Cruise report from the coordinated ecosystem survey and SALSEA salmon project with M/V "Libas" and M/V "Eros" in the Norwegian Sea, 15 July- 6 August 2009

Cruise report: Survey number 2009 818 (Libas) and 2009 820 (Eros)

Period: 15 July – 6 August 2009

Vessels: M/V "Libas" (LMQI), M/V "Eros" (LIVA)

Area: Norwegian Sea and adjacent areas (62º30-80º00N, 24º00E-18º00W)

Main purpose: Study abundance, spatiotemporal distribution, aggregation and feeding ecology of Northeast Atlantic mackerel, Norwegian spring-spawning herring, blue whiting and Atlantic salmon in relation to oceanographic conditions, prey communities and marine mammals.

Sub-goals:

- Map concentration and distribution of non-targeted species such as horse mackerel and capelin.
- Systematic marine mammal sightings for species identification, group size and behaviour. Concurrent digital filming and photo for scientific purposes and validation.
- Provide samples of post smolts for genetic, pathologic and physiological analyses
- Quantify migration speed and direction of tracked herring and mackerel schools at different spatial scales on multibeam sonars in the upper water masses (0-50m).
- Counting of total number of detectable herring and mackerel schools on the multibeam sonars, with corresponding estimated school size.
- Sonar recordings of marine mammal detections, group size, target strength (TS) measurements and underwater swimming behaviour at closer range 50-300 m.
- Ecological studies on predator-prey interactions and avoidance behaviour of pelagic fish, krill and marine mammals using acoustics, visual observations and sampling.

Personnel:

"***Libas***": Leif Nøttestad (cruise leader, project leader, (IMR)), Ruben Patel (IMR), Valantine Anthonypillay (IMR), Øyvind Tangen (IMR), Inger Henriksen (IMR), Vidar Wennevik (IMR), Bjørnar Ellertsen (IMR), Julio Erices (IMR), Herdis Langøy (IMR), Matteo Bernasconi (IMR/Univ. St. Andrews, Scotland), Lena Petterson (Tromsø), Igor Golyak (PINRO, Russia), Jens Christian Holst (IMR), Shale Rosen (Scantrol).

"***Eros***": Marianne Holm (cruise leader (IMR), Helga Gill (IMR), Hector Pena (IMR), Jaime Alvarez (IMR), Bente Skjold (IMR), Knut Hansen (IMR), Jarle Kristiansen (IMR), Magnus Johannessen (IMR), Monica Bente Martinussen (IMR), Guro Løkka (Norwegian Veterinary Institute), Bill Mulligan (CEFAS, UK)

Content

1) Summary

Two chartered Norwegian fishing vessels M/V “Libas” and M/V “Eros” performed an ecosystem survey from 15 July to 6 August 2009 in the Norwegian Sea and adjacent areas. The abundances of Northeast Atlantic mackerel (*Scomber scombrus* L.), Norwegian spring-spawning herring (*Clupea harengus* L.) and blue whiting (*Micromesistius poutassou* L.) were measured acoustically. Estimated biomass of mackerel was calculated to 4.4 million tons in the Norwegian Sea. Mackerel was distributed over larger areas than previously documented in the Norwegian Sea in July. Furthermore, a northwestern distribution was more pronounced in July 2009 compared to previous years. Repeated offshore catches of one and two year’s old individuals indicate that the Norwegian Sea is now also an important nursery and feeding ground for immature mackerel. The 2005- and 2006 year classes dominated with 26% and 25% of total catches, respectively. Large mackerel ate adult capelin north of Iceland, which has never been reported before. Estimated biomass of herring was 13.6 million tons. Herring had a typical donout shaped distribution, and the majority of individuals were distributed feeding in the colder and frontal waters in the western, northwestern and northeastern part of the Norwegian Sea. The 2002- and 2004 year classes were most abundant representing 27% and 22% of total trawl catches, respectively. Estimated biomass of blue whiting was 2.3 million tons in the Norwegian Sea in July. The 2004 year class dominated with 29% of the catches, followed by the 2003 and 2002 year classes with 23% and 20% of total catches. No young year classes less than 4 years of age were found during the survey. Large blue whiting also ate adult capelin north of Iceland, representing new scientific information. A total of 87 salmon were caught on Libas and Eros. The majority, 76 individuals were caught north of 69°N and on Eros in the northern central part of the Norwegian Sea, whereas only 11 individuals were caught on Libas in the central and southern parts.

Surface waters in the northwestern part of the Norwegian Sea in the Jan Mayen zone and in Icelandic waters were considerably warmer compared to the last two decades, and coincided with increased presence and concentrations of large herring and mackerel in the area. The northernmost areas were in contrast colder than previous years, limiting the extent of northern migration by herring and mackerel compared to the last few years. Coastal waters off Norway were also colder than recorded in previous years.

Zooplankton concentrations including *Calanus finmarchicus*, krill and amphipods were generally low, except a few locations with elevated biomasses (18.2-22 g/m^2) of *C. finmarchicus* in the northern areas. The average concentration of zooplankton was only 4.8 g/m^2 in the Norwegian Sea in July, suggesting a reduction in biomass compared to previous years.

Very few marine mammals, except sperm whales, were present in the Norwegian Sea in July 2009, based on dedicated whale observations on Libas and opportunistic sightings on Eros. Both herring and mackerel swam predominantly in small and loose aggregations as recorded from sonars and echosounder, making it difficult for marine mammals to prey cost efficiently on schooling fish. Low concentrations of krill and amphipods also suggest why baleen whales such as humpback whale and minke whale were scarcely present in the Norwegian Sea in July.

Tail fins were sampled from salmon, herring, mackerel, blue whiting and horse mackerel in the Norwegian Sea for genetic studies and stock identification.

Key words: Norwegian Sea, planktivorous fish, herring, mackerel, blue whiting, salmon, abundance, distribution, feeding ecology, schooling behavior, predator-prey interactions, genetics.

2) Introduction

Ecosystem survey

We aim to use these coordinated cruises with chartered vessels as part of an integrated platform to perform quantitative and qualitative ecological studies on the interplay between ecologically and economically very important pelagic fish species in the Norwegian Sea during summer. It is of great importance and interest for our understanding of the functioning of the Norwegian Sea ecosystem, how the 3-D and 4-D distribution, aggregation and diet of mackerel, herring, blue whiting and horse mackerel are and to what extent they overlap in space and time. We therefore collected a wide range of data including hydrographical measurements (CTD casts), current measurements from ADCP, plankton samples (WP 2 nets, ringnet, bongo-bongo, krill trawl) and full biological analyses of pelagic fish species for each station applying epi-pelagic trawling at surface and deeper in the water column. Acoustic measurements and registrations were performed using multi-frequency acoustics from Simrad ER60 echosounder, as well as high-frequency medium range Simrad SH 80 (Libas and Eros) and low-frequency long-range Simrad SP 90 (Libas) and Simrad SX (Eros) multi-beam sonars. A new software developed by Ruben Patel to analyse fish schools on Simrad SH80 sonar was tested for the first time. The aim here is to be able to automatically count number of fish schools along the cruise track and record relevant data on school size, swimming speed and direction.

The three weeks cruise is part of a long-term project to collect updated and relevant data on abundance, distribution, aggregation, migration and ecology of major pelagic species. The Institute of Marine Research, Bergen, Norway chartered two commercial vessels, M/V “Libas” and M/V “Eros”, both fulfilling the required scientific specifications set for this ecosystem study. Both vessels have a drop keel installed and in operation when performing acoustic survey, in order to avoid bubble and surface generated noise during acoustic operation in Open Ocean under different sea state conditions. A scientific quota of 1000 ton mackerel, 1000 ton capelin and 400 ton herring was provided to IMR from the Directorate of Fisheries and accepted by the Ministry of Fisheries and Coastal Affairs as an economical compensation for the chartered vessels operating as platforms for the scientific activities performed.

SALSEA

Rationale for the salmon investigations

Despite management measures taken over the past two decades, the stocks of Atlantic sampling have been declining. The specific reasons for the decline are as yet unknown, but an increasing proportion of the salmon are believed to die at sea during the oceanic feeding migration. Salmon populations may migrate to different marine zones, whose environmental conditions may vary. To date it has been difficult to sample and identify the origin of sufficient numbers of wild salmon at sea to enable this vital question to be addressed. The greatest challenge in salmon conservation is to gain insight into the spatial and ecological use of the marine environment by different regional and river stocks.

Aim of SALSEA

The SALSEA-Merge project (2009-2010) is aimed at providing basis for advancing our understanding of oceanic-scale, ecological and ecosystem processes. Such knowledge is lacking for salmon, and is fundamental to the future sustainable management of this species. Through a partnership of 9 European nations the programme will deliver innovation in the areas of genetic stock identification techniques, new genetic marker development, fine scale estimates of growth, the use of novel high seas pelagic trawling technology and individual stock linked estimates of food and feeding patterns.

3) Material and Methods

Calibration of echosounder transducers

Libas and Eros were calibrated after standard hydro-acoustic calibration-procedure for each frequency prior to the cruise (Foote, 1987). The transducers are placed in the drop keel onboard Libas and Eros. The calibration on Libas took place inside a wind and wave protected area at Sandviksflaket, just outside the harbour of Bergen, Norway. The frequencies calibrated involved 18, 38, 70, 120 and 200 kHz. We calibrated 38 kHz and 200 kHz transducers with 60 mm copper sphere (Cu 60). CTD measurements with a SAIV SD200W instrument were taken in order to get the correct sound velocity as input to the echosounder calibration settings. A similar calibration took place outside Longyearbyen in Spitzbergen prior to the survey.

Cruise tracks

Libas and Eros followed predominantly predetermined survey lines with pre-selected pelagic trawl stations and occasionally performed pelagic trawl stations on registration from acoustics (Figure 1). An adaptive survey design was also adopted, due to uncertain geographical distribution of our main pelagic planktivorous schooling fish species. Some modifications in the central western part in between Icelandic and Jan Mayen and were performed due to higher concentrations of herring and mackerel in these areas. The cruising speed was 12.0 knots if the weather permitted it, otherwise 10.0 knots. CTD stations (0-500 m) using a SAIV SD200 CTD sensor in combination with WP2 net samples (0-200 m) were taken systematically on every pelagic trawl station (Figure 1). A ringnet of 1.5 m diameter sampled plankton organisms in the upper 50 m of the water column. A bongo-bongo net was towed with 2.5-3.0 knots in 20 min at the surface after trawling. Krill trawling was occasionally done when salmon was caught in the surface trawl.

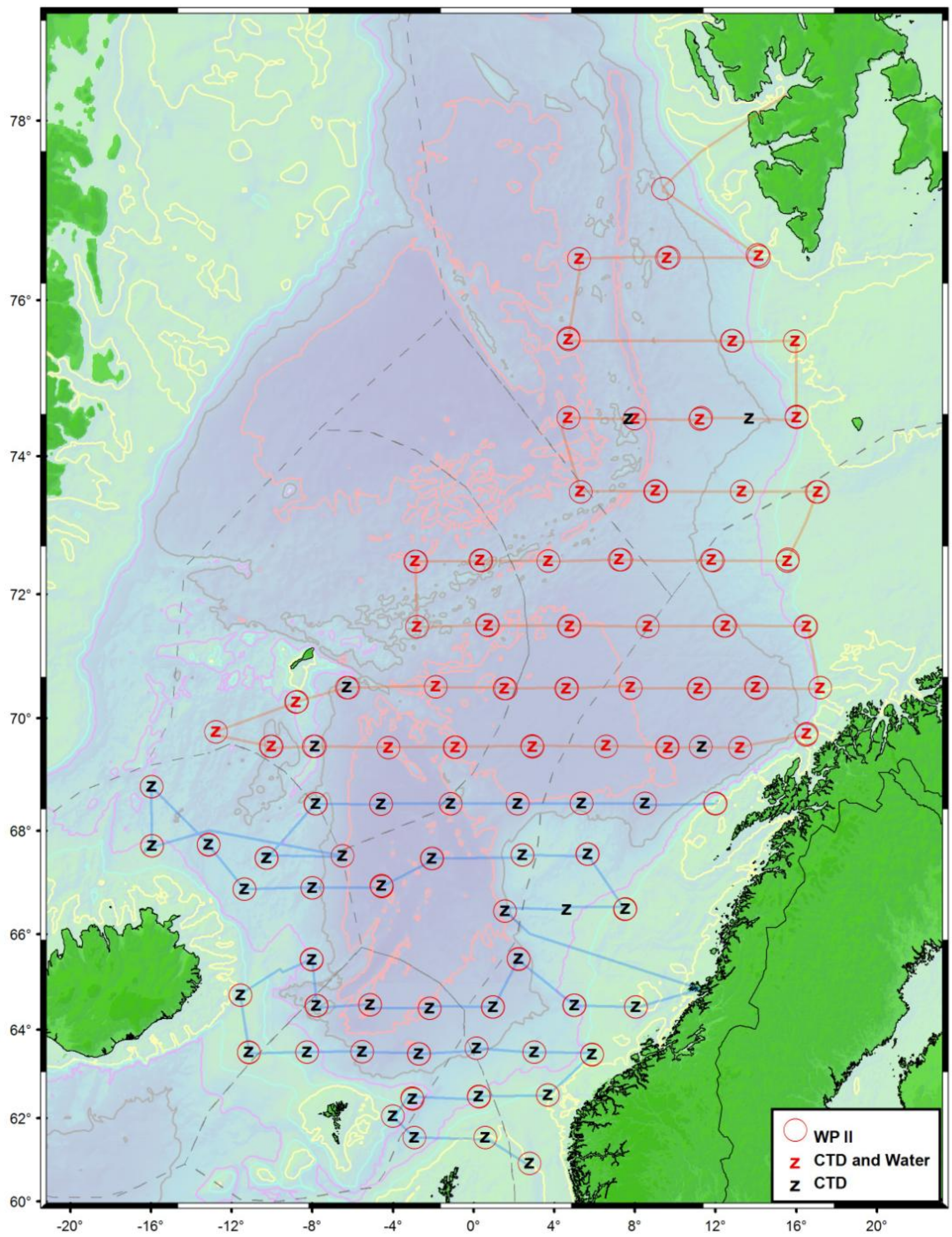

Figure 1. Survey lines along the cruise tracks with pre-defined CTD stations (0-500 m) and WP2 samples (0-200 m) for M/V"Libas" and M/V"Eros", 15 July – 6 August 2009. This large ocean area included the following Economical Exclusive Zones (EEZ): Norwegian EEZ, United Kingdom EEZ, Faeroe Island EEZ, Iceland EEZ, Jan Mayen fishery protection zone, Spitzbergen protected area and International waters.

Biological sampling

Pelagic planktivorous fish species

Trawling was done with a small specially designed pelagic trawl from Åkra trawl with a trawl opening between 10-13 m, spread of 60 m using 300-350 m wire length. Most of the trawling was done in the surface area with floats attached to the wings and the headline. Towing speed at the surface was 4.2-5.3 knots and towing time was normally 1 hour. Targeted herring and blue whiting trawl hauls on registrations were performed with a capelin/herring trawl from 10-250 m depth. This trawl had an opening of 45 m and spread of 70 m using 200-600 m wire length. The tow duration was maximum 30 min. Towing speed at depths varied between 3.5-4.8 knots depending of the vessel performance, current, wind and wave conditions. The catch was sorted at each station and full biological sampling including otoliths of up to 25 mackerel, herring and blue whiting was taken in addition to length and weight measurements of 100 specimen and stomach samples of 10 individual per species (Alvsvåg et al. 2003, Mjanger et al 2007). We aimed to study possible interactions between species, and therefore decided when several pelagic species was caught in the same trawl haul that the sampling procedure should be adapted to enable to study ecological questions in more detail. Length and weight were measured for all other non-target species caught in the pelagic trawl hauls, as well as total weight for each species. Estimated biomasses for mackerel, herring and blue whiting were done in situations where not all the fish could be sampled and weighted from a pelagic trawl haul.

SALSEA-Merge salmon sampling

The salmon postsmolts were photographed, measured, weighted, sexed, scale loss was estimated, number of lice counted and stored, and visual inspection of cataracts, external tags, finclip for internal tags, deteriorated fins/escapee, scars etc. Following samples and recordings were taken (and stored if applicable) on every fish: scale sample, pectoral fin for DNA sample, disease sample (gill filament, pyloric caeca, spleen, kidney on three places), ISA disease sample 4 (gill filament and kidney), Isotope sample (liver, dorsal muscle, adipose fin, heart, tip of caudal fin), lipid sample (dorsal muscle), stomach sample, otolith sample. The carcass was labeled and stored.

Hydrography

Libas and Eros were both equipped with SAIV SD200 CTD sensor recording temperature, salinity, pressure (depth) from the surface down to 500 m, or when applicable as linked to maximum bottom depth. The SAIV sensor was programmed to record data every 2 seconds and the speed of the wire during measurements was set to 0.5 m/s providing data approximately every 1 m in the water column. The sensor was positioned at about 1 m depth for 1 min at each station in order to let the instrument sensors adapt to the seawater from being stored dry between stations on the vessel. CTD data from the downcast were used for further analyses. Sea surface temperature (6 m depth) was also recorded manually from a bottom-mounted temperature sensor with a display on the bridge systematically every hour during cruising between stations for both vessels. Libas had also a SEABIRD CTD sensor with a water rosette, but did not work during the survey. The SEABIRD was not properly tested by IMR instrument people prior to the survey when the vessel was in the harbour at Nykirkekaien.

A thermosalinograph recorded surface temperature and salinity every 1 min throughout the cruise onboard Eros. Temperature at 6 m depth was noted each hour during the entire cruise onboard Libas.

Plankton sampling

Zooplankton sampling was performed at 44 stations on Libas and 47 stations on Eros. With few exceptions due to bad weather conditions the following sampling procedure was followed:

- A WP-2 net, 180 μ m mesh size, from 200 m depth to the surface
- A 160 cm diameter net (T-160), 375 μ m mesh size, from 50 m depth to surface
- A 2 x 60 cm diameter Bongo, mesh size 375 μ m, trawled horizontally in the very surface layer for 20 min. at a speed of 2.5 knots

A Macrozooplankton trawl (krill trawl) was used onboard Eros with tow duration of 30 min at the surface, 5 m spread and about 7-8 m vertical opening. The trawl was operated without trawl doors and buoys attached to the wings to keep the trawl as high as possible in the water column.

Sample treatment

Macroplankton trawl

Samples were sorted, species identified and length measured according to working standards. All subsamples were frozen to -30°C and the whole sample was frozen after length measurements in those cases were the total samples were small.

WP2 net

Plankton hauls were collected with a WP-2 plankton net, 56 cm in diameter and a mesh size of 180 μm on M/V "Libas" and M/V "Eros". One plankton haul was sampled on each predefined station from 200 m – 0 m depth. The choice of depth range was taken to link plankton concentrations directly within the depth ranges were the pelagic schooling species (mackerel and herring) are actively feeding during summer. The hauling speed should not exceed 0.5 m/s in order to avoid bucking effect. The vertical deviation on the wire should not exceed 30º and all plankton samples were repeated if this situation appeared. The plankton net is each time flushed with seawater to collect plankton from the net itself inside the cup, while the net is still hanging outside the railing. Furthermore, the area above the cup is flushed on deck to secure that the whole plankton sample is properly collected. The cup is detached from the net inside a bucket, to avoid losing part of the plankton sample. The plankton sample is divided in to fractions; 1) taxonomic analyses (taxonomic species, size, and stadium composition, and 2) biomass estimates. The WP-2 samples were split into to equal parts, one for formaldehyde preservation, the second part for dry weighing. This part was separated into three size categories by filtering at 2000, 1000 and 180 mesh size sieves. The biomass in each size fraction was transferred into alumina trays for drying. The content of 2000 um fraction was identified, dependent upon species group the organisms were length measured and the various groups transferred to individual trays for drying. Weighing of trays took place at IMR laboratory after ended survey.

T-160 ringnet

Samples were conserved in borax neutralized 4 % formaldehyde. Special findings were noted in the zooplankton cruise journal.

Bongo

All Bongo and large ring net samples were preserved in borax neutralized 4 % formaldehyde after a brief visual examination. Special findings were noted in the zooplankton cruise journal.

Acoustics

Sonar

Two sonars were used simultaneously and continuously as a high priority activity during the survey, in order to identify and sample mackerel and herring schools along the entire cruise track. The high frequency sonar, Simrad SH80 (from 110 to 122 kHz), was used as primary sonar onboard Libas, which software includes the option to save the sonar raw data using a “Scientific Output” through an Ethernet connection. The processing of these data is time-consuming task that will be done in a later stage and is not included in the present cruise report. Raw data from areas with school detections were stored for both Simrad SH80 and SP90. Extraction and visualization of number, position, size, density and shape of schools as well as swimming direction and speed on automatically detected individual schools were performed.

An overview of the operational sonar settings for the different multibeam sonars is given in Table 1. The range used for this sonar was 400 m.

Manuel school detection using Simrad SH80 module in LSSS

The SH80 module in LSSS was tested for school detection (Figures 2-5). SH80 data was collected during trawling and at slow cruising speed in calm conditions. The three following figures shows some of the SH80 interpretation. The module worked well, but the interpretaion task was time consuming. And some filtering of the data is necessary to speed up the process. We encountered one serous error for some files, this wil be reported to the Christian Michelsen Research (CMR).

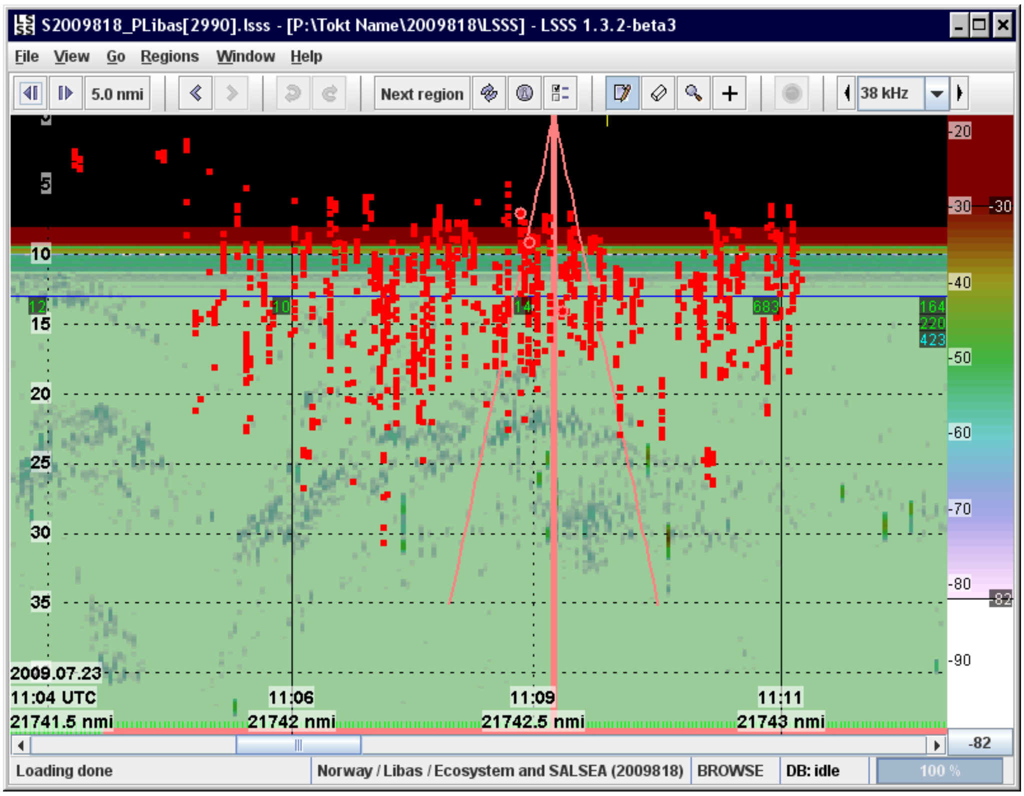

Figure 2. Sonar (SH80) echogram layer in LSSS. Red dots indicate manually detected schools from SH80 data projected to echogram. Schools in echogram might not correspond to detected schools due to non overlapping beams between the sonar and echo sounder. Pink line at bottom indicates correspondence in time for echo sunder (EK60) data and SH80 data. Vertical pink line indicates position of SH80 ping in ER60 data. Tilted line indicate ray intersection from SH80 into EK60 data, ray bending not taken into account.

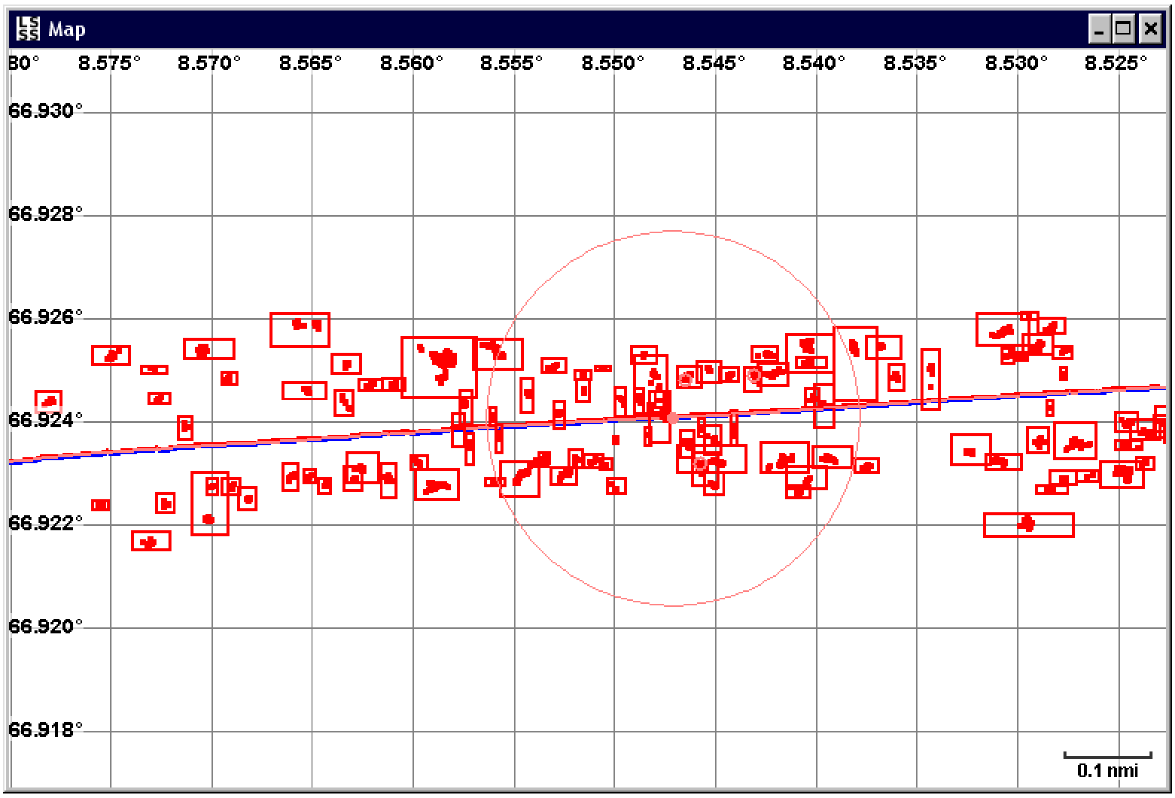

Figure 3. SH80 overlay in map module in LSSS. Pink thick line indicates presences of SH80 data, blue line indicate presences of EK60 data. Pink circle shows geographic perimeter of selected SH80 ping. Red dots show detected schools in each ping. Red squares show one school trough several pings.

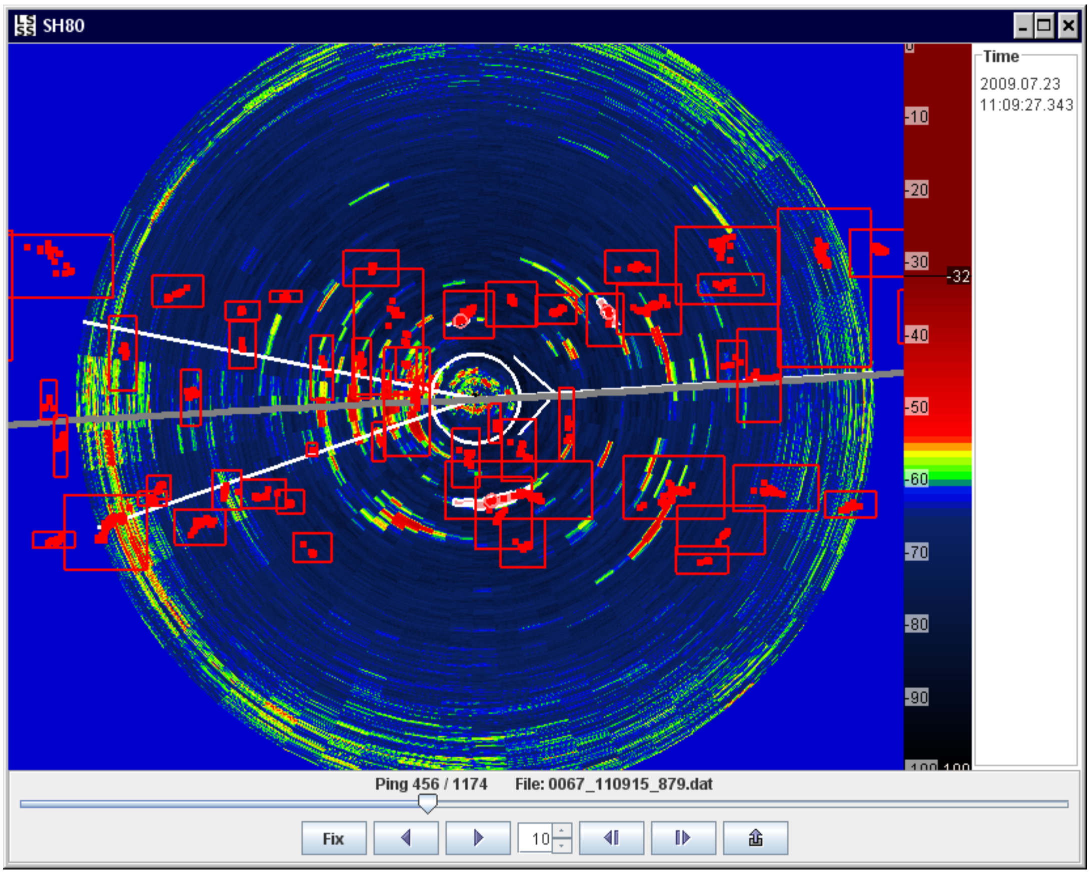

Figure 4. Main interpretation window of SH80 module in LSSS. Controls at bottom are used for maneuvering between SH80 pings. Gray line shows sonar track. White arrow shows sonar traveling direction. School growing is limits are shown by the tilted white lines and white circle. Red dots show detected schools in each ping. Red squares show detected school trough several pings.

Automatic school counter.

Research on automatic school counting was done during the cruise. The SH80 interpretation module gives the possibility to make an accurate count of the schools. This data will be used to guide and develop the automatic school detector and counter.

A program was made to show SH80 data in an geographical context, this is necessary to be able to use several pings to determine if a school is present or not. The method is based on SH80 data being gridded from local polar coordinates to a geographical regular grid. Using mat labs built in grid function was to slow (minutes), other MATLAB routines for gridding the data was tested this was a bit faster (tens of seconds), but still too slow for real-time processing of the data. A great amount of work was put in making a routine which uses the Graphic Processor Unit (GPU) to transform form polar to Cartesian coordinates and do a bilinear interpolation of the data instead of using the computers CPU. This routine was much faster than the other two and could process one ping in around 0.5 seconds, which enables us to do real-time processing of the sonar data.

Figure under shows a geographical plot based on several pings from the SH80

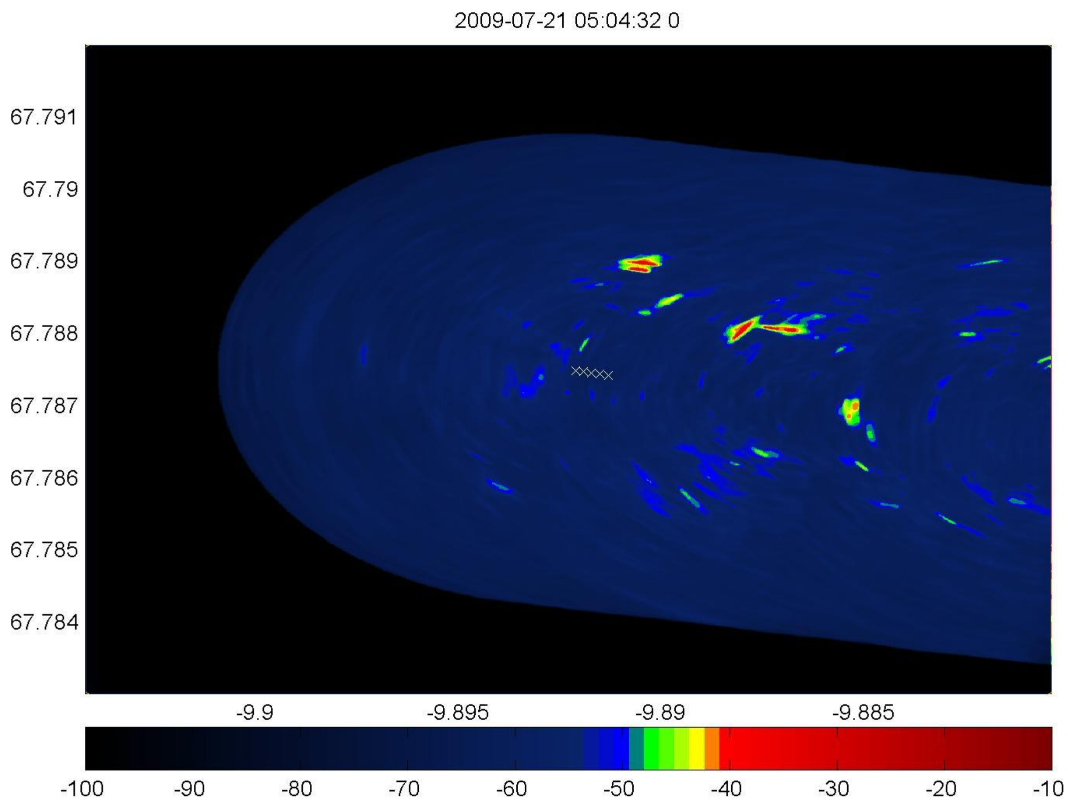

Figure 5. A geographical plot based on several pings from the Simrad SH80 sonar

Sonar settings

In the last three years two Simrad omnidirectional sonar units were tested to evaluate their future use for quantitative application during surveys: the low frequency SP70/90 (20-30 kHz) and the high frequency SH80 (110-120 kHz). Three main application scenarios were set to test the sonar:

I. Data collection on large whale target strength (TS)
II. Automatic tracking of school detections along the ship course
III. Sonar calibration experiment for quantitative correction of the data

The data collection during the 2009 survey considers the experience previously achieved in 2007 and 2008 about this instrumentation.

The SP sonar series showed great potentiality, in particular for its range of detection and for its better resolution for what concern the whale applications. Unfortunately the digital output didn't allow a quantitative acoustic analysis. For these reasons big hopes are focus on the new Simrad Sx90 sonar series that seems to allow the quantitative approach we need for our objectives.

This summer the effort was focus on the reliable SH80 scientific output and its acoustical quantifiable data. Previously tested, using the SH80 unit imposes the definition of a batch of setting to keep during the whole survey.

The parameters to define are: frequency, pulse form and detection range. For obvious reason the frequency has its own effect on the range and on the response on the target. The lower SH80 frequency (110 kHz) was chosen due to the effect that frequency probably have on cetacean's body reflectivity (Au 1996; Lucifredi and Stein 2007). The results of the 2008 calibration test showed a more stable response of the continuous wave (CW) pulse form for this reason chose over the Frequency modulates (FM) pulse form less explore even by the Simrad engineers (Dr. Lars Nonboe Andersen personal communication). The choice of the range setting was instead determined by the data just analyzed (Bernasconi et al. 2009). The Simrad omnidirectional sonar pulse duration is indeed determined automatically by the change of the range parameter. The choice of more than one setting has a drastic consequence of the ship time need for calibration. The data showed also how the SH80 data are well analyzable at a max distance of 400 m giving enough reason to set this experimental range. At 400m with a CW the options were three: short pulse, normal pulse or long pulse (See table).

Table 1: CW and FM pulse duration and auto mode for different ranges (range in meters and pulse duration in milliseconds)

Range	CW Short	CW Normal	CW Long	Auto	FM Short	FM Normal	FM Long	PSK1
50	0,4	0,8	1,2	FM / 6,4	3,2	6,4	6,4	10.4
75	0,6	1,2	2,0	FM / 6,4	3,2	6,4	6,4	10.4
100	0,8	1,5	2,5	FM / 6,4	3,2	6,4	6,4	10.4
150	1,2	2,5	4,0	FM / 6,4	3,2	6,4	6,4	10.4
200	1,5	3,0	5,0	FM / 12,8	3,2	12,8	12,8	10.4
300	2,3	4,5	8,0	FM / 12,8	3,2	12,8	12,8	10.4
400	3,0	6,0	10	FM / 25,6	3,2	12,8	25,6	10.4
500	3,8	7,5	13	FM / 25,6	3,2	12,8	25,6	10.4
600	4,5	9,0	15	FM / 25,6	3,2	12,8	25,6	10.4

In 2008 was observed a good stability of the beams with no big differences of response between one and another. Instead it has been noticed a large difference between the theoretical dB level (dBl) of the calibration sphere and the measured value with pulse duration variation. Short pulses (pulse duration < 2.5 ms) resulted in bigger differences.

Considering all this information the standard setting for the quantitative use of the SIMRAD SH80 system during ecosystem surveys is: a frequency of 110 kHz, a range 400 m and a CW normal pulse.

Sonar position on Libas

It is important to know before start using the sonar unit its position on the vessel, especially if tracking is one of the objective of the data collection. Usually the homnidirectional sonar units are located in the ship bow and lowered down into the water from a hutch. Onboard Libas this is the position of the SP90 transducer. The SH80 unit is installed onto a drop keel at a total depth of 8.5 m (figure 1). To set the correct transducer and GPS offset we need to activate from the SH80 setting the test menu of the sonar and turn on the Installation menu. We then select from the command bar: Ownship\Instrument Position Offsets\ Transducer. There we will have to choose the X and Y offset position of the sonar. X corresponds to the ship length starting from astern, while Y represent the ship width from the center (negative values on the left, positive on the right). From the menu Ownship we also need to enter the ship length and the GPS offset. Table 2 shows the SH80 and SP90 values for Libas.

Table 2. SH80 Offset settings in meters for Libas

Ship length	94
SH80 X Offset	50
SH80 Y Offset	-6
SP90 X Offset	80
SP90 Y Offset	0
GPS X Offset	45
GPS Y Offset	0

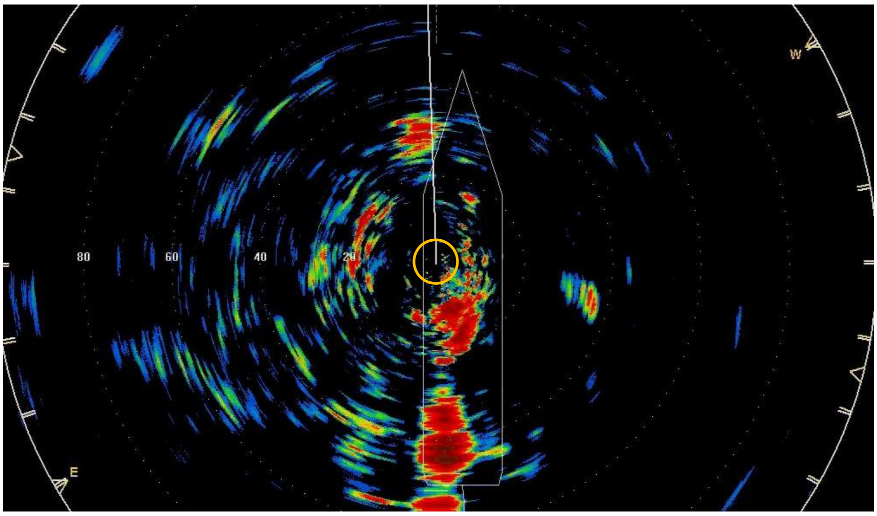

Figure 6: Sonar view showing the offset position of the SH80 transducer onboard Libas (orange circle).

CTD and the use of Lybin: determination of the detection area

During surveys the sonar operator has to deal with continuous environmental changes that affect the acoustic detections. The perception and judgment on what is observed on the screen can be highly affected by the effect of temperature variation (e.g. thermoclines) in the water column.

During the survey CTD data are constantly collected and use to generate updated soundspeed profile and ray tracing simulation using the software Lybin 4.0. These simulation are particular important when performing the whale TS measurements experiment. Indeed, when the animal is particularly close to the vessel a blind detection zone is present especially if the target has to be insonify close to the surface (figures 7 and 8).

Lybin allows generating manually sound speed profiles and work on detection modeling simulating different environmental scenarios. Furthermore the scenario during a survey is preset by the condition find at sea and the data are available from CTD data. The combined use of this software and the portable CTD unit SAIV SD204 make a perfect tool. Indeed the SAIV application software is capable of creating directly sound speed profile in the Lybin format.

The CTD sampling of the water column depends on two factors: the speed of the winch that sends the instrument at depth and the CTD unit sampling rate. Most of the winch adopted on research vessels has the wired length and the descending speed constantly controlled by electronic devices. When the survey is handled from a different platform such as a fishery vessel these tools may not be available and the winch speed can compromise a correct CTD sampling. For this reason we set our data sampling rate to 1 sec to overcome the possible error produced by the winch speed. The result was excellent with an average sampling rate of 1.3 m.

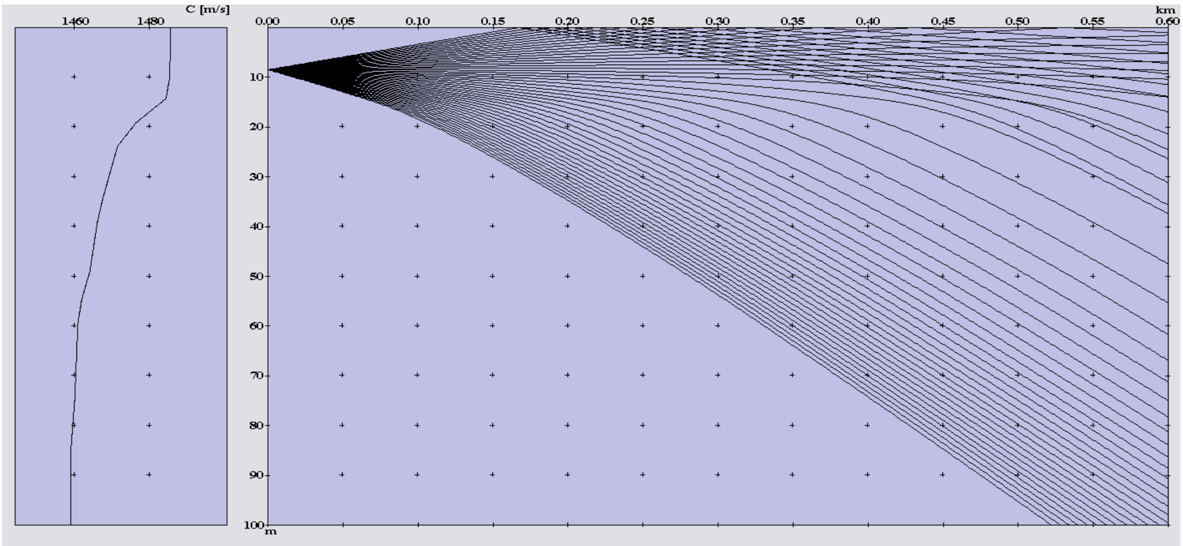

Figure 7: Station 7 - Tilt angle 0 degrees; resulting in a blind zone of 160 m

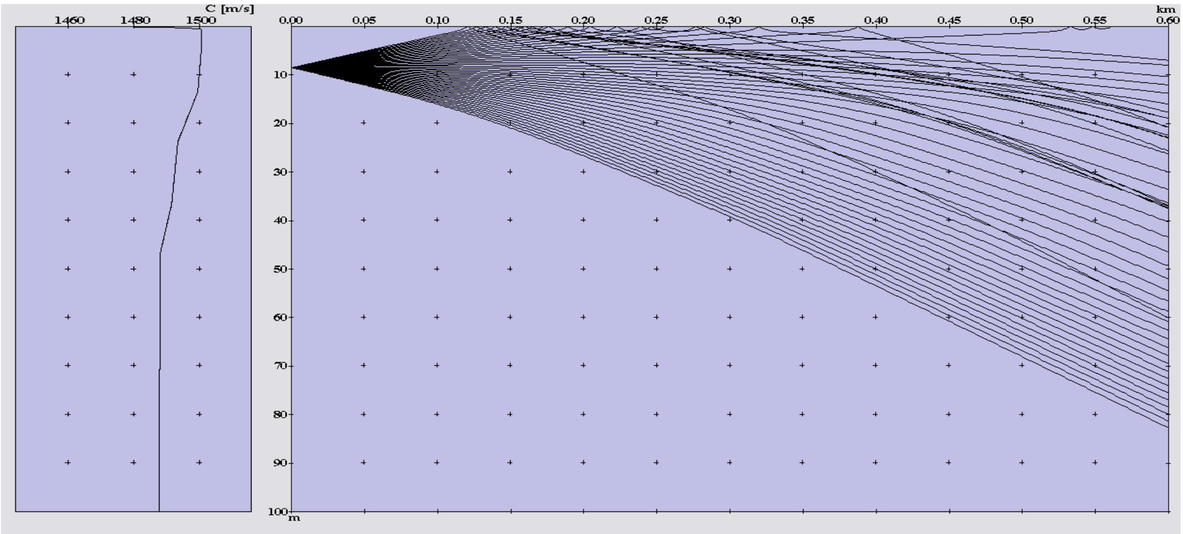

Figure 8: Station 41 - Tilt angle 0 degrees; resulting in a blind zone of 115 m

The primary sonar used onboard Eros was the brand new low frequency Simrad SX90 (from 20 to 30 KHz) with horizontal selected range from 750 m to 1200 m. The long-range sonar was used mainly in a range between 500 to 1200 m. Selected raw data and screen dumps were obtained and stored from all the Simrad sonars. Each sonar registration was obtained at time intervals according the speed of the vessel and the range of the sonar, ensuring that the schools registered in each event were outside the screen before the next registration, avoiding a double counting the schools. For this report a relative biomass of the schools was calculated for each event, as a product between the number of schools and the estimated size of each school.

Herring and mackerel schools and aggregations were tracked with Simrad SH80 and SP70 multi-beam sonars onboard Libas. Parameters such as position, size, swimming-speed and -direction were logged continuously while tracking on both vessels with the NMEA-datalogger.

Whale target strength (TS) measurements

Few studies have been reported up to date about cetaceans' body reflectivity. Active acoustic detection of whales could offer an alternative approach to damaging mitigation associated with seismic operations, providing real-time detection capabilities. At the moment visual observations and passive acoustic monitoring (PAM) are the standard methods used to detect cetaceans during seismic operations at sea. However, visual detection is limited by visibility and sea state, and PAM is strongly dependent on whales actively vocalizing. Cetaceans are acoustically active mostly during foraging (a limited period), and their vocalizations are highly directional: vocalizations not directly in line with a passive listening array may go undetected. There are thus limitations to both presently used techniques, limitations that could fail to prevent conflict between human activities and cetaceans.

Target strength (TS) is the “best way” to describe the acoustic reflection by a organism in an intensity based acoustic description and is specific for each organism for a given frequency. In the two years we developed a method to collect TS measurements from knowing target and advance our knowledge describing the TS at all insonified aspect for what concern the fin whale (*Balaenoptera physalus*). The information database produced up to date has to be consider unique and the whale tracking tool idea is getting real and closer. The set of data collected this summer will give us the overview of another cetacean species, the humpback whale (*Megaptera novaeanglie*). In addition we were able to get a remarkable result. Indeed we could record some pings with the whale at depth (figure 1). This small cluster of data represents an important goal, which will allow us to test some mathematical model based on the idea of a TS depth dependency.

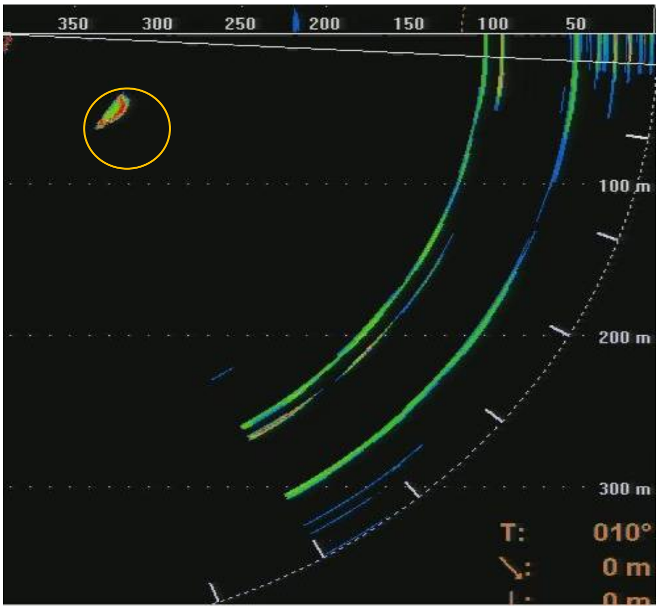

Figure 1: Echo generated by the humpback whale we tracked swimming at a depth of approximately 50 m (orange circle).

The data were all collected with the Simrad SH80omnidirectional sonar (110 kHz). Its reliable output guarantee us to collect important information about cetaceans body reflectivity overcome the common opinion that sonar in general are just a source of disturbance. The high frequency use is well above the Baleen whale hearing threshold and it seems not affecting drastically the animal behavior. The tracking data collected with the sonar showed low swimming speed with a whale breathing rate that doesn’t show particular stressing situation. It is clear, that the lower frequency of 20 kHz is better to be use to reach our goal of a whale detector (figure 9). For this reason we are planning to test the new Simrad SX90. This omnidirectional sonar of new generation seems capable to generate quantitative data set more reliable to studies like ours.

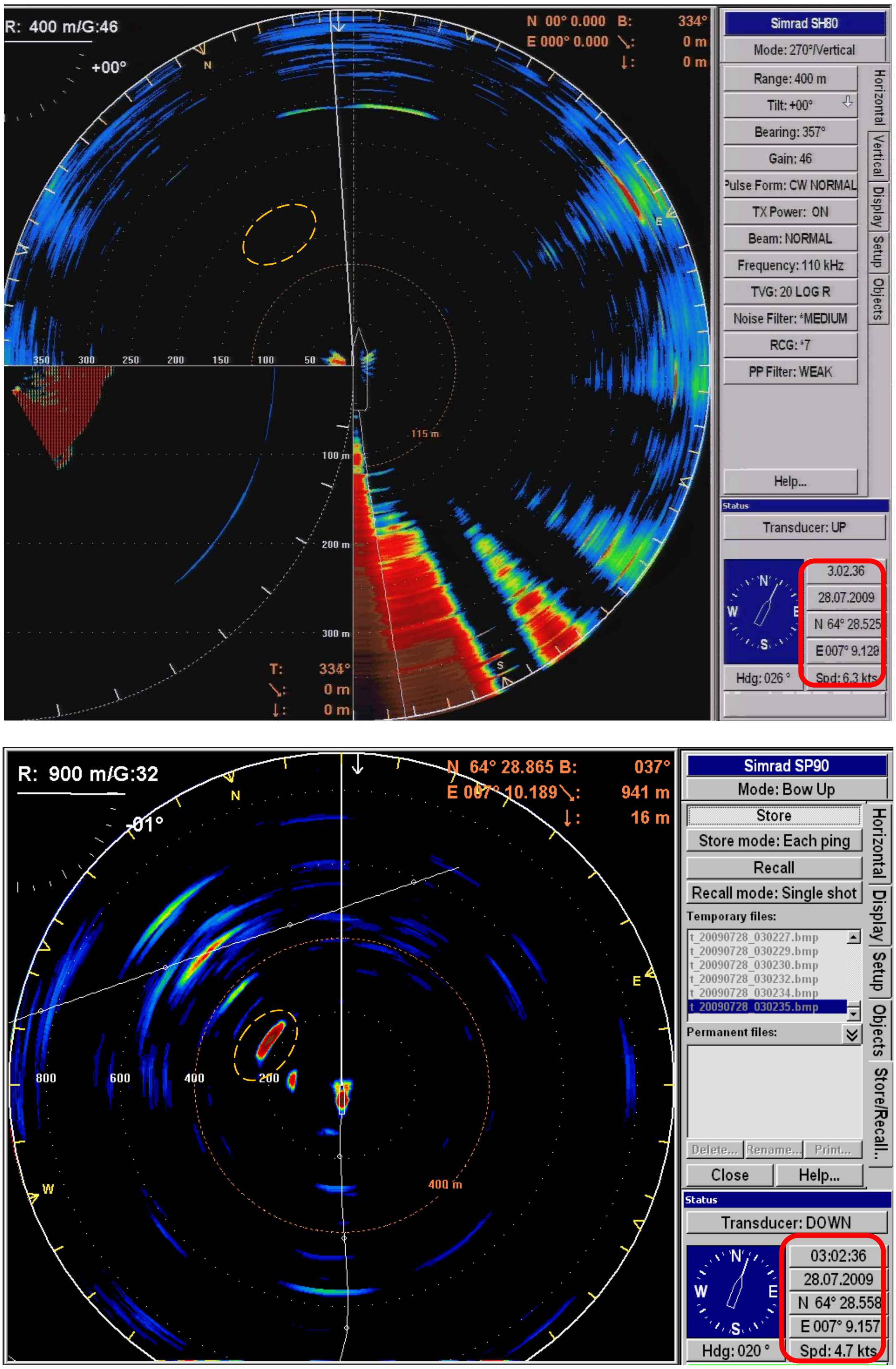

Figure 9. Comparison of the detections of a minke whale at close range at the same moment. It is clear how the response of the whale body is significantly stronger at 20 kHz, while it is unable to detect the minke whale on the screen of the 110 kHz sonar unit.

Echosounder

Continuous data-logging and raw data recording from 18, 38, 70, 120 and 200 kHz Simrad ER60 echosounder were performed down to maximum 500 m depth on both Libas and Eros. The data collection was done using standard settings for later echo-integration calculations distance based reference using GPS data for position and vessel speed. The quantitative acoustic analyses and NASC species allocation were done with the software program Large Scale Survey System (LSSS) (http://www.marec.no/). The analyses were based on the following species and groups of species:

Main target species: mackerel, herring, blue whiting

Usable species: capelin, mesopelagic fish, plankton

Other species: redfish, krill, amphipods.

Marine mammal observations

Both vessels, Libas and Eros, conducted observations of marine mammals and basking sharks as well. There was opportunistic observing on board Eros without specialized personnel. Two dedicated marine mammal observers were present on board Libas. Observing was held from the roof or from the bridge when the weather conditions were bad (Beaufort scale > 7). Two observers were watching permanently. Among the equipment were: angle boards, binoculars 7x50 with reticles, portable two-way radio for communication with bridge, GPS device, microphones connected to personal computers with special software for the sound recording and simultaneous registration of the vessel’s position. Each observer monitored a 90 degree sector, starboard and port side respectively, in the line of the course. They shifted the sides every hour and took short breaks every two hours. The main sector of observation was 45 degrees port and starboard of the course line. The priority periods of observing were during the transport stretches from one trawl station to another. When the weather conditions were nearly excellent, observing was also conducted during the trawl stations with the purpose of tracking marine mammals, which could possibly appear. Weather conditions were noted every hour of observation. Sightings were spoken into a microphone. Later, the recordings were transcribed to a special Sighting form. Fields in the sighting form included date, time, position, species, number, group size, behavior, angle from the vessel course and swimming direction. A diary summarizing each day’s activities was kept by the observers. Data were summarized and presented in tables and a distribution map. Scientific personnel and crew members on board Libas and Eros also recorded incidental sightings of marine mammals more or less continuously on the bridge. Digital filming and photos were taken whenever possible for each registration from scientists onboard.

Meterology

Wind conditions as derived from the Baufort scale, air temperature, weather, cloud coverage and sea state were monitored and noted in the cruise logger program at each station for both vessels.

Digital photos and filming

Digital photography with Nikon D70 digital filming with Sony TCR TRV50 were done throughout the cruise for documentation of trawl catches, various scientific activities and visual observations of marine mammals and seabirds along the cruise track.

Toktlogger program

Toktlogger is a software to manage, log and keep updated the activities during a sea survey. The results of its work is clear in the data postprocessing where a correct timeline can be retraced during the analysis. The logged activities, when stored to disk, are synchronize directly to the cruise data (see <u>Cruise view</u> window) trough a DOS application called BI500 Bro running in the background. The function of this application is to link via Ethernet the different instruments output to the Toktlogger (e.g. Echosounder and GPS unit).

The log files are updated and saved every time an activity is logged and archived every day automatically.

The archived activity log are saved into two different file format: CSV and txt.

Tokt view window

Tokt

Platform: every ship correspond to a number (e.g. Libas is number 6)

Tokt nr: is a code corresponding to the survey (e.g. 2009818)

<u>Botton:</u> You start the logging at the begin of the survey and stop it at the end (you also stop the effort if you are docking for a single day, then you restart it)

Stasjon

Referansestasjons nr:

Lokal stasjons nr: the sequential number of the station of the survey (always check the previous station to save them in the right order).

Lokalstasjonstype: In this scroll window there is a list of option as COMPLETE THIS WITH A LIST

Kommentar: in this space we can add a comment or choose from a list of specific comments representing for example the specific net name or activity that you want to log.

Botton: Slett stasjon: Delete station

Send stasjon: Send station

Cruise view window

Dato: Date

Klokke: Time

Bredde: Latitude

Lengde: Longitude

Kurs: Heading

Hastighet (knt): Speed

Logg (nm): Log (show the total nautical miles sailed up to date)

Dyp (m): Depth

Trålstasjon data window

REDSKAP (Tool/Instrument)

Antall: number

Kode: Is a 4 digit code representing the net type in use. (3530 Pelagic trawl)

Series Nr: 5 digit number (the last 2 is the Lokal stasjons nr)

Wire (m): Cable used for the tralwing

FISKEDYP (Fishing depth)

Min (m): net minimum depth

Max (m): net maximum depth

Åpning: Opening

Spredning: Spreading

Weather view window

Luft temperatur °C: Air temperature

Vind hastighet m/s: Wind speed

Vind retning: Wind direction

Luft fuktighet: Air humidity

Vær: Weather

Sjø:Sea (sea state)

Skydekke: cloud cover

Is forhold: ice presence

Lys: Light

History view window

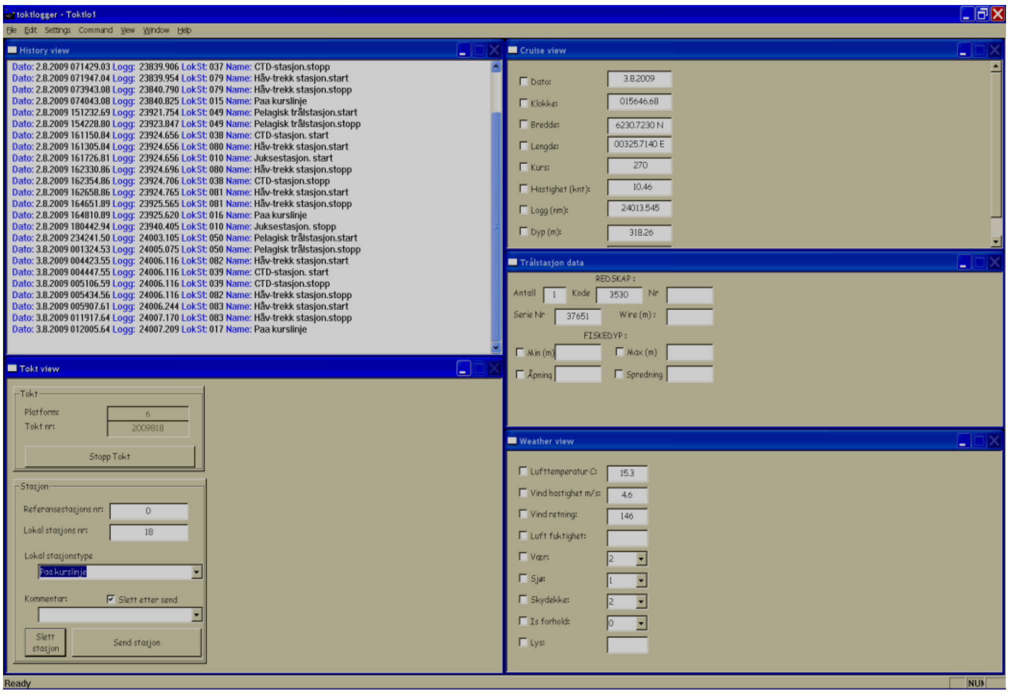

Figure 10. This window shows a chronological recap of the stored data in the Toktlogger program.

Data management

All collected data onboard Libas and Eros were stored on a server PC installed on each vessel under the area P:\\nas\HI-Libas\Tokt Name\2009818 on Libas and P:\\nas\HI-Libas\Tokt Name\2009820 on Eros. Collected data originating from echosounders, sonars, epi-pelagic and pelagic trawling, krill trawling, CTD stations, WP2 net sampling, ringnet, bongo-bongo nets, sea surface temperatures, marine mammal observations, weather station, diary, cruise logger and digital photos were all stored on this server with advanced backup system. A timestamp synchronized the clock on all essential instrumentation and for all activities onboard each vessel and between the two vessels in order to ensure correct temporal comparison between different data sources collected during the cruise. All data were copied to two external hard drives for proper backup.

4) Results

Hydrography

There were considerable changes in the temperature regime in the Norwegian Sea and adjacent waters in July 2009 compared to previous periods (Figure 11).

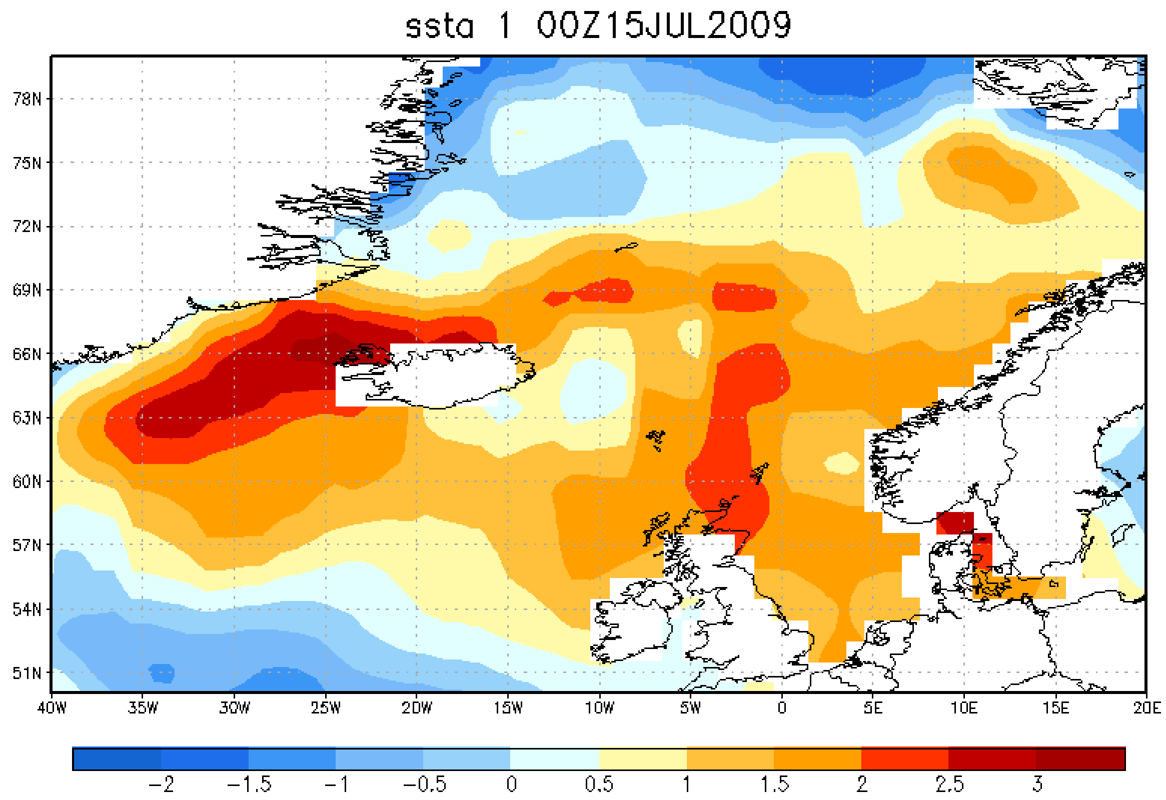

Figure 11. Sea surface anomalies (centered in week 15 july) showing warm conditions in all the area in comparison to a 20 year average.

Temperature maps were produced in Surfer 9.0 and ArcGis 10.0 based on 90 CTD casts from Libas (43) and Eros (47). Surface waters in the northwestern part of the Norwegian Sea in the Jan Mayen zone and in Icelandic waters were considerably warmer compared to the last two decades, and coincided with increased presence and concentrations of large herring and mackerel in the area. The northernmost areas were in contrast colder than previous years (Figure 12), limiting the extent of northern migration by herring and mackerel compared to last few years. Coastal waters off Norway were also colder than recorded previous years (Figures 12 and 13).

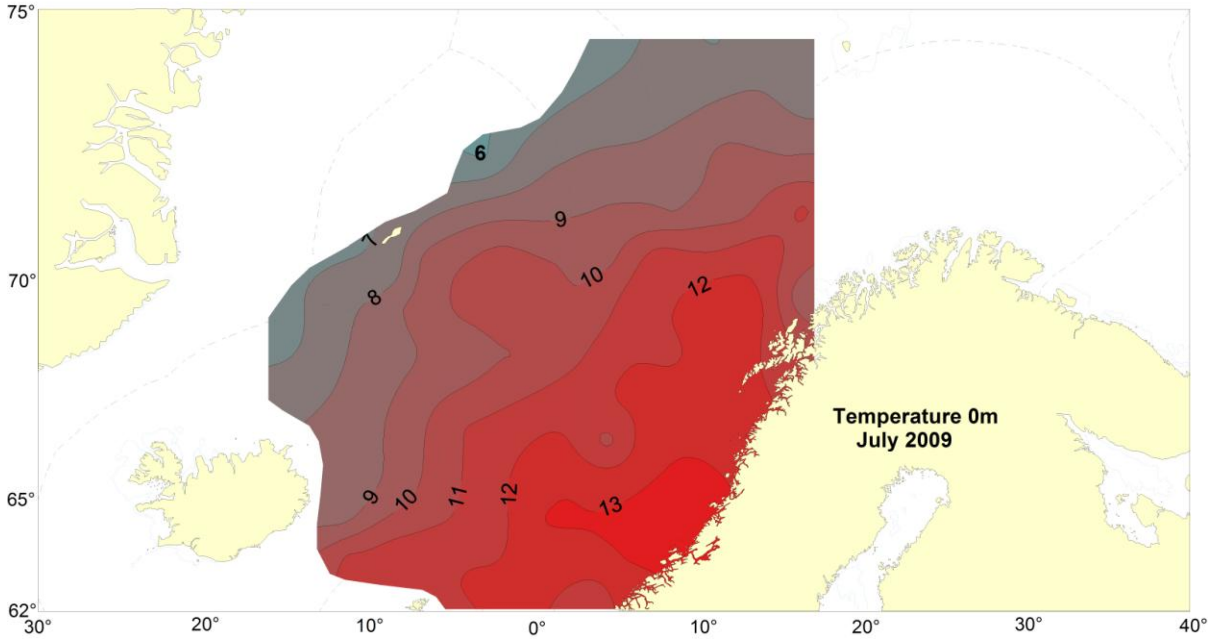

Figure 12. Sea surface temperature (SST) in the Norwegian Sea, 15 July - 5 August 2009.

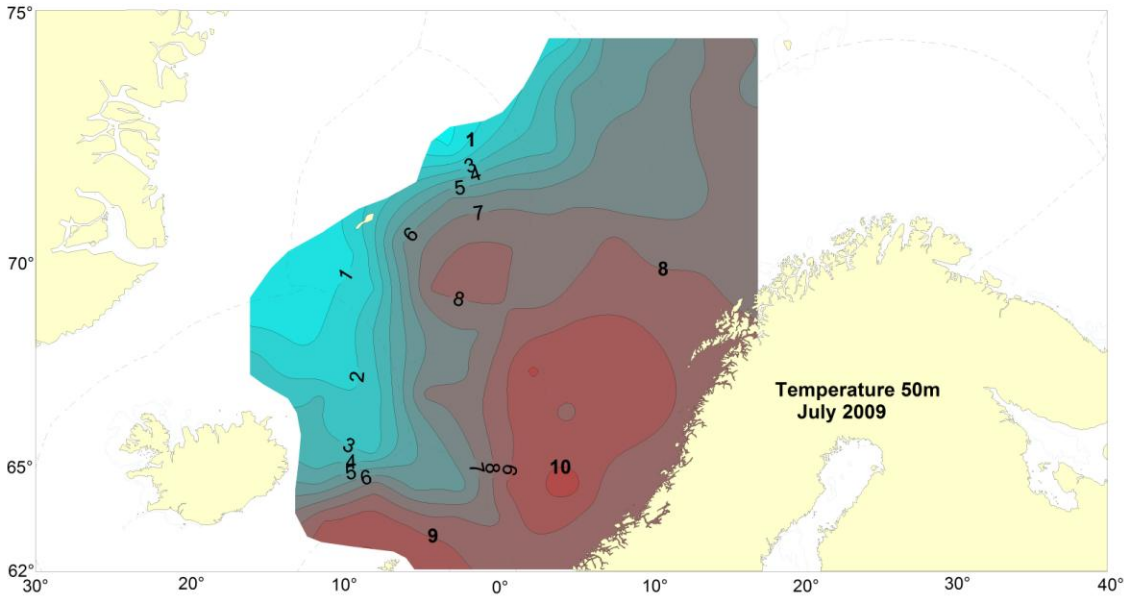

Figure 13. Temperature at 50 m depth in the Norwegian Sea, 15 July -5 August 2009.

Biological samples

Libas performed in total 54 pelagic trawl stations, while Eros performed 56 pelagic trawl stations (Figure 14).

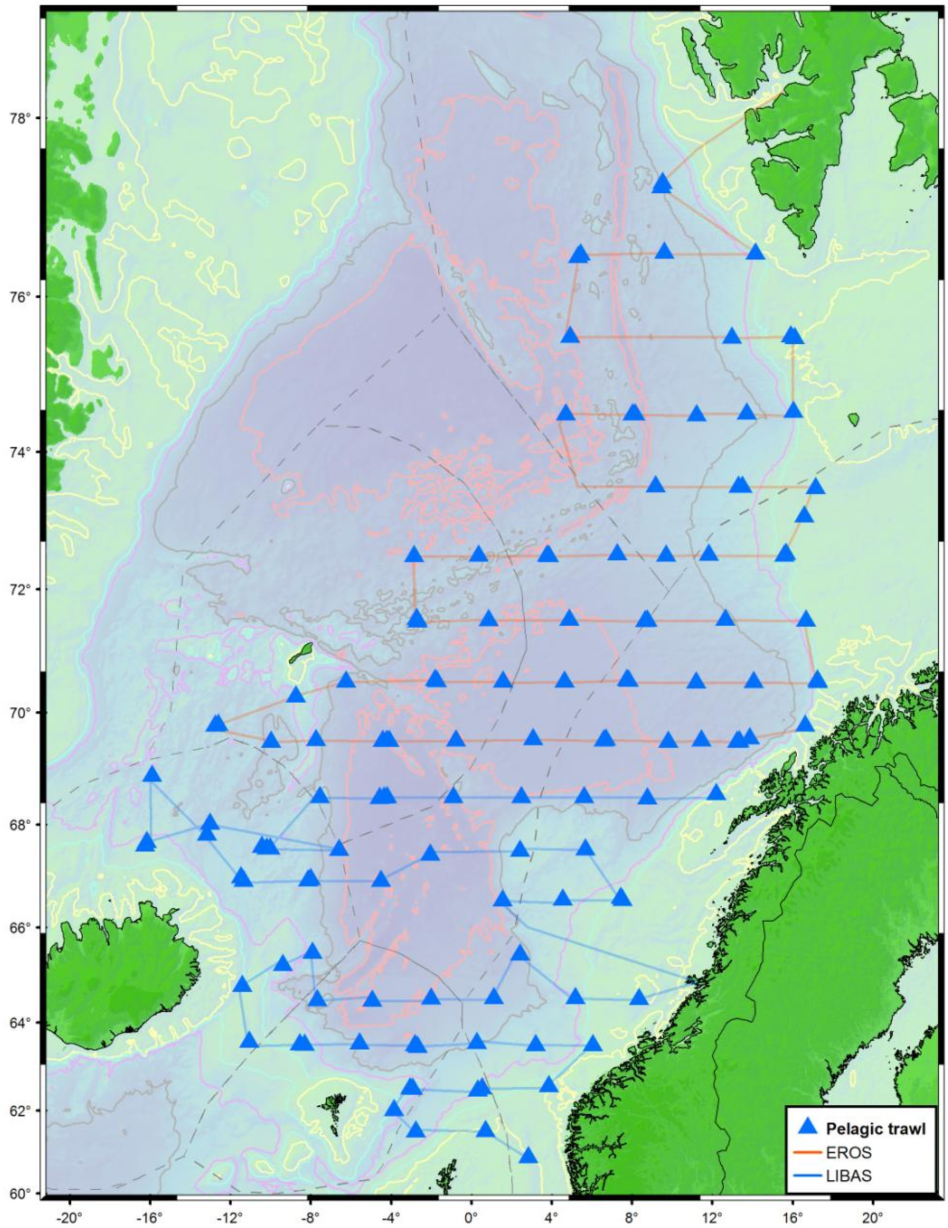

Figure 14. Map showing pelagic trawl hauls taken on Eros and Libas during the ecosystem survey.

Salmon

Totally 87 postsmolts and salmon were caught during the ecosystem survey in the Norwegian Sea. A total number of 76 salmon were caught on M/S Eros in the northern survey area. The largest salmon caught was 5.3 kg. In total, 11 salmon were caught in the survey areas covered by M/S Libas. Nine of these were postsmolts (average weight 144 g), and two adults. The adults were most likely 1sw fish, judging from size and weight (average weight 1833 g). Both adult fish were in good condition. Of the nine postsmolts, one individual was fin-clipped, and will be scanned for presence of a coded wire tag. This individual was also significantly larger than the other postsmolts, indicating that it was of hatchery origin. None of the salmon were classified as escaped farmed fish. All salmon were caught in the northern part of the survey area (see figure 16). The northernmost catches of salmon were done at 74.5 degrees latitude. The southernmost catch was a single individual caught at 64.5 degrees latitude. This distribution of catches indicates that the survey area covered by M/S Libas probably only overlapped with postsmolt distribution during the most northerly transects. All salmon were measured, and samples were taken according to the procedure described above (Figure 15). However, scale loss was in most cases significant due to trawling without a live box, and meaningful counts of number lice on the fish was impossible to obtain. Lice were only observed on a few individuals. Also, very few salmon remained alive until sampling could be initiated, and gonad samples in Bouin's fix were therefore only collected from two individuals.

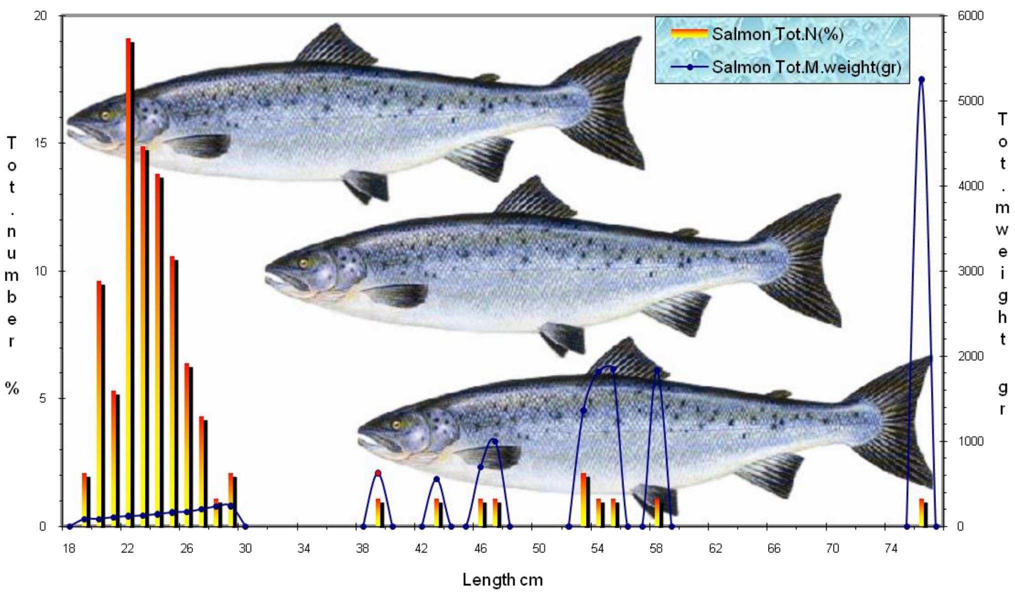

Figure 15. Length (cm) and weight (gram) distribution of salmon caught in the Norwegian Sea, 15 July-6 August 2009

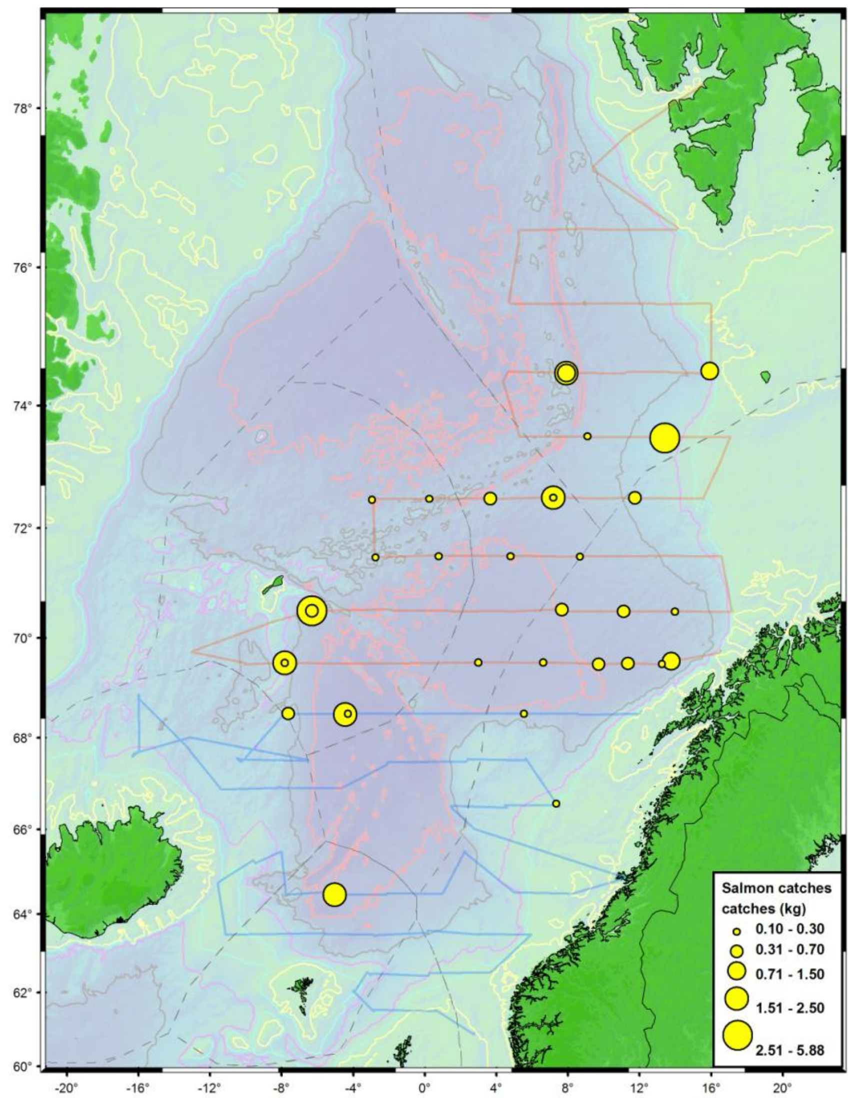

Figure 16. Salmon catches (kg) taken on epi-pelagic trawl hauls along the cruise tracks for Libas and Eros combined.

Mackerel caught in the pelagic trawl hauls on Libas and Eros varied from 22 cm to 45 cm in length distribution with the concentration of individuals between 32-34 cm. Mackerel weight (g) distribution varied between 100 to 820 g (Figure 17). The 2005-year class of mackerel together with the 2006-year class dominates the mackerel population in the Norwegian Sea with more than 50% (Figure 18).

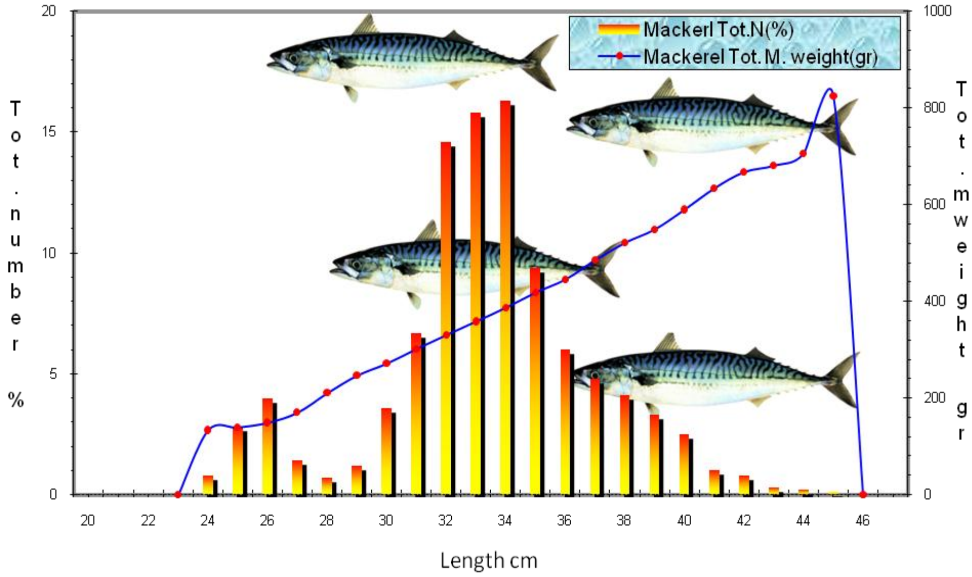

Figure 17. Total length (cm) and weight (g) distribution in percent (%) for mackerel in all catches.

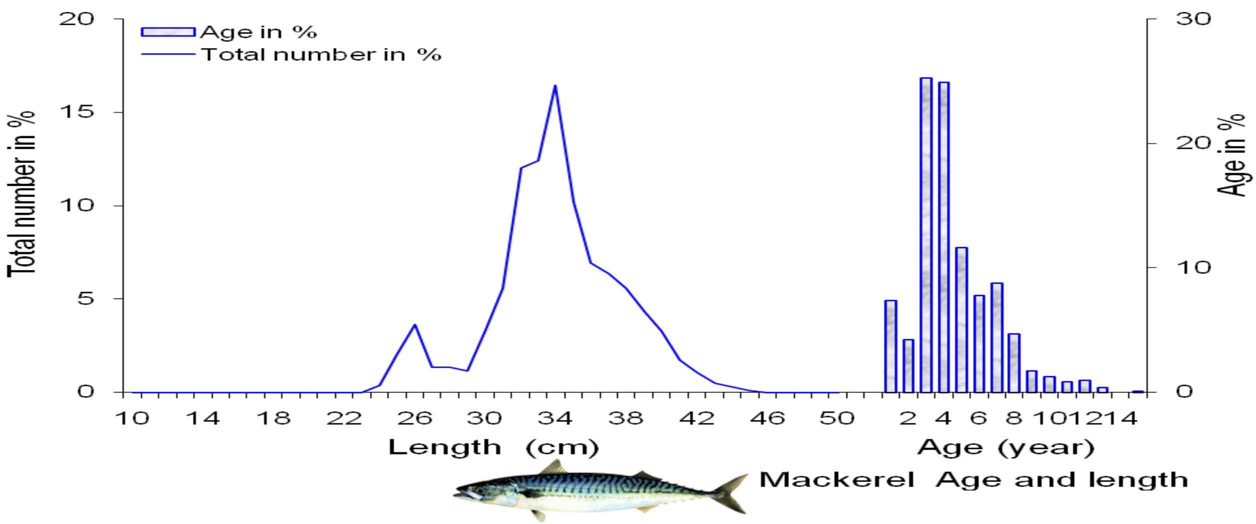

Figure 18. Age and length distribution in percent (%) of Atlantic mackerel in the Norwegian Sea.

Norwegian spring-spawning herring had a length distribution from 19-38 cm with a peak at 31-34 cm in length, and a weight distribution from 50-410 gram (Figure 19).

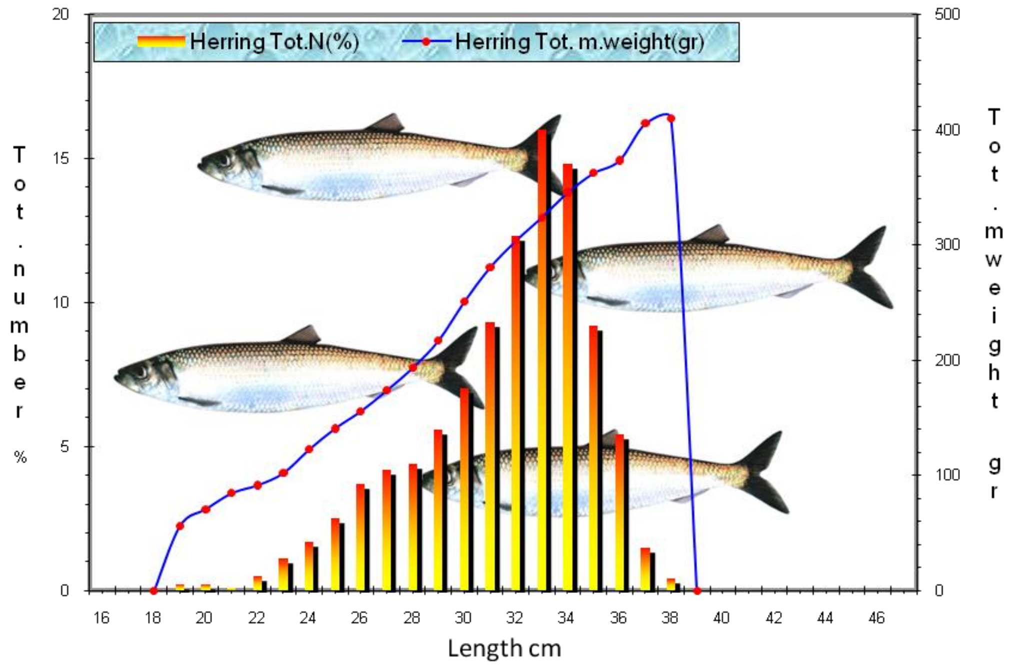

Figure 19. Length and weight distribution of herring in the pelagic trawl catches.

The age distribution in herring shows dominance of the 2002 year class. They constitute 27% of the total population. The 2004- (22%) and 2003 (15%) year classes are the second and third most dominant herring year classes, respectively. Younger herring than 3 years was practically absent in the trawl catches (Figure 20).

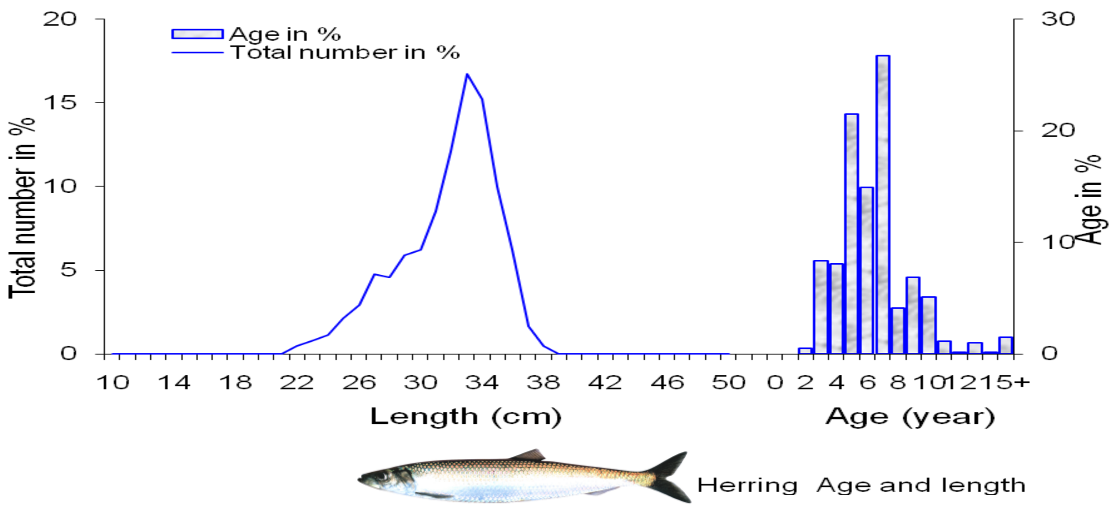

Figure 20. Herring age and length distribution in the pelagic trawl catches.

Blue whiting length distribution was from 27-36 cm and individual weight distribution was 100-240 gram. Blue whiting between 30-32 cm dominated the catches (Figure 21).

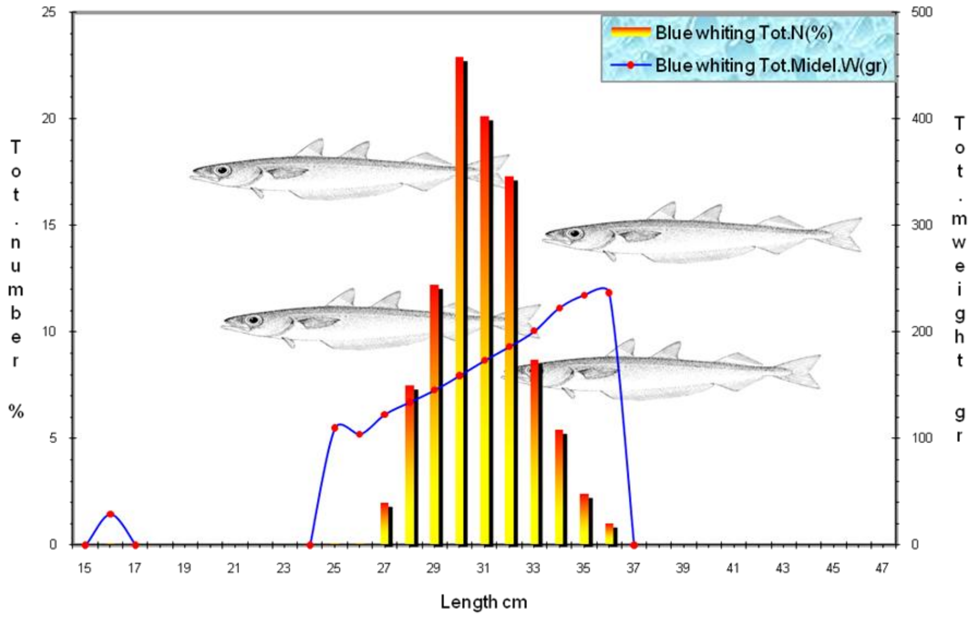

Figure 21. Length and weight distribution of blue whiting in the pelagic trawl catches.

The age distribution of blue whiting showed a dominance of 2003 year class (37%) followed by the 2004 year class (25%) and 2002 year class (22%). Blue whiting younger than 4 years of age was practically absent in the trawl catches (Figure 22).

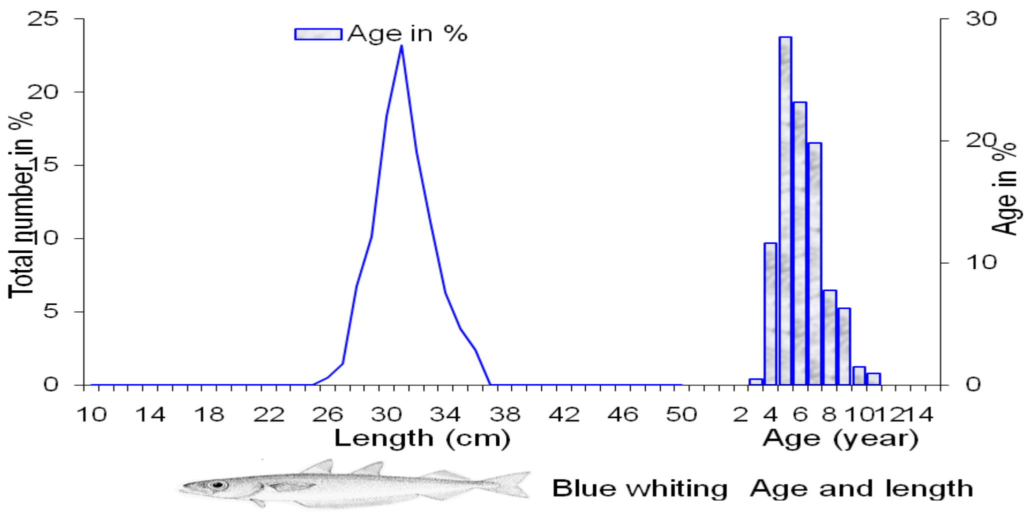

Figure 22. Blue whiting age and length distribution in the pelagic trawl catches.

Highest mackerel catches (kg/nmi) dominated in the southern and western Norwegian Sea and adjacent areas from 61ºN to 68ºN in the northwestern and northern areas with Arctic water masses (Figure 23). We have to note that only the small salmon trawl was used in the northern areas, whereas a larger pelagic trawl was used on Libas at the southernmost cruise tracks.

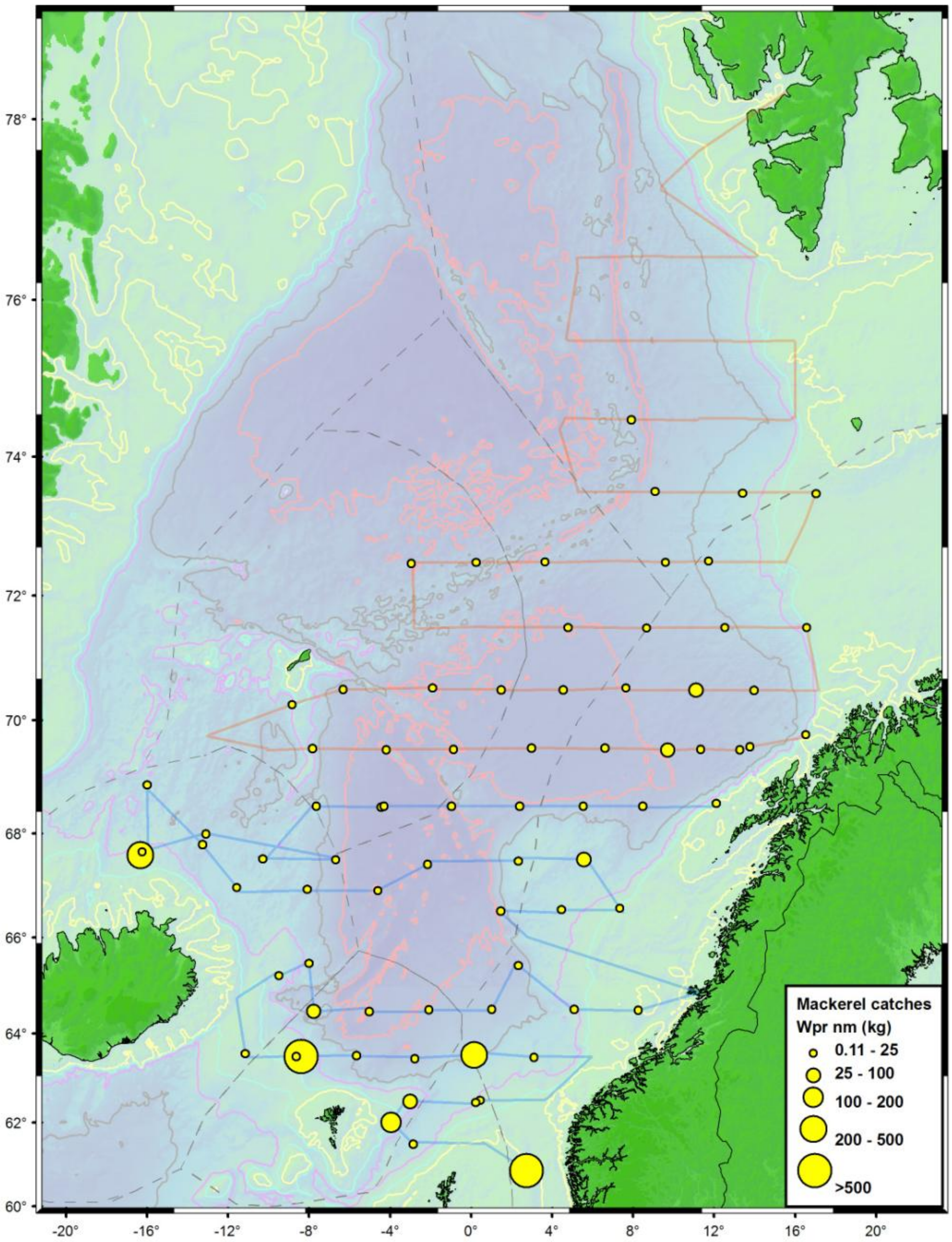

Figure 23. Mackerel catches (kg/nmi) from Libas and Eros combined in the Norwegian Sea, 15 July- 6 August 2009.

Mean mackerel weight (g) within a category is shown for each biological station (Figure 24). A general trend is that the largest mackerel is found in the western and northwestern part of the Norwegian Sea.

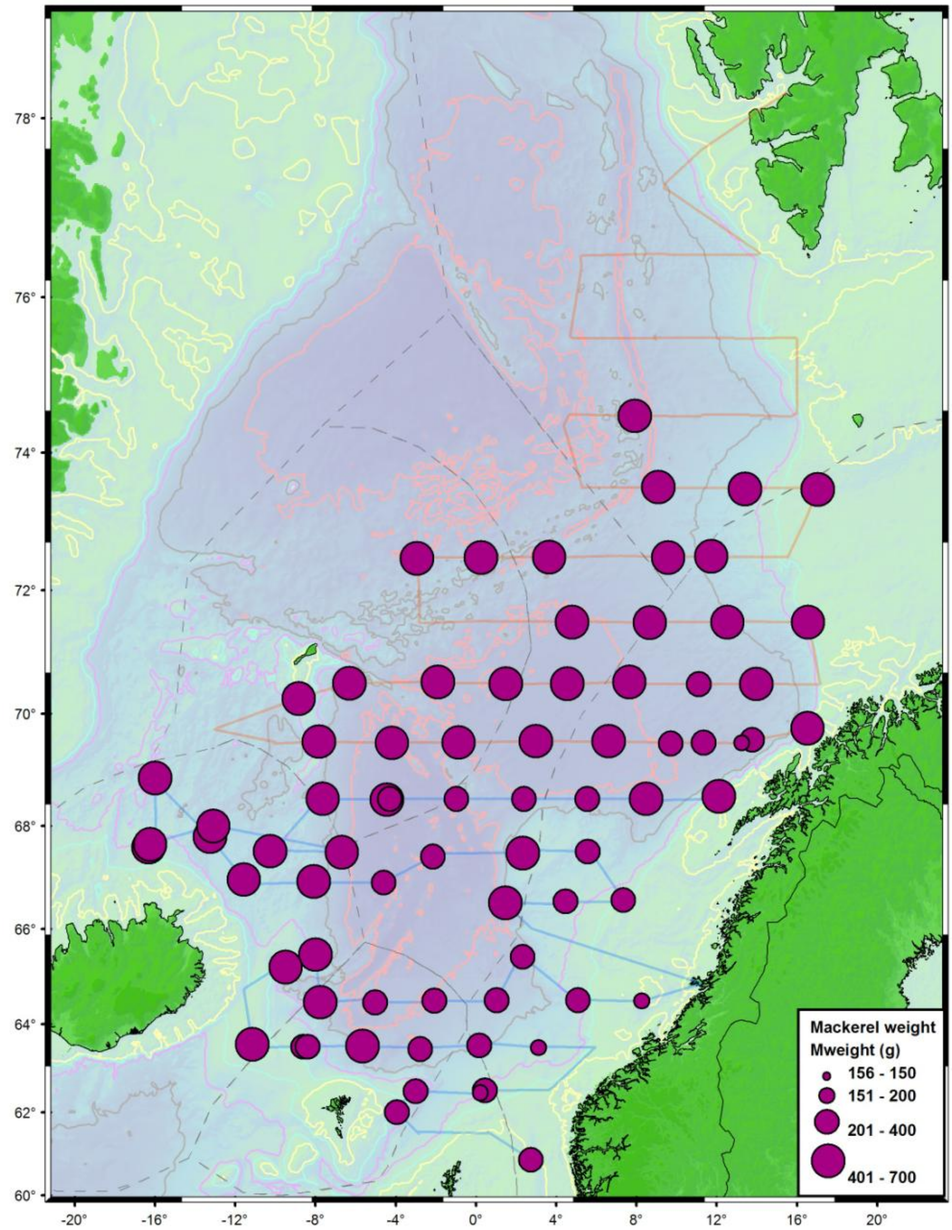

Figure 24. Mean mackerel weight (g) represented for each station within the categories shown. No catch of mackerel is indicated as a blank along the cruise track.

Mean mackerel length (cm) within each category is shown for each biological station (Figure 25). A general trend is that the longest mackerel is found in the western and northwestern part of the Norwegian Sea.

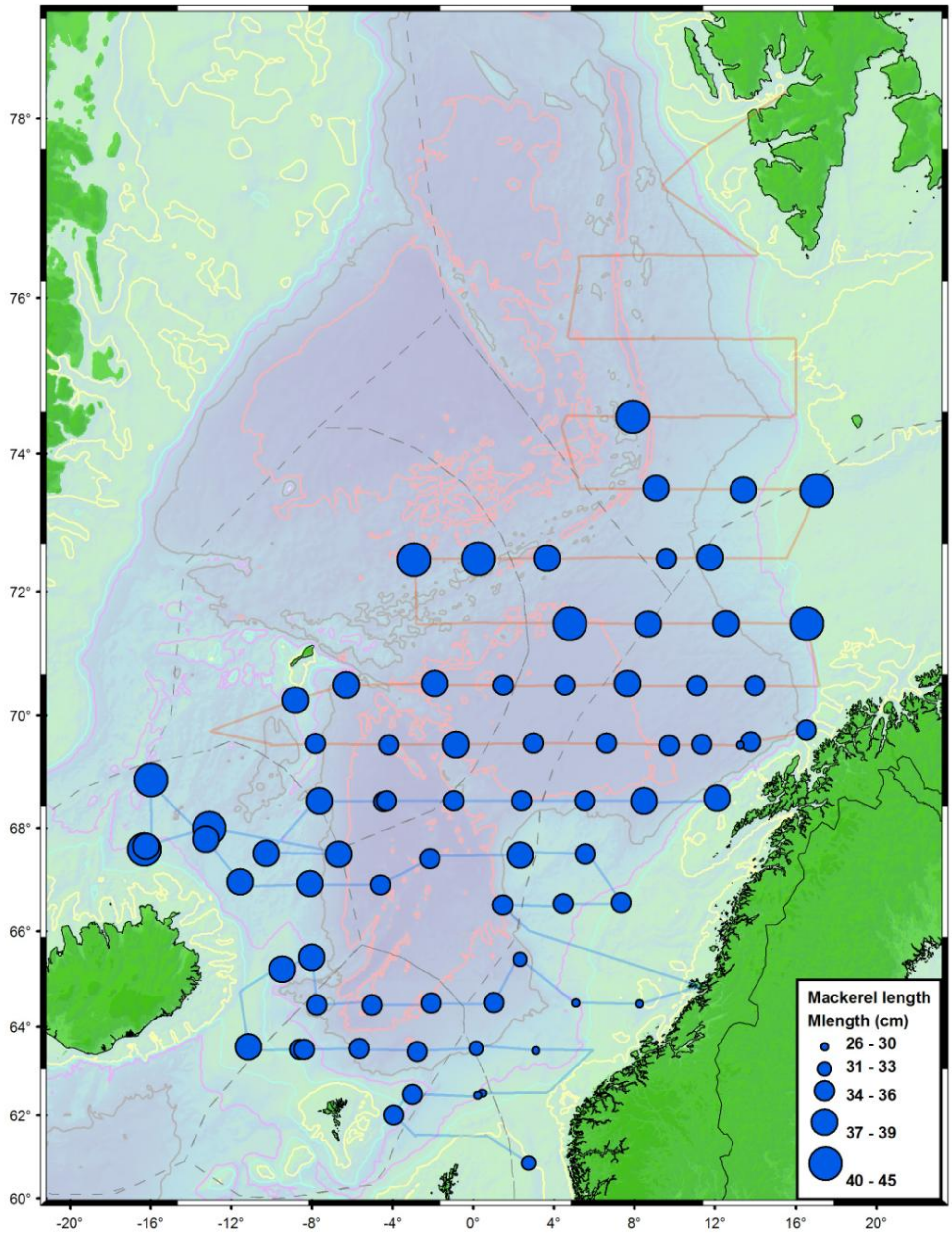

Figure 25. Mean mackerel length (cm) represented for each station within the categories shown. No catch of mackerel is indicated as a blank along the cruise track.

Mean herring wight (g) is shown in figure 10. We can see from the figure that herring is distributed over a substantial feeding area within the study area. The largest herring are found in the northern and western areas, with a relatively clear weight dependent migration pattern was found.

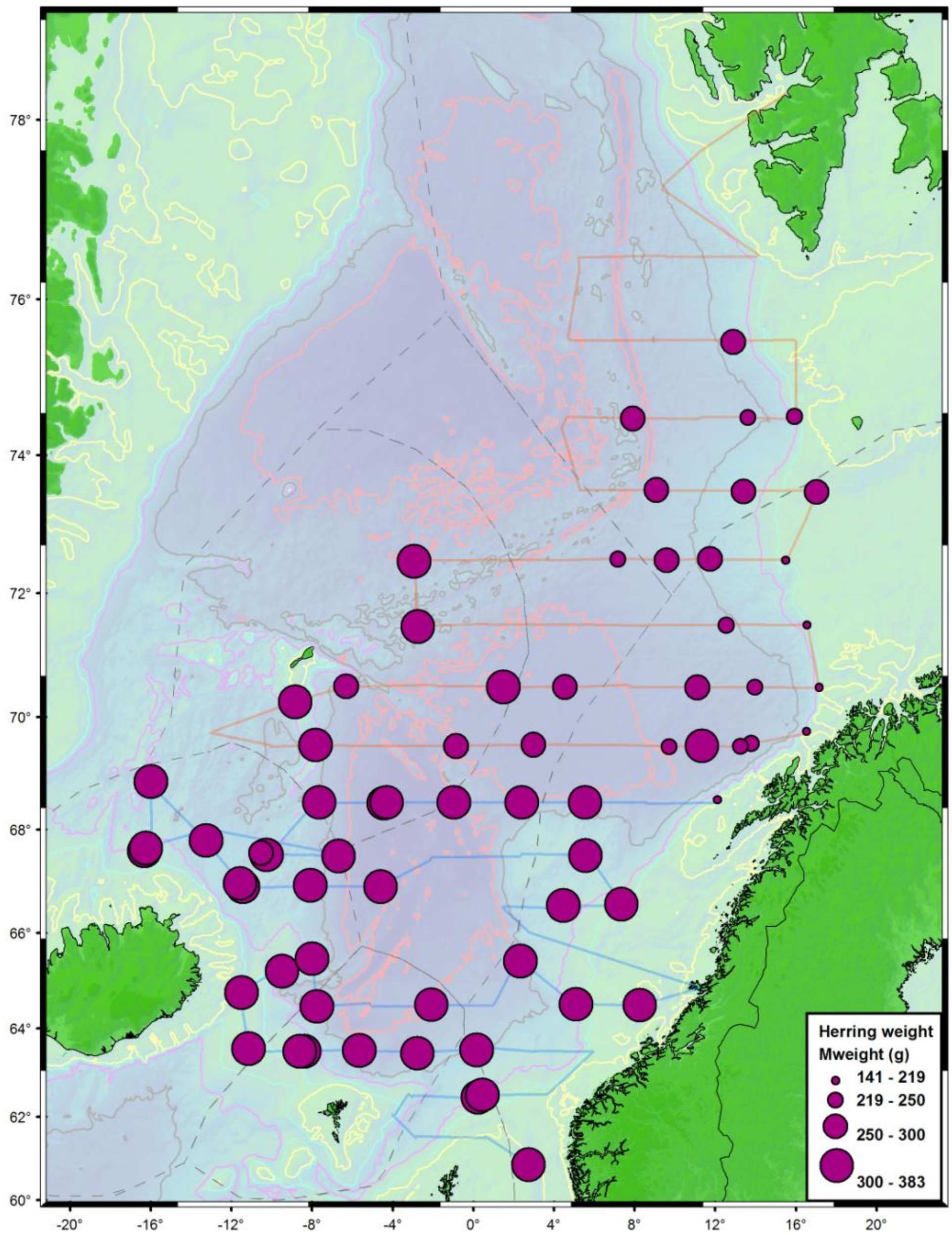

Figure 26. Mean herring weight (g) for herring represented for each station within the categories shown. No catch of mackerel is indicated as a blank along the cruise track.

Mean herring weight (g) is shown in figure 27. We can see from the figure that herring is distributed over a large feeding area within the study area. The longest herring were found in several areas with predominance in the southwestern and western part. A length-dependent herring migration was found.

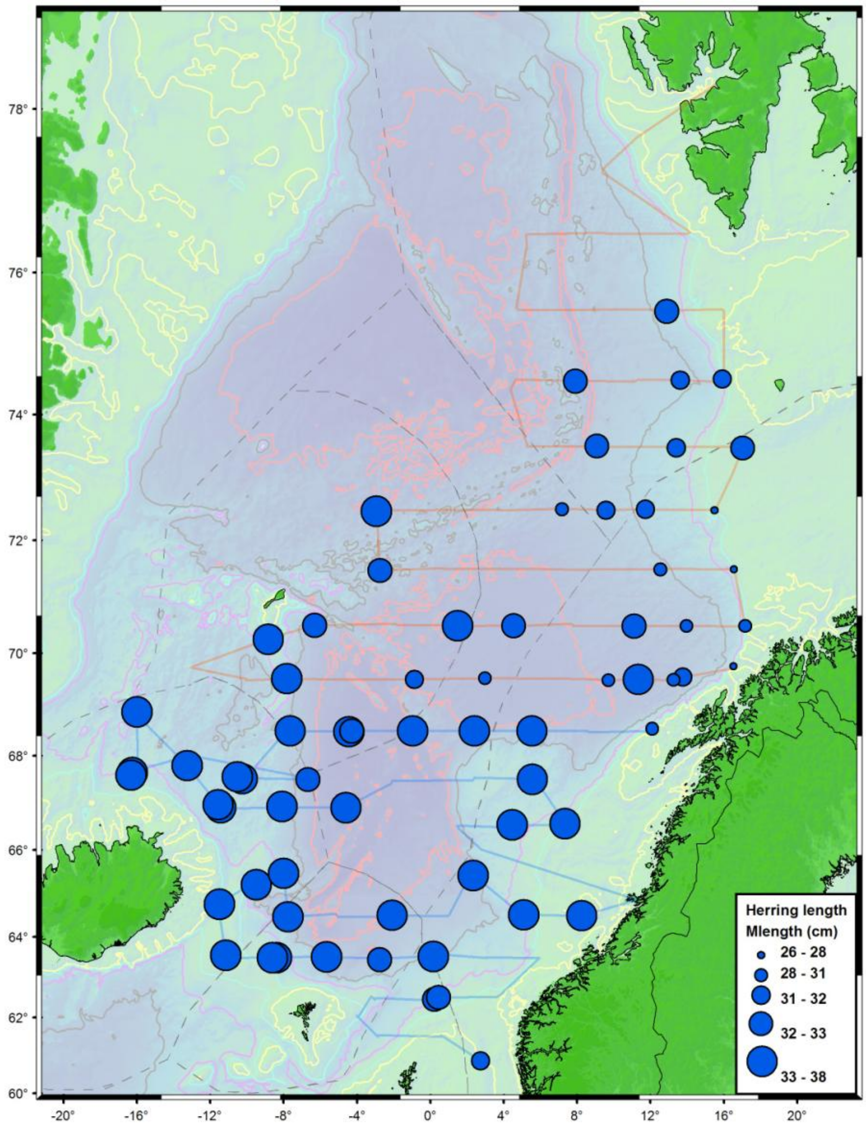

Figure 27. Mean herring length (cm) for each station within the different categories shown.

In order to illustrate and visualize the spatial and temporal overlap between mackerel, herring, blue whiting and salmon catches, we presented the catches for all species at each station to see where the abundant pelagic planktivorous species were present and compare their normalized catch rates (kg/nmi) from epi-pelagic trawling (Figure 28).

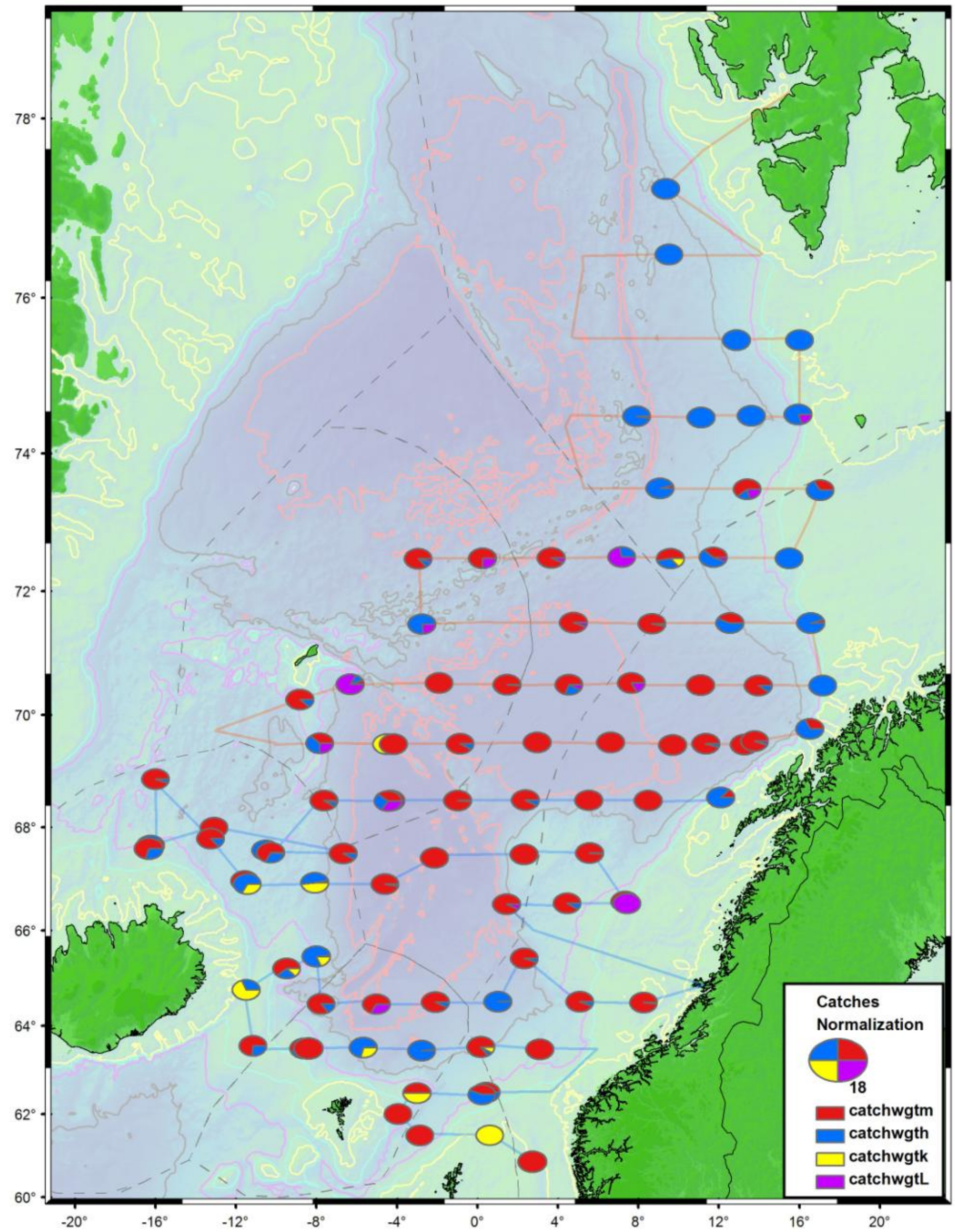

Figure 28. Distribution and spatial overlap between mackerel (red), herring (blue), blue whiting (yellow) and salmon (violet) in the Norwegian Sea between 15 July and 6 August 2009.

The spatial overlap between mackerel and herring were mostly found in the southwestern part of the Norwegian Sea. Altogether 24 stations contained both mackerel and herring in the trawl samples. Herring were caught alone in the northeastern and northern part, whereas mackerel were caught alone in trawl catches in the coastal areas off Norway and central part of the Norwegian Sea. Blue whiting was predominantly caught in western part of the Norwegian Sea in Arctic and frontal water masses. Blue whiting and herring had spatial overlap in frontal and Arctic waters, whereas blue whiting had overlap with mackerel in the western areas, whereas little spatial overlap with mackerel in the central part of the Norwegian Sea.

Acoustics

Sonars

Mackerel schools detected on the sonars during the survey were located predominantly in the central Norwegian Sea. Nevertheless, sonar registrations were also detected in the southwestern and northwestern part of the ocean in Faeroe Island, Icelandic and Jan Mayen area. This is a new situation compared to previous years and clearly shows a wider distribution pattern of mackerel as well as more westerly migration pattern than observed previously. The pelagic schools from mackerel were generally small in size and found in loose aggregations with low densities when tracked with Simrad SP90 and SH80 sonars. A similar tendency was found for herring with smaller sized schools and looser aggregations than previously found in July in the Norwegian Sea. School depths were from the surface down to approximately 50 m. Interschool distances between neighbouring schools were quite consistent varying between 20-80 m in more densely aggregated areas.

Echosounders

Quantitative analyses of abundance, aggregation and distribution of mackerel, herring and blue whiting concentrations were also performed continuously based on Simrad ER60 raw data using 38 kHz as the primary frequency for fish species and nautical area scattering coefficient (NASC) allocation. Mackerel allocation was based on the formula:

$TS_{mackerel} = 20 \log L - 84.9$

where TS is the target strength of mackerel and L is the length of mackerel in cm. The S_v thresholds applied in LSSS to allocate mackerel from other species were in the range from -69 to -75dB.

Herring allocation was based on the formula:

$TS_{herring} = 20 \log L - 71.9$

where TS is the target strength of herring and L is the length of herring in cm.

The S_v thresholds applied in LSSS to discriminate and allocate herring from other species were in the range from -50 to -55dB.

Blue whiting allocation was based on the formula:

$TS_{blue\ whiting} = 20 \log L – 64.2$

The S_v threshold applied in LSSS to discriminate and allocate blue whiting from other species was -68 dB.

Judging of the acoustic data was performed daily by two experienced scientists applying the post processing system Large Scale Survey System (LSSS) http://www.marec.no/ .

Abundance estimation of pelagic fish

Acoustic abundance estimation using Large Scale Survey System (LSSS) was done for Norwegian spring-spawning herring, mackerel and blue whiting.

The herring population within the covered cruise tracks and areas was estimated to be 13.6 million tons consisting of 47 billion individuals. The average weight of herring was 286.9 gram and mean length was 31.8 cm. Altogether 14 different year classes were present in the catches, whereas only five year classes constituted more than 5% of the catches.

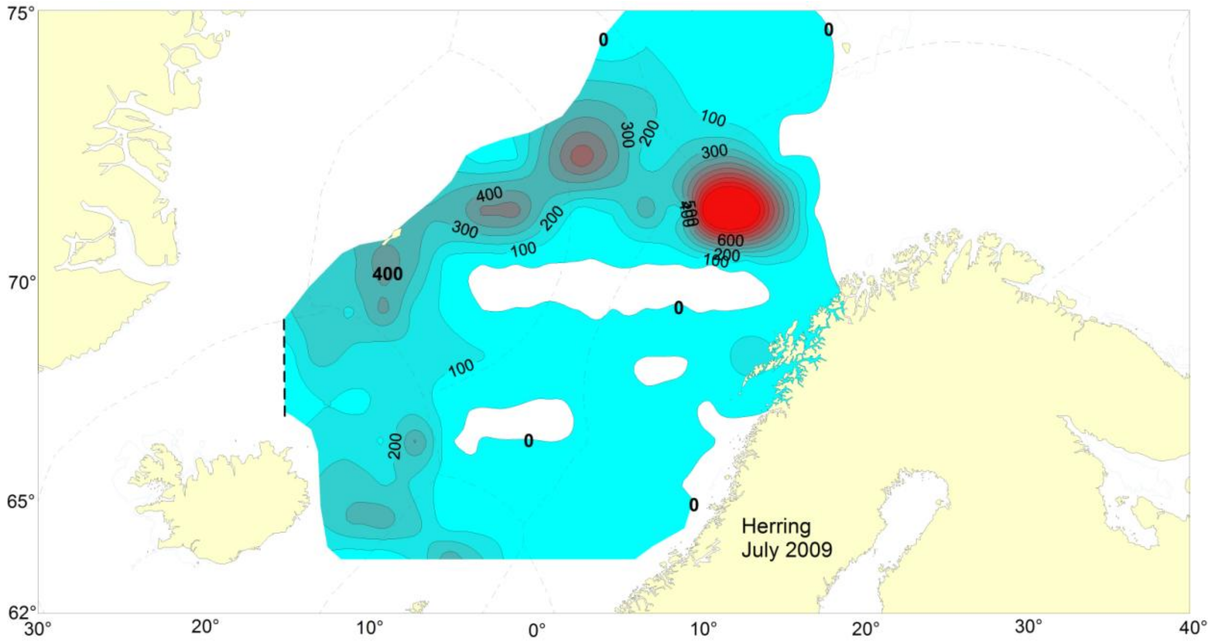

Figure 29. *Sa or Nautical Area Scattering Coefficient (NASC) values of herring along the cruise track.*

Acoustic detection of and NASC allocation to Atlantic mackerel were done based on the multi-frequency response of the acoustic echoes and especially the characteristic frequency response on 200 kHz. Biological samples taken at each station were used in tight combination with sonar and echosounder data to allocate NASC values to mackerel.

The mackerel population within the covered cruise tracks and areas was estimated to be 4.4 million tons consisting of 11.9 billion individuals. The average weight of mackerel was 371.4 gram and mean length was 33.9 cm. Altogether 13 different year classes were present in the catches, whereas seven year classes constituted more than 5% of the catches.

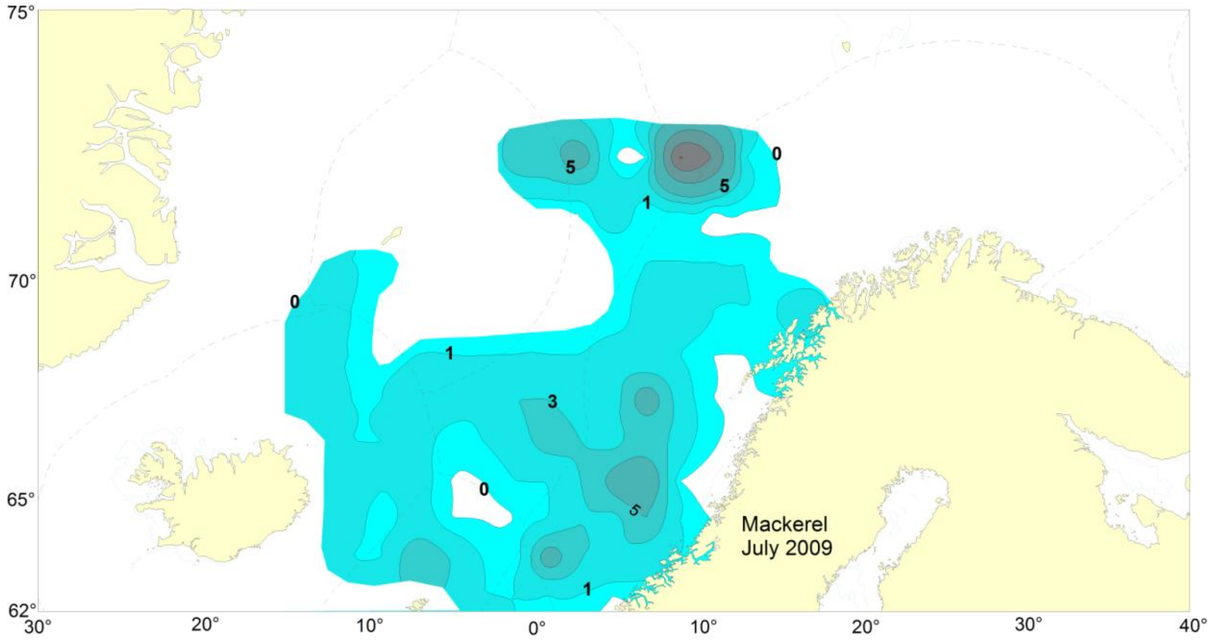

Figure 30. Sa or Nautical Area Scattering Coefficient (NASC) values of mackerel along the cruise track.

The blue whiting population within the covered cruise tracks and areas was estimated to be 2.3 million tons consisting of 14.9 billion individuals. The average weight of blue whiting was 155.9 gram and mean length was 30.1 cm. Altogether 10 different year classes were present in the catches, although only four year classes constituted more than 5% of the catches.

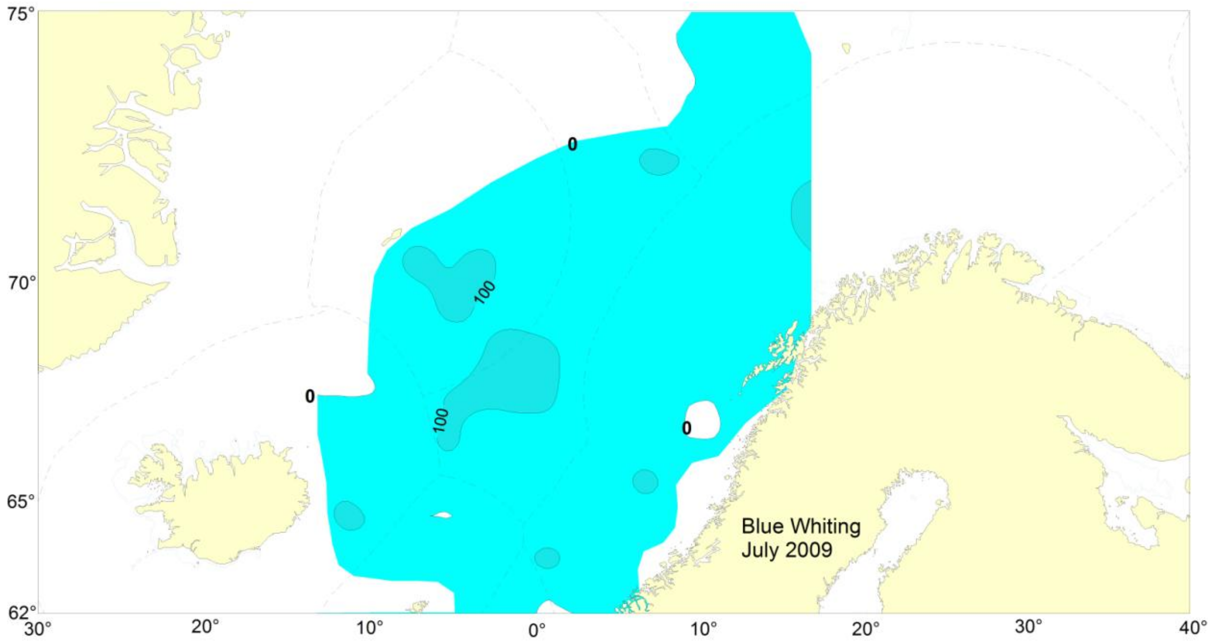

Figure 31. *Map of blue whiting distribution and aggregation showing the Sa or Nautical Area Scattering Coefficient (NASC) values estimated acoustically in the Norwegian Sea ecosystem.*

Horse mackerel

Catches of horse mackerel were done in the southernmost region of the survey (Figure 32). The horse mackerel was measuring 28-43 cm in length and 190-500 gram in weight (Figure 33).

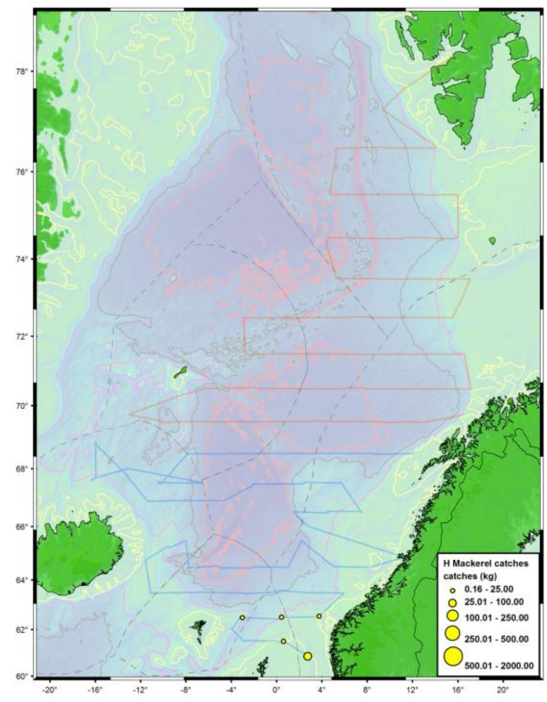

Figure 32. Map of horse mackerel distribution from pelagic trawl catches.

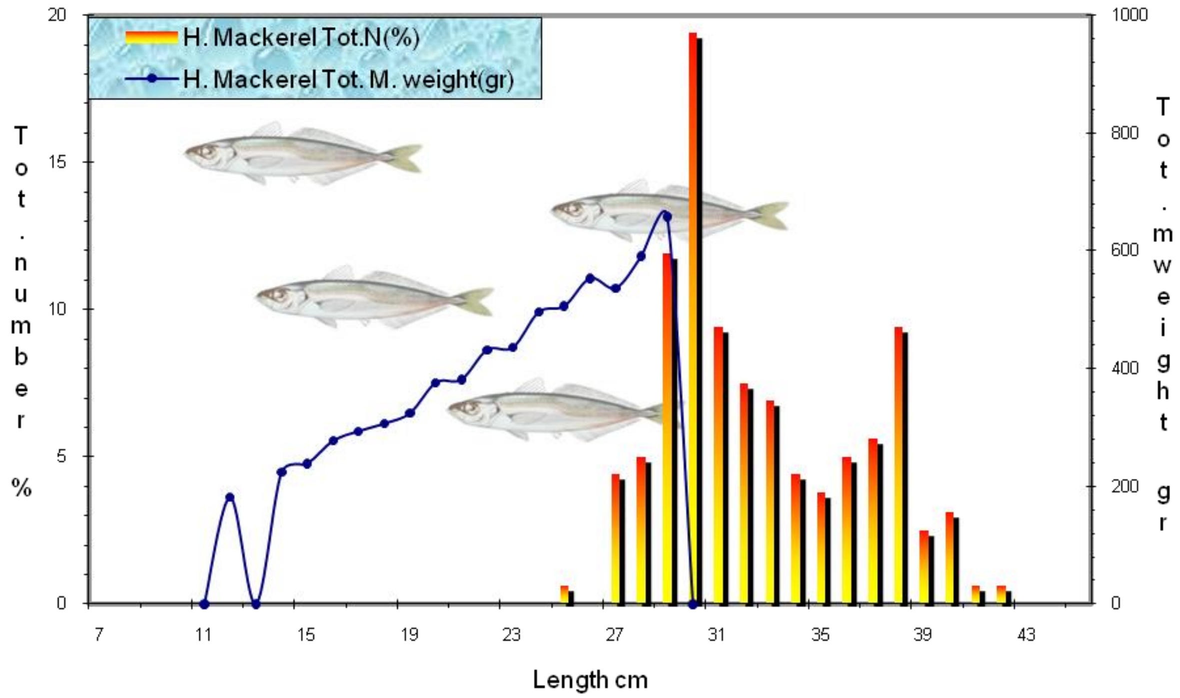

Figure 33. Length (cm) and weight (gram) distribution of horse mackerel caught in the southern part of the Norwegian Sea.

Lumpsucker

Lumpsucker was caught in most of the trawl hauls in the northern areas of the Norwegian Sea (Figure 33). Based on the range in size distribution from very small individuals to large adults, we believe the lumpsucker population is presently increasing and showing some good recruitment in the Norwegian Sea.

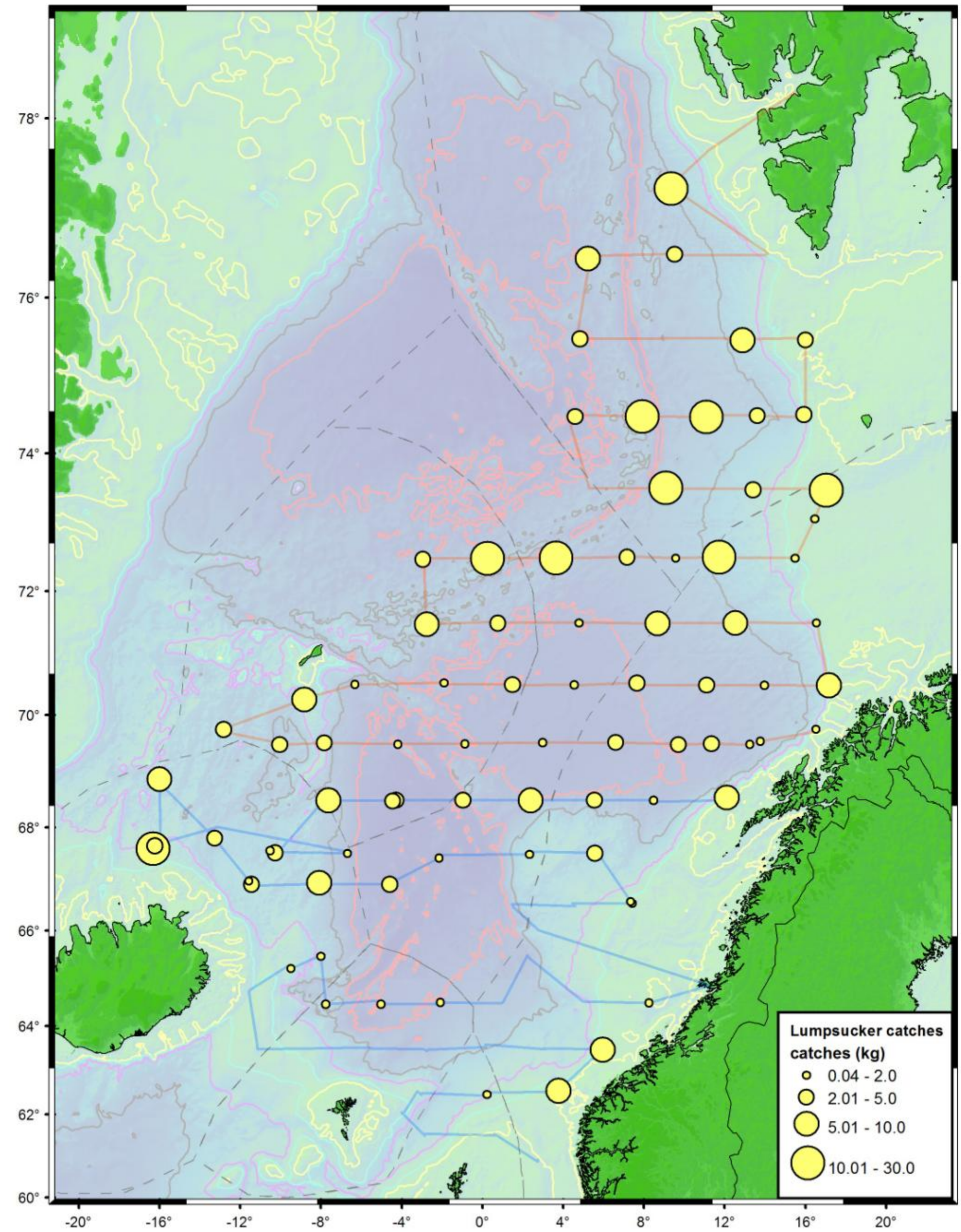

Figure 33. Distribution and catches of lumpsucker in the Norwegian Sea, 15 July – 6 August 2009.

Plankton

Libas

The overall impression during the cruise was that zooplankton biomasses were low in most part of the investigated area. The average zooplankton biomass for the total area investigated south of 68 ^{o}30´N was 3.6 g m^{-2}. As expected the main part of the biomass consisted of the copepod *Calanus finmarchicus* regardless of sampling method, mainly copepodite stages IV-V and adults. At a few stations copepod nauplii were observed, indicating an ongoing production of a new generation. This was the case both east of Iceland to the west and over the Vøringen plateau to the east.

The Bongo samples also contained large amounts of the blue surface dwelling copepod *Anomalocera patersoni*. In the eastern and central part of the area to about 2^{o} W the cirriped *Lepas* sp. was occasionally found clinging to drifting sea-weed, indication a southerly origin of the water masses.

A large number of the Bongo samples also contained the 2-3 cm long silvered juveniles of rockling, probably *Rhinonemus cimbrius*, from the Norwegian coast westwards to about 8 ^{o}W, i.e. north of the Faroes. A few capelin larvae (*Mallotus villosus*) were observed in Bongo net samples in the western part of the ocean.

Euphausiids were observed only sporadically as most krill will not be caught in the nets used. However, at a few stations krill were observed stuck within the finer meshes of the fishing trawl. In one occasion, north of Iceland, the medium sized *Thysanoessa inermis* were identified, in some occasions closer to the Norwegian coast the larger *Meganyctiphanes norvegica* were observed. A few WP-2 and Bongo samples also revealed the presence of *M. norvegica* to the east.

Small 5-10 mm large individuals of the amphipod *Themisto abyssorum* were observed in Bongo samples, scattered throughout the area.

The larger copepod *Calanus hyperboreus* was not observed at all during the survey. This cold water species was expected to be found in rather large numbers in the area north of Iceland.

The zooplankton biomass varied throughout the area. The highest biomass, 15 g dry weight per m^{2} was observed off Lofoten. Stations with biomasses above 5 g m^{-2} were found scattered both east and northeast of Iceland and in central parts of the ocean (Fig.). In the East Icelandic Current the biomasses varied between 1.4 and 6.0 g m^{-2}. The average zooplankton biomass for the total area investigated south of 68 ^{o}30´N was 3.6 g m^{-2}. As a comparison the average biomasses at the Svinøy section in early to mid July 2008 was 4.6 g m^{-2}, supposed to decline towards the end of the month. Thereby the data from summer 2009 indicate only a minor decline in zooplankton biomass in relation to the same period previous year.

Eros

WP2 net

The average amount of zooplankton concentration sampled with the WP2 net was 5.9 g/m^2 dry weight in the northern part of the survey area covered with Eros. The highest concentrations were between 18-22 g/m^2 dry weight dominated by *Calanus finmarchicus* in three stations between 72.30- 75.30 ^oN. Average registrations of *C. finmarchicus* during the period 1994-2002 were 7 g/m^2. Amphipods were found at 23 out of 43 locations, and highest numbers were found in the northernmost areas dominated by *Themisto libellula* and *Themisto abyssorum*. Chaetognatha (*Sagitta elegans, Sagitta maxima, Eukronia hamata)* were found at 41 out of 43 stations, with the largest specimen and highest concentrations in the northernmost stations up to Spitzbergen. Only 15 specimens of krill (*Thyssanoessa longicaudata, Thyssanoessa inermis, Euphausiacea)* were caught in the WP2 net. Calanus hyperboreus was only found at five stations. Paraeuchaeta was found at 26 out of 43 locations. Catches from T-160 ringnet has not been properly analyzed yet, although Themisto *libellula*, Copepods, *Limacina helicina* and gelatinous plankton were sampled.

Bongo

Amphipods (*Themisto libellula)* dominated the catches at the surface in the northern locations together with some copepods, whereas *Calanus finmarchicus* were most abundant further south. Other species caught included blååte, *Limacina helicina* and *Limacina retroversa*.

Krill trawl

A total number of 16 trawl hauls with the macroplankton trawl was done and six of the hauls had no catch. Krill were only caught in three hauls, exclusively in the northernmost survey area. The largest catch was 6.6 kg of krill caught south of Longyearbyen. Drifting fish larvae from various pelagic and demersal species were found in several hauls.

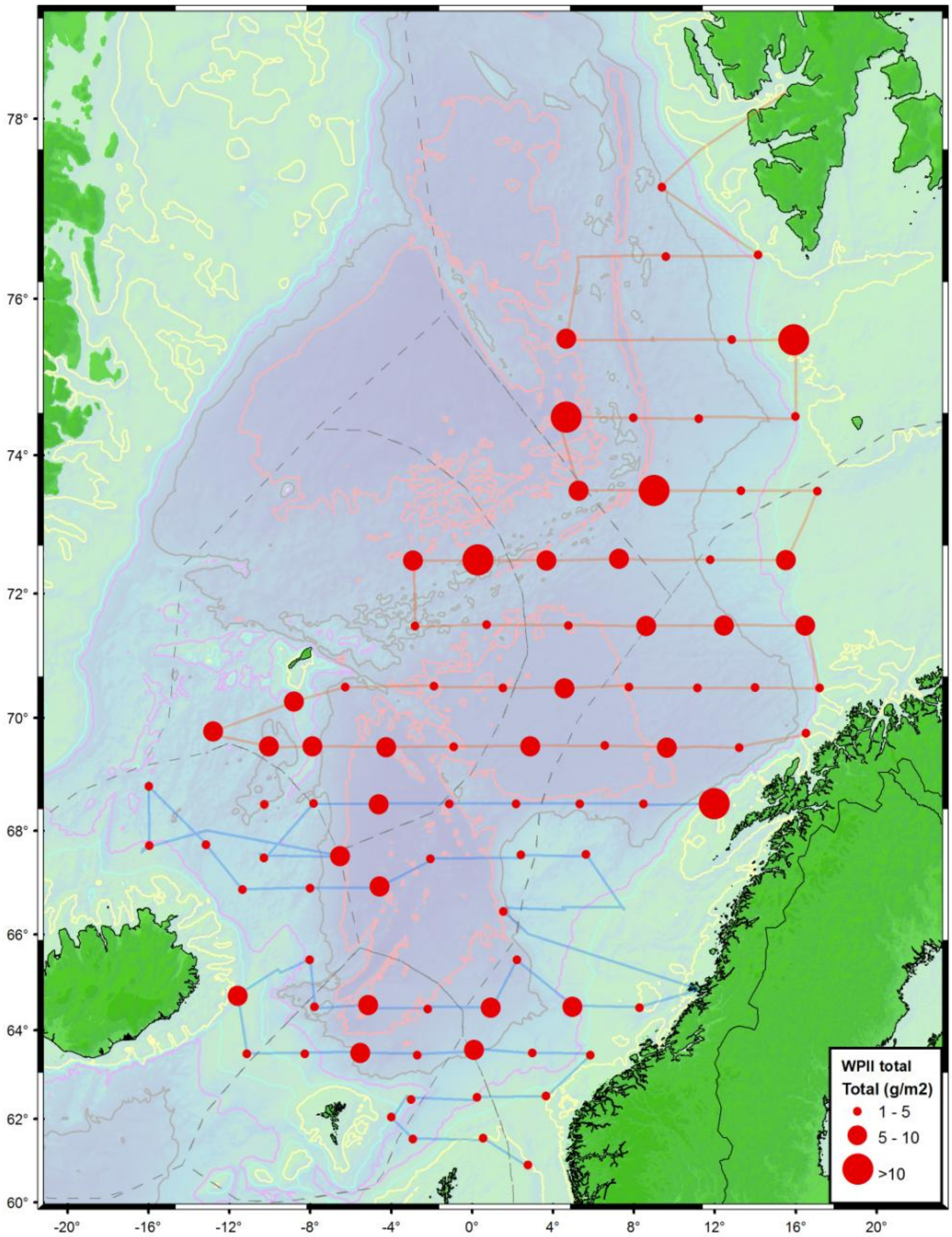

Figure 34. Map of total zooplankton concentrations (g/m^2) from WP2 net samples (0-200 m).

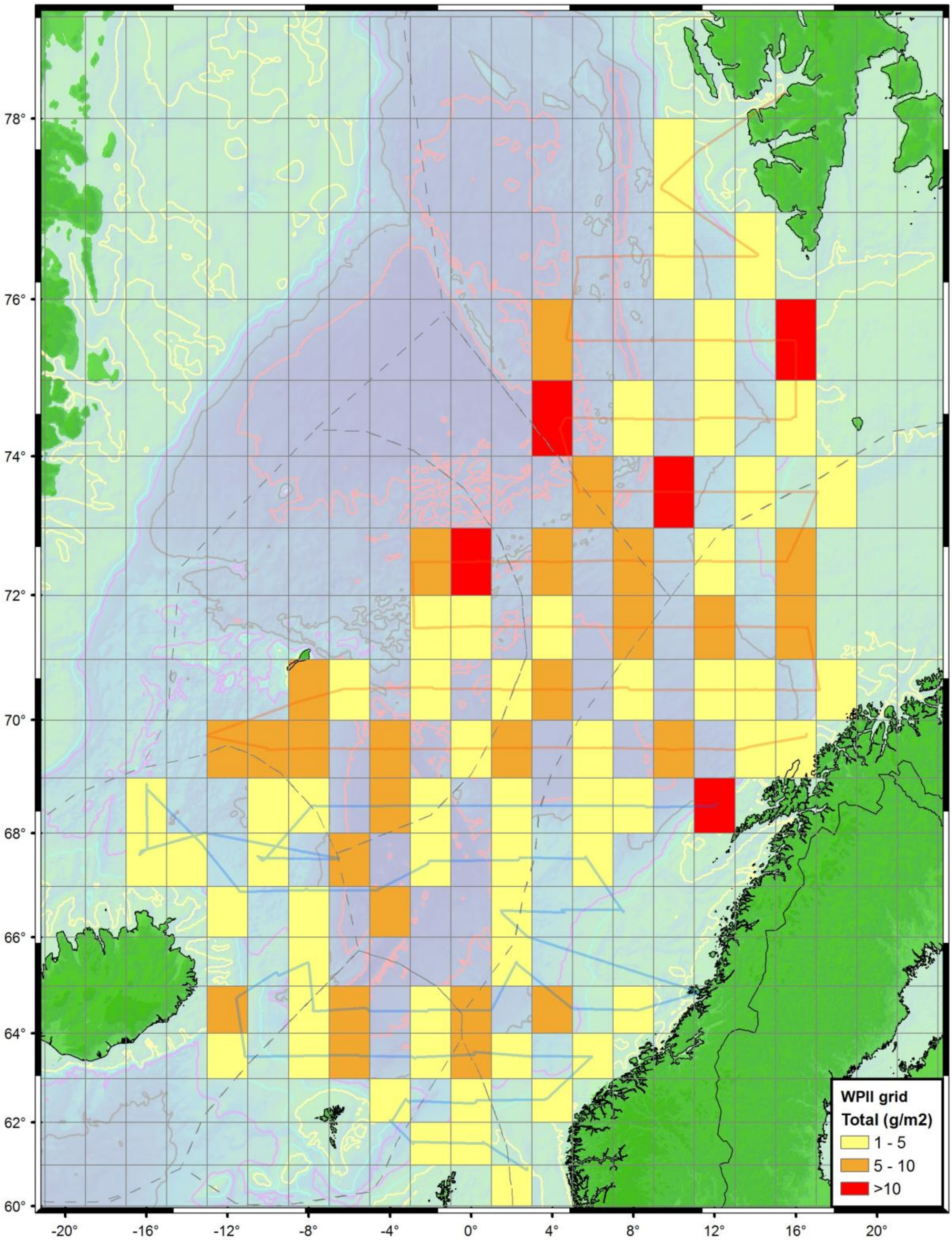

Figure 35. Total biomass of zooplankton (g/m^2) represented in grids from WP2 net samples (0-200 m).

Marine mammals

The weather conditions were good and calm enough during the majority of the scientific cruise for carrying out dedicated observations from the roof according to marine mammal sighting procedure. In total, 132 hours were spent for dedicated observations onboard Libas. The distribution of marine mammals and basking sharks is presented in figure Z. Incidental sightings made by other scientists and crew members on board Libas and Eros were also used in creating the overall distribution map.

Although the observations were implemented precisely, there were generally very few observations of marine mammmals, compared with previous years in the Norwegian Sea in July-August. There were especially few whales and almost no dolphins south of 69°N. The observations showed sperm whales along the deep continental slopes off Norway and in the northern part of the Norwegian Sea. Minke whales were detected in several areas, but mostly there were single animals or one small group. Fin whales were met only four times; two sightings in the western part and two in the northern part of the investigated area. Humpback whales were only sighted twice in the western part not far from Iceland. There were some observations of killer whales with a school size ranging from 1 to 15. A small group of pilot whales was sighted to the east of the Faroe Islands. The majority of dolphins were found north of the polar circle at 66.33°N. The basking shark appeared three times in the western and eastern parts of the survey area. Total number of sightings and registered animals is shown in the table Z.

Table. Number of sightings and registered marine mammals and basking shark.

SPECIES	Sightings (N_{total})	Animals (N_{total})
Sperm whale	35	36
Minke whale	22	30
Fin whale	4	5
Humpback whale	2	4
Killer whale	9	36
Pilot whale	1	6
Unidentified whale	24	32
Unidentified dolphin	9	74
Basking shark	3	3

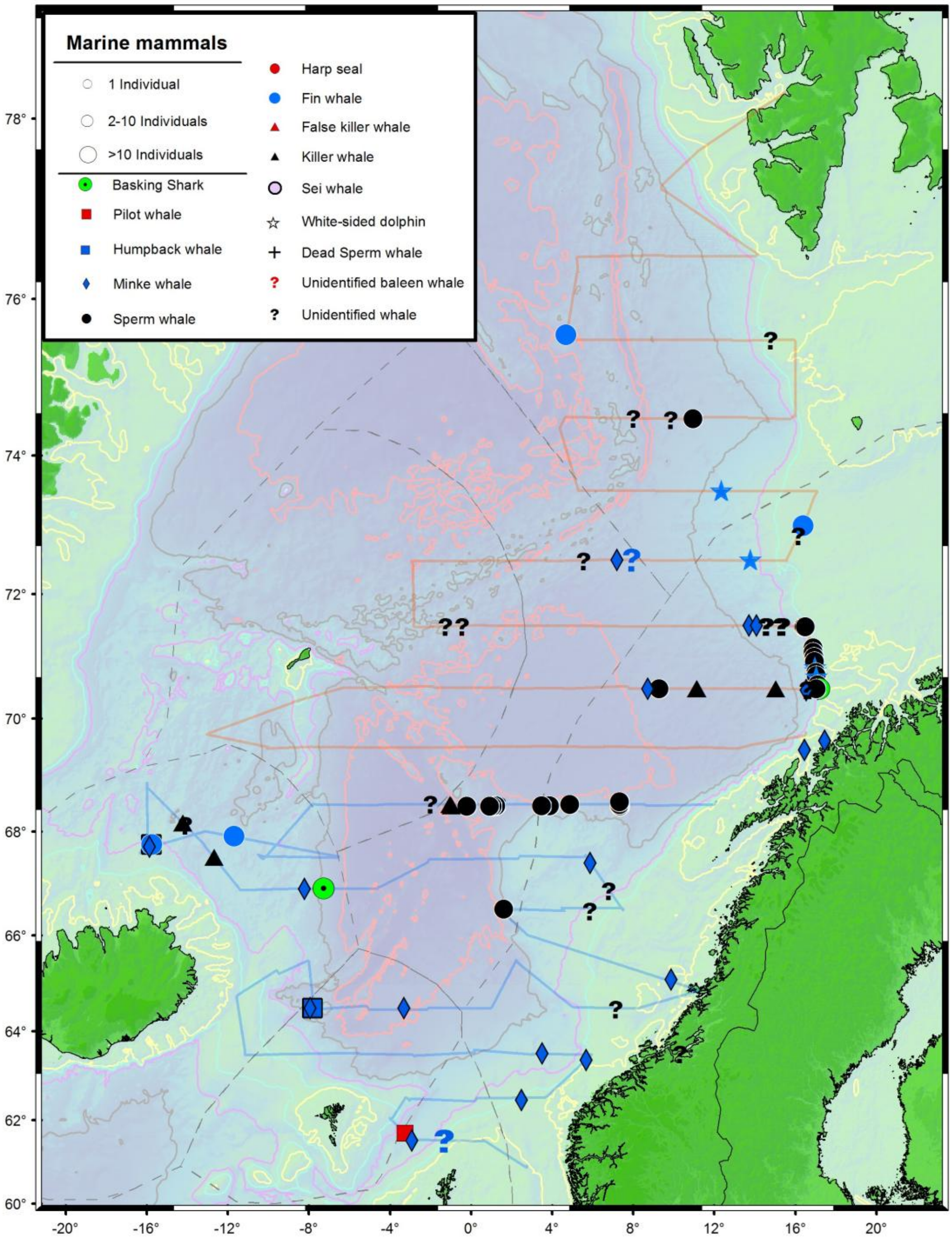

Figure 36. Marine mammals and basking sharks observed in the Norwegian Sea onboard “Libas” and “Eros” between stations in daylight hours, 15 July –6 August 2009.

Total number of marine mammals sighted was significantly less than expected, with the highest sighting rates found along the continental shelf break north of Tromsø (Figure 37).

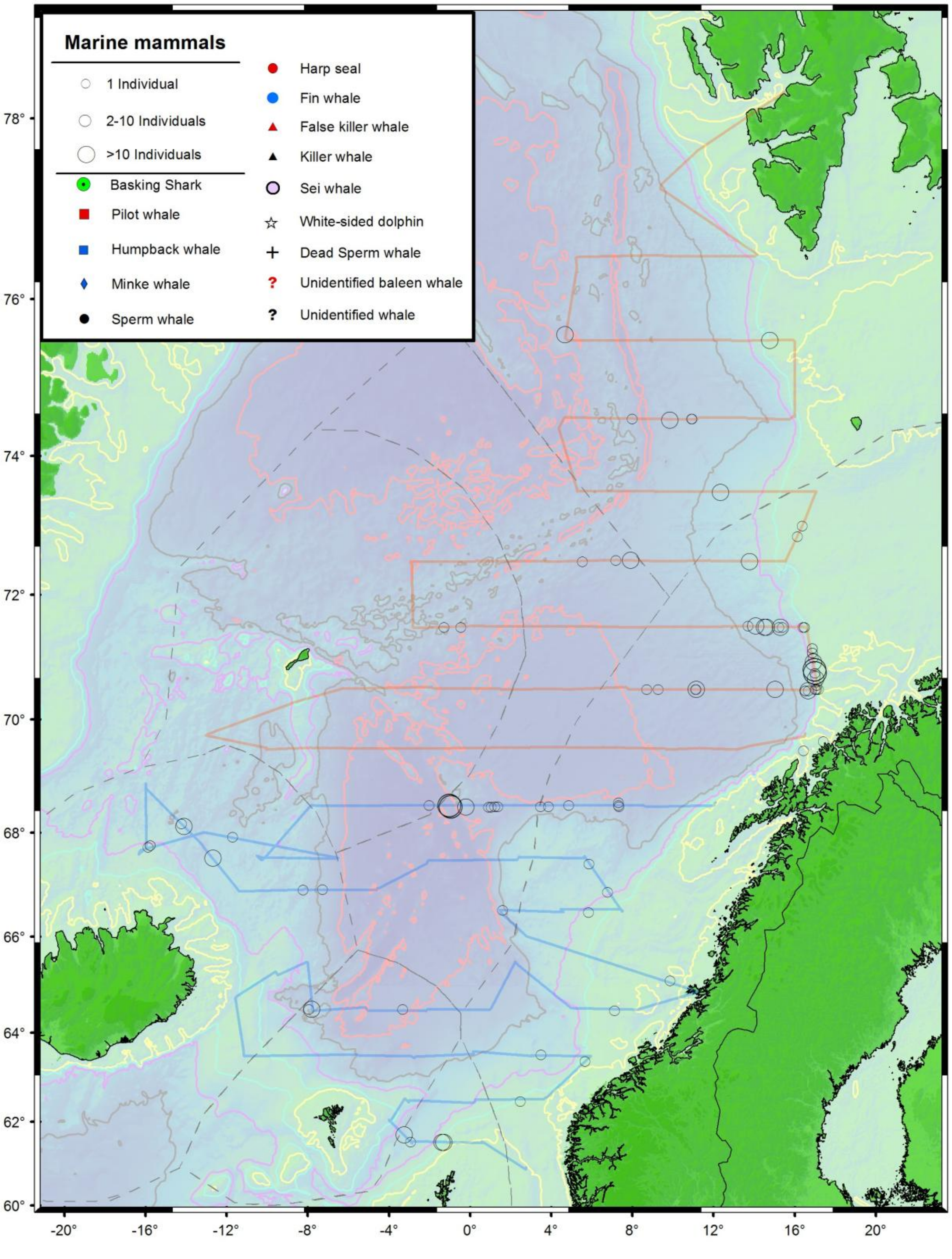

Figure 37. Total number of marine mammals sighted onboard Eros and Libas along the cruise tracks in the Norwegian Sea, 15 July-6 August 2009.

Weather conditions

The weather conditions were mostly favourable for acoustic recordings and visual sightings with low wind speed (Baufort scale: 0-3): However, wind speed reached Baufort scale 4-6 some days within the survey tracks for both Libas and Eros in the Norwegian Sea in July. Low precipitation and limited rainfall provided good visibility throughout the cruise. Fog and fogbanks were mostly experienced in the westernmost area south of Jan Mayen and near Bear Island.

5) Discussion

The ecosystem survey managed to cover the most central areas for the distribution and aggregation of mackerel, herring and blue whiting in the Norwegian Sea in summer. July-August is the feeding period where all the three major planktivorous species have their maximum geographical distribution. A major aim of this study was to map almost the entire populations of mackerel, herring and blue whiting in the Norwegian Sea. Based on the continuous acoustic recordings from hydro-acoustics and extensive pelagic trawling near the surface and midwater, we managed to cover the vast majority of these species and consequently their maximum spatial distribution.

Chartered commercial fishing vessels are suitable and well-equipped platforms for large-scale mapping of pelagic fish species such as mackerel, herring and blue whiting. Modern combined stern trawlers/purse seiners are also practical for more dedicated ecological studies. Since both Libas and Eros has drop keel the vessels can be used for abundance estimation using hydro-acoustic recordings with scientific echosounders and multibeam sonars. This combined methodology will ensure more reliable abundance estimation and distribution patterns of pelagic fish during the feeding period from May to August in the Norwegian Sea.

The shallow distribution and absence of dense schooling behaviour in both mackerel and herring within most of the study area in July-August, challenges the quantitative value and credibility of acoustic recordings from echosounder measurements. Substantial concentrations of pelagic species (mackerel, herring, horse mackerel) were present above and close to the transducer depth. The

upper acoustic blind zone is in the order of 10-15 m due to the drop keel on Eros and Libas. Furthermore, pronounced vessel avoidance during summer feeding may complicate these studies even more when applying standard echosounder technology.
Nevertheless, a complementary approach with continues use of multibeam sonars and multi-frequency ensures a complete coverage of the water column along the cruise track.

Systematic stomach content analyses of our most important pelagic species mackerel, herring and blue whiting, combined with concurrent zooplankton analyses, mapping of marine mammals and measurements of the oceanographic conditions are paramount for a deeper understanding of the feeding ecology, potential inter-specific feeding competition, spatiotemporal overlap and migration patterns of mackerel, herring and blue whiting in the Norwegian Sea.

Acknowledgement

We thank skippers and crew members onboard Libas and Eros for outstanding collaboration and practical assistance on the ecosystem cruise in the Norwegian Sea.

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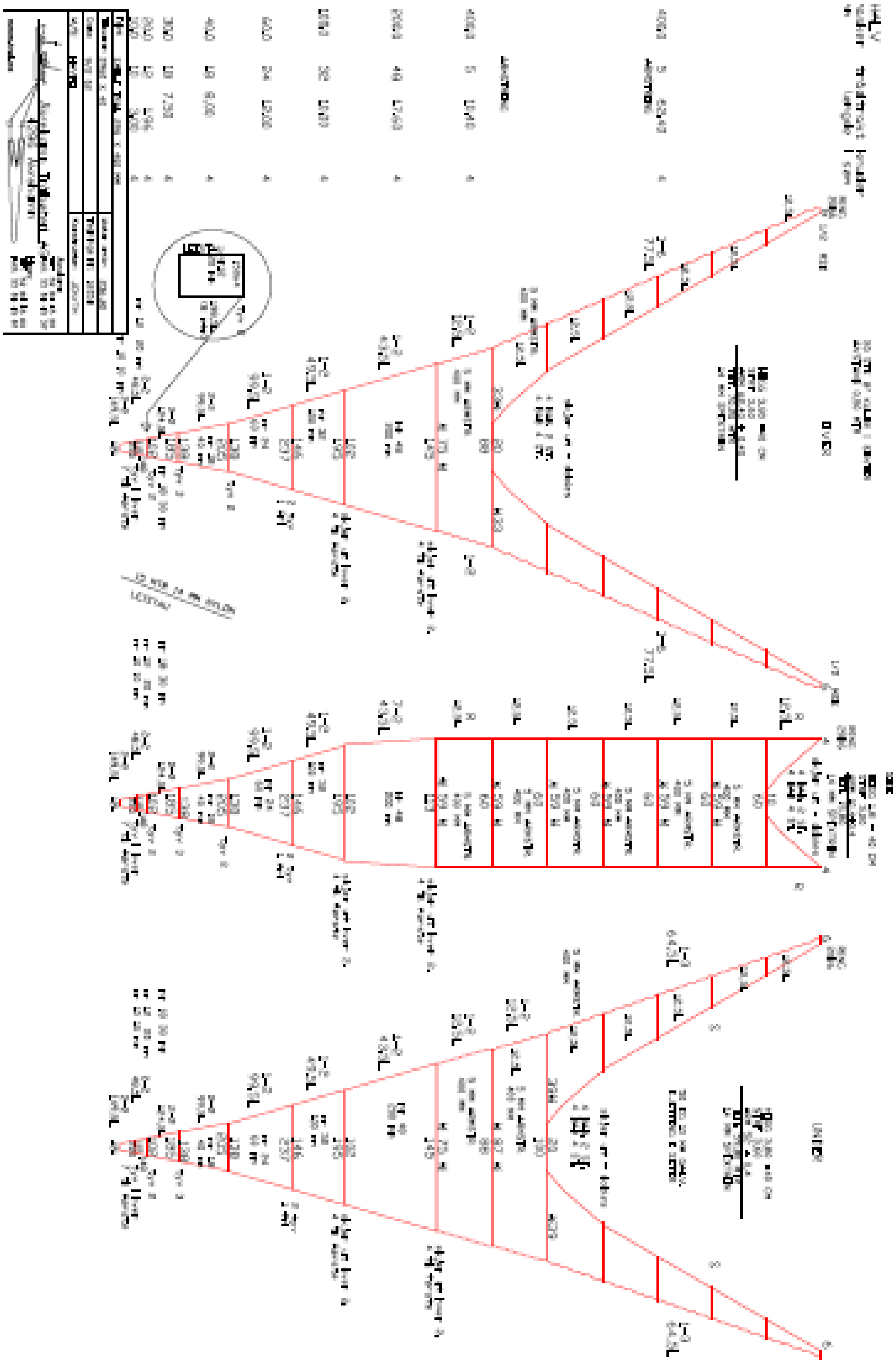
Appendices

Appendix 1



Appendix 1. Drawing of design and dimension for the pelagic salmon trawl used on Eros and Libas during the cruise.