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ICES/GLOBEC Sea-going Workshop for Intercalibration of Plankton Samplers

A compilation of data, metadata and visual material

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1 Introduction

A Sea-going Workshop for intercomparison and evaluation of methods for sampling and determination of zooplankton in terms of biomass and species composition was held in a fjord environment (Storfjorden at Møre, western Norway) from 2 to 13 June 1993. The workshop was carried out with the German Research Vessel “A.v. Humboldt” (Chief Scientist Lutz Postel) and the Norwegian Research Vessel “Johan Hjort” (Chief Scientist Hein Rune Skjoldal) and involved a total number of 38 scientific personnel from eight countries. The Workshop had two objectives. The first was to assemble a number of instruments to collect zooplankton data and to conduct a series of field experiments that would enable an intercomparison of their results (Table 1). The intercomparisons included gear such as MOCNESS, BIONESS, MULTINET, LHPR, OPC, CPR, WP-2 net (Figure 1), and acoustical recordings at four frequencies (18, 38, 120, 200 kHz). The sampling experiments and some results were presented in a preliminary report (Skjoldal *et al.*, 1993). Some of the data have appeared in more recent publications (Hays, 1994; Wieland *et al.*, 1997; Halliday *et al.*, 2001).

The second objective was to conduct a seminar workshop onboard Research Vessel “Johan Hjort” during the period of the two ship field work, which was attended by 20 scientists. The purpose of the seminar was to discuss issues related to net sampling and use of optical and acoustical techniques for determination of biomass and distribution of zooplankton.

Both of these activities were intended to provide background for material for the ICES Study Group of Zooplankton Production (now the ICES Working Group on Zooplankton Ecology), which was in the process of beginning the task of preparing the “ICES Zooplankton Methodology Manual” (Harris *et al.*, 2000).

The field data collected during the Storfjorden gear intercomparison study have been assembled and produced on this four CD-ROM set along with relevant text, images, and video loops. These represent one of the tangible results of the ICES Sea-going Workshop held on board the Research Vessels “Johan Hjort” and “A.v. Humboldt” in 1993.

The information on the CD-ROMs is organized as follows:

CD-ROM 1 contains most of the data which has been analysed from the Sea-going Workshop including:

- Hydrography and environmental data, including CTD data, plant pigments, relative and surface light and meteorological data;
- Zooplankton biomass, species counts and length/weight information;

- Phytoplankton species counts including relative abundance information;
- Data collected from the Optical Plankton Counter;
- Pictures of the work at sea;
- A 20-minute video, Zooplankton Sampling, in MPEG format.

Included are two reports in PDF format: (1) the original plan and (2) the preliminary results. These are also attached as Appendix 1 and Appendix 2, respectively, to this report.

CD-ROM 2 contains selected acoustics files from the first portion of the cruise. The acoustics files are available in four frequencies:

- 18 kHz
- 38 kHz (from both vessel-mounted and towed transducers)
- 120 kHz
- 200 kHz.

All the acoustics data from the Workshop would not fit on one CD-ROM. Thus, CD-ROM 2 contains the 18 kHz and 200 kHz data as well as Matlab files and instructions about how to display the data using those files. When the zipped acoustic files are expanded on some computer platforms (e.g., PCs), the original long names appear. These long file names can be cumbersome to use. For convenience, you may wish to shorten the names in the Matlab workspace before using the Matlab display programs.

CD-ROM 3 contains more acoustics files from the first portion of the cruise. CD-ROM 3 contains the 38 kHz, the towed body 38 kHz, and the 120 kHz data as well as Matlab files and instructions about how to display the data using those files.

CD-ROM 4 contains the same video available on CD-ROM1, but in a different higher resolution format. The MPEG2 video streams on this CD need dedicated hardware for playback. The company that converted the video, Fabelaktiv in Norway, recommends a RealMagic MPEG2 card. MS Mediaplayer will not play the MPEG2 files without MPEG2 hardware.

The index of each CD-ROM will **open automatically** when the CD-ROM is in the drive **if** the operating system is a PC running Windows. If a different operating system is being used, see ‘How to Use this CD-ROM’ below.

2 A word about the data

Most of the non-figure data that appears on this CD-ROM set is in two forms: the format in which the final version

was received (usually Excel), and ascii text format. The ascii text versions were created primarily to facilitate viewing the data with a web browser. In the interests of readability, some values may have been rounded to fewer decimals than the original data which was submitted. Anyone wishing to use the data is strongly encouraged to work with the data in the Excel file.

The data contained herein are the intellectual property of the collecting investigator(s). Any person making substantial use of a data set should communicate with the investigators who acquired the data prior to publication and anticipate that the data collectors will be co-authors of published results. For information contact: ices.cd@globec.who.edu

3 How to use the use this CD-Rom

This CD-ROM set (Compact Disc-Read Only Memory) has been produced in accordance with the ISO 9660 CD-ROM Standard and is therefore capable of being read on any computing platform that has an appropriate CD-ROM driver software installed.

This CD-ROM was designed to be used with a WWW html compatible browser. An introductory or index page will open automatically when each CD-ROM is in the drive if the operating system is a PC running Windows. For non-PC systems (i.e. Macintosh- or Unix-based systems), from your browser select OPEN LOCAL FILE, and open the file readme1.htm from CD-ROM 1 or index.htm from one of the other CD-ROMs. Be aware that some pages of the CD may have a different appearance depending on which browser you use, although the editors sought to minimize this.

While most links are within the CD-ROM, there may be some links that point to other Web sites. Your computer must be connected to the Internet in order to view these external documents.

The VIDEO images are designed to be viewed via a Web Browser on either Macintosh or Windows platforms (2k, 9x, NT). You may have trouble playing the video from a Unix or Solaris system.

It is possible to view these movies by accessing the CD-ROM directly from your video display software. This may be preferable, especially for those who have insufficient disk space to temporarily store the video images for use by the browser. However, you may not be able to play back from the Macintosh environment directly.

4 Acknowledgments

The data on this CD-ROM set represent the work of a large number of individuals in a number of Institutions too numerous to name. We thank all these individuals for their contributions and their patience as we worked together to produce the material for this CD-ROM set. We also thank the officers and crew of the Research Vessel A.v. Humboldt and the Research Vessel Johan Hjort for their excellent support during the Sea-going Workshop. The images of the Workshop scenes supplied by Tor Knutsen were taken by Karsten Hansen.

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Table 1. A list of sampling devices used during the Sea-Going Workshop.

Net systems:

1-m² Multiple Opening/Closing Net and Environmental Sensing system (MOCNESS)
 10-m² MOCNESS
 1-m² Bedford Institute of Oceanography Net and Environmental Sensing System (BIONESS)
 MIK net
 MultiNet
 Bongo nets
 WP2 - UNESCO Standard net (or Working Party 2)
 Longhurst-Hardy Plankton Recorder (LHPR) with Optical Plankton Counter (OPC)
 Continuous Plankton Recorder (CPR)
 High Speed Plankton Sampler “Nackthai” (known as Gulf V, a modified version of the Gulf III) with an OPC
 YF trawl
 Isaacs-Kidd Midwater Trawl (IKMT)
 Ring-Trawl Net (similar to the 1-m CalCOFI standard plankton sampler)

Pumps:

Hufsa pump

Acoustics:

EK500, hull mounted on Research Vessel J. Hjort, with transducers operating at 18, 38, 120, and 200 kHz. The first three were split beam transducers.
 EK500, towed body deployed from center-well on Research Vessel J. Hjort, with a 38 kHz split beam transducer.
 ADCP operating at 150 kHz.
 Simrad sector scanning sonar operating at 2 MHz (Mesotech)
 Portable EK500 operated with a 120 kHz split beam transducer

Other sampling systems:

In *situ* camera system
 OPC
 CTD/Rosette
 Light profiling gear (spectral radiometer)
 Continuous surface irradiance meter

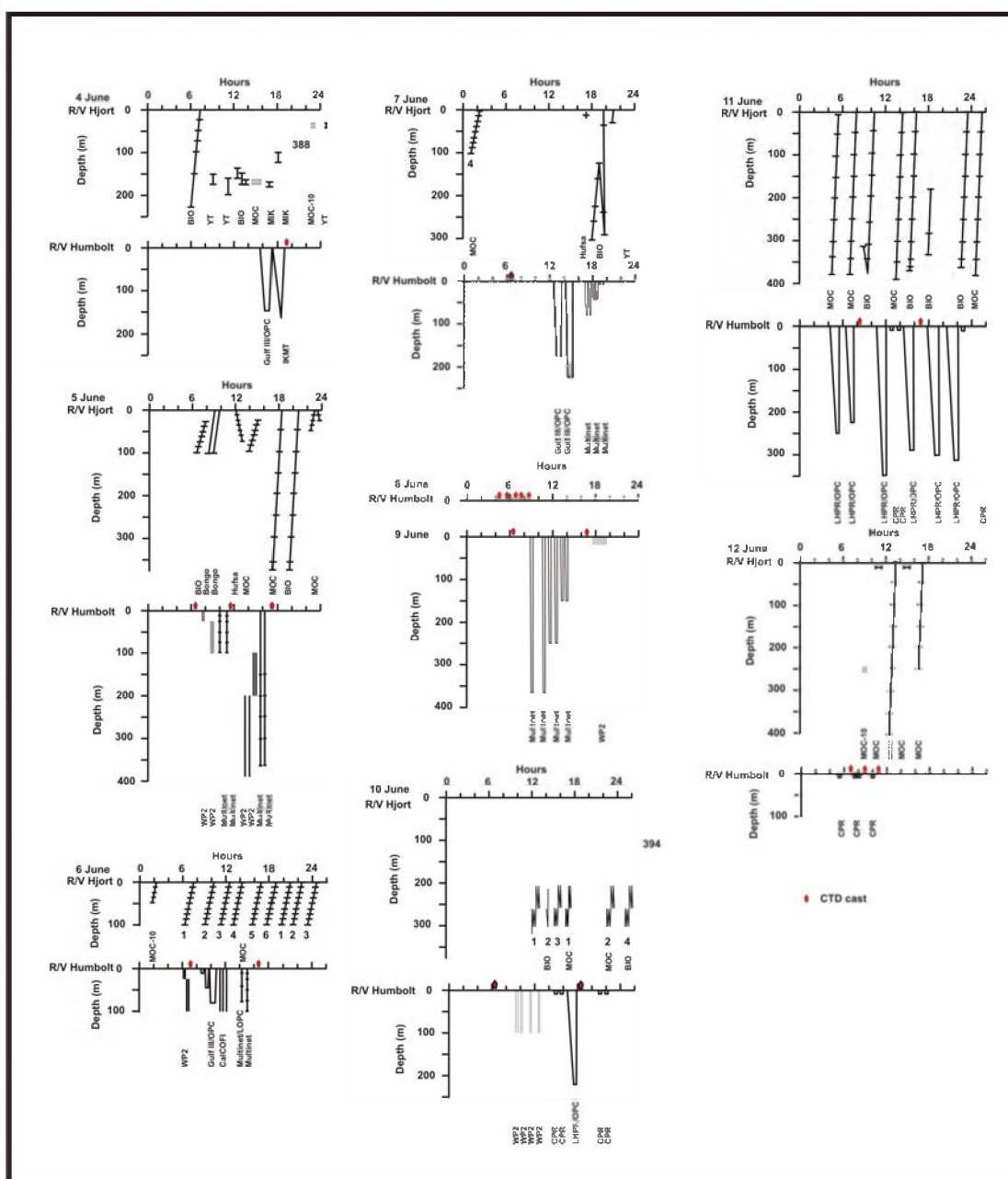


Figure 1. Timetable of sampling events that took place during the 1993 Sea-going Workshop.

Appendix 1: ICES Sea-going Workshop on Zooplankton Sampling and Biomass Determination Norway, 2–13 June 1993

Conveners: H. R. Skjoldal, and L. Postel

Plan And General Description Of Study Area

1 General description of study area

The Workshop will be carried out in the Storfjord at Møre, western Norway (62°30' N, 05° E) (Figure 1). The Storfjord is part of a larger fjord system with several branches (Figure 2). It is an intermediate sized fjord with depths from 350 to 650 m. The mean width of the fjord is approximately 2 km while the length of the fjord is 50 nm (93 km) long. A narrow channel 200–250 m deep extends as a prolongation of the fjord onto the about 150 m deep continental shelf, which acts as a barrier or sill with respect to intrusion of Atlantic water to the fjord basin. Renewal of the deep fjord water below sill level is most prominent during spring.

The summer situation is characterized by river runoff and outflow of brackish water in the surface. Restricted exchange between coastal shelf water and intermediate layers of the fjord can also occur. Figure 3 shows the temperature, salinity and nitrate conditions along a transect from Storfjorden to the continental slope region during June 1991. Special features to be noted are the lower nitrate values (<1M) in the upper 25m, both in the fjord and in the open ocean areas. The salinity and temperature show strong stratification in the upper 75m of the fjord, and the Norwegian coastal current can be easily seen as a lower salinity wedge extending seawards across the continental shelf.

During the last decade the shelf area outside the fjord has been of major interest in several Norwegian research programs aimed at studying larval fish ecology and zooplankton population dynamics. The hydrography, current patterns and general biology of the area are well known. The narrow continental shelf, approximately 40 nm wide, makes it possible to quickly reach the shelf break and to undertake studies along the continental margin and deeper parts of the Norwegian Sea.

2 Biology

The Storfjord offers good working conditions to plankton ecologists. The plankton community of the fjord is dominated by a restricted number of zooplankton species from small copepods to large macroplanktonic

euphausiids and mesopelagic shrimps. Of the mesozooplankton *Calanus finmarchicus* is the dominating species.

The fish assembly consists of the mesopelagic lantern fish *Benthosema glaciale*, Müller's pearlside (*Maurolicus muelleri*), herring (*Clupea harengus*), sprat (*Sprattus sprattus*), the Greater argentine (*Argentina silus*) and blue whiting (*Micromesistius poutassou*). Also larger fish like Arcto-Norwegian cod (*Gadus morhua*) and saithe (*Pollachius virens*) are regular inhabitants of the fjord ecosystem.

The different components of the pelagic ecosystem usually inhabit different strata in the water column. During daytime the large mesopelagic shrimps *Sergestes* and *Pesiphea* sp., the krill *Meganyctiphanes norvegica*, *Benthosema glaciale*, and the older age groups of *Maurolicus muelleri* occupy the deep layers of the fjord below 200 m depth. Juvenile *M. muelleri* is usually confined to a shallow scattering layer between 100–150 m depth. Other inhabitants of the deep pelagic community are the copepods *Calanus hyperboreus* and *Euchaeta norvegica* and chaetognaths (*Eukrohnia* sp. and *Sagitta* sp.), which at certain times of the year constitute a considerable part of the deep pelagic biomass.

During vertical migration there is an increased interaction among the different components of the pelagic ecosystem. The major migrants are the krill *M. norvegica*, *Pasiphea* sp. and the O-group *Maurolicus muelleri* which rise to the surface layer during night. The other components of the deep pelagic community might extend their vertical distribution at night but the light conditions during June still favour these organisms to stay deep. Figure 4 shows the vertical and horizontal distribution of the nighttime scattering layers of macroplankton, micronekton and fish in a restricted part of Storfjorden in June 1991.

In the upper part of the water column (0–50 m) smaller copepods and especially *Calanus finmarchicus* dominate. Herring larvae might also be an important component at this time of the year, being introduced from the shallow shelf spawning areas outside the fjord.

Figure 5 shows typical scattering layers of the deep ocean and shelf areas outside Storfjorden and indicate that the fjord community constitute an integral part of the open ocean ecosystem. The pelagic communities of the fjord are as such influenced by advective processes and intrusion of new populations from the open ocean. Due to

the short duration of the workshop and the time of the year it is however unlikely that major changes in the zooplankton populations take place.

3 Scientific aim

The main scientific goals of the Workshop as outlined in the report from the first meeting of the Study Group on Zooplankton Production (Bergen, Norway, 23–26 March 1992) is to:

- a) provide a basis for evaluating the performance of a variety of methods or gears; and
- b) explore combinations of instruments and experimental approaches that can most effectively be used to measure zooplankton production.

The principal objective was more specifically stated at the meeting in Las Palmas 8–12 March 1993:

Intercompare, characterize and evaluate the performance of gear and techniques for quantitative description of zooplankton distribution, biomass and production in a fjord habitat.

Specific objectives were stated as follows:

- 1) Quantitative descriptions of structure and abundance of the pelagic community through use of a range of sampling gears and acoustical and optical instrumentation.
- 2) Direct and indirect quantification of avoidance.
- 3) Evaluate and characterize sampling performance with regard to spatial resolution and selectivity of single and combined application of gears and techniques.
- 4) Compare and evaluate methods for estimating zooplankton production and metabolism.

The primary variables to be measured are biomass, species composition, size distribution and vertical and horizontal distributions of the organisms studied. Data obtained with sampling gears will be used in combination with simultaneously sampled acoustical and optical data.

When sampling with traditional sampling gear like trawls and different types of nets, sampling efficiency and avoidance of gear by zooplankton are central problems. One of the key issues of the Workshop will be to apply and evaluate methods for determining the magnitude of zooplankton avoidance of sampling gear. One technique is to use a short range scanning sonar to quantitatively study the distribution of zooplankton in front of plankton trawls and nets.

In situ target strength measurements of mesopelagic fish, shrimps and krill will be attempted. Such measurements are few and new results could improve the precision in

acoustic estimates of the biomass of these species, which constitute important links in pelagic food webs.

4 Sampling design and statistical procedures

A particular part of the fjord e.g., 30 nm will be chosen as the main study area. Within this area a shorter main sampling track, along fjord, e.g., 10 nm will be repeatedly sampled with different gears. However specific details concerning the sampling programme must be worked out up to the Workshop. It might also be necessary to adjust the sampling programme along the course of the Workshop if local conditions should impose specific constraints.

Statistical aspects will be given consideration, e.g., replicate and between sample variance. Geostatistical techniques will be used when analysing the data.

5 Calibration and survey design

To assure good and comparable quality of data sampled a calibration programme of all acoustical equipment should be carried out. Intercalibration of the hull mounted transducers on board the Research Vessel Johan Hjort and Research Vessel A.v. Humboldt should be performed.

To assess variability in biomass and distribution and to get information on possible advection of zooplankton in the study area, an acoustical survey with sampling will be carried out at intervals during the period of investigation (e.g., start, middle, end). The survey will be designed to cover the area of investigation within the fjord either in a zigzag pattern or in a pattern, which assures a proper coverage both of the shallow and deeper parts of the fjord. Information on the night and day differences in biomass and distribution within the area will be obtained. Due to the short night and long day, the major intercomparison exercises will be carried out during daytime.

6 General description of environmental conditions

There is a need for a description of the environmental conditions where the comparison of gears will be performed. To monitor the current pattern and trace advective transport of water, current meters should be deployed at the mouth of the fjord. Small transportable current meters could be used to monitor local currents in the area investigated. Also the shipborne ADCP will give information on the local current patterns and will be run concurrently with the acoustical survey.

Additional environmental parameters will also be measured, such as salinity and temperature to characterize

water masses, and also oxygen and nutrients. The food conditions of herbivores in terms of phytoplankton biomass (chlorophyll, chlorophyll fluorescence, phytoplankton abundance), species composition (in a limited number of samples), and primary production in the euphotic layer will be determined. In relation to primary productivity, zooplankton vertical distribution and zooplankton net avoidance, the vertical light regime must be known. Therefore Secchi depth readings and radiation measurements (PAR) should be carried out while CTD-, oxygen- and fluorescence profiles are measured on Research Vessel "Johan Hjort" and on Research Vessel "A.v. Humboldt".

7 Vertical sampling systems

It is suggested that one set of comparison takes place in the upper 0–100 m of the water column. The gears to be compared are Multinet, WP2 nets, water bottles (30L Niskin and others), and pump systems. Replicate hauls (e.g., 10) will be performed for each net. Replicate profiles (e.g., 5) with pump and water bottle will be taken; each set constituting 8 sampling depths.

An equivalent series of net hauls should be performed in the deeper part of the water column (100–400 m), covering a different community and size range of organisms.

Both the deep and shallow net sampling series will be compared to samples from towed gears like the MOCNESS, LHPR and optical systems covering the same depth interval.

8 Towed samplers

The following sampling procedures are suggested:

a) Discrete scattering layers are sampled simultaneously along a parallel track using different gears. In this way one obtain estimates of abundance and biomass either in one specific depth interval or several depth intervals if the gear is a multiple plankton sampler.

Simultaneous sampling of acoustical data using echosounders with 3–4 different frequencies will give additional acoustical estimates of zooplankton and micronekton biomass which can be compared to traditional sampling gear estimates of zooplankton abundance and biomass.

b) The Longhurst-Hardy Plankton Recorder (LHPR) could be used to study the spatial distribution and small scale patchiness (10–100 m level) of zooplankton both within and outside scattering layers. Biomass, species composition and size distribution could be compared to samples obtained with MOCNESS operating in the same depth interval and equipped with a similar meshed net.

c) Measure the avoidance of zooplankton on sampling gear by a 2Mhz Mesotech 971 short range (<5m) scanning sonar. The sonar will be mounted on different types of plankton trawls to scan either horizontally or vertically. Thus it should be possible to study the distribution of organisms both in front and on the side of the mouth opening.

8.1 Optical system

The Ichthyoplankton recorder (IPR), Optical plankton counter (OPC) and the Video profiler (VP) will hopefully be available during the Workshop.

The IPR is designed mainly to sample fish larvae. It concentrates the organisms by a Gulf III like net prior to "sampling" by a video camera on the cod-end side of the system. The OPC is a different system, towed or vertically deployed and designed to count and size zooplankton. Thus the OPC record the organisms as they are dispersed either vertically or horizontally *in situ*. The VP is a French system which is operated vertically as a drop sonde and data are logged continuously on a video recording system. An intercomparison of these gears are of prime importance in understanding their strengths and limitations. However it is also necessary to compare them to more traditional gear like WP2 nets, Multinet, MOCNESS and LHPR systems.

Other techniques include the use of an underwater photo camera and strobe mounted on a specifically designed frame, and operated as a drop sonde. This technique might be a valuable supplement to estimate the relative and/or absolute vertical abundance of meso-, macrozooplankton and small mesopelagic fish. It might also be a valuable tool to help identify organisms.

8.2 Acoustics

Traditional hull mounted echosounders using several different frequencies (18, 38, 120 and 200kHz) will be used from Research Vessel Johan Hjort. Acoustic data from all frequencies will be obtained and stored during each sampling case and then analysed and compared to biomass estimates obtained by traditional sampling gear. Post processing of data will be possible both on board the Research Vessel Johan Hjort or later on shore.

A towed split beam transducer working at 38 kHz with 800 m conducting cable operated from Research Vessel Johan Hjort makes it possible to study the deep scattering layers with a better resolution than the hull mounted transducers. It might be a valuable tool when trying to measure *in situ* target strength of organisms in deep scattering layers consisting of one or a restricted number of species. The use of towed transducers is especially important when rough weather conditions limit the use of hull mounted transducers and might thus improve the acoustic estimates of plankton and fish.

A 2Mhz Mesotech 971 short range scanning sonar will be used to study the avoidance of zooplankton.

It is emphasized that acoustical techniques and instrumentation must be applied and operated together with traditional sampling gear. Thus these techniques will be an integral part of the comparison case studies using traditional sampling gear.

9 Target strength determination

Experiments to measure target strength of macrozooplankton and mesopelagic fish like *Benthosema glaciale* and *Maurolicus muelleri* will be performed both *in situ* and in a tank on board Research Vessel "Johan Hjort". These experiments will be supplemented by measurements of biochemical composition, (total lipids and protein), sound speed, and density of key species. Such data are important when modelling target strength as is usually done when using multiple frequency techniques.

10 Rate measurements

Especially on board Research Vessel "A.v. Humboldt" rate measurements will be performed to get some information on the zooplankton metabolic conditions. This will be done in size fractions (50–100 μm , 100–200 μm , 200–500 μm , 500–1000 μm , and 1000–2000 μm). To convert specific rates to *in situ* total rates (per m^3), biomass of zooplankton of at least one net type (e.g., WP-2) should be available for the same size classes. Respiration and excretion (ammonia and phosphate release) will be measured. This can be performed in one experiment and gives information on the general metabolic condition and of the food quality used by the plankton (O/N -ratio). Furthermore the respired part of primary production is estimated by this approach. The measurements will be carried out by the classical balance method using near surface plankton. A vertical resolution of these metabolic rates can be obtained by using enzymatic methods (ETS, GDH). In the same assay ATC (aspartate transcarbamylase) could be measured. It gives some information on potential growth. To compare it relatively with another method, egg production measurements of *Calanus finmarchicus* should be performed.

11 Research vessels

The fieldwork will be conducted from the Norwegian research vessel Research Vessel Johan Hjort and the German vessel Research Vessel A.v. Humboldt. A brief outline of the research vessels instrumentation and facilities are given below.

11.1 Research Vessel Johan Hjort

The Norwegian research vessel Research Vessel Johan Hjort was built in 1990, is of the size of 1950 Gross Tons, is 64.4 m long and travels with 14 kn in maximum. Of special interest is the standard acoustic instrumentation:

- SIMRAD EK500 Scientific Echosounder.
- Transducers: 18, 38, 120 and 200 kHz.
- Bergen Echo Integrator. A Unix workstation and a set of software for post processing echosounder data.
- Acoustic Doppler Current Profiler (ADCP).
- Towed 38kHz split beam transducer with 800m conducting cable.

During the workshop the following additional instrumentation will be available:

- Mesotech 2Mhz Scanning sonar;
- Transportable 120 kHz splitbeam transducer with 200 m conducting cable.

The ship is equipped with several winches. One winch is equipped with an 8 mm, 3000 m coaxial cable dedicated to deploy the CTD. Another winch is dedicated to vertical net sampling, while at least two other winches can be used to deploy towed instruments and gear. These winches are however not equipped with conducting cables. A large winch operating across the stern and equipped with a 12 mm, 3000 m long coaxial cable, is used to deploy the MOCNESS and other gear where a single conducting coax is sufficient to transmit signals between the instrument and the deck display or control unit.

One portable winch (with 9 mm, 1000 m long coax) will be mounted on board Research Vessel Johan Hjort to run the Multinet system or other vertically operated gears which need a conducting cable.

Scanmar depth sensors can be attached to trawls and gear both to trace actual depth, distance to bottom and the opening area of pelagic trawls.

The ship has five laboratories in front of the main deck. From one of the laboratories the CTD, water bottles and vertical nets are deployed. One laboratory is specifically designed to handle large trawl catches and another for treating zooplankton samples. The remaining laboratories are large and generally built to store and mount different types of equipment, and to perform chemical and other analyses.

An instrumentation laboratory contains the echosounder display units, the BEI acoustical post processing workstation, the MOCNESS and CTD display and control units, operated from network attached PC's. Several IBM compatible PC's are also available for personal use, statistical analysis and presentations.

The ship also offers good facilities for small working groups and plenary discussions.

11.2 Research Vessel A.v. Humboldt

Research Vessel. "A.v. Humboldt" belongs to the county of Mecklenburg/Vorpommern (Germany), is of the size of 1270 Gross Tons, is 64 m long and travels with 12 kn in maximum. It's equipped with an ATLAS echosounder, satellite navigation, and communication. There are two winches with conductivity cable, one for CTD, oxygen, and fluorescence probe, the other for operations with

multiple nets, video systems, LHPR, etc. Furtheron there are two winches with wires of 3 mm and 5 mm respectively. Both can work together with the CTD winch during calm weather conditions. There is also an A-frame at the stem, but net catches could also be performed at one of the ships sides. Meteorology will be measured automatically, including solar radiation.

There are four, so called dry laboratories, one wet lab, one CTD lab, a workshop and a photo laboratory. For hosting double cabins are available.

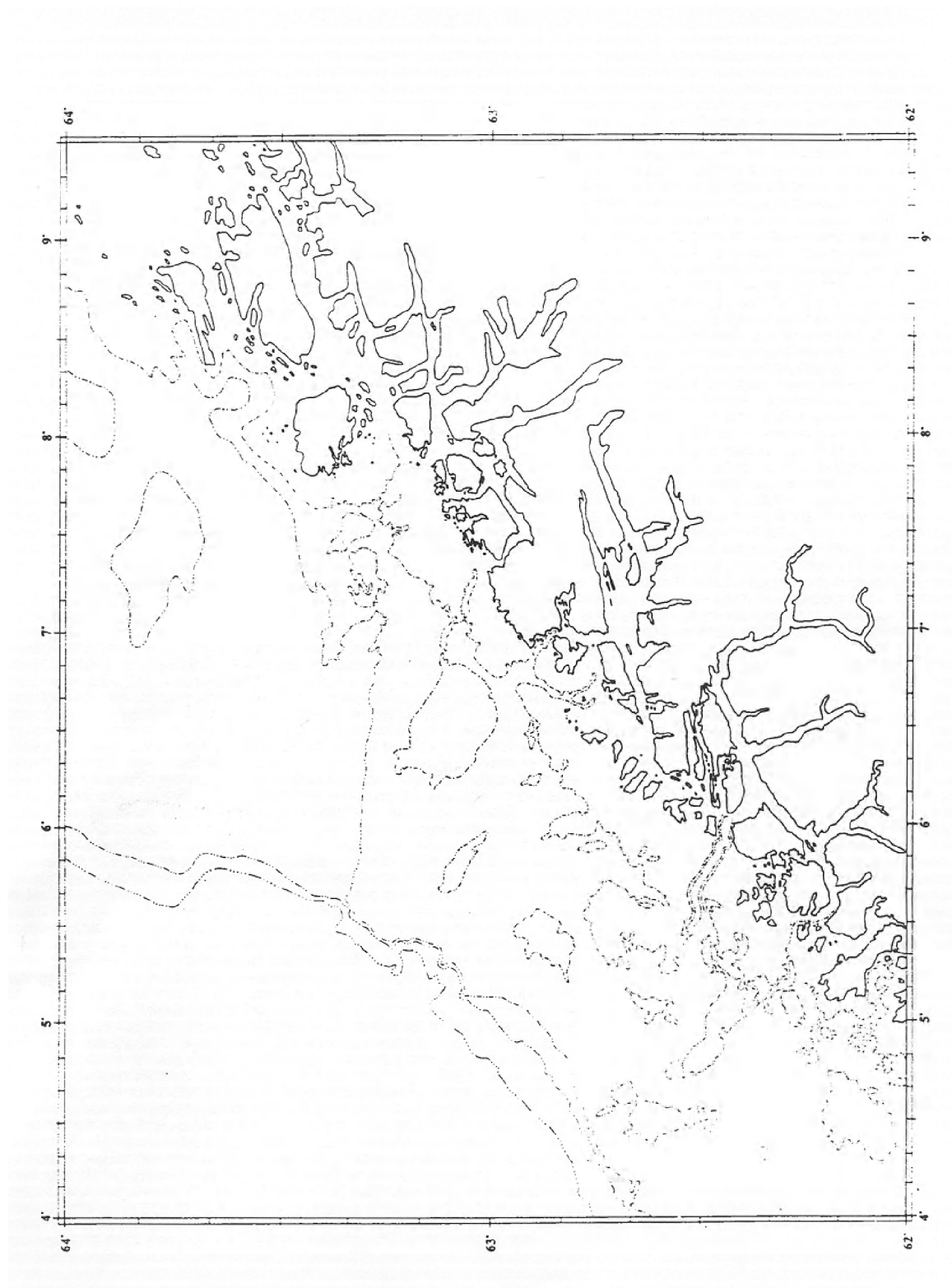


Figure A1.1. The More shelf, slope and fjord area with bottom contours. Dotted lines represent 100 m depth intervals.

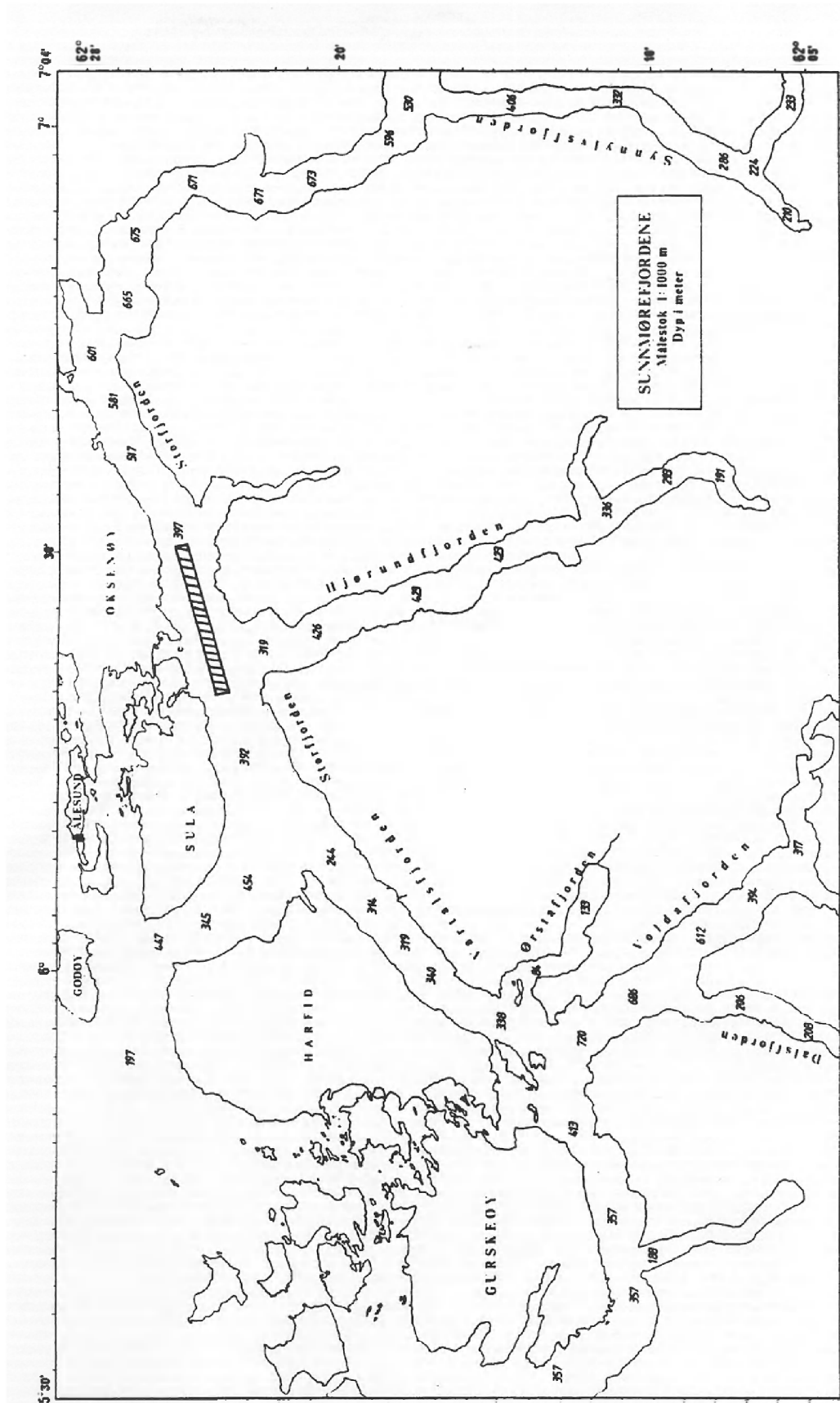


Figure A1.2. Storfjorden and adjacent fjords at More. Numbers represent depth in meters.

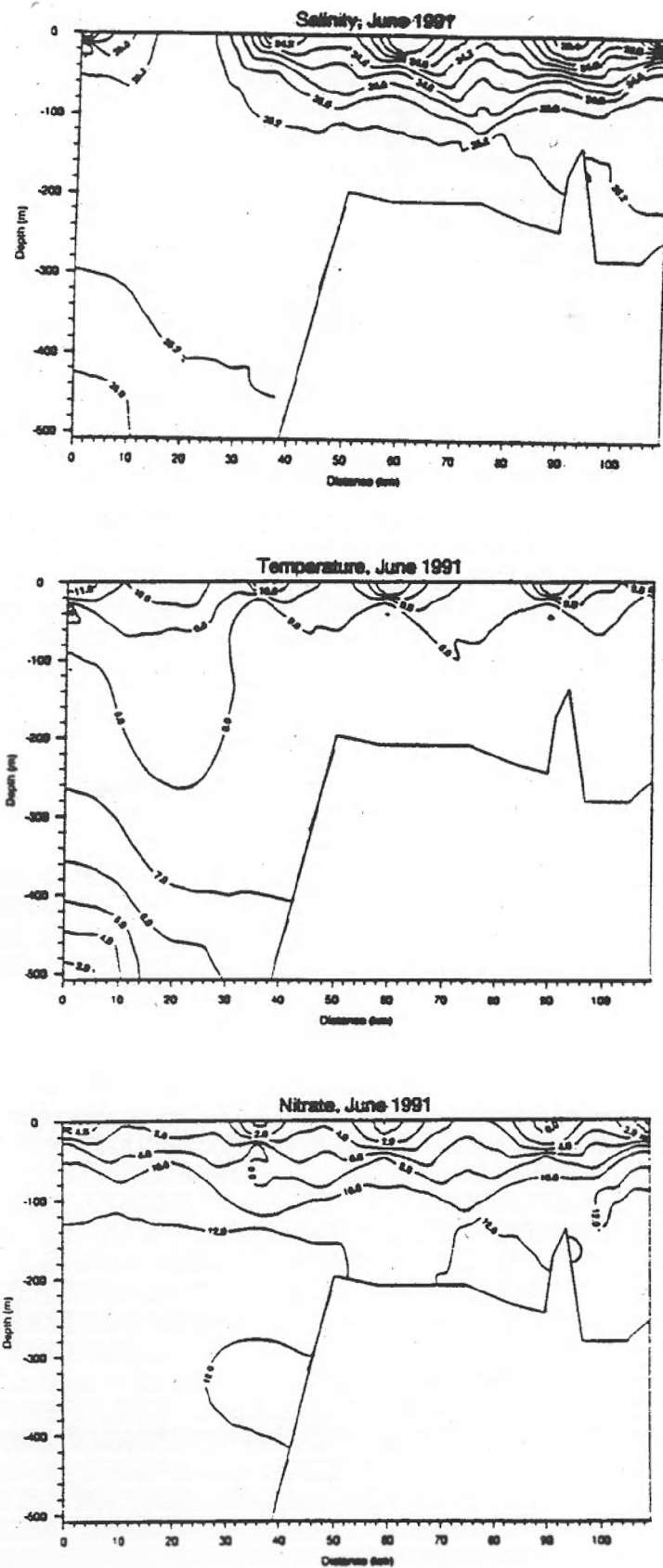


Figure A1.3. Salinity, temperature ($^{\circ}\text{C}$), and nitrate (μm) along a transect from Storfjorden to the eastern part of the Norwegian Sea during June 1991.

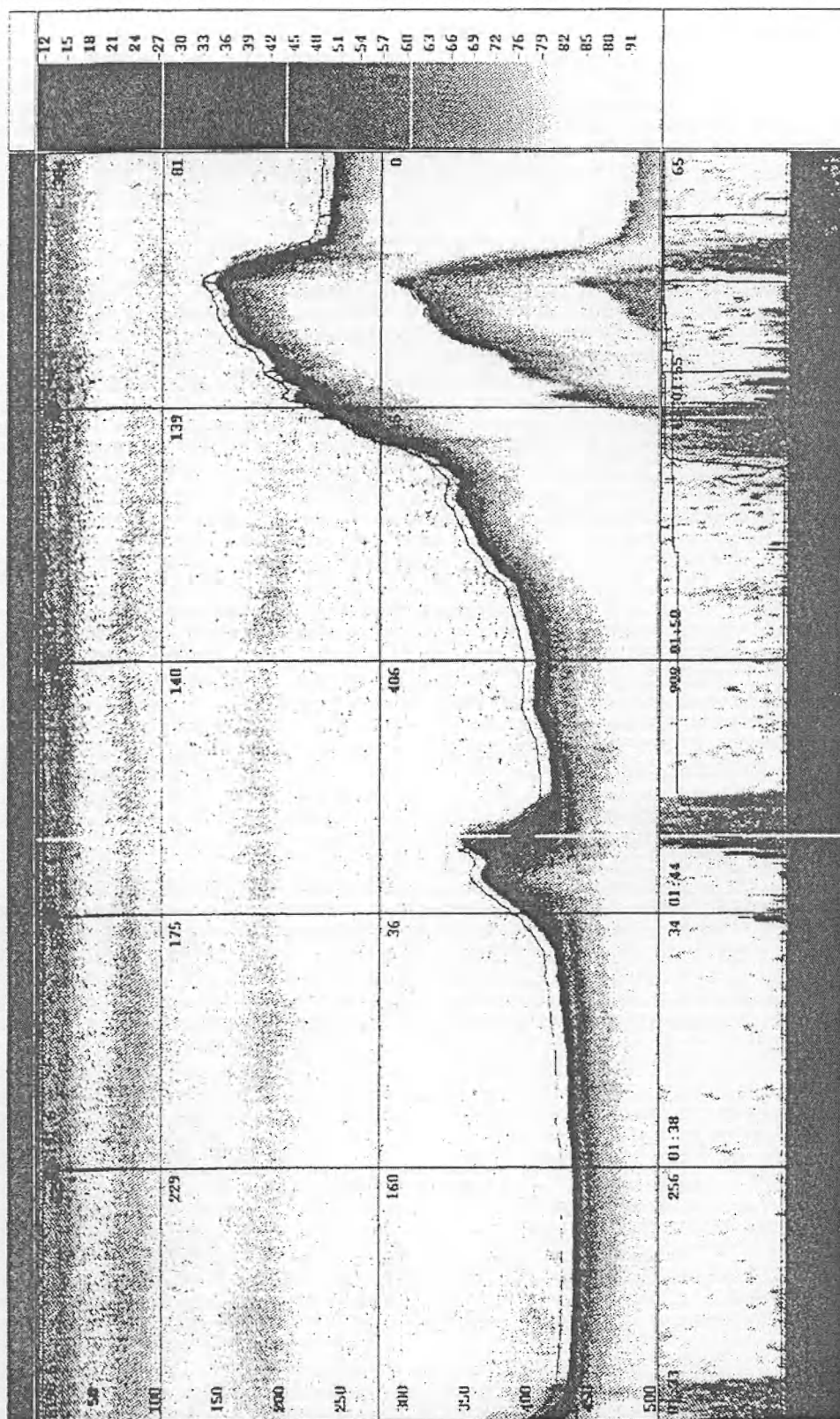


Figure A1.4. Nighttime acoustic scattering profile (5 nm) from Storfjorden during June 1991 as detected by the SIMRAD EK500 Scientific echosounder at 38 kHz.

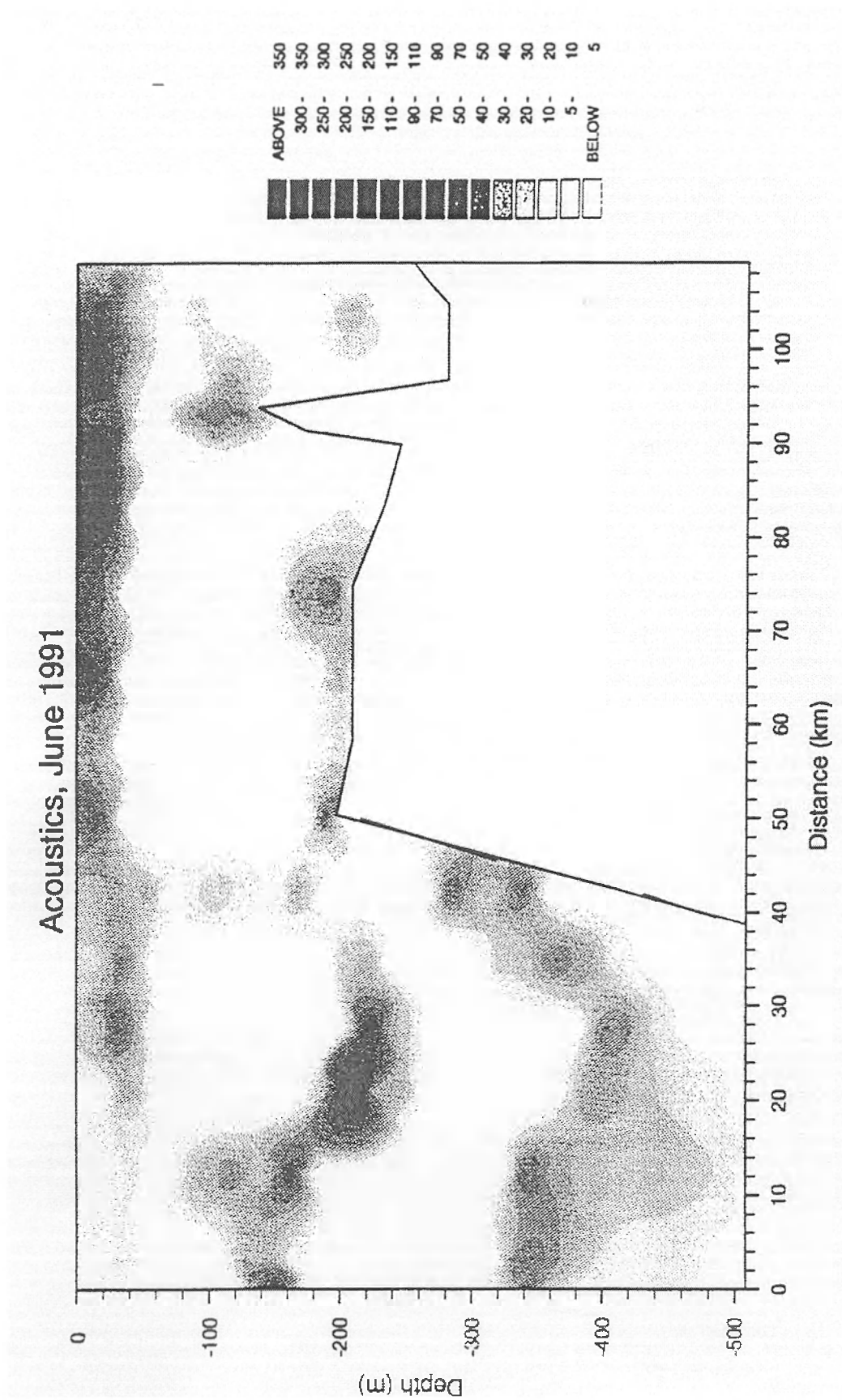


Figure A1.5. Total echo integrator values (m^2/nm^2) showing acoustic scattering layers from Storfjorden to the eastern part of the Norwegian Sea during June 1991.

Appendix 2: Preliminary Report from the Sea-going Workshop in Norway June 1993

on

Intercomparison and Evaluation of Methods for Sampling and Determination of Zooplankton Distribution and Biomass (ICES Study Group on Zooplankton Production)

Hein Rune Skjoldal, Peter Wiebe, Tor Knutsen and Lutz Postel

(ICES CM 1993/L:45)

1 Abstract

A Sea-going Workshop was arranged from 2 to 13 June 1993 in Storfjorden at Møre on the west coast of Norway. The workshop was a two-ship operation involving the Norwegian Research Vessel "Johan Hjort" and the German Research Vessel "A.v. Humboldt". The principal objective was to intercompare, characterize and evaluate the performance of gear and techniques for quantitative description of zooplankton distribution, biomass and production. During the last two days of the cruise, a seminar series of lectures was presented which highlighted various aspects of the sampling and samplers. A total number of 38 scientists and technicians from Canada, France, Germany, Iceland, Norway, Spain, United Kingdom and USA took part in the workshop and/or the seminar. A wide range of sampling gears and instruments were deployed. These included BIONESS, MOCNESS (1 and 10 m²), LHPR, CPR, Gulf III, Optical Plankton Counter, and various other plankton nets and trawls. Sample treatment usually involved splitting the samples in two halves for determination of size-fractionated dry weight biomass and species enumeration, respectively. The dry weight biomass samples were worked up during the workshop and will form the principal material for the gear intercomparison. Acoustical registrations were made with Simrad EK500 echo sounders operated at 4 frequencies (18, 38, 120, and 200 kHz). This report gives a brief description of the work carried out during the workshop and a few preliminary results. A full report describing the results from the workshop will be prepared and reviewed by the Study Group of Zooplankton Production.

2 Introduction

This report summarizes the events and accomplishments associated with the Sea-going Workshop arranged by the ICES Study Group of Zooplankton Production. The workshop took place during the period 2–13 June 1993 in Storfjorden at Møre on the west coast of Norway (62.4° N, 06.45° E). The rationale for this workshop was provided in the "Report of the ICES Study Group on Zooplankton Production, Bergen, Norway, 23–26 March, 1992". A

more detailed plan for the workshop was discussed and described in the "Report of the 2nd meeting of the ICES Study Group on Zooplankton Production, Las Palmas, Canary Islands, Spain, 8–11 March 1993" (CM 1993/L:11). Given that GLOBEC will be focussing its attention primarily on the production of marine zooplankton, the Study Group felt that there should be agreement on approaches for measuring biomass and turnover rates. This is especially important because three of the new sampling technology and experimental approaches are now being applied or under development.

The workshop was a two-ship operation involving the Norwegian Research Vessel "Johan Hjort" and the German Research Vessel "A.v. Humboldt". The cruise goals were to provide a basis for evaluating the performance of a variety of methods and to explore combinations of instruments and deployment strategies that can most effectively provide spatial and temporal data on zooplankton populations. During the last two days of the cruise, a seminar series of lectures was presented which highlighted various aspects of the sampling and samplers.

3 Participants

A total number of 38 scientists or technicians participated in part or the whole of the workshop. The participants were from Canada, France, Germany, Iceland, Norway, Spain, United Kingdom, and USA (Table 1).

4 The site

Storfjorden is a long and deep fjord located at Møre on the west coast of Norway (Figure 1). It was chosen as the site of the workshop due to its proximity to the Norwegian Sea and the similarity in fauna, and because there existed a fair amount of background information on this fjord from previous investigations. Storfjorden, like most Norwegian fjords, is well protected from winds, and seas remained flat for the duration of the cruise. This made handling of gear over the side and stern of the vessels relatively easy.

A 5 nm long sampling transect was Chosen in the outer part of Storfjorden where the bottom depth was about 400 m (Figure 1). The majority of work was carried out along this transect. Research Vessel “Johan Hjort” worked this section repeatedly about 65 times while doing acoustical recordings at four frequencies and towing various sampling gears. Research Vessel “A.v. Humboldt” also worked this section repeatedly towing sampling gears, and in addition occupied stations along the section doing vertical profiling and sampling.

A number of CTD-O2-Fluorescence profiles were made to the bottom of the fjord. Surface temperatures varied from 10 to 12°C and declined to about 8°C by 20 m. The interior waters of the fjord, from about 30 m to the bottom, had temperatures around 7.5°C.

A broad subsurface chlorophyll maximum occurred between 10 m and 35 to 40 m, i.e., in and below the pycnocline and largely below the 1% light level (Figure 2). The chlorophyll maximum often showed two peaks at approximately 15 m and 30 m. These maxima were variable both in the magnitude and placement of the peak values. On some occasions both peaks occurred, and on others, one or the four other peak dominated the profile.

The diel cycle of light (measured at the surface) was used to define dawn (03:30–05:29), daytime (05:30–20:29), dusk (20:30–22:29) and nighttime (22:30–03:29) periods.

Information on the species composition of the zooplankton community in Storfjorden was gained by examination of some of the samples under a stereo microscope during the course of the workshop. In most of the near surface samples the cladoceran *Evadne nordmanni* was by far the most abundant species followed by the copepod *Temora longicornis*. Eggs of the mesopelagic fish *Maurolicus muelleri* were abundant. Also occurring frequently were various jellyfish and ctenophores. At greater depths (generally below 200 m), the copepods *Calanus finmarchicus* (mainly stages IV–VI), *Metridia lucens*, *Pseudetideus armatus*, and *Euchaeta norvegica* were the most numerous species. At these depths, the krill *Meganyctiphanes norvegica*, and various species of shrimps (*Pasiphea* sp. and *Sergestes arcticus*) also were caught.

The species composition was not as hoped when the workshop was planned. It was expected that *Calanus finmarchicus* and krill, both *Meganyctiphanes norvegica* and *Thysanoessa* spp., would have been more abundant and dominant in the zooplankton community of the upper layer. These forms were present mainly in the deeper layer and in fairly low densities.

A dominant feature in the acoustic records and in the trawl collections from daytime depths of 150 to 200 m and at night in the upper 100 m, was the mid water fish, *Maurolicus muelleri*. Very few individuals of other species of similar size (e.g., *Meganyctiphanes norvegica*, *Pasiphea* spp.) co-occurred in the trawl samples with this

species when it was at the daytime depths. The acoustic records showed high backscattering volume in the upper 30 m and low backscattering between 50 and 100 m during daytime (Figure 3). This provided a situation with marked vertical structure and a large span of values for the comparison between acoustic records and sampled biomass and species abundance.

5 The gear

In spite of funding difficulties expressed by most of the non-Norwegian participants, an impressive set of instruments and samplers were assembled and deployed. The following is a list of the systems used one or more times.

Net systems:

- * I-m² MOCNESS
- * 10-m² MOCNESS
- * I-m² BIONESS
- * MIK (Methot Isaac-Kidd)
- * IKMT
- * MULTINET
- * Bongo nets
- * WP-2 net
- * LHPR
- * CPR (Continuous Plankton Recorder)
- * Gulf III/OPC
- * Young-fish trawl (10*10 m)
- * Pelagic fish trawl (Harstad-trawl)

Pumps:

- * Hufsa pump

Acoustics:

- * EK500, hull-mounted, with transducers operating at 18, 38, 120, and 200 kHz. The first three were split beam transducers.
- * EK500, towed body deployed from center-well on Research Vessel Johan Hjort, with a 38 kHz split beam transducer.
- * ADCP operating at 150 kHz.
- * Simrad sector scanning sonar operating at 2 MHz (Mesotech)
- * Portable EK500 operated with a 120 kHz split beam transducer.

Other sampling systems:

- * *In situ* camera system

- * OPC (Optical Plankton Counter)
- * CTD/Rossette
- * Light profiling gear (spectral radiometer)
- * Continuous surface irradiance meter

The Research Vessel “Johan Hjort” deployed the large trawls (pelagic fish and young fish trawls, MIK), multiple net systems (BIONESS, 1-m² and 10-m² MOCNESS's), and the Hufsa pump, made CTD and light profiles with a spectral radiometer, made multi-frequency acoustic recordings, and made continuous surface light measurements.

The Research Vessel “A.v. Humboldt” deployed plankton net systems (WP-2, MULTINET, - LHPR, Gulf III, and IKMT), made optical measurements with an OPC (deployed on both the Gulf III and LHPR), and conducted zooplankton and phytoplankton rate measurements.

6 The strategy of sampling and intercomparison

A transect of 5 nautical miles along the mid-line of the Storfjorden (62°23.8' N 06°20.0' E – 62°25.1' N 06°30.5' E) was selected as the site for intercomparison of the acoustical system (four frequencies) and the net systems. Essentially all of the sampling for the intercomparison study was done along this 5 nm transect. The sequence of deploying the nets and other instruments was designed to provide information relating to the objectives of:

- Intercomparing the various net systems, especially the multiple net and cod-end sampling systems.
- Examining the effects of avoidance on the various systems.
- Comparing the acoustical data with the net tow samples both with respect to total biomass and size frequency apportioned biomass.

The initial set of oblique intercomparison tows were designed to provide information about the vertical structure of the plankton and nekton species in the fjord in relation to the light regime and vertical temperature and salinity structure of the water column. Based on this information, selected depths were horizontally sampled sequentially with multiple net systems. In addition, the trawls were used to sample the larger nekton that inhabited the layers to see the extent to which these animals were avoiding the smaller net systems. The 1-m² MOCNESS was used in a 24-hour study comparing the acoustic registrations at all four frequencies and the biomass of plankton in the upper 100 m.

A second more extended comparison of the multiple net systems was done making repeated oblique tows from 375 m (one 25 m interval, seven 50 m intervals) to the surface over a 36-hour period. This intercomparison also

included UWR with the Optical Plankton Counter (OPC) mounted to the LHPR frame.

There were several specialized experiments. One involved deploying the 1-m² MOCNESS with the sector scanning sonar mounted so that the transducer could scan the net mouth and areas to the side of the net. The deployment was designed to test the feasibility of using this sonar to look for and quantify the effects of avoidance.

A second experiment involved deploying the towed body with the 38 kHz split-beam transducer at a series of depths to compare the acoustic registrations with those obtained from the hull mounted 38 kHz system. The specific objective was to look at changes in echo integration values and TS distribution at given depths as the transducer was towed deeper in the water column (125, 150 and 200 m) and closer to the layer of Müellers pearlside.

Experiments with animals captured in the net hauls involved measuring their sound speed and target strength (using the portable 120 kHz unit).

A long transect into the head of the fjord was made on 12 June. The CPR was deployed during this transect and samples were taken with MOCNESS at selected stations for comparison.

7 Sample treatment

A standard set of procedures to process the plankton samples were used for most of the samples throughout the cruise on both ships. These procedures are developed and used routinely at the Institute of Marine Research in Bergen. On deck, nets were washed and the cod-end buckets then taken into the ships laboratory. The samples were initially divided into two fractions, one for formalin preservation and later species identification, and the second one for dry weight measurements. The sample used for dry weighing was separated into 3 size fractions. Individual euphausiids, shrimps, and fish were removed from the dry weight fraction, and then the rest of the sample was sieved into three size fractions (180–1000 µm, 1000–2000 µm and >2000 µm). For dry weighing, the animals were then placed on pre-weighed aluminium trays and frozen. Periodically during the course of the workshop, the samples were picked up by a chartered boat and taken to a laboratory located in a nearby technical institute where they were dried and weighted.

The dry weight was also determined for the sorted groups of euphausiids, shrimps and fish. During the latter part of the workshop, in addition to the treatment above, these groups were counted and length measured.

Processing of the LHPR samples were done following different procedures. Seven hauls were completed taken a total of 175 samples. Samples for species identification and size measurements were preserved in formalin from

hauls 1, 2, 3, 4 and 7, with the most complete set being taken on the later two hauls. A fault in the flowmeter pick-up invalidated the coarse mesh flow data on hauls 1 and 2; taxonomic and size analysis will still be carried out on these samples for comparison with OPC data. A series of 53 μm fine mesh samples were taken on haul 1 together with the 200 μm coarse mesh samples; these fine mesh samples will be analysed for the vertical distribution of nauplii and copepodite stages of copepods and other microplankton. However, due to a reed switch failure of the coarse mesh system on haul one, the separate samples could not be discriminated and were thus bulked to give a single integrated sample for the tow. For subsequent hauls only the 200 μm coarse mesh system was used, the failed reed switch having been replaced with the one from the 53 μm system.

While the results from the taxonomic analysis, standardized as species abundance per unit volume filtered, will be used for comparisons with the catches of the concurrent MOCNESS and BIONESS hauls, the most immediate comparison will be from size fractionated biomass estimates from the samples taken on LHPR haul six. In the short time available, allowing several hours after an LHPR tow for handling typically over 90 size fractionated samples from a single haul, there was insufficient time for any further hauls on biomass. Haul six was used for size fractionated enzyme studies.

Catches of the MIK-trawl and fish trawls were sorted to species or groups and their wet weight or volume were determined for sub samples or the total catch. For fish length measurements were also taken.

8 Processing of EK500 data

The EK500 Simrad echo sounder operating with 4 frequencies, 18, 38, 120, and 200 kHz, was used with the Bergen Echo Integrator software to produce echo sounding images and target strength histograms. These provided an indication of the vertical distribution of the plankton and were used to guide the net sampling.

All “raw” EK500 ping data are recorded and ultimately stored on tape. During the workshop cruise several gigabytes of data were acquired. These data are processed in real-time using the Bergen Echo Integrator (BEI) software and entered into a database system, which forms the backbone for all subsequent reporting, plotting and further processing. A difficulty noted during the workshop involved the reporting of the echo integration data, which were given to the nearest unit of $1 \text{ m}^2/\text{nm}^2$ when in fact there should have been good data to $10\text{--}5 \text{ m}^2/\text{nm}^2$. The lower volume backscattering levels are typical of zooplankton, but ignored by the BEI system because of the emphasis on fish. Part of the problem was due to a threshold of $0.01 \text{ m}^2/\text{nm}^2$ for data entering the database. This was changed by the end of the cruise, but only the last days data were stored in the database with the lower thresholding. Data for the first part of the

workshop must be re-entered as raw data and processed into the database with the lower thresholding. This could not be accomplished before the end of the cruise.

A second problem involved the procedure for storing data in the database. The standard practice is to let the ships log determine the rate of entering data to the database. On this cruise, the interval was set to 0.1 nm. The difficulty with this approach for our study was that often the ship was not moving and data were not recorded for those time intervals, or the ship was moving slowly enough so that ship drift due to wind or current added or subtracted from the logged distance. In the latter case, estimates of echo-integrated biomass will be overestimated or underestimated in proportion to the added or subtracted distance. This requires a correction to some of the data prior to comparison with net sampled biomass. The recording of data in space units rather than time units complicates the comparison between acoustic records and net samples since the nets were not opened or closed at locations that exactly coincided with the beginning or end of an acoustic space interval.

9 Preliminary results from BIONESS/MOCNESS intercomparisons

The vertical distribution of biomass as obtained with 1-m^2 MOCNESS revealed a maximum in the upper 12.5 m, with values decreasing with increasing depth to very low biomass values between 75 and 100 m (Figure 4). Most of the biomass in the upper layers were made up of organisms in the $<1 \text{ mm}$ size fraction, predominantly the cladoceran *Evadne nordmanni*. The biomass in the $1\text{--}2 \text{ mm}$ and $>2 \text{ mm}$ size fractions were much lower than for the smallest size fractions. Figure 4 shows the variability based on 6 subsequent MOCNESS hauls made during daytime on 6 June. The coefficient of variation (standard deviation/mean, 100%) ranged from 27 to 103% for the total biomass and from 28 to 118% for the $<1 \text{ mm}$ size fraction. The variability was in general larger for the two largest size fractions, with CV values typically about 100%.

An initial start at making comparisons of the data from various net systems and data from the acoustical systems has been made by assembling the dry weight data sets for the BIONESS and MOCNESS. A comparison was made of the catch of the BIONESS and the MOCNESS from paired depth specific sample intervals. There were six comparisons, in which a relatively complete sample series was obtained by both systems, i.e., with one or no missing samples from either system. They were paired on the basis of time and sampling strategy. Four comparisons were between the BIONESS with $333 \mu\text{m}$ mesh nets and the MOCNESS with $180 \mu\text{m}$ mesh nets; for two comparisons both systems had nets with $333 \mu\text{m}$ mesh nets.

These initial comparisons revealed some consistent trends. Prior to more rigid statistical treatment of the data and further sample analyses, some preliminary conclusions can be drawn from these intercomparisons:

- 1) There was clearly a higher catch by MOCNESS when 180 μ m mesh nets were used on MOCNESS and 333 μ m mesh nets were used on BIONESS.
- 2) The catch differential was substantially reduced when both nets were equipped with 333 μ m mesh nets.
- 3) There was evidence for higher avoidance of MOCNESS by larger individuals of fish, shrimp, and krill than BIONESS.
- 4) In spite of this avoidance bias, MOCNESS caught more total biomass than BIONESS because the smaller organisms making up the size fractionated biomass dominated the total biomass.

These results were to some extent anticipated. MOCNESS was towed at 1.5 to 2.5 knots while BIONESS generally was towed between 3 and 4 knots. The faster towing speed was expected to reduce the avoidance bias for larger animals and the results support this expectation. With faster towing speeds, however, there is increased filtration pressure on the meshes and increased extrusion (escapement) of the smaller animals through the meshes. This latter effect would be expected to be more severe with the BIONESS than MOCNESS. The higher catch rate of the smaller animals by MOCNESS supports this contention.

10 Workshop seminar

A series of talks concerning the various aspects of sampling and determination of distribution and biomass with emphasis on new technologies and their impact on measurement of zooplankton were presented on the last two days of the workshop at sea. A separate document summarizing these presentations is being prepared as an input to the work of the Study group on zooplankton production. An outline of the talks and the presenters is given here.

12 June 1993:

08:30: Workshop at Sea Summary of activities in Storfjorden (H.R Skjoldal)

- General
- Data
- Reporting

10:45: Optics (U. Kils)

OPC (Wieland, Sameoto, Hay)

12:00: Underwater video profiler (Gorsky)
 13:00: Plankton and herring studies using optics (Kils)
 13:45: Gulf ill Imaging system (Wieland)
 14:00: Discussion
 14:30: Biomass Measurement Errors (Postel)
 15:30: Net Sampling Systems (Sameoto)
 20:00: Video documentaries on zooplankton sampling presented by S. Hay

13 June 1993:

09:15: Acoustics (Wiebe, Sameoto, Korneliussen)
 13:00: General discussion

- Strengths and limitations of gear and techniques
- Improvements
- Standardization

11 Further plans

A full intercomparison of the net sampling systems will be performed based on the dry weight biomass data. A limited number of plankton samples will be analysed for species composition and numerical abundance. This will be done particularly for the intercomparisons of MOCNESS and BIONESS against the LHPR Sample processing for species identification will also be done to check trends or interpretations derived from the biomass intercomparisons.

The acoustical data will be reprocessed and the set of recordings of volume back scattering will be explored and compared across the four frequencies and against the biomass sampled by the net systems.

It is the aim to have a draft report of the results prepared for discussion and finalization in the next meeting of the Study Group on Zooplankton Production in early spring 1994. The report could be published in the ICES Cooperative Research Series, with a summary of main results and conclusions published in an international journal.

12 Acknowledgements

We thank all the participants to the workshop and the seminar for their dedicated effort. The support from the Institute of Marine Research in Bergen and the Institute for Baltic Sea Research in Warnemünde in providing ship time is gratefully acknowledged. We would also like to acknowledge the support of Eastern Marine in Canada who supplied the BIONESS for the workshop.

Table A2.1. List of participants to the Sea-going Workshop of the ICES Study Group of Zooplankton Production.

CANADA
Doug Sameoto (4–13 June)
Dan Wellwood
FRANCE
Gabriel Gorsky (11–12 June)
GERMANY
Lutz Postel
Kai Wieland
Uwe Kiels
Günter Breuel, Peter Wlost, Anneli Postel, Heide Sandberg, Reinhard Kay
ICELAND
Olafur Astthorsson
Asthor Gislason
Jon Jonsson
NORWAY
Herman Bjørke
Tor Knutsen
Stein Kaartvedt
Hein Rune Skjoldal
Per Bratland
Karsten Hansen
Kaare Hansen
Arvid Romslo
Egil Øvretveit
Trygve Gytte (2–8 June)
John Dalen (2–8 June)
John W. Valdemarsen (2–4 June)
Gunnar Pedersen (4–7 June)
Sven Ove Linde (9–13 June)
Rolf Korneliussen (11–13 June)
Rolf Nielsen (6–8 June)
Trevor Ward (4–6 June)
SPAIN
Irene Montero
UNITED KINGDOM
Steeve Coombs (8–13 June)
John Nichols (8–13 June)
Steve Hay (8–13 June)
Graeme Hays (8–13 June)
USA
Peter Wiebe

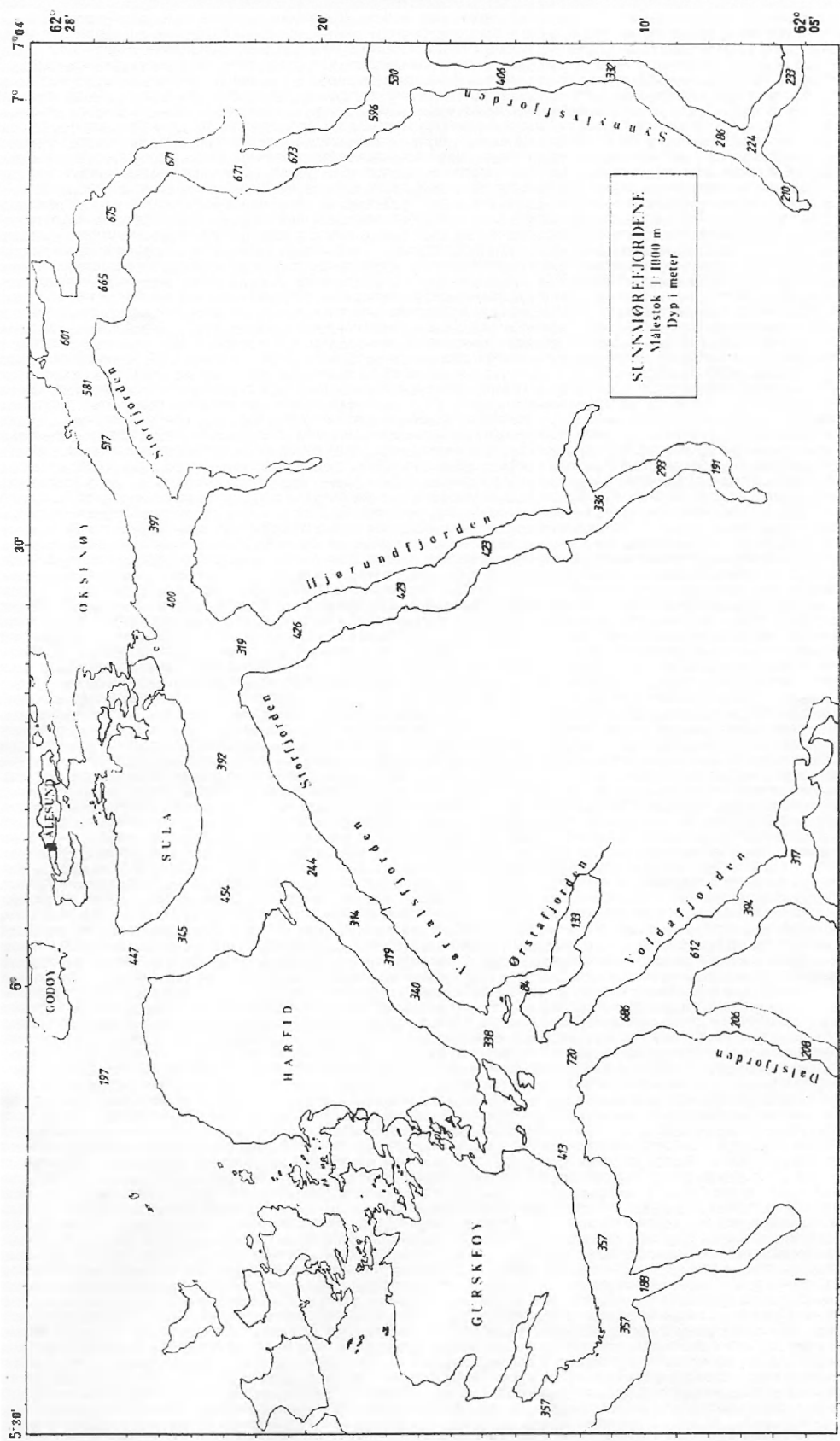


Figure A2.1. Map of Storfjorden at More showing the main 5 nautical mile sampling transect (hatched area). Numbers represent depths in meters.

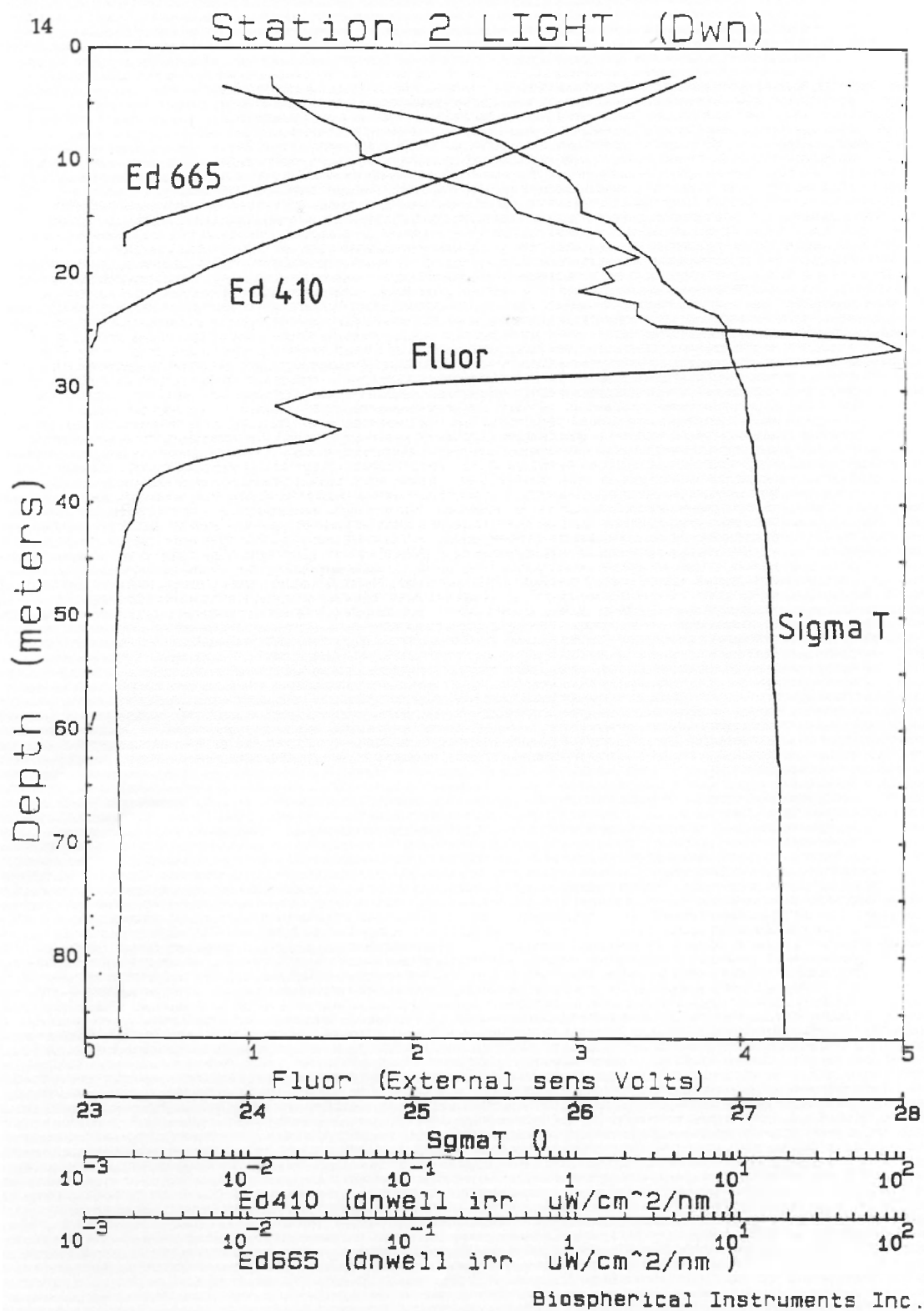


Figure A2.2. Vertical profiles of *in situ* fluorescence, sigma-t water density, and downwelling irradiance at 410 and 665 nm wavelengths.

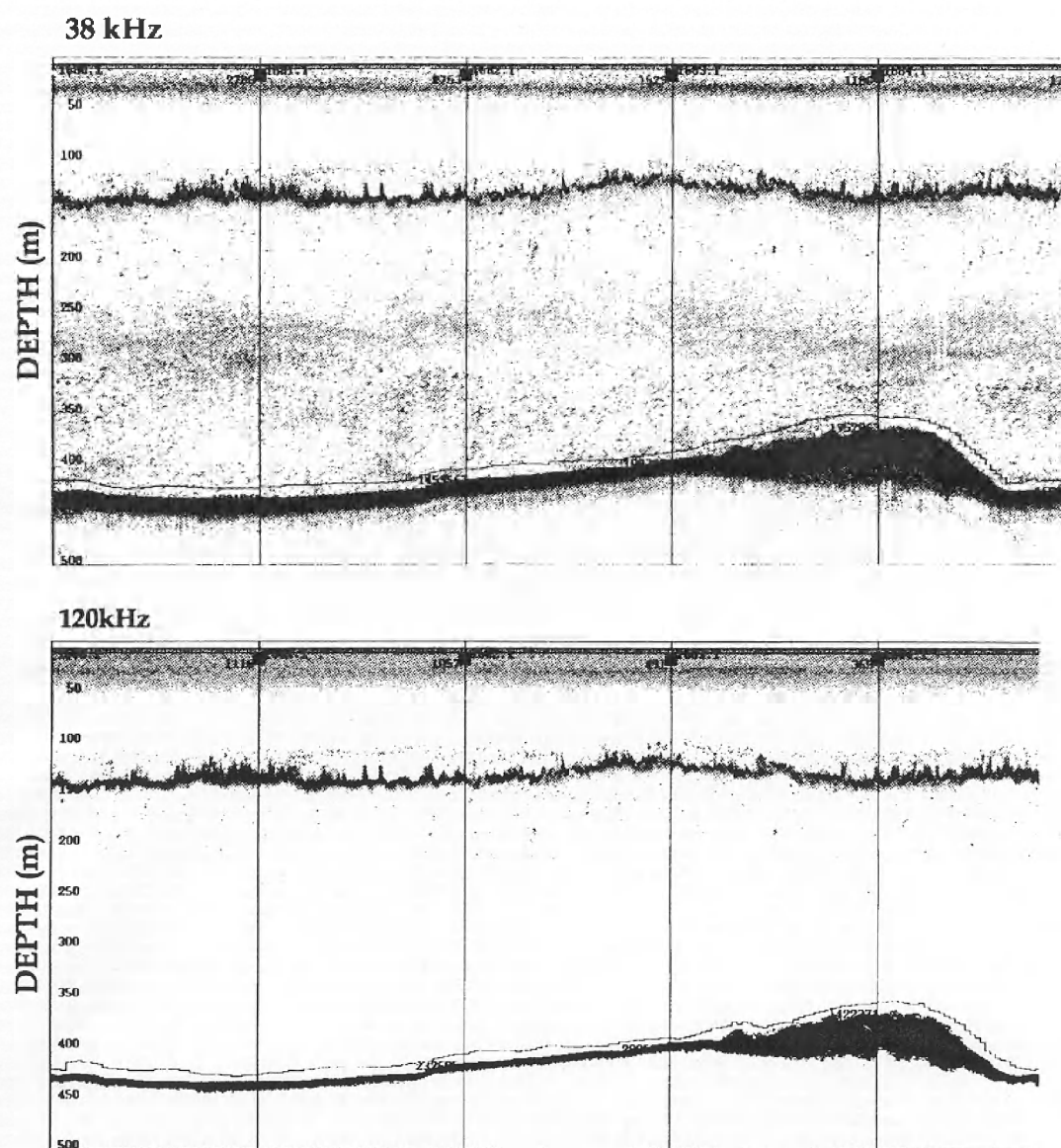


Figure A2.3. Acoustical recordings along the main sampling transect obtained with 38 (upper) and 120 kHz (lower) Simrad EK500 splitbeam echosounder.

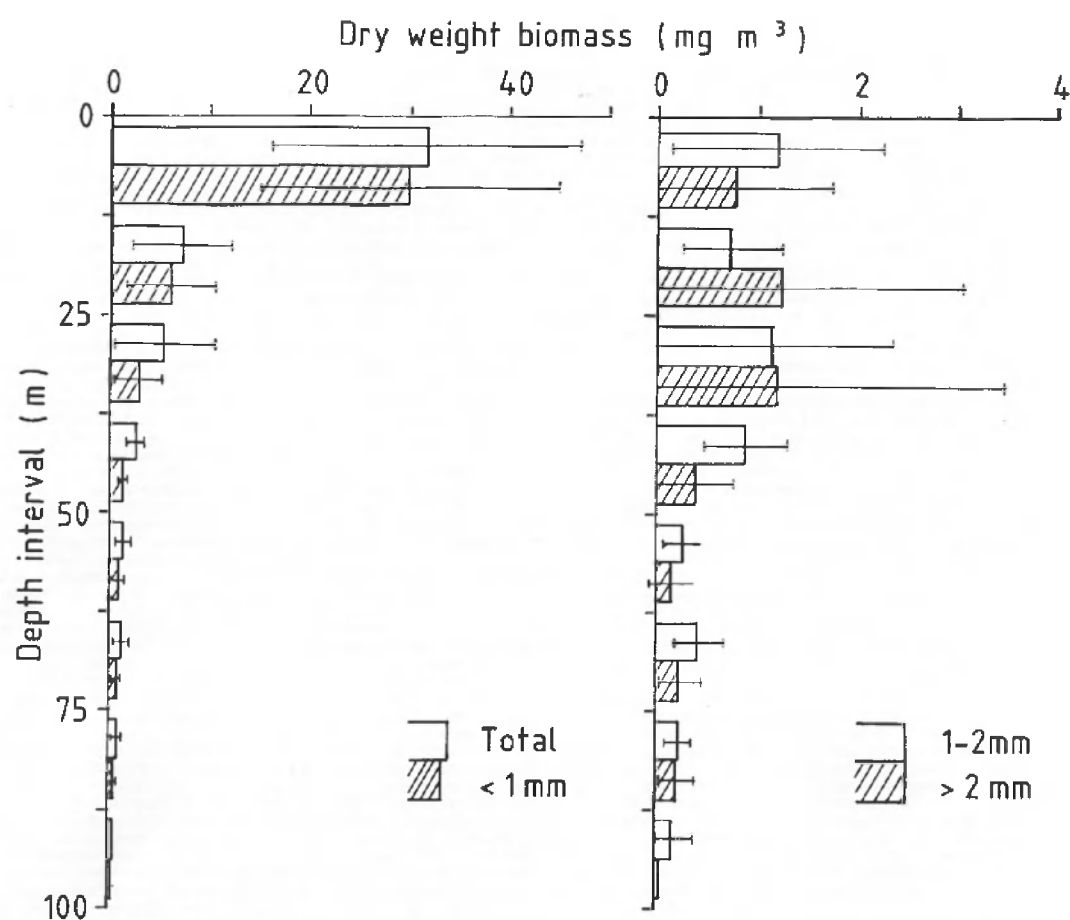


Figure A2.4. Vertical distribution in the upper 100 m of dry weight biomass obtained with 1-m³ MOCNESS equipped with 180 μm mesh nets. Means and SD for six subsequent hauls taken during daytime are shown for total biomass and the size fractions <1 mm, 1–2 mm, and >2 mm.