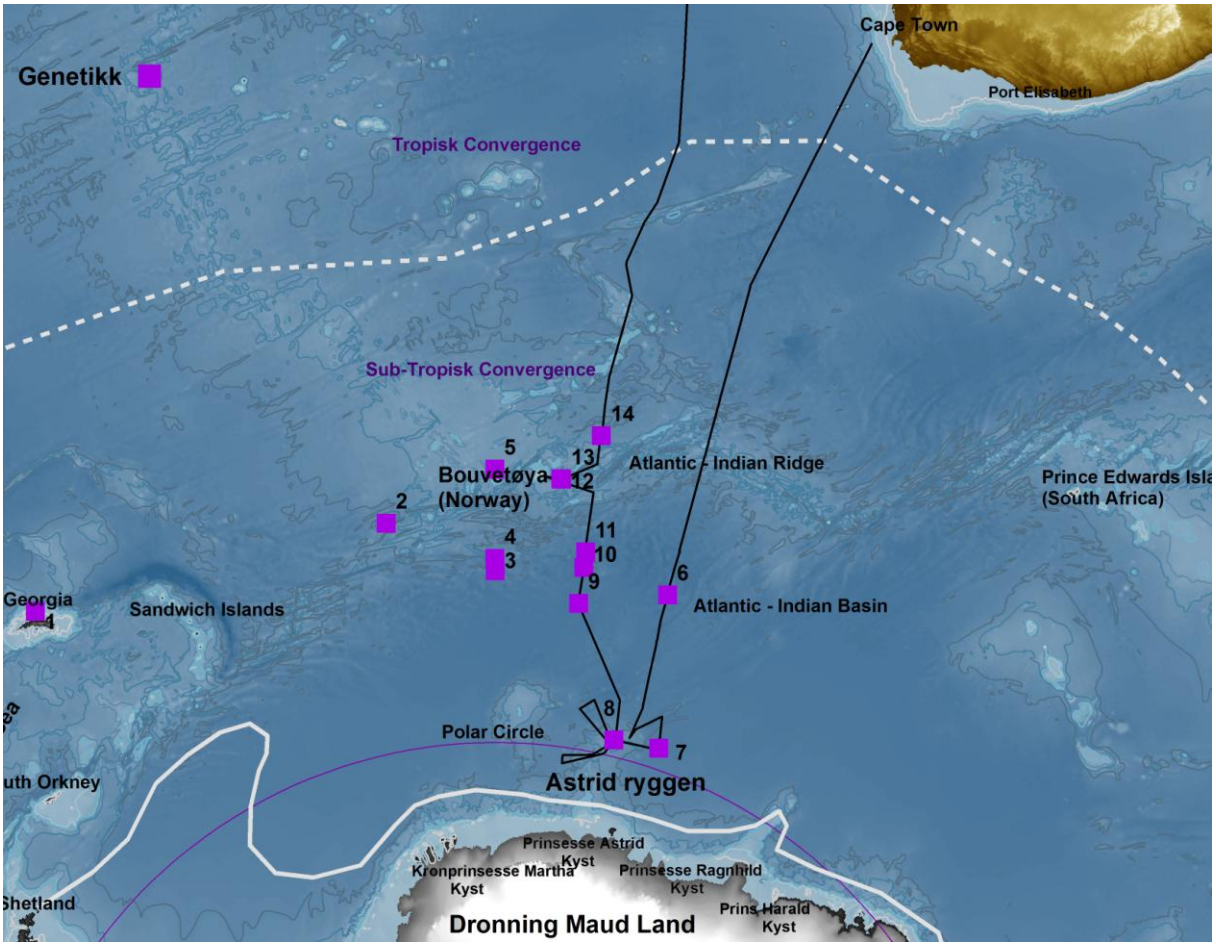


Figure 14.1. Map of samplings stations for genetic analyses (allozymes; DNA analyses) during the G.O. Sars AKES research surveys. AKES 1 is represented by Trawl station 3 to 5; while samples from Trawl stations 6 – 14 were collected during the AKES 2 period.

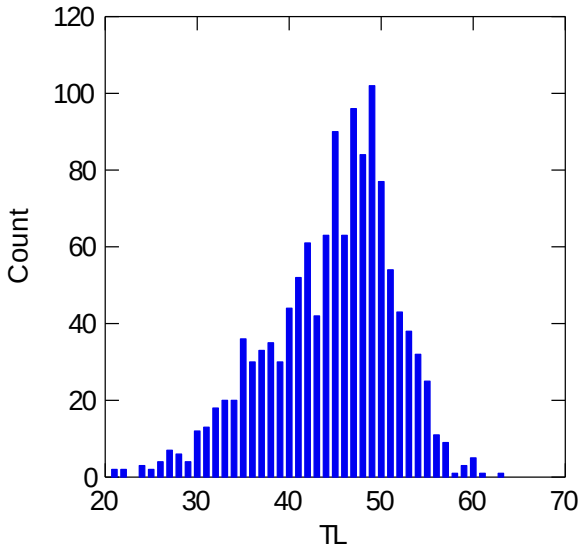


Figure 15.1. Krill measurements from the Atlantic-Indian sector of the Southern Ocean.

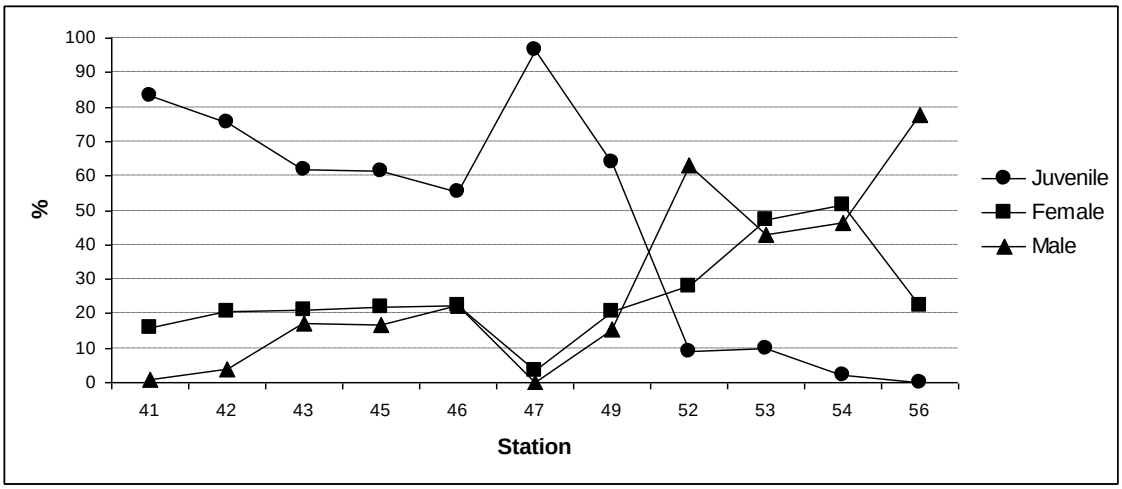


Figure 15.2. Percentages of each maturity sex stages in each station.