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Committee

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)

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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 R/V "Johan Hjort" and the German R/V "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 m^2), 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-fractioned 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 eccho 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.

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 - March 23-26, 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" (C.M. 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

of the new sampling technology and experimental approaches now being applied or under development.

The workshop was a two-ship operation involving the Norwegian R/V "Johan Hjort" and the German R/V "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.

PARTICIPANTS

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

THE SITE

Storfjorden is a long and deep fjord located at Møre on the west coast of Norway (Fig. 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 (Fig. 1). The majority of work was carried out along this transect. RV "G. O. Sars" worked this section repeatedly about 65 times while doing acoustical recordings at 4 frequencies and towing various sampling gears. RV "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-O_2-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 (Fig. 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

other peak dominated the profile.

The diel cycle of light (measured at the surface) was used to define dawn (0330-0529), daytime (0530-2029), dusk (2030-2229) and nighttime (2230-0329) 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*, *Pseudaetideus 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 midwater 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 (Fig. 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.

THE GEAR

Inspite 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:

* 1-m^2 MOCNESS
* 10-m^2 MOCNESS
* 1-m^2 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 RV Johan Hjort, with a 38 kHz split beam transducer.
* ADCP operating at 150 kHz.
* Simrad sector scanning sonar operating at 2 MHz (Mesotech)
* Portable EK 500 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 irradience meter

The RV "Johan Hjort" deployed the large trawls (pelagic fish and young fish trawls, MIK), multiple net systems (BIONESS, 1-m^2 and 10-m^2 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 RV "A.v. Humboldt" deployed plankton net systems (WP-2, MULTINETT, 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.

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 (4 frequencies) and the net systems. Essentially all of the sampling for the intercomparison study was done along this 5 n.m 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-m^2 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 LHPR with the Optical Plankton Counter (OPC) mounted to the LHPR frame.

There were several specialized experiments. One involved deploying the 1-m^2 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.

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 3 size fractions (180-1000µm, 1000-2000µm and >2000µm). For dry weighing, the animals were then placed on pre-weighed aluminum 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 euphausids, 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 analyzed 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 1 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 6. 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 6 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 subsamples or the total catch. For fish length measurements were also taken.

PROCESSING OF EK 500 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 m^2/nm^2 when in fact there should have been good data to 10^{-5} m^2/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 m^2/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 data base 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 data base. 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.

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 (Fig. 4). Most of the biomass in the upper layers were made up of organisms in the < 1 mm size fraction,

predominantly the cladoceran *Evadne nordmanni*. The biomass in the 1-2 mm and > 2 mm size fractions were much lower than for the smallest size fractions. Fig. 4 shows the variabality 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 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 µm mesh nets and the MOCNESS with 180 µm mesh nets; for two comparisons both systems had nets with 333 µm 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 µm mesh nets were used on MOCNESS and 333 µm mesh nets were used on BIONESS.

(2) The catch differential was substantially reduced when both nets were equipped with 333 µm mesh nets.

(3) There was evidence for higher avoidance of MOCNESS by larger individuals of fish, shrimp, and krill than BIONESS.

(4) Inspite 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.

WORKSHOP SEMINAR

A series of talks concerning the various aspects of sampling and determination of distribution and biomass with emphahsis 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

0830: Workshop at Sea Summary of activities in Storfjorden (H.R. Skjoldal)
- * General
- * Data
- * Reporting

1045: Optics (U. Kils)
OPC (Wieland, Sameoto, Hay)
1200: Underwater video profiler (Gorsky)
1300: Plankton and herring studies using optics (Kils)
1345: Gulf III Imaging system (Wieland)
1400: Discussion
1430: Biomass Measurement Errors (Postel)
1530: Net Sampling Systems (Sameoto)
2000: Video documentaries on zooplankton sampling presented by S. Hay

13 June 1993

0915: Acoustics (Wiebe, Sameoto, Korneliussen)
1300: General discussion
Strengths and limitations of gear and techniques
Improvements
Standardization

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 backscattering 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.

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 shiptime is greatfully acknowledged. We also like to acknowledge the support of Eastern Marine in Canada who supplied the BIONESS for the workshop.

Table 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
- 6 technicians

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 Gytre (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

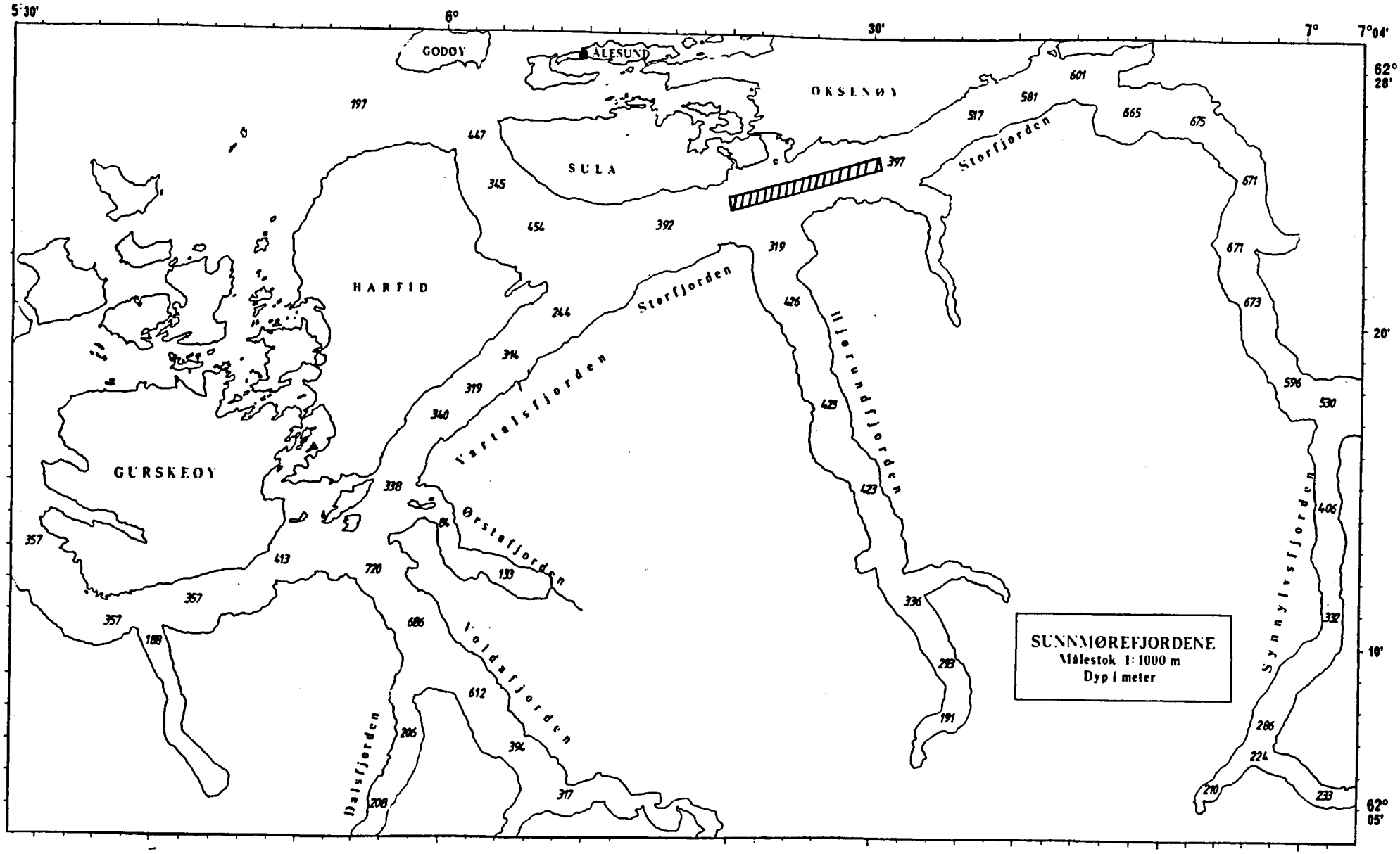

Fig. 1. Map of Storfjorden at Møre showing the main 5 nautical mile sampling transect (hatched area). Numbers represent depths in meters.

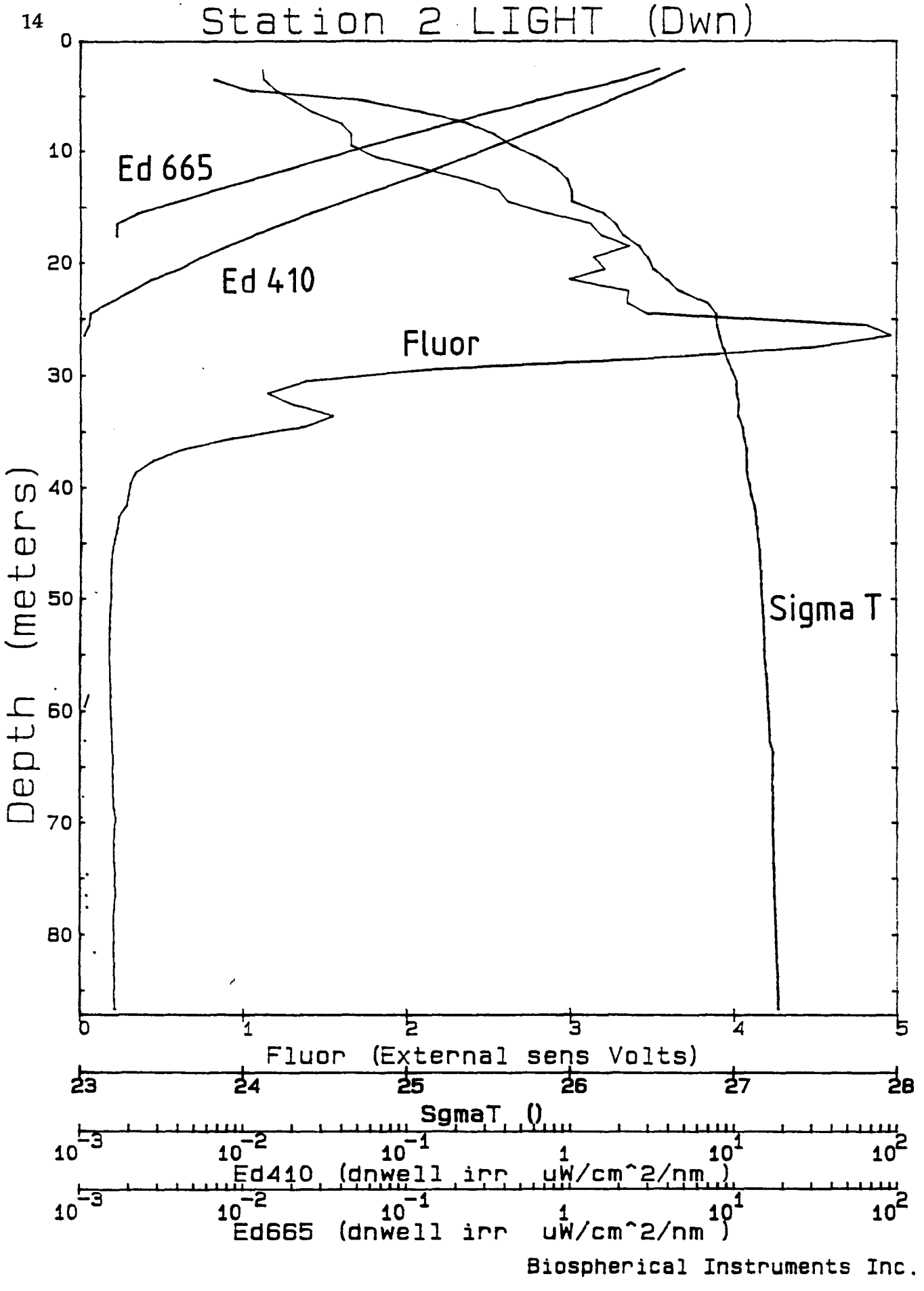

Fig. 2. Vertical profiles of <u>in situ</u> fluorescence, sigma-t water density, and downwelling irradiance at 410 and 665 nm wavelengths.

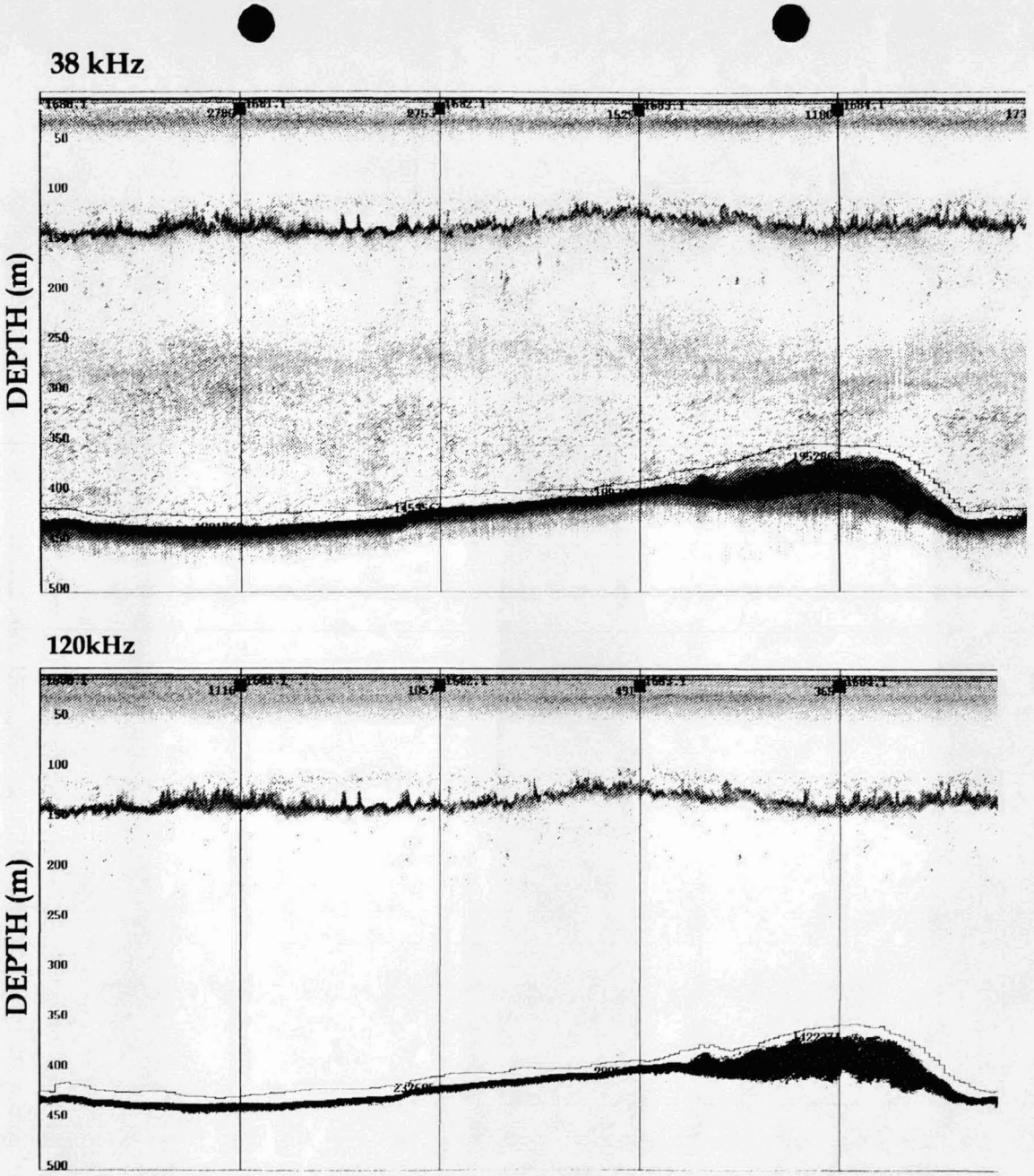

Fig. 3. Acoustical recordings along the main sampling transect obtained with 38 (upper) and 120 kHz (lower) Simrad EK500 splitbeam ecchosounder.

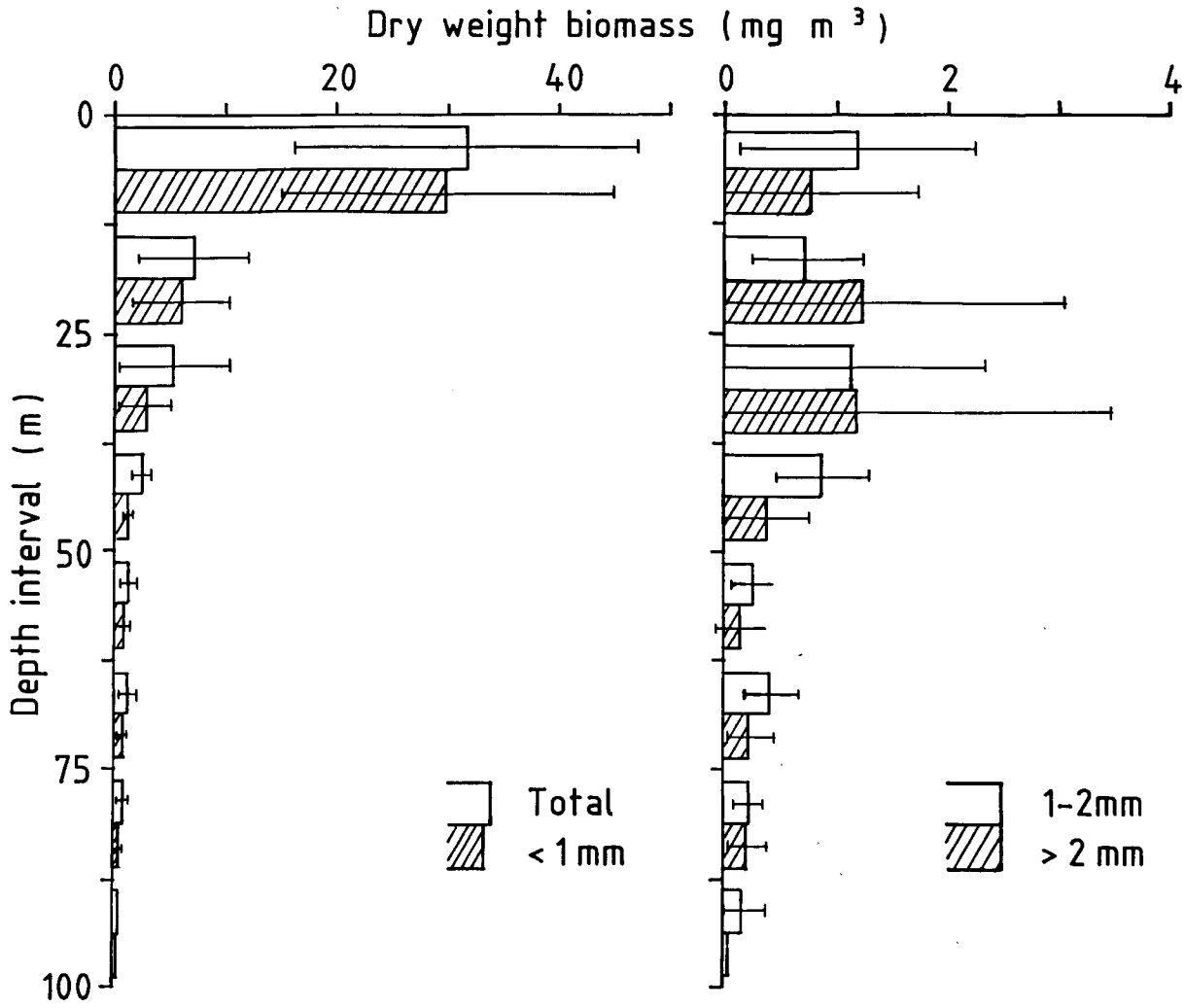

Fig. 4. Vertical distribution in the upper 100 m of dry weight biomass obtained with 1-m3 MOCNESS equipped with 180 µm mesh nets. Means and SD for 6 subsequent hauls taken during day time are shown for total biomass and the size fractions < 1 mm, 1-2 mm, and > 2 mm.