# CRUISE SUMMARY REPORT 2004 113

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MINIERROR: Audun Pedersen, Radiation: Bjørn Lind

The cruise is a part of the following projects:

- Species Identification Methods From Acoustic Multi-frequency Information (SIMFAMI)
- Calculation of acoustic and biological abundance and estimate the geographical extent of the Atlantic mackerel stock at this time of year (internal project at IMR)
- Non-linear effects in echo sounders (MINIERROR. Institute of Marine Research (IMR), University of Bergen (UoB), Christian Michelsen Research (CMR), Simrad)
- Use of LIDAR to detect mackerel near surface
- Investigations of radiation (Cooperation between IMR, Norwegian Radiation Protection Authority NRPA)

**Cruise no:** 2004 113
**Vessel:** G.O. Sars (3)
**Departure:** Bergen 18 October 2004
**Arrival:** Bergen 8 November 2004

**Purpose:**
1. SIMFAMI: 10108
2. Acoustic abundance estimation of mackerel
3. MINIERROR: 10109
4. LIDAR: 10233

**Covered waters:**
Northern North Sea (59-62N, 1E –4W)

**Participants (from Institute of Marine Research, 18 October – 8 November):**

| | |
|---|---|
| Rolf Korneliussen | (cruise leader) |
| Dankert W. Skagen | (scientist) |
| Aril Slotte | (scientist) |
| Bjarte Kvinge | (instrument chief) |
| Terje Haugland | (instrument engineer) |
| Sigmund Myklevoll | (assistent) |
| Anne Liv Johnsen | (assistent) |
| Helga A. Gill | (assistent) |
| Eirik Tenningen | (PhD student - LIDAR) |

**Guest scientists:**

| | | |
|---|---|---|
| Audun Pedersen | (PhD student, Physical Institute, UoB. MINIERROR | Oct. 18-20 and Oct.29-Nov.8) |
| Maria Antsalo | (M.sc student, Institutt for Fiskeri og Marinbiologi, UoB | October 18 – November 8) |
| Bjørn Lind | (NRPA | October 18 – November 8) |
| Jon Drefvelin | (NRPA | October 18 – November 8) |
| Alexander Lisovsky | (PINRO, Russia – LIDAR | October 18 – November 8) |
| Egil Eide | (LIDAR) | October 18 – 20 |

## INTRODUCTION

The 2004 survey was a continuation of surveys from 1996, 1997, 1999, 2000, 2002, and 2003, with the main purpose of finding distribution of Atlantic mackerel during fall annually, and to estimate abundance through acoustic methods. In 1996 and 1997, a standard version of the scientific echo sounder EK500 was used. From 1999, techniques for multi-frequency data-collection and post-processing were developed systematically. RV "G.O. Sars" (2) was used until 2002, as that was the best available vessel for multi-frequency data-collection. During the years 1999 – 2002, a special version of EK500 was used to improve multi-frequency analysis of the acoustic data, with the same pulse-duration 0.6 ms on all available acoustic frequencies, 18, 38, 120 and 200 kHz. Experience gained through the early years of this period was used as input to Simrad AS when the new scientific echo sounder EK60 was developed and modified, and when the new research vessel RV "G.O. Sars" (3) was designed. EK60 was tested during the survey in 2002, and was used through the whole survey when RV "G.O. Sars" (3) entered service in 2003.

EK60 has the same pulse-duration of 1.0 ms on all frequencies. The transducers were mounted as tight as possible on one protruding instrument keel of RV "G.O. Sars" (3). The echo-sounder systems were carefully calibrated at the sheltered location at Uggedalseidet, Norway. In 2003 and 2004, the acoustic frequencies 18, 38, 70, 120, 200 and 364 kHz were used.

The Bergen Echo Integrator (BEI) system for post-processing acoustic data has been expanded and developed for the use with multi-frequency acoustic data. Especially the sub-system of species identification has been given attention through the years. This is due to the surveys being a part of first a national mackerel project, and then the EU-financed project SIMFAMI for identifying species from multi-frequency acoustic information. To be able to verify plankton identification, plankton samples were taken with MOCNESS and WP2 in 2001, 2002, and 2003 in addition to trawl sampling for fish.

In 2004, verification of fish was the only purpose, and therefore only a few plankton samples were taken.

The ICES Planning Group for Acoustic and Aerial Surveys for Mackerel (PGAAM), was established in 2001 to coordinate mackerel investigations internationally. The acoustic surveys of Norway and UK have to some extent been coordinated since 2002. In 2004, the Norwegian and Scottish surveys were performed during the same period, with similar east-west cruise-lines. After the first complete coverage done by each vessel, a common coverage was done at the end of the survey at the locations where mackerel was found during the first period. One of the cruise-lines was used for inter-calibration between RV "Scotia" and RV "G.O. Sars". The results of the surveys will be compared during the winter.

### Carrying through the survey

The survey was n a broad sense designed as an abundance estimation survey with parallell east-west cruise-lines with 7.5 - 15 n.mi. distance between each. The planned cruise-lines were adapted to the registrations from previous years and to the waters of the fishing activity, so that the shortest distance between the cruise-lines were the highest density of mackerel were expected to be found. The are of coverage was between 59$^{o}$ N, 62$^{o}$ N, 1$^{o}$ W and 4$^{o}$ E. It was one call in Lerwick 29/10 to avoid paying tax on the fuel according to Norwegian rules. The cruise-lines are shown below.

## ACOUSTICS

### Calibration

The acoustic transducers of RV ”G.O. Sars” is mounted with multi-frequency analysis in mind (Figure 1) in accordance with the recommendations in Korneliussen et al., 2004. The split-beam EK60 was used at the frequencies 18, 38, 70, 120, 200 og 364 kHz. Calibration was done with instrument settings according to the recommendation (pulse-duration, transmission-power). See Table 1.

The conditions during the calibrations and the results of the calibrations were excellent at all frequencies both in 2003 and 2004, except at 364 kHz. The 364 kHz is not symmetric, and was checked after the 2003 cruise. The GPT was working properly, and both tested wide-band 400 kHz composite transducerers worked properly. The reason for the unsymmetric beam is therefore thought to be due to mismatch between the 363.6 kHz GPT and the det 400 kHz transducer. The 364 kHz acoustic data should therefore be used with care.

*Tabell 1. Transducers and calibration (2003 and 2004)*

| | **18kHz** | **38kHz** | **70 kHz** | **120 kHz** | **200 kHz** | **364 kHz** |
|---|---|---|---|---|---|---|
| **Transducer** | ES18-11 | ES38B | EC70-7C | EC120-7C | ES200-7C | ES400-7C |
| **Area [$10^{-3}$ $m^2$]** | 200 | 100 | 30 | 10 | 4.4 | 1.1 |
| **Opening angle 3dB. [$^o$]** | 10.75 | 7.0 | 6.6 | 6.5 | 6.5 | 5.9 |
| *2003: Power [W]$^*$* | *2000* | *2000* | *1000* | *250* | *120* | *60$^{**}$* |
| *2003: Power per $m^2$* | *10* | *20* | *33* | *25* | *27* | *54$^{**}$* |
| **2004: Power [W]$^*$** | 2000 | 2000 | 800 | 250 | 120 | 60$^{**}$ |
| **2004: Power per $m^2$** | 10 | 20 | 27 | 25 | 27 | 54$^{**}$ |
| **Receiver bandw.[kHz]** | 1.574 | 2.425 | 2.859 | 3.026 | 3.088 | 3.114 |
| **Pulse duration [ms]** | 1.024 | 1.024 | 1.024 | 1.024 | 1.024 | 1.024 |
| **Calibration sphere** | CU64 | CU60 | WC38.1 | WC38.1 | WC38.1 | WC38.1 |
| **TS of sphere** | -34.22 | -33.6 | -41.3 | -39.50 | -39.20 | -39.53 |

* Recommended input power (Korneliussen, Diner, Ona and Fernandes, 2004) is 25 kW/$m^2$.

** 364 kHz was deliberately used at too high input power due to the interference with the non-linearly generated third harmonic of 120 kHz. ”120 kHz” in EK60 is really 121.3 kHz, and “364 kHz” is 363.6 kHz.

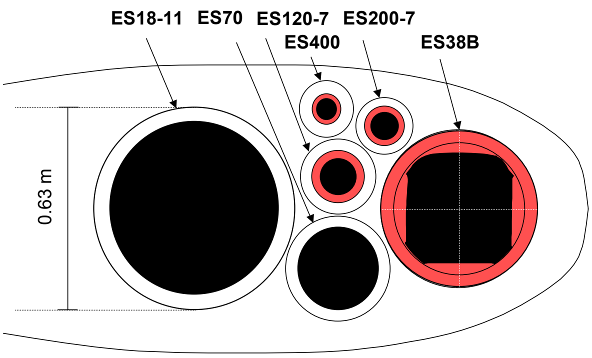



*Figure 1. Relative positioning of transducers on protruding instrument keel of RV ”G. O. Sars” (3)*

**Collection of acoustic survey data for files and database**

The protruding instrument keel was fully out during all of the survey, i.e. at 8.5 m depth below the surface, 2.5 m below the hull. The acoustic registrations were not bad, although backscatter from bubble-clouds was a problem starting with wind-speed 20 – 30 knots depending on the heading of the ship as compared to the wind direction. One suggested solution to avoid this problem in the future is be to extend the protruding instrument keel to a maximum length 3.5 – 4.0 m below the hull.

The echograms were scrutinized by the use of Bergen Echo Integrator, BEI (Korneliussen, 2004). The scrutinized echograms were stored in a database with a resolution of 1.0 n.mi. horizontally and 10 m vertically. All echograms where mackerel were identified were scrutinized at all frequencies (18, 38, 70, 120, 200 and 364 kHz), with an exception for 364 kHz in those cases where the mackerel were only found at depths beyond the range of 364 kHz, i.e. beyond approximately 100 m below the surface. The echograms were also interpreted automatically by the categorization system of BEI (Korneliussen and Ona, 2002, 2003). The results of the automatic mackerel identification are not presented here.

See below (Scrutinizing Acoustic Data of Mackerel) for description of topics of the scrutinizing process.

**Collection of data for modeling of mackerel backscatter**

During the survey, density and sound speed of mackerel flesh were measured. This was also done in 2003, but in 2004, the number of sound-speed measurements was increased, and numerous reference measurements of sound speed in seawater and fresh water was also done. Trygve Gytre, IMR, made the probes and equipment for doing these measurements.

Some mackerel were frozen with measurements of fat content in mind. The bones of mackerel are to be used for measurements of acoustic backscatter at the acoustics laboratory at the Institute of Physics, University of Bergen, Norway.

**NONLINEAR EFFECTS: MINIERROR** (Authors: Audun Pedersen, Rolf Korneliussen)

The motivation of the MINIERROR project is that non-linear effects have been proven to occur even at moderate output power of echo sounders especially at high frequencies. There is a need to investigate how non-linear effects can be reduced to an ignorable level, and also to investigate if historical data can be corrected for non-linear effects. The common scientific echo sounder EK500 also used at the mackerel surveys until 2002 used input powers of 1000 W at 120 and 2000 kHz.

While still on the calibration site, the reference sphere system was used for measurements of attenuation in the frequencies 120 kHz and 200 kHz due to non-linear sound propagation. The power settings for both frequencies were alternated between 50 W, 100 W, and 1000 W throughout the measurements. A calibration sphere (WC38.1) was positioned in the sound beams using the split-beam functionality. Beam patterns from the central part of the main lobes (± 3° athwart ship) were measured at ranges of 22 m (200 kHz) and 45 m (both frequencies). Measurements were also made with the sphere in several points along the axis of the 200 kHz sound beam at depths of 8 m to 45 m below the transducer. Throughout the measurements, the transducers were positioned on the protruding instrument keel 8 m below the sea surface.

The axis measurements showed an increased range-dependent attenuation when the output power was increased to 1000 W. Also, the results from the 200 kHz beam pattern measurements showed the consequential flattening of the main lobe. The phenomenon was visible, but somewhat less obvious in the 120 kHz beam patterns.

At two times during the cruise (05.11.2004 and 06.11.2004), schools of mackerel were located in order to investigate the effects of non-linear distortion on $s_v$ measurements. The first school was situated between 150 m and 250 m depths. On the other occasion a large number of schools were observed, with different densities, from depths of approximately 40 m to 150 m.

Several passes were made over each school. The output powers of the 120 kHz and 200 kHz frequencies were alternated between the values chosen for the survey (250 W and 120 W, respectively), and the echo sounder's maximum power of 1000 W. The data from all frequencies was retained in order to estimate expected $s_v$ values for the 120 kHz and 200 kHz frequencies. Such estimates could form a basis for comparison with $s_v$ values obtained with 1000 W output power. This way a measure of errors in $s_v$ measurements due to non-linear propagation effects might be calculated.

During these passes, the EK60/364kHz-system was used in both active and passive mode, both with 120 and 200 kHz at its normal input power (250 and 120 W) and at high power (1000 and 1000 W). Note that the system known as the "120kHz-system" really runs at 121.3kHz, and that the 364kHz system runs at 363.6kHz, i.e. at the same frequency as the third harmonic of 121.2kHz.

## BIOLOGICAL SAMPLES

### Trawling and multisampler

The pelagic doors "ET Speed Light Pelagic" with 7.5m$^2$ area was used during the pelagic trawl hauls. The experiences with these doors have been good since they were first used in 2002. Two similar Åkra pelagic trawls were used during the survey, one connected to the multiple codend system, and one standard single net trawl. The use of a single-net trawl was considered necessary to avoid destroying the multi-sampler in bad weather. The Åkra trawls are designed for towing at approximately 4 knots. IMR had no trawls designed for towing at higher speed.

Partly due to comments from scientists, there was a meeting between scientists and ship officers prior to the survey to discuss optimal setup of the trawl. Senior scientist John Willy Valdemarsen gave some advices of how to improve catch ability of mackerel. The use of proper trawl-weights and trawl-sonar was discussed.

The catch ability of mackerel may have been optimal for the available pelagic trawls, but was not considered to be very good. Unfortunately, some of the best acoustic registrations for mackerel were seen during the 12 hours period where no pelagic trawl was available.

Trawling was done largely due to acoustic registrations, both on supposed mackerel schools, and on registrations considered difficult to scrutinize. Trawling was done at the positions shown in Figure 2.

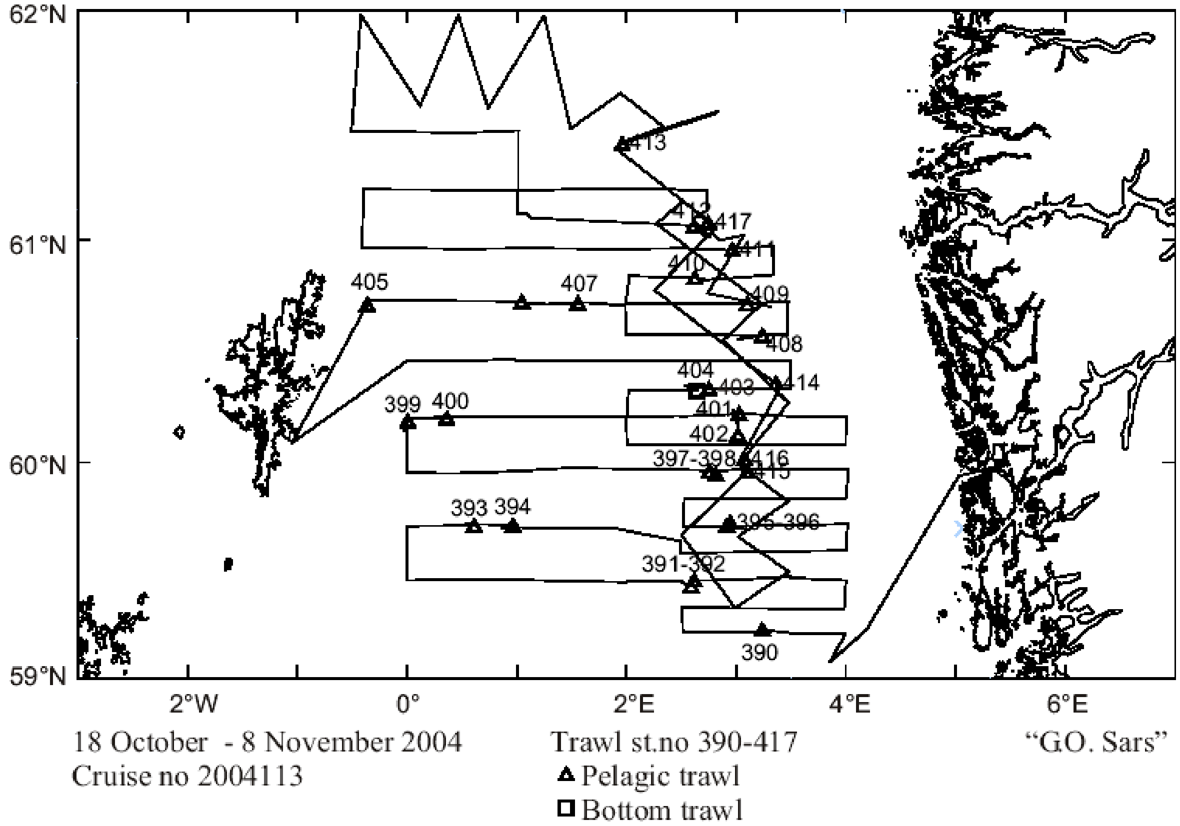



*Figure 2. Positions of and station number trawl stations. Triangles is pelagic trawl stations, squares is bottom trawl stations. (Figure provided by Karen Gjertsen, IMR)*

**Biological sampling of zooplankton - MOCNESS and WP2**

There was a desire to collect zooplankton samples in 2004 as in 2003 and 2002 both to separate mackerel from some zooplankton registrations, but also to investigate a more complete ecosystem. However, due to experience from 2002 and 2003, the effort and time needed to process such samples after the survey was too long considered the termination of the SIMFAMI project by the end of 2004 to defend collection of such data. For this reason, only a few vertical net, WP2, was collected.

**Processing of biological samples**

Fish: All fish (or at least a representative sub-selection in the case of large cathces) was measured for length and weight. Otoliths were taken for a maximum of 100 specimens of mackerel in each haul for determination age as a part of the standard procedure.

Plankton: There was no processing of zooplankton onboard. The few zooplankton samples collected will be processed later.

**HYDROGRAPHIC DATA**

CTD data was collected as vertical samples with SeaBird sonds. A total of 80 vertical CTD stations distributed throughout the covered area were taken. Figure 3 shows the positions and numbering of the CTD stations.

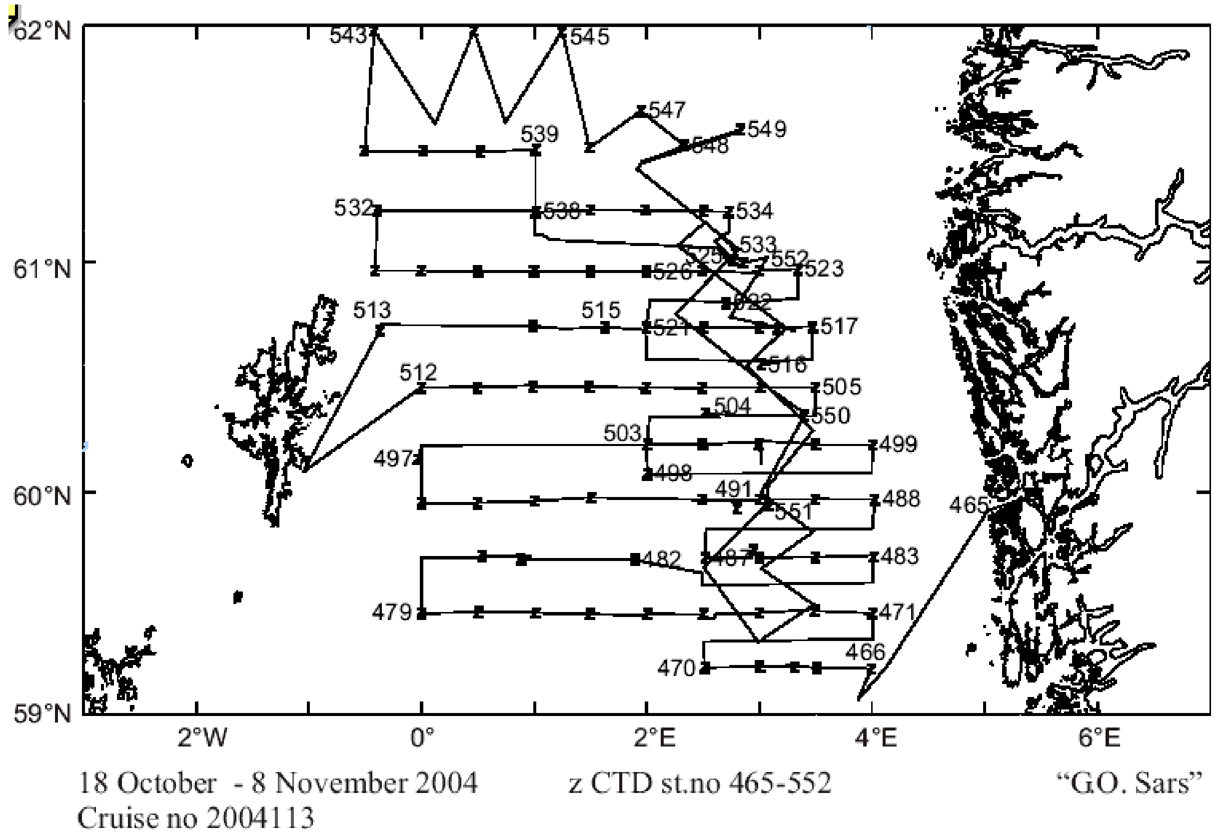
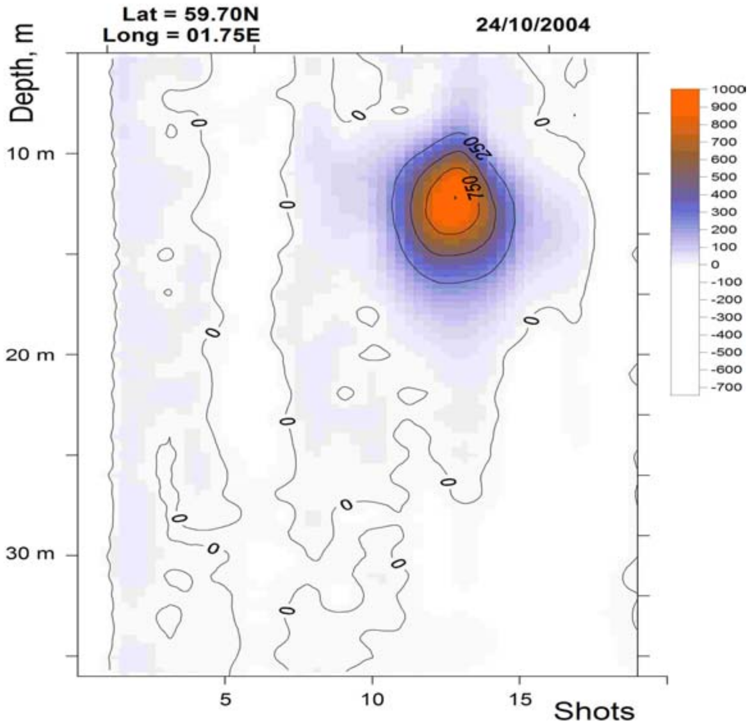



*Figure 3. Positions and numbering of 88 CTD stations. (Karen Gjertsen, IMR)*

**LIDAR** (Author: Eirik Tenningen, IMR)

IMR and NTNU have built a LIDAR (LIght Detection And Ranging) for mapping of fish and plankton close to the surface. It will mainly be operated from an aircraft, but was tested on this cruise for direct calibration with the echo sounders and to observe the close-to-surface area where these do not cover. The LIDAR transmitter is a green laser (532 nm) emitting 30 pulses per second of 15 ns duration towards the sea surface. Some of the light is reflected from the sea surface, while the rest penetrates the water column and is reflected by fish, plankton, or other objects. By using a negative lens in front of the laser, the light is spread to a disk with a diameter of about 1 m on the surface. The receiver is a telescope pointing in the same direction as the laser. The received signal is sent to a photo multiplicator and converted to an electrical signal. The signal is digitised and stored on a computer along with the GPS position. From this lidargrams similar to echograms in acoustics can be constructed. Under ideal conditions the lidar penetrates down to about 50 m, but seldom more than 30 m during this cruise.

During the first days, the LIDAR was adjusted for the use onboard a vessel. The laser energy was reduced to about 1/100th to compensate for the reduced height above the sea surface and due to safety considerations. Still there were some problems with saturation due to strong surface reflections. The waves and foam from the boat also created some problems. These data must be discarded and a program for detecting and removing this data was written. The rest of the post processing will be finished after the cruise.




Data was collected during days with moderate wave height resulting in usable data from a total of 9 days. These data are mainly from areas where mackerel was present and they were collected both during trawling and during cruising speed along the cruise lines. Towards the end of the cruise a power failure prevented the laser from lasing and data were not collected. Figure 4 shows an example of a lidargram of a small school is given (ca 1m x 5m)

*Figure 4. Example of lidargram, i.e. similar to echogram but using LIDAR instead of echo sounder.*

**RADIATION: Monitoring of radioactive contamination in Norwegian Marine Environment - Sample collection during the cruise** (Author: Bjørn Lind, NRPA)

The issue of potential and radioactive contamination in the marine environment has received considerable attention in Norway in recent years. Due to the economic importance of the fishing industry and its vulnerability to contamination as well as any rumours of radioactive contamination, one of the main objectives is to document levels and trends of radionuclides in the Norwegian marine environment. There are currently two monitoring programmes concerned with radioactivity, both coordinated by the Norwegian Radiation Protection Authority (NRPA) and in collaboration with i.a. Institute of Marine Research, IMR. One is funded by the Ministry of the Environment and focuses of monitoring of radioactivity in the marine environment both in costal areas and in the open seas, the other by the Ministry of Fisheries with focus on monitoring of radioactivity in commercially important fish species. Each year, expeditions with collection of seawater, sediments and marine organisms in Norwegian costal waters and adjacent seas are performed.

Earlier in 2004, samples from expeditions in Skagerrak and southern part of Northern Sea have been collected. NRPA have participated on the cruise in the Northern Sea with G. O. Sars in the period from 8th November to 18th October and have collected in total approximately 80 samples of seawater (surface- and subsurface water), sediments from the seabed and fish samples (mainly mackerel, herring and cod) from 15 localities. Samples of seawater with focus on monitoring of natural radionuclides (for instance radium) in water produced by the oil installations have also been collected during the cruise. All samples will be analysed in laboratories on shore, and the results will be presented in forthcoming report from the Norwegian National Monitoring Programme.

## ABUNDANCE ESTIMATION FROM ACOUSTIC DATA PREVIOUS TO 2004

Figure 5 shows the distribution of mackerel 1999 – 2004 based on acoustic data from surveys similar to the 2004 survey. Figure 6 shows the bottom topography of the surveyed area recorded acoustically during all surveys 1999-2004. Table 2 shows the calculated abundance for mackerel 1999 – 2004. Note that the ship did not have permission to enter British waters in 1999, and did not have permission to trawl in British waters in 2002. As an alternative to the results of the abundance calculations shown in Table 2, Table 3 shows the similar calculated abundance for mackerel using length and weight distribution from commercial catches.

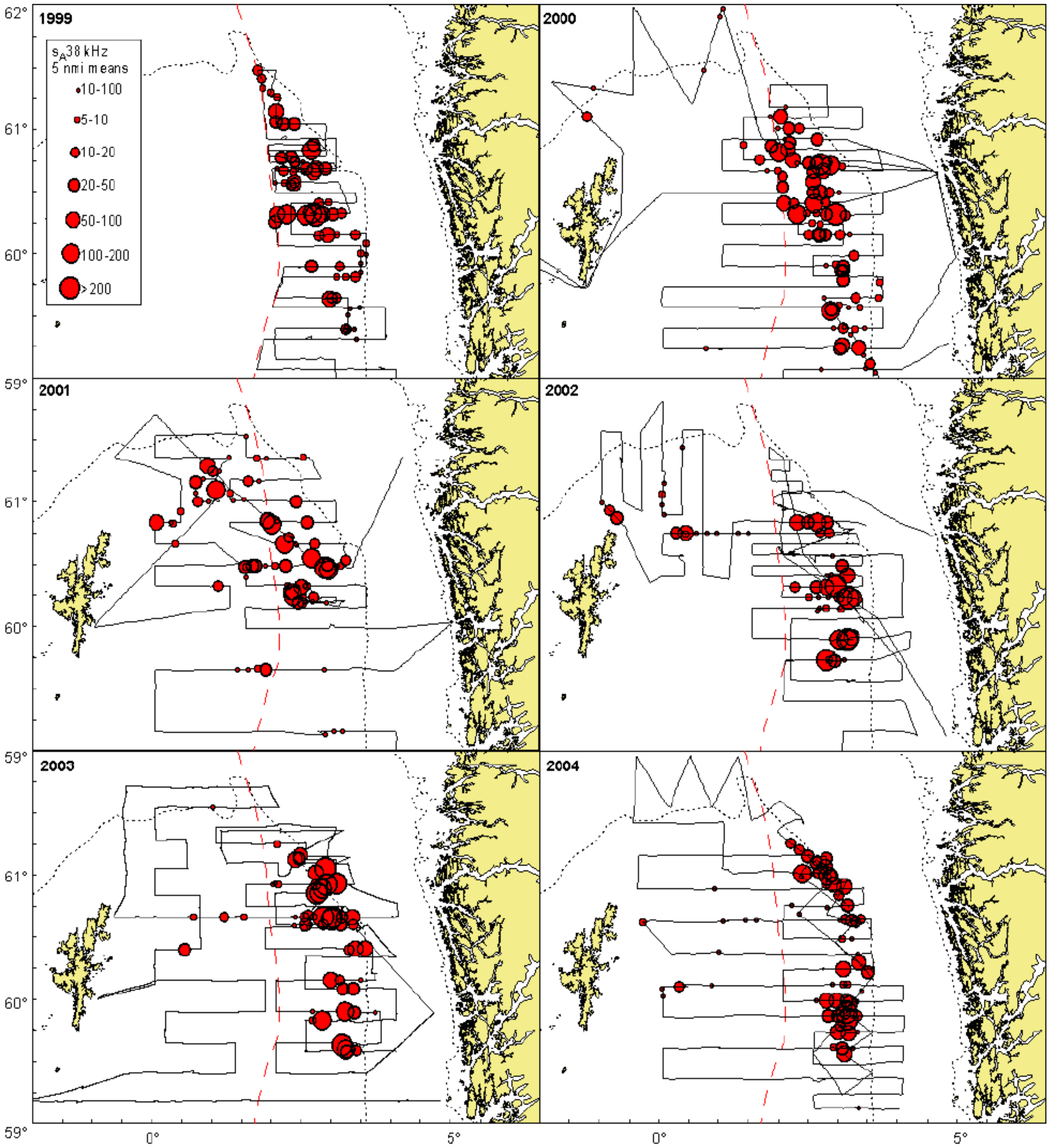


*Figure 5. Distribution and density (in terms of $s_A$) of mackerel during October-November in the years 1999-2004. The size of the discs show the area density averaged over 5 n.mi. sailed distance.*

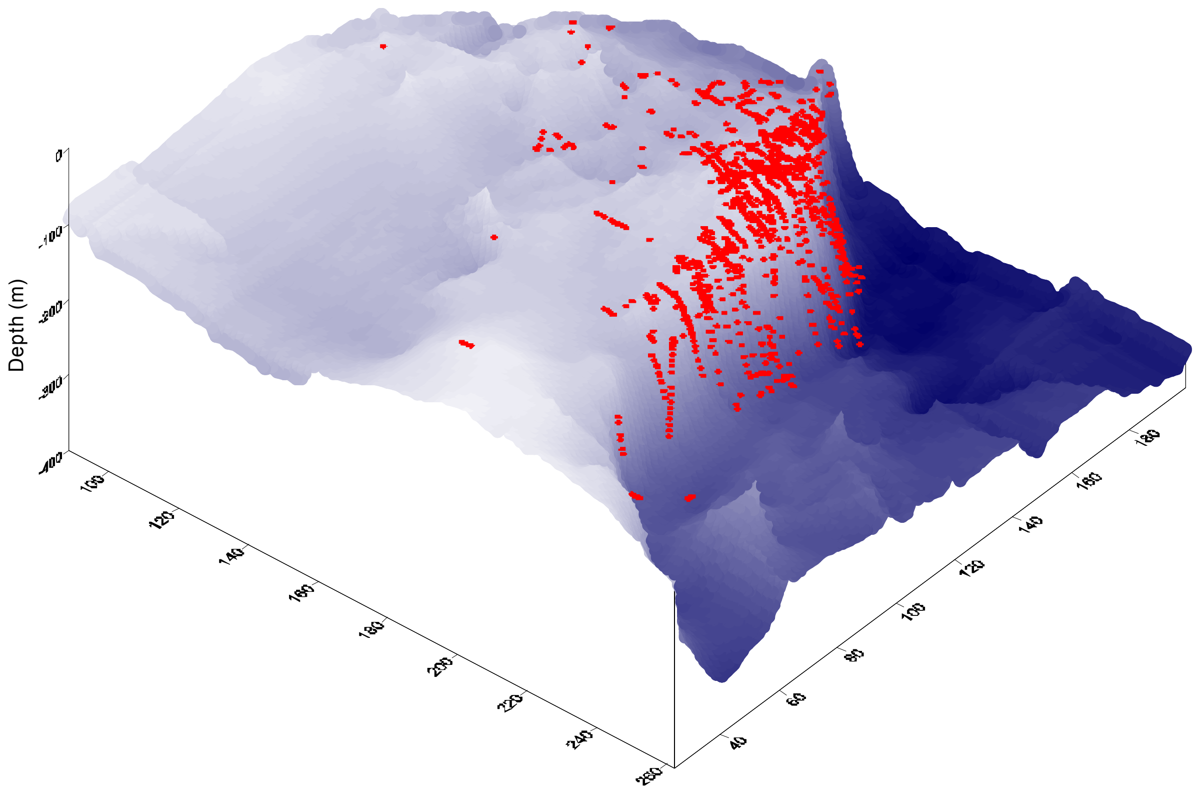



*Figure 6. Bottom topography of the surveyed area based on 1 n.mi. bottom depths recorded acoustically during all surveys 1999-2004. The average depth of mackerel based on 1 n.mi. data from the same period is marked with red spots.*

*Table 2. Area, time, length, weight and total biomass based on acoustic registrations 99 - 04*

| Year | Dates | Area | Average length [cm] | Average weight [gr.] | Biomass [$x10^3$ tonn] |
|---|---|---|---|---|---|
| 1999 | 12. Oct. – 22. Oct | Norwegian waters north of $59^0$ N | 34.9 | 358 | 828 |
| 2000 | 15. Oct – 5. Nov | North of $57^0$30' N | 32.8 | 286 | 541 |
| 2001 | 8. Oct. – 25. Oct. | North of $57^0$30' N | 36.3 | 418 | 409 |
| 2002 | 15. Oct – 3. Nov | North of $59^0$ N partly with RV "Scotia" | 33.3 | 295 | 535 |
| 2003 | 16. Oct – | $59$-$62^0$ N; $1^0$ W – $4^0$ E | 33.0 | 296 | 581 |

| | | | | | |
|---|---|---|---|---|---|
| | 6. Nov | partly with “Scotia” | | | |
| 2004 | 18. Oct – 8. Nov | 59-62$^0$ N; 1$^0$ W – 4$^0$ E with RV “Scotia” | 34.1 | 322 | 375 |

*Table 3 Biomass of Atlantic mackerel calculated from acoustic data at 38 kHz using size distributions from own catches and commercial catches respectively.*

| | **Biomass [x10$^3$ ton] based on trawl samples RV ”G.O. Sars”** (mean length, mean weight) | **Biomass [x10$^3$ ton] based on biological samples from commercial fishing** (mean length, mean weight) |
|---|---|---|
| 2003 | 535 (33.3 cm, 295 g) | 779 (38.6 cm, 577 g) |
| 2004 | 375 (34.1 cm, 322 g) | |

## SCRUTINIZING ACOUSTIC DATA OF MACKEREL

Generally, the scrutinizing of the acoustic registrations should be aided by results of the biological sampling. In addition, the length and weight distributions have to be used when abundance and biomass is calculated from integrated acoustic abundance, $s_A$. The biomass of each species found in the trawl samples is generally not proportional to the real biomass. Fast swimming fish like Atlantic mackerel are probably under represented in the catches compared to fish swimming at lower speed, especially when we are forced to tow a relatively small pelagic trawl at the slow speed as during these surveys. This has to be taken into consideration when the trawl samples are used during the scrutinizing process.

The echograms were scrutinized by the use of Bergen Echo Integrator, BEI (Korneliussen, 2004). Schools are classified as mackerel if the multi-frequency acoustic data seem to be mackerel, and that these data are supported by the trawl samples. The relative frequency response, r(f), first defined and used in Korneliussen and Ona, 2002, is a useful tool during the scrutinizing process. r(f) is used both during the traditional scrutinizing process to distinguish between different acoustic categories, but it is also the main acoustic feature used by the system categorizing all echograms automatically. During the scrutinizing process, distinct schools were easy to identify by the help of r(f) in the “manual” scrutinizing process, while this was more difficult to identify mackerel acoustically if it was found in more distributed registrations, especially when found in dense zooplankton registrations.

Note that some acoustic registrations that appeared to be a single school at one frequency appeared to be two different scattering categories of when all frequencies were considered. In years mainly previous to 2004, it occasionally was found “schools” that had a different frequency response above a temperature threshold than below, and occasionally different in the beginning of a “school” as compared to at the end. Figure 7 shows how the relative frequency response, r(f), to distinguish between some acoustic categories.

The echograms were also interpreted automatically by the categorization system of BEI (ref Korneliussen and Ona, 2002, 2003). The results of the automatic mackerel identification from previous years have been published previously partly to illustrate the method (Korneliussen and Ona, 2002) and partly as working or ICES papers (Korneliussen and Ona, 2004). The results of applying this method from several years will be submitted for publication later.

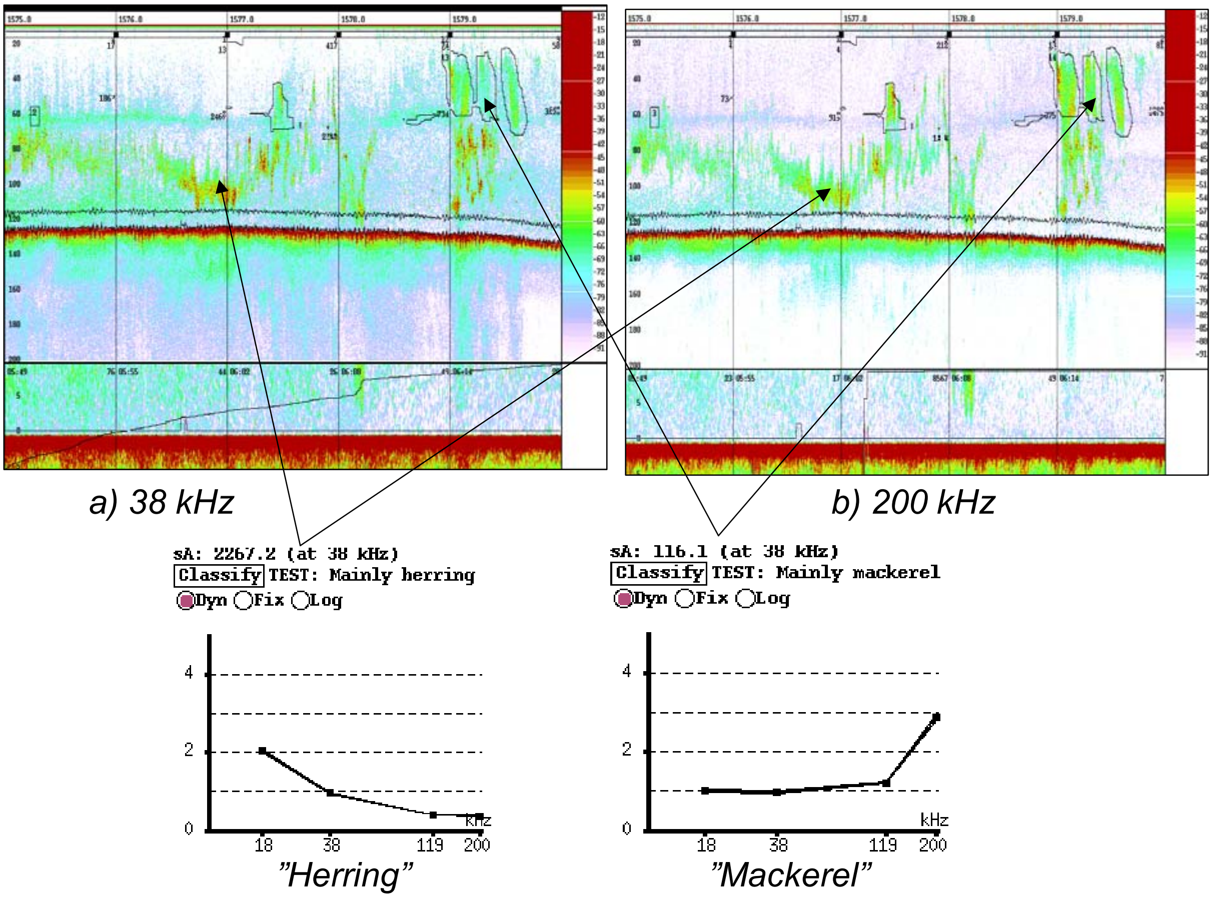



*Figure 7. Echogram of 20 October 2002 with several schools of mackerel and herring (mainly below the mackerel). The registrations of zooplankton at 60 m coincide with the termocline.*

## RESULTS OF 2004

As for the previous years 1999 - 2003, the highest density of Atlantic mackerel was found in a relatively narrow zone close to or down in the Norwegian trench. As in 2003, the highest density was partly 30 – 50 n.mi. west of the Norwegian trench, and partly down in the western side of the Norwegian trench. The distribution of mackerel in 2004 is shown in Figure 8 and 5.

Calculations of biomass is based on acoustic registrations of the Nautical Area Scattering Coefficient, $s_A$, at 38 kHz. The $s_A$ was averaged over rectangles of 10' (geographical minutes) latitude and 20' longitude, which in these waters cover approximately 10 x 10 n.mi.$^2$ (squared nautical miles), and was used to calculate number of fish using the formula:

$N = s_A A/(4\pi 10^{\sigma/10})$ where A is the area of the geographic rectangle,

$TS = 10\log_{10}(\sigma/4\pi) = 20\log_{10}L - 84.9$

L is the average length of fish in the region.

The mean length increased from West to East. Hence, for the calculations, the area was divided into 3 strata, West of 1°E, from 1°E to 2°E and East of 2°E, with length distributions and mean lengths taken from the samples in each area. Mean weights at length were taken from all samples, and a common age-length key was used to derive the age distribution from the length distributions. The biomass was calculated by multiplying average weight with number of fish. Only acoustic registration from the planned cruise-track was used to calculate abundance, since the use of schools searched for with e.g. SONAR will obviously give a too large estimated biomass.

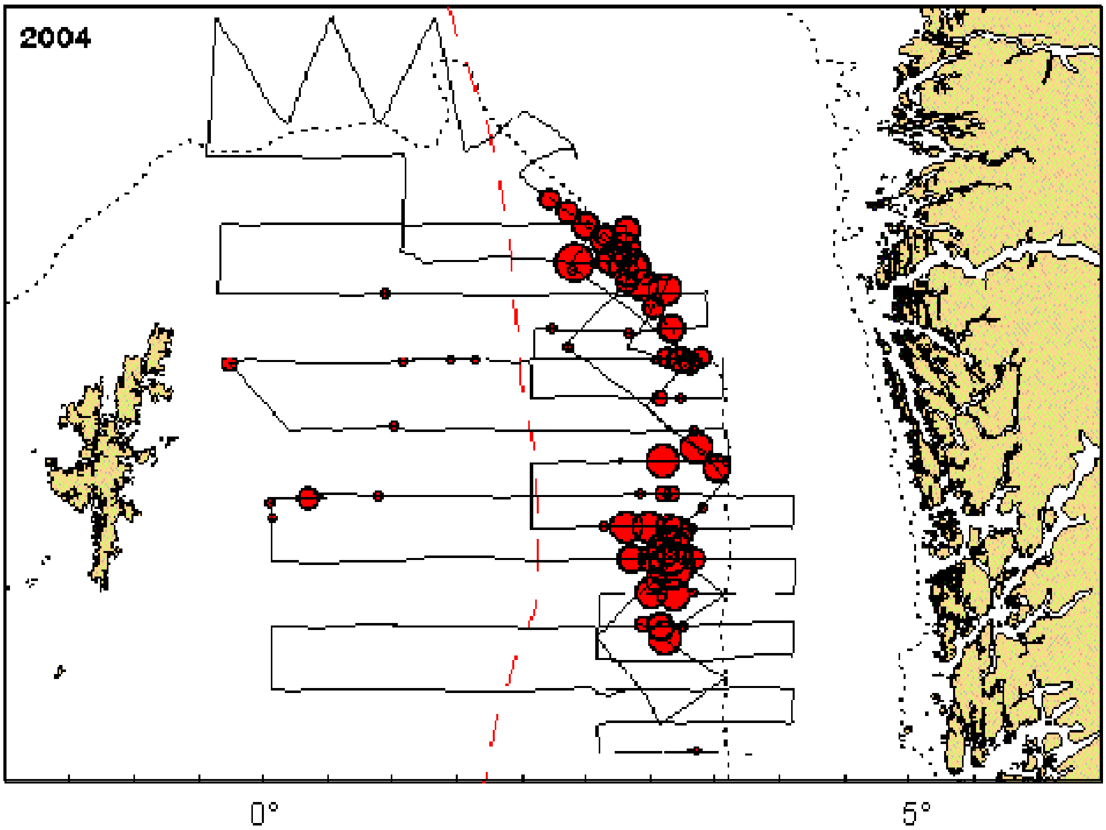



*Figure 8. Cruise-track with RV "G.O.Sars" (3) and acoustic abundance, $s_A$,. Area density of mackerel averaged over 5 n.mi., where the size of the discs increase with increasing $s_A$.*

Note that the used value of σ is known to be too low, but is the one used due to agreements in ICES/PGAAM. Substituting 84.9 in the formula above by 86 find a better estimate, i.e. closer to what is expected to be the real abundance of mackerel. However, although the calculated biomass is given in tons as an absolute value, it is to be considered as an "index", i.e. where an increase in calculated biomass from one year to another indicate an increase in biomass.

The age 2-3 fish dominate more than in previous years. Both these year classes are believed to be abundant (ICES 2005), but one may also suspect that the older fish has been under-sampled. This has been a problem in previous years, where the mean length in the commercial fishery in the same area and at the same time as the survey, was considerably higher. This year, the fishery had almost finished by the time the survey was carried out, and again, the mean length in the commercial catches was considerably higher, with a preliminary value of 38.2 cm.

In 2004, the complete area was covered during the same time as the British RV "Scotia", by applying essentially the same planned cruise-tracks. The cruise-lines of RV "G.O. Sars" is shown in e.g. Figure 3. RV "G.O. Sars" started in south-west, progressing north, with a distance 7.5 n.mi. between the east-west cruise-lines in the westernmost area where mackerel was expected to be found in the largest density, and 15 n.mi. distance between the cruise-lines further west. In the northernmost area, the parallel east-west cruise-lines were substituted by north-south sig-sag cruise-lines to account for the change in geographical shape (i.e. orientation) of the Norwegian trench entering the North Atlantic current. RV "Scotia" started in north-east and progressed south with east-west cruise-lines. At the end of the cruise, there was a common coverage with sig-sag cruise-lines over the Norwegian trench, and finally ending with an inter-calibration to be able to compare the performance of the two vessels.

Calculation of biomass is based on acoustic abundance, $s_A$, averaged over rectangles of $10^o$ latitude and $20^o$ longitude, which in the North Sea is approximately 10*10 n.mi.$^2$ A mean length distribution was allocated to each rectangle. Whenever possible, trawl samples from the rectangle was used.

Figures 10 and 11 and 12 shows length- and age- distributions of mackerel according to the samples weighted by the acoustic abundance. Figure 11 shows the mean weight at age.

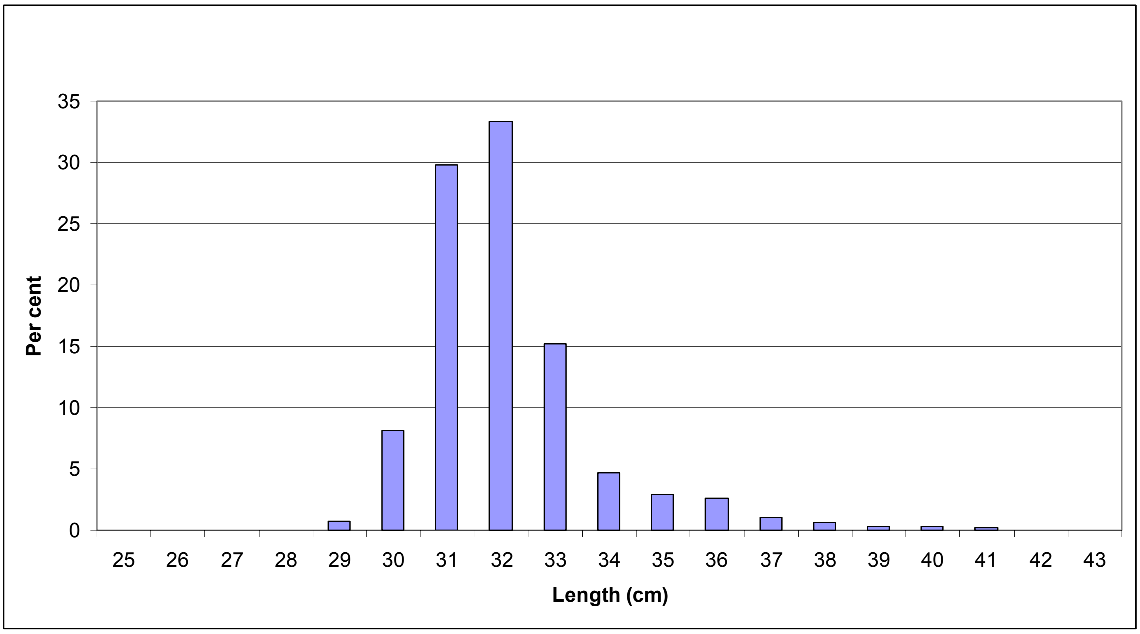



*Figure 9. Length distribution of acoustic estimate of mackerel.*

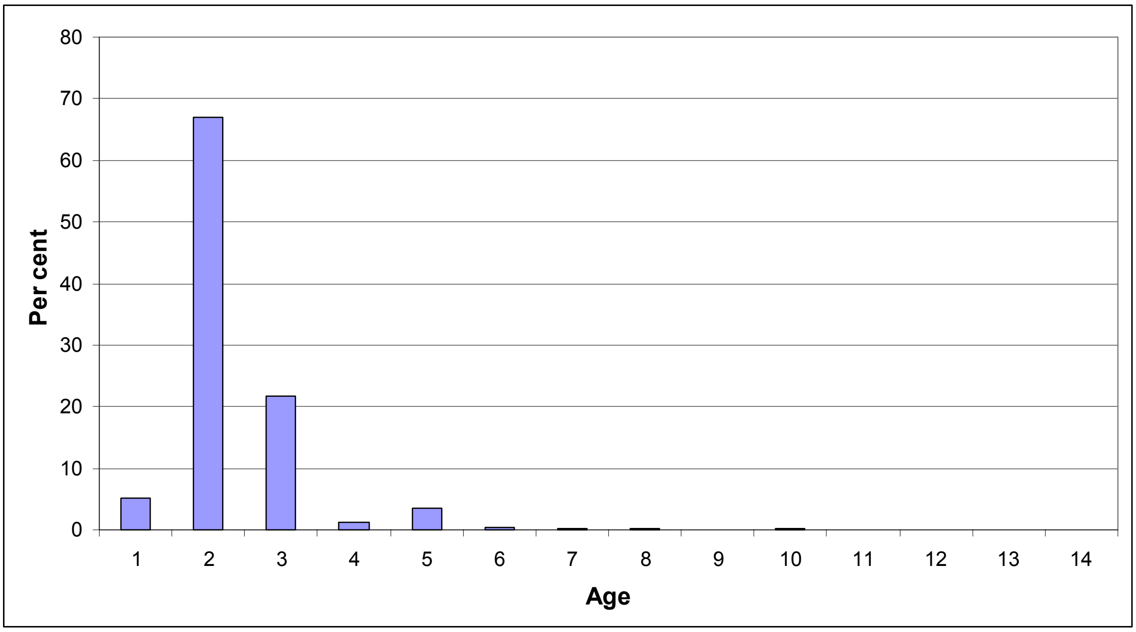



*Figure 10. Age distribution of acoustic estimate of mackerel*

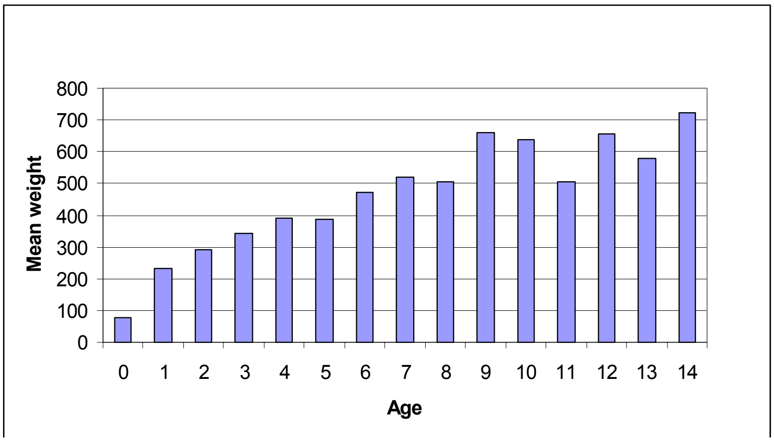



*Figure 11. Mean weight at age in samples for mackerel*

**Results of data collected with acoustic modeling of mackerel in mind**

Density and sound seed of mackerel flesh were measured during the surveys of 2003 and 2004. Some mackerel were frozen for measurement of fat-content. Sound speed was measured with acoustic probes developed by Trygve Gytre, IMR. Some fish were stored for future measurements of fat content.

*Results 2003*

Sound speed at 14°C: c=1515±15 [m $s^{-1}$] (back: c=1511±15 [m $s^{-1}$], dorsal side: c=1519±15 [m $s^{-1}$]). Density of meet: 1005 [kg $m^3$] (g=0.979). Of 6 pieces of mackerel meet, all float in salt water. 4 of those pieces (back) sink in fresh water, while 2 (side/dorsal) floats also in fresh water.

*Results in 2004, and quality measurements in 2003 and 2004*

Due to the relatively large uncertainty of the measurements of density and sound speed of mackerel flesh, new measurements were done in 2004. The sound speed measurements are better referred to calibration data, i.e. measurements of sound speed in fresh water and salt water at measured temperatures. The density measurements were also done for larger volumes of flesh, and are therefore expected to be better than the 2003 measurements. Average density of mackerel flesh from the back: 1054±5 [kg/$m^3$]. For a density of salt-water of 1026 [kg/$m^3$], this give: g=1.027±0.005. Note that all pieces of flesh sink in fresh water, and that 29 of 30 sink in salt water. The only piece that does not sink in salt water and floats very deep in fresh water, i.e. has a density close to sea water. The average sound speed of mackerel back flesh was 1564±15m$s^{-1}$, but with differences of sound-speed depending on weather the measurements were done close to head, in the middle back, and close to the tail. The sound speed was also dependent on the temperature and the size of the fish (fat dependency?).

**Herring** was found in large portions of the covered area. The biomass of herring was not calculated from the 2004 acoustic data. The complete dataset is not considered to be sufficient to calculate herring biomass. The dataset is, however, considered to be useful to support abundance estimation of herring.

**Pearlside** is together with Atlantic mackerel, the species that appears to be the most easy to be identified. This may be due to resonance in the swim bladder at acoustic frequencies close to 18 kHz.

**Blue Whiting** was found both acoustically and in the trawl hauls in and near the Norwegian trench. The survey design is, however, not considered to be sufficient to estimate a meaningful estimate of the Blue Whiting biomass.

## HYDROGRAPHIC DATA WITH MACKEREL (2003 and 2004)

There were collected enough CTD data in both 2003 and 2004 to compare mackerel with the temperature distributions. Figure 12 shows the geographical distribution of mackerel in 2003 and 2004. Figure 13 shows the depth of 9-10°C isoclines in 2003 and 2004, and the related the average depth of mackerel.

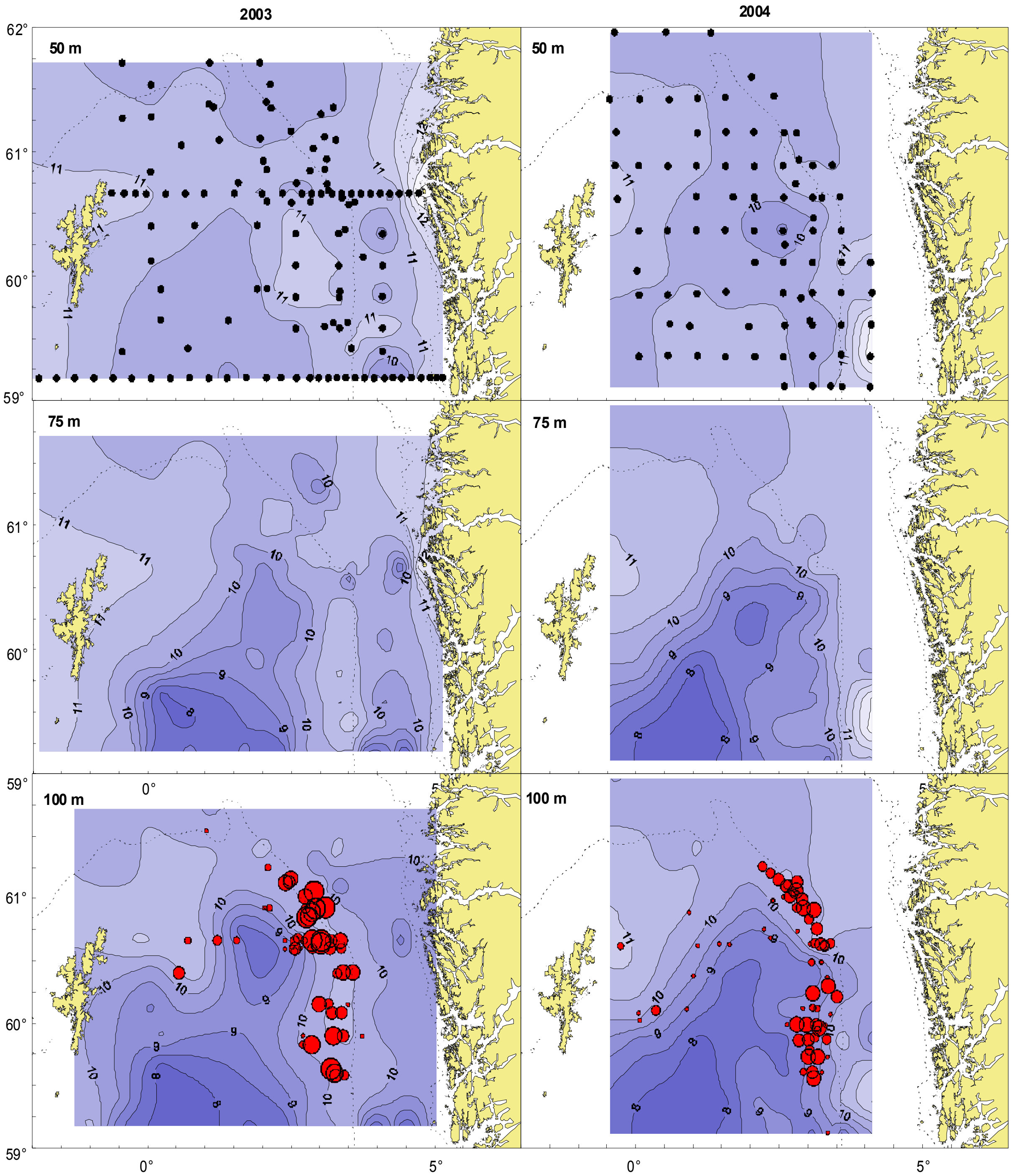



*Figure 12. Temperature contour plots at various depths (50, 75 and 100 m) in the surveyed areas in 2003 and 2004. The belonging CTD-positions are given in the upper panel and the related mackerel distribution.*

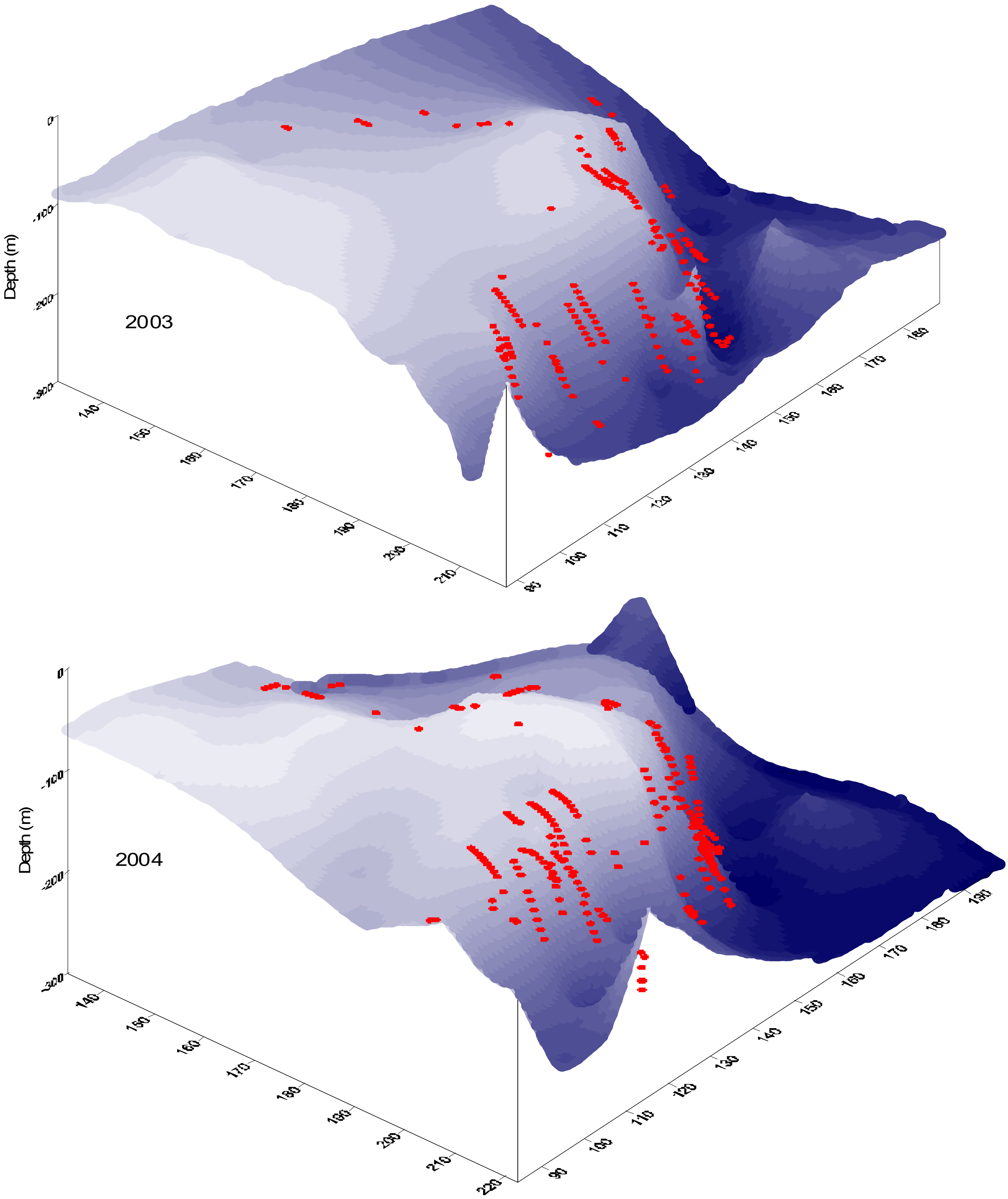



*Figure 13. The depth of 9-10℃ isoclines in 2003 and 2004, and the related the average depth of mackerel (red spots) based on 1 n.mi. acoustic data.*

# REFERENCES


Anon. 1968. Smaller mesozooplankton. Report of Working Party No. 2. Pp. 153-159 *in*: Tranter,D.J. (ed.) *Zooplankton sampling. (Monographs on oceanographic zooplankton methodology 2.*). UNESCO, Paris. 174 pp.

Korneliussen, R .J. and Ona, E (2002) An operational system for processing and visualizing multi-frequency acoustic data. ICES Journal of Marine Science, 59: 293-313.

Korneliussen, R .J. and Ona, E (2003) Synthetic echograms generated from the relative frequency response. ICES Journal of Marine Science, 60: 636-640.

Korneliussen, R. J., and Ona, E. 2004. Verified acoustic identification of Atlantic mackerel. ICES CM2004/R:20, 14 pp.

Korneliussen, R. J., Diner, N., Ona, E., and Fernandes, P. G. 2004. Recommendations for the collection of multi-frequency acoustic data. ICES CM2004/R:36, 15 pp.

Godø, O.R, Hjellvik, V., Iversen, S., Slotte, A., Tenningen, E. and Torkelsen, T. (2003) Migration behaviour of mackerel schools during summer feedeing in the Norwegian Sea. ICES Journal of Marine Science, (in press??)

Holst, J.C. and Iversen, S.A. (1992) Distribution of Norwegian spring-spawning herring and mackerel in the Norwegian Sea in late summer, 1991. ICES CM 1992/H:13

ICES (2002) Report of the Planning Group on Aerial and Acoustic surveys for Mackerel ICES CM 2002/G:03

ICES 2003 Report of the Herring Assessment Working Group for the Area South of $62^0$N ICES CM 2003/ACFM??

MacLennan, D. N., Fernandes, P. G., and Dalen, J. 2002. A consistent approach to definitions and symbols in fisheries acoustics. ICES Journal of Marine Science, 59: 365–369.

Wiebe, P.H., Burt, K.H., Boyd, S.H. and Morton, A.W. 1976. A multiple opening/closing net and environmental sensing system for sampling zooplankton. J. mar. Res. 34: 313-326.

Wiebe, P.H., Morton, A.W., Bradley, A.M., Backus, R.H., Craddock, J.E., Barber, V., Cowkes, T.J. and Flierl, G.R. 1985. New developments in the MOCNESS, an apparatus for sampling zooplankton and micronekton. Mar. Biol. 87: 313-323.