SENTER FOR MARINT MILJØ

HAVFORSKNINGSINSTITUTTET

INTERN TOKTRAPPORT

SHIP: F/F G.O. SARS

DEPARTURE: Bergen January 3rd, 1700 GMT.

ARRIVAL: Bergen January 19th, 0420 GMT

AREA: NORWEGIAN TRENCH, CONTINENTAL SHELF OFF MØRE AND ADJACENT FJORDS, EASTERN PART OF THE NORWEGIAN SEA.

PURPOSE: Study the horizontal and vertical dynamics of the overwintering zooplankton community and the biological activity with respect to respiration and excretion. Compare baseline values of nutrients, chlorophyll and fluorescence in different water masses (Fjord water, Coastal water, Norwegian Trench water and Norwegian Sea water).

PERSONELL: Berit Endresen, Berit Hofstad, Kirsten Arnesen (3.1-6.1), Julio Erices (6.1-19.1), Magnus Johannessen, Jens Nejstgaard, Tom Noji and Tor Knutsen.

INSTRUMENT PERSONELL: Martin Dahl, Egil Øvretveit.

AREA OF INVESTIGATION

The primary area of investigation is the continental shelf off Møre where the main spawning grounds for Norwegian spring-spawning herring are located. Figure 1a & b shows the surveyed area. Due to the localisation of the main study site other areas of interest are the upstream areas of the Norwegian Coastal Current and Trench areas off the west coast of Norway. In these southern areas primary and secondary production might be initiated earlier than at the Møre shelf. Thus the northward transport of the Norwegian Coastal Current probably influence the Møre shelf by advective production. Another important area is the deep water off the shelf in the Norwegian Sea, where overwintering copepods inhabit the deep waters migrating to

the surface waters in early spring to feed and reproduce. This area is also important with respect to large populations of euphausiids which inhabit the slope and deep waters of the Norwegian Continental Shelf. The fjords at Møre are important reference areas with respect to their zooplankton stocks and the onset of the phytoplankton bloom. Early stratification of the water column in the fjords due to freshwater input, might be a key facor in initiating the primary and secondary production here. The seaward transport of surface waters containing stocks of phytoplankton and zooplankton, might significantly influence the shelf waters and shallow archipelago outside the fjords, where the first spawning of herring takes place.

MATERIALS AND METHODS

Sampling

Mesozooplankton were sampled by a new piece of equipment called MULTINET borrowed from the University of Kiel. It was run on a portable CTD winch with 1500 m of cable. The 0.25 m^2 MULTINET is equipped with 5 nets of 180µm mesh size and is especially designed for multiple vertical hawls.

Macrozooplankton (and mesozooplankton) were sampled between 0-700 m by a 1m^2 MOCNESS equipped with 8 nets of 180 µm mesh size. Samples were stratified according to possible zooplankton registrations observed with the EK500 echo sounder (38 and 120 khz). On each station echo integration was performed for the same depth interval as sampled with the MOCNESS and MULTINET.

A HARSTADTRAWL and IKMT (Isaac-Kidd Midwater Trawl) was used to sample and identify scatterers observed by the EK500 echo sounder at 38 and 120 khz. The Harstad trawl is a pelagic trawl with an opening of 16 x 16 fathoms. On the cod-end side it is lined with a 4-5 m inner net with a 5 mm stretched mesh size. The IKMT is a smaller pelagic trawl with a length of 13.3 m and a mouth area of 4 x 3 m. It has a mesh size that changes from 25 mm close to the mouth of the net, to 5 mm in the last 4 m close to the cod-end. An inner net of mesh size 1.15 mm and a length of 1.75 m is mounted in front of the cod-end.

Live copepods and krill for metabolism, gut fluorescence and defecation experiments were collected at some stations as described below.

At certain localities fecal pellets were sampled with 30 l Niskin water bottles at selected depths and collected on a 30 µm net.

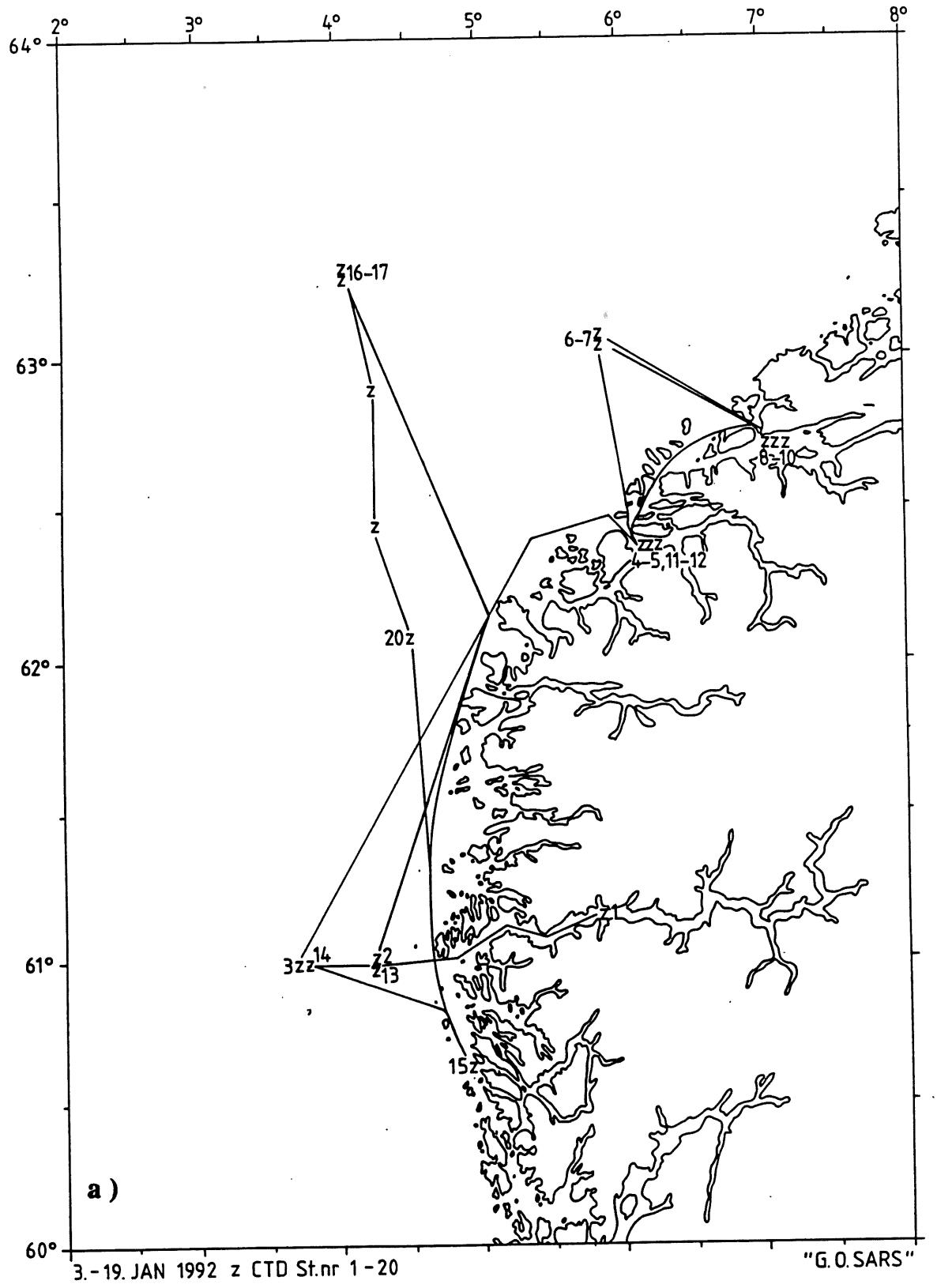

Figure 1. Survey area. a) CTD stations. b) Biological sampling.

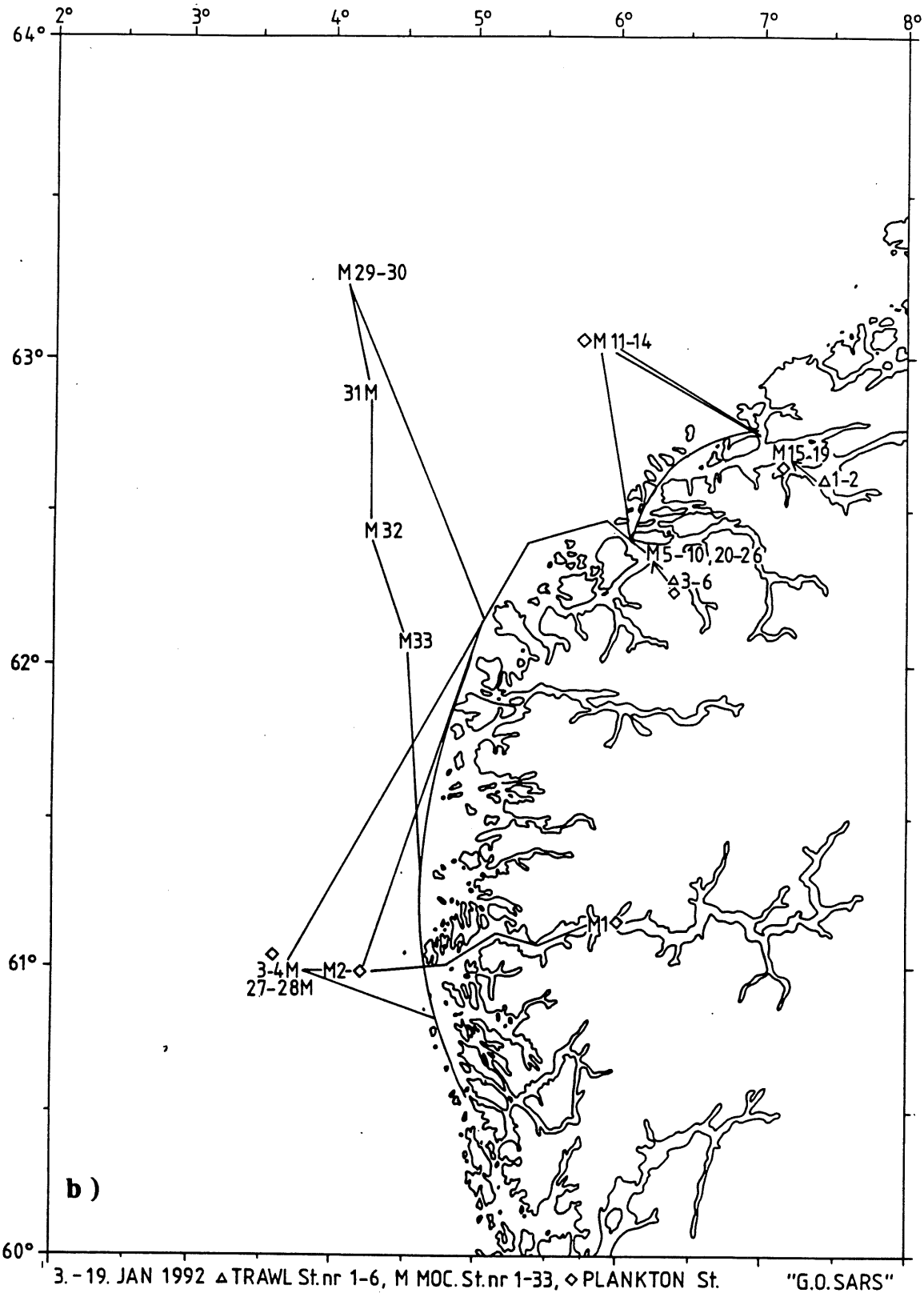

Figure 1 continued.

Experiments

The metabolic activities of copepods and krill were measured by shipboard incubation experiments at six selected stations (Table 1). Water for the incubation experiments was collected with 30 l Niskin water bottles. Surface water was usually taken between 20-10 m, while deep-water was sampled within some distance from the bottom, depending on the maximum depth at the stations (Table 1). The sampled water was filtered through GFF filters, thoroughly mixed in 25 l polycarbonate bottles and cooled to *in situ temperature*.

Live animals for the experiments were collected at selected depths during night (Table 1). Krill were caught in surface waters by short (20 min) hauls with an IKMT equipped with a non-filtering cod-end. Copepods were collected at selected depths using a 0.8 m^2 net (mesh size 375 μm) with a Nansen closing system and a 16 l water tight cod-end.

Care was taken to minimize disturbance to the animals and inclusion of damaged specimens in the experiments. The copepod net was retrieved at low speed (0.2-0.3 ms^{-1}). Upon arrival at the surface the contents of the water tight codends were immediately diluted in 40 l containers with *in situ* tempered surface water and sorted by eye into the incubation bottles under low light conditions. Seemingly undamaged copepods were pipetted into small monospecific batches of approx. 20-45 individuals. The batches of copepods (5-8 ml) were rinsed by adding filtered tempered sea-water (35-40 ml) and subsequently adjusting the volume to 5 ml by reversed filtration. The rinsed batches of copepods were then immediately transferred to air-tight 250 ml glass bottles containing pre-tempered filtered sea-water, and incubated in darkness for 10 to 29 h (see Table 1).

Krill were sorted from the sample by catching 1-5 specimens in a specially constructed small coarse-net sieve (1.4 mm mesh). After removing other animals and rinsing with filtered sea-water, the krill were transferred to air-tight 1 l glass bottles, and incubated as described for the copepods. For each series of incubations 3-5 additional bottles were used as blanks. Blanks were treated as the incubation bottles, except that the batches of rinsed water added at the start of the incubations contained no animals.

In the copepod experiments stage CV copepodites and females of *Calanus finmarchicus* (Gunnerus) were normally selected for the experiments. However, in some cases sufficient amounts of *C. finmarchicus* could not be found, and and other dominating species were included; as *Metridia longa* (Lubbock) (experiment #3,#5 and #6), and *Pleuromamma robusta* (Dahl) (experiment #6).

In most of the krill experiments *Meganyctiphanes norvegica* (M. Sars) was incubated. An exception was experiment #3 for which animals were caught in the Onadeep. At this locality *Thysanoessa inermis* (Krøyer) was the dominating species, and was therefore used in the experiments.

Table 1. Respiration and excretion experiments.

	Geographical position	Date	Sample depth Water	Sample depth Animals	Total# animals	Incub. time(h)
1 Norwegian Trench	60°59',03°42'	05.01.92				
Copepods	No experiment performed					
Krill			30 m		12	10
2 Storfjord	62°23',06°18'	07.01.92				
Copepods (Surface)			10 m	200-0 m	92	29
(Deep)			300 m	400-300 m	167	27
Krill			10 m	10 m	24	27
3 Onadeep	63°04',05°50'	09.01.92				
Copepods			10 m	190-0 m	129	19
Krill			10 m	20-10 m	22	14
4 Moldefjord	62°41',07°02'	10.01.92				
Copepods (Surface)			50 m	100-30 m	22	15
(Deep)			400 m	450-250 m	171	13
Krill			10 m	20-0 m	20	14
5 Norwegian Trench	60°59',03°40'	15.01.92				
Copepods			20 m	335-0 m	186	13
Krill			20 m	20-10 m	29	14
6 Norwegian Sea	63°14',04°09'	17.01.92				
Copepods			75 m	100-50 m	101	12
Krill	No experiment performed					

At the end of the incubations the activity of the animals were checked before sampling, and a few cases of mortality were noted. Duplicate samples for oxygen, ammonium and phosphate were taken from each bottle, except from the copepod flasks where only one oxygen sample could be taken due to the smaller incubation bottle volume.

In addition to the experiments on metabolic activity two gut defecation experiments on *C. finmarchicus* and *M. longa* were conducted on January 12th and 13th in Moldefjorden and Storfjorden respectively. Both experiments were conducted during the night. In the first experiment we compare *in situ* gut fluorescence and microscopical determined gut content, in freshly collected

copepods from deep (450-230 m), respective surface waters (100-0 m). In the second experiment we simultaneously analyze the *in situ* fecal pellet production and the microscopically determined gut evacuation in copepods from surface waters (100-0 m) during a times series. Freshly collected animals were incubated in *in situ* tempered GFF-filtered sea-water for intervals ranging from 15 minutes to 6 hours.

Studies of vertical migration

On the main localities, where the experiments where performed, diurnal studies of vertical migration within the plankton community were also undertaken. The main gear used was MOCNESS which was run approximately every 4th hour. Other types of gear like MULTINET, IKMT and Harstad trawl was run when possible.

At these localities water samples for analyzing silicate, phosphate, nitrate, nitrite, phosphate, ammonia, particulate organic carbon (POC), particulate organic nitrogen (PON), particulate organic phosphate (POP) and oxygen were taken. Phosphate and ammonia were analyzed manually on board the vessel and oxygen was measured by a modified Winkler method.

On selected localities krill and copepods were sampled for genetic studies and stored at -90°C.

Calibration

The MOCNESS flow meter #2 was calibrated during the cruise on two occasions in Storfjord using GPS positioning above ground as a reference of sailed distance. The results show a calibration factor of 4.7 and 4.25 respectively, given a combined factor 4.5 which has been used as the calibration factor for MOCNESS tows during the cruise.

The MOCNESS depth sensor was tested against the SCANMAR depth sensor in the upper 100 m. No significant differences between the depth recorded by the two sensors were found.

RESULTS - FIELD STUDIES

Temperature and salinity

Temperature and salinity at the four major sites of investigation are representative of the winter situation to be found in these specific marine regimes. Although these are first results and are liable to modification during further data processing, some patterns can be established.

At Station 3 located in the Norwegian Trench off Sognefjorden, temperature and salinity (Fig. 2 a & b) ranged from about 7° to 9° C and 35.0 to 35.3 ‰, respectively. The watermasses observed at this station seems to be of true Atlantic origin. The well-mixed water from the surface down to a depth of 100m is probably a result of intense mixing and winter cooling but might also be slightly influenced by near coastal and North Sea water.

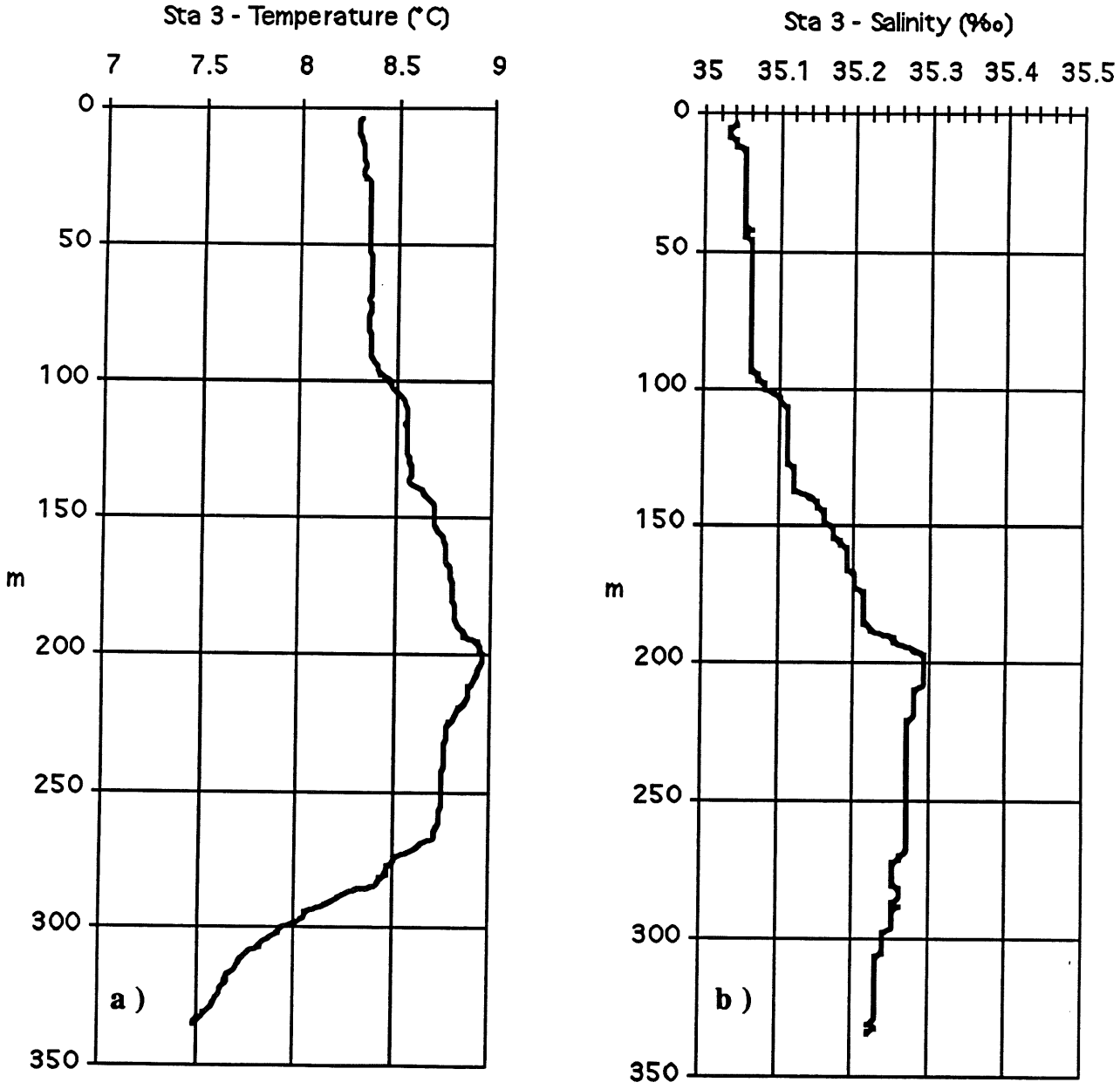

Figure 2. a) Temperature and b) salinity profiles for Station3.

A transition zone from a well-mixed surface layer to a warmer and more saline water type occurred between the depths of 100 and 200 m. The peak values of temperature and salinity at about 200m depth indicate a major inflow of Atlantic Water to the Norwegian Trench.

Below a depth of about 270 m temperature decreased, indicating that the deep water of the Trench was less influenced by the major Atlantic inflow.

In contrast, at Station 4 in Storfjorden, the vertical distribution of temperature and salinity (Fig. 3 a & b) was less oceanic in character. Lowest salinities were found at the surface as a result of freshwater runoff into the fjord. Values increased with depth as a result of mixing with higher-salinity waters at the bottom of the fjord. Salinities above 35 ‰ were measured below about 250 to 300 m depth, which indicated the presence of Atlantic

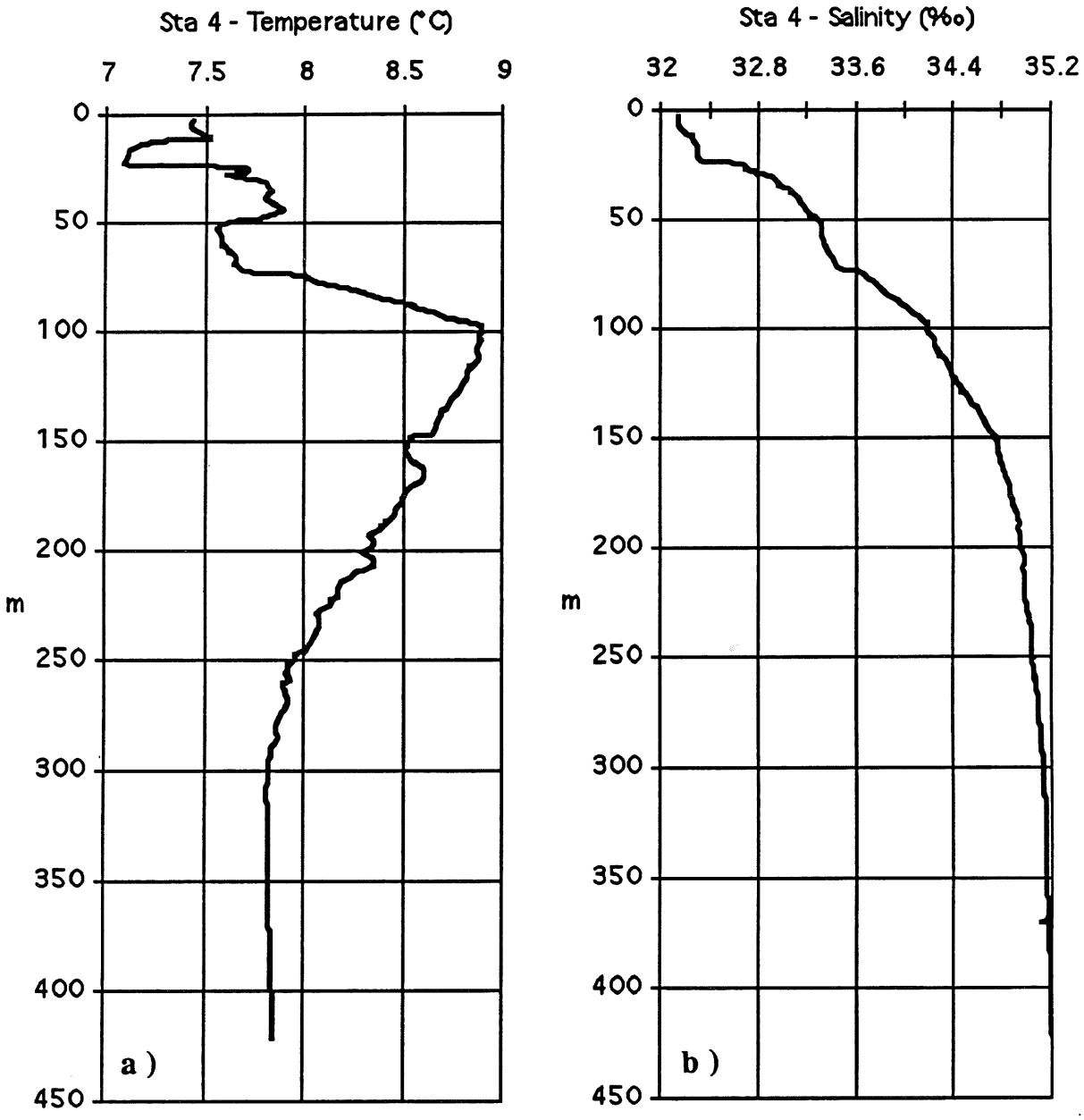

Figure 3. a) Temperature and b) salinity profiles for Station4.

water at these depths. The lower temperatures in the surface waters are probably a result of winter cooling near the surface and the input of colder freshwater. In the upper 100m the variable temperature indicates the presence of several layers and a complex current regime. Temperature increased to a depth of about 100 m probable due to mixing with the deep water. Below 100 m values again decreased to a depth of 300 m, where they stabilized with the presence of Atlantic Water.

The situation at Station 6 on the shelf at Møre (Fig. 4 a & b) presents yet another scenario. Relatively warm, low-salinity coastal current water formed a distinct layer from the surface to about 20 m, and below 160 m the warmer water with higher salinity appeared to be of Atlantic origin. Between these two depths was a zone of gradual transition.

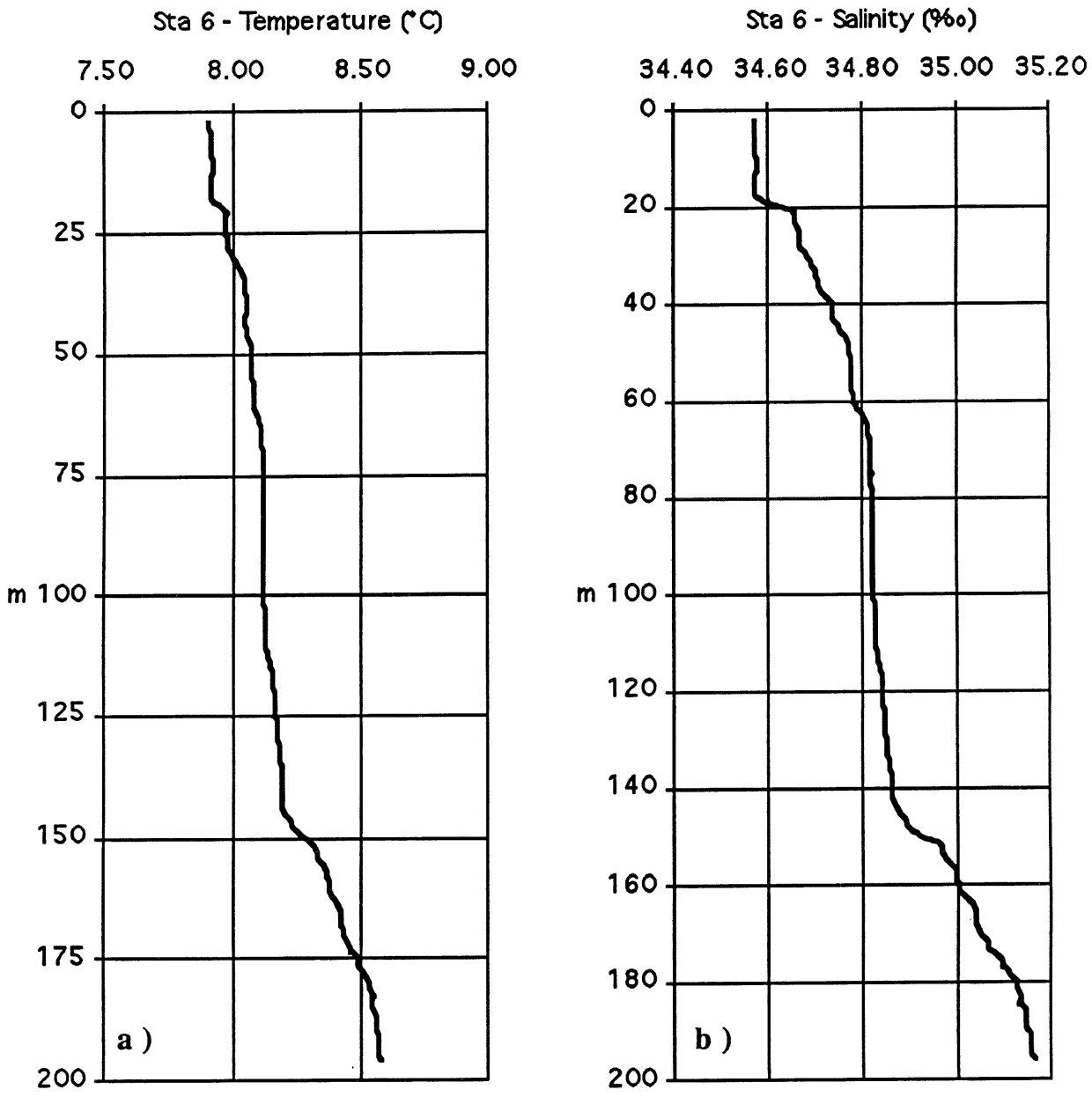

Figure 4. a) Temperature and b) salinity profiles for Station6.

Station 8 in Romsdalsfjorden (Fig 5 a & b) was similar to that in Storfjorden with respect to the general pattern of temperature and salinity with relatively cold less saline water near the surface and more oceanic conditions at depth. Distinct cooling of surface water and thermal discontinuities were indicated in the upper 100 m of the temperature profile.

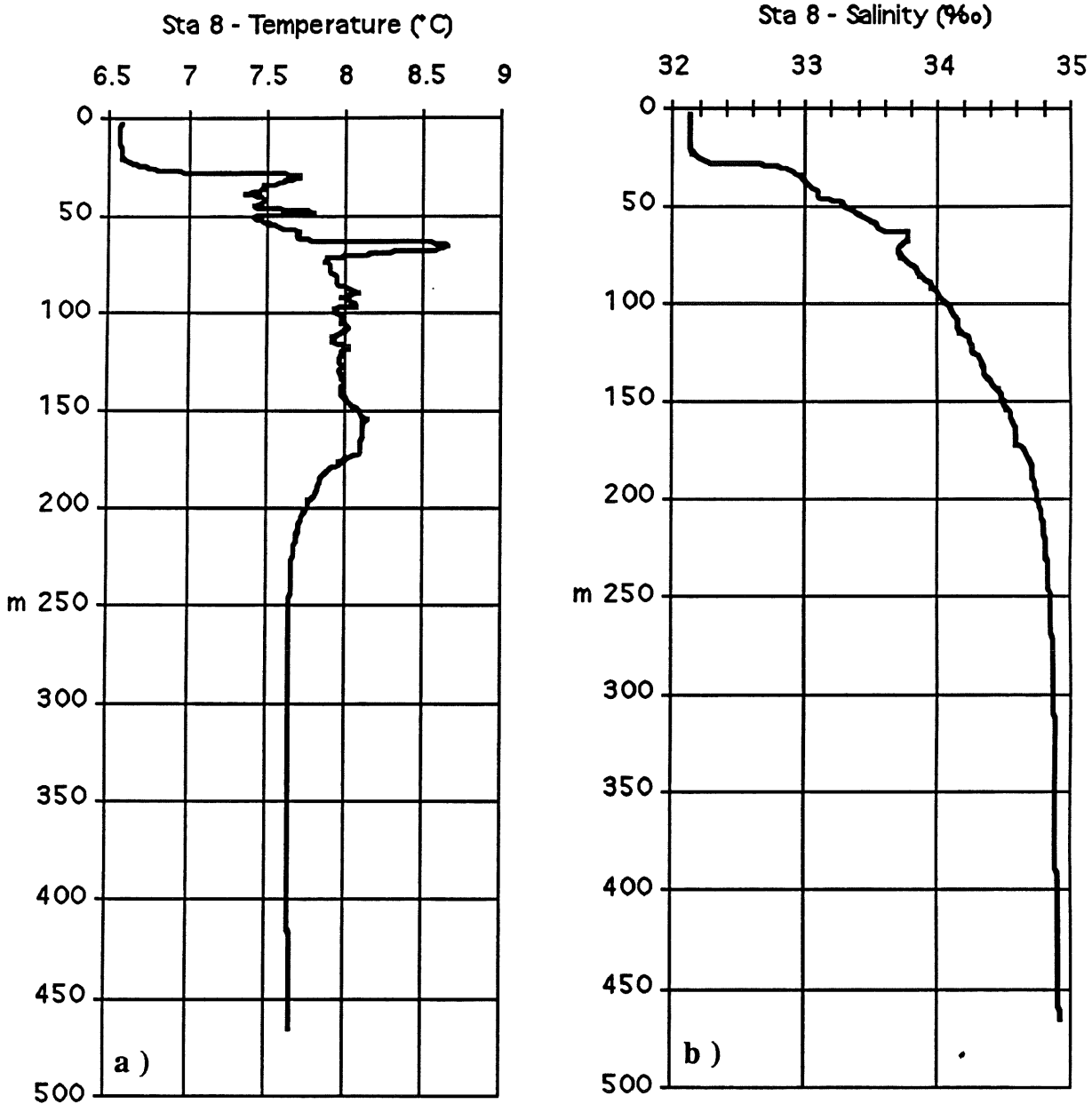

Figure 5. a) Temperature and b) salinity profiles for Station8.

The Norwegian Sea station (Station 16) was characterized by typical oceanic temperature and salinity profiles (Fig. 6 a & b). Relatively warm, high-salinity Atlantic Water extended from the surface down to several hundred meters depth, and cold, lower-salinity Norwegian Sea Deep Water prevailed at greatest depths. In addition, a transition zone of Intermediate Water was recorded between 200-600m.

A general observation was that the surface temperatures of the fjord and shelf stations seem to be quite high compared to the long term mean values for this part of the Norwegian coast.

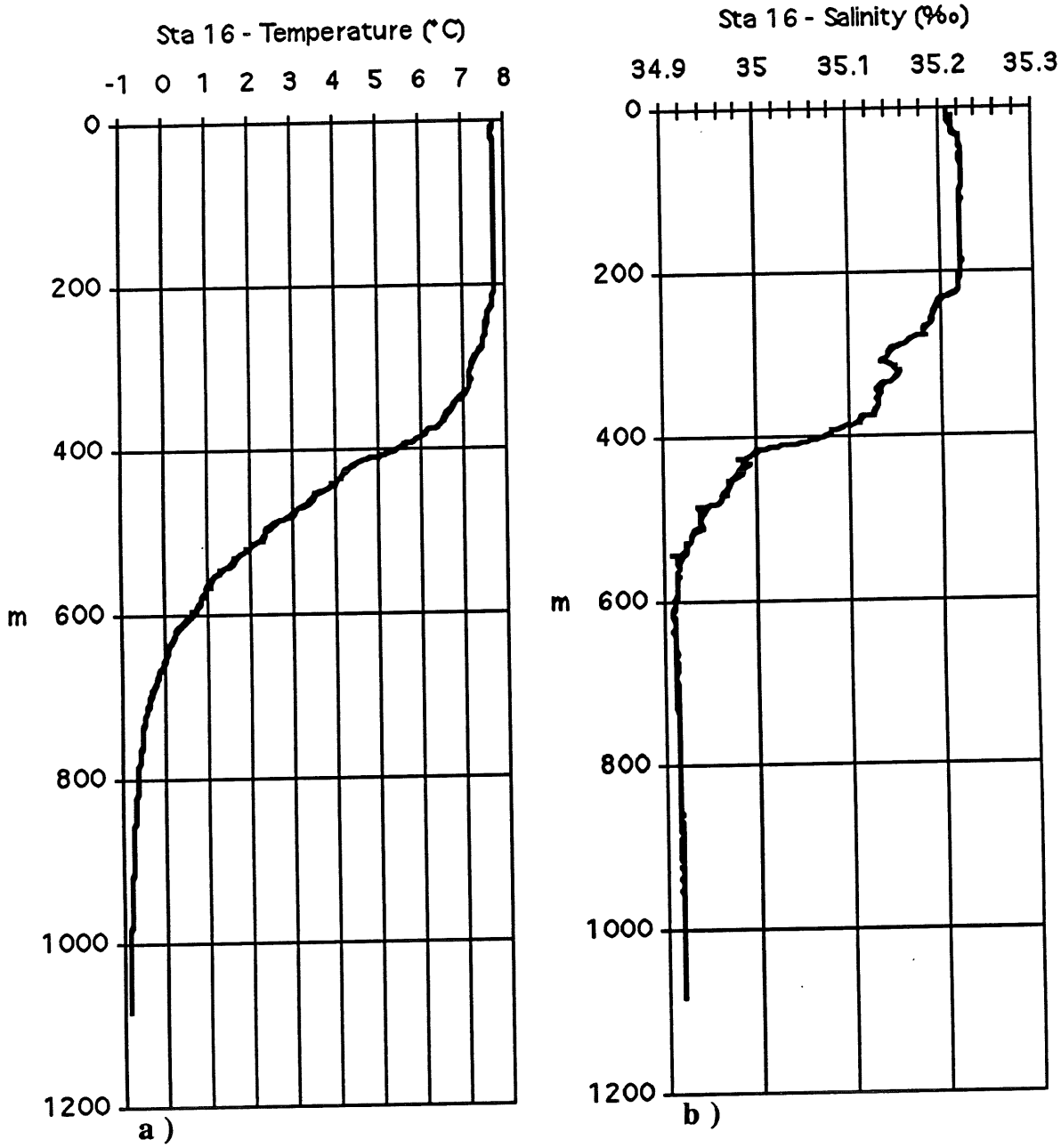

Figure 6. a) Temperature and b) salinity profiles for Station16.

Phosphate and ammonium

Preliminary findings for phosphate and ammonium were also typical of the winter situation winter in these regions. Phosphate concentrations were high relative to values in late spring and summer, at which times phosphate may be almost depleted in surface waters by intensive uptake by phytoplankton. Fall/winter mixing renews these depleted surface waters with phosphate. Ammonium, in contrast, was present in low concentrations relative to conditions in spring and summer. As ammonium is largely supplied by excretion from zooplankton and higher trophic forms, the former which is at an annual minimum in terms of biomass and activity, winter concentrations are typically low.

An example of the vertical distribution of phosphate and ammonium is presented in Fig. 7 a & b. The findings are from the station between Langgrunnsbanken and Buagrunn at Møre (Station 6).

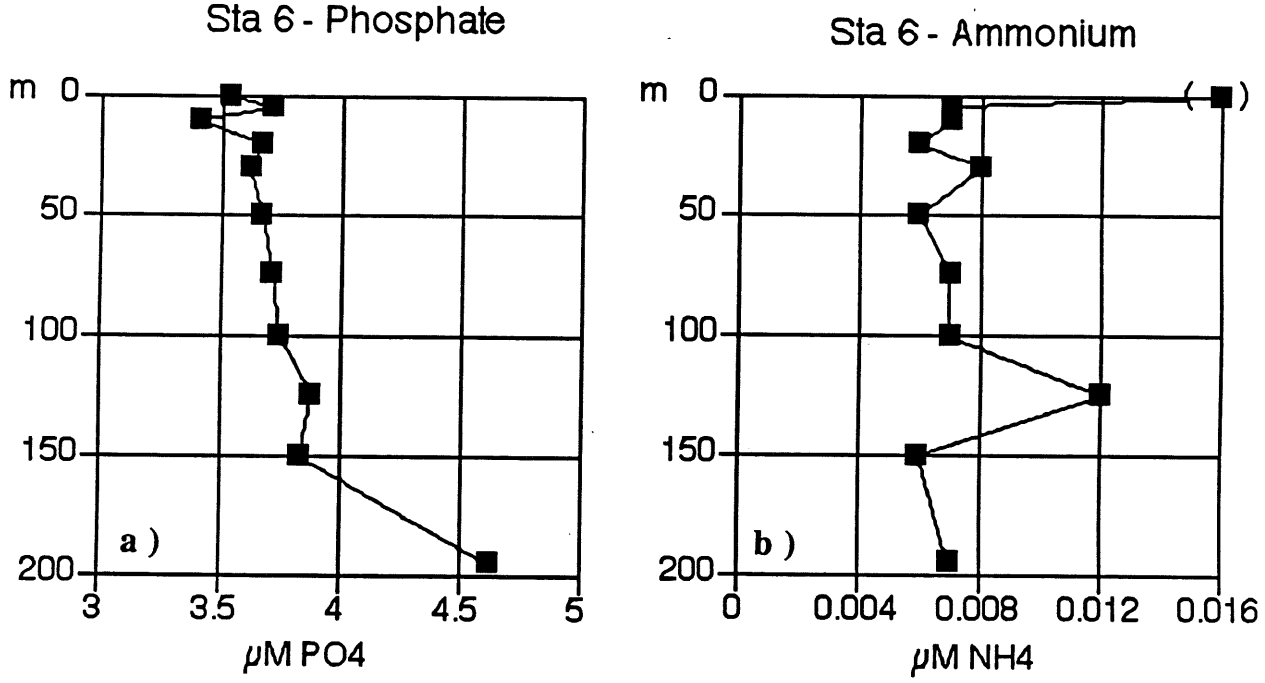

Figure 7. a) Phosphate and b) ammonium profiles for Station6.

It is noted that the high phosphate value at 190 m at Station 6 may reflect nutrient remineralization from the sediments at about 200 m. The relatively high surface value for ammonium may be due to excretion by swarms of krill observed at the surface of this station.

Fluorescence

The very low values of the continual vertical profiles of fluorescence (Fig. 8 a-e) at all stations reflect the typically low concentrations of suspended chlorophyll, i.e. phytoplankton, in winter along the Norwegian coast and in the fjords. Generally fluorescence decreased slightly with depth. At Station 3 in the Norwegian Trench there was a distinct peak at about 20 m as well as an increase in values at depth (Fig. 8a). The latter may be due to resuspension of material from the sediments or from hyperbenthic nepheloid layers.

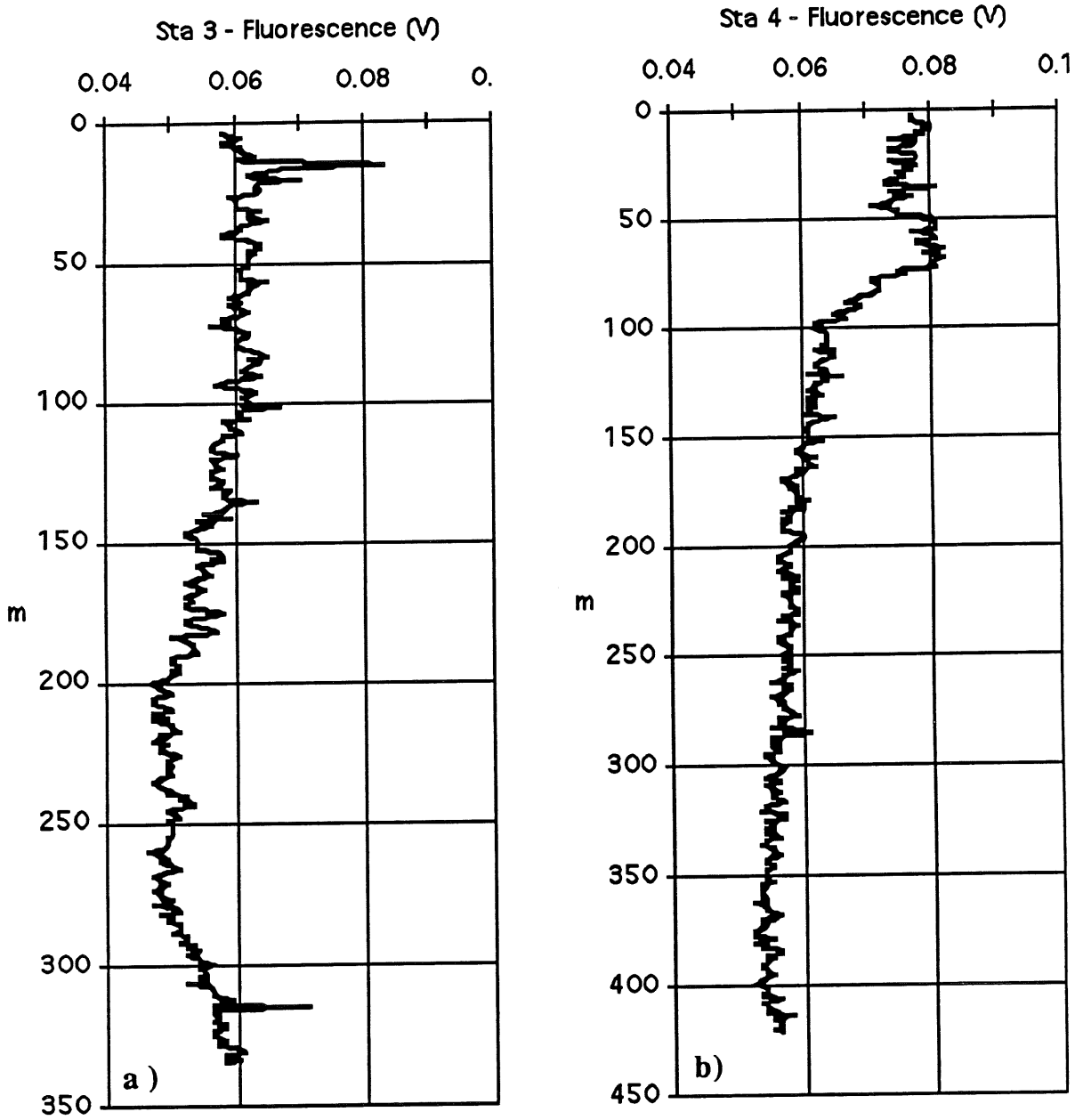

Figure 8. a) Fluorescence Station 3, b) fluorescence Station 4, c) fluorescence Station 6, d) flurescence Station 8 and e) fluorescence Station 16.

The stations at Storfjorden (Station 4, Fig. 8b) and Romsdalsfjorden (Station 8, Fig. 8d) each exhibited distinctly higher values for fluorescence near the surface relative to lower depths. A single peak near the surface was evident at the Møre station (Station 6, Fig. 8c).

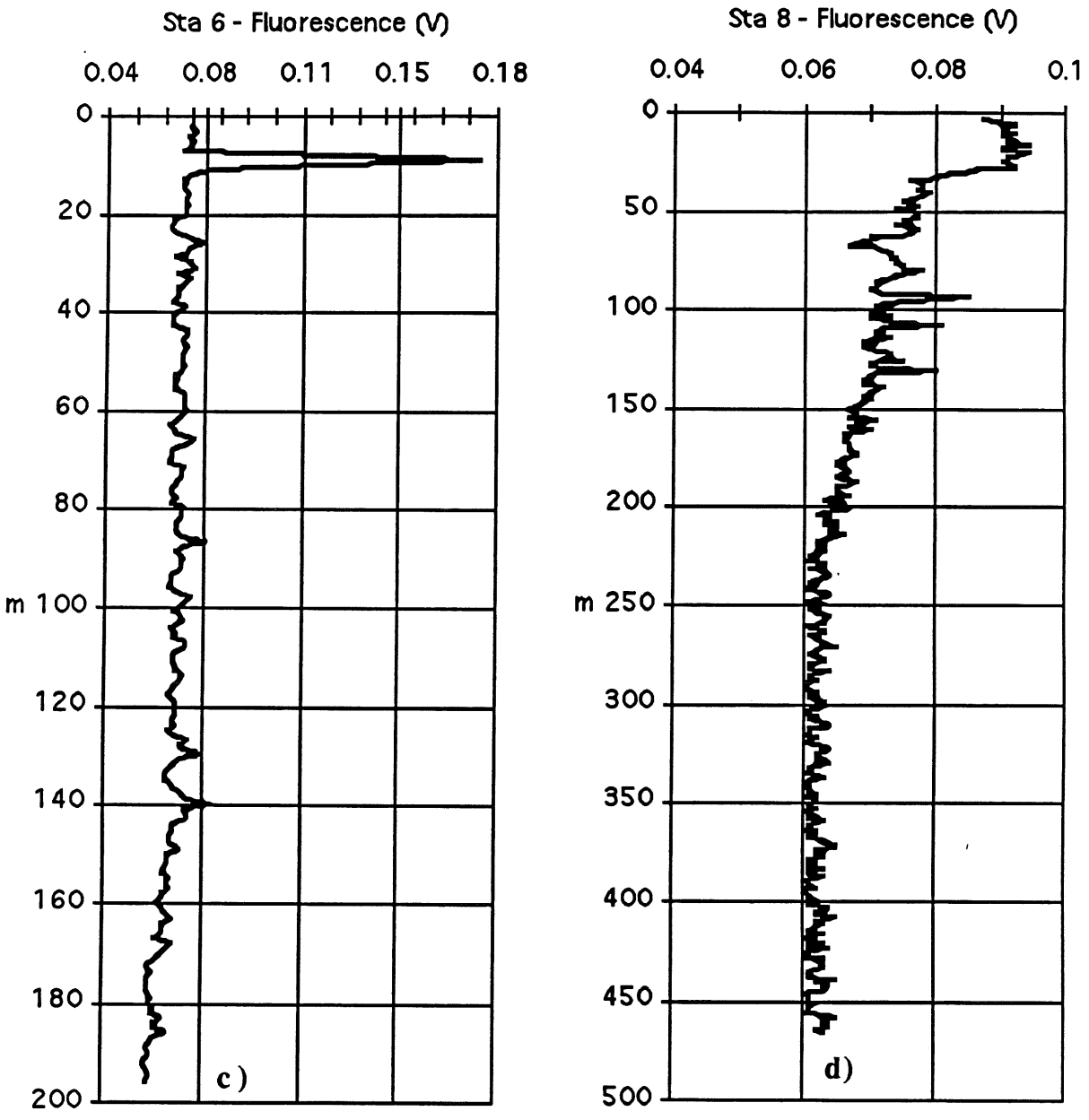

Figure 8 continued.

Fluorescence at the Norwegian Sea station (Station 16, Fig. 8e) was low throughout the water column. These values were the lowest of all stations during this cruise and presumably reflected the extremely low concentrations of chlorophyll in these waters.

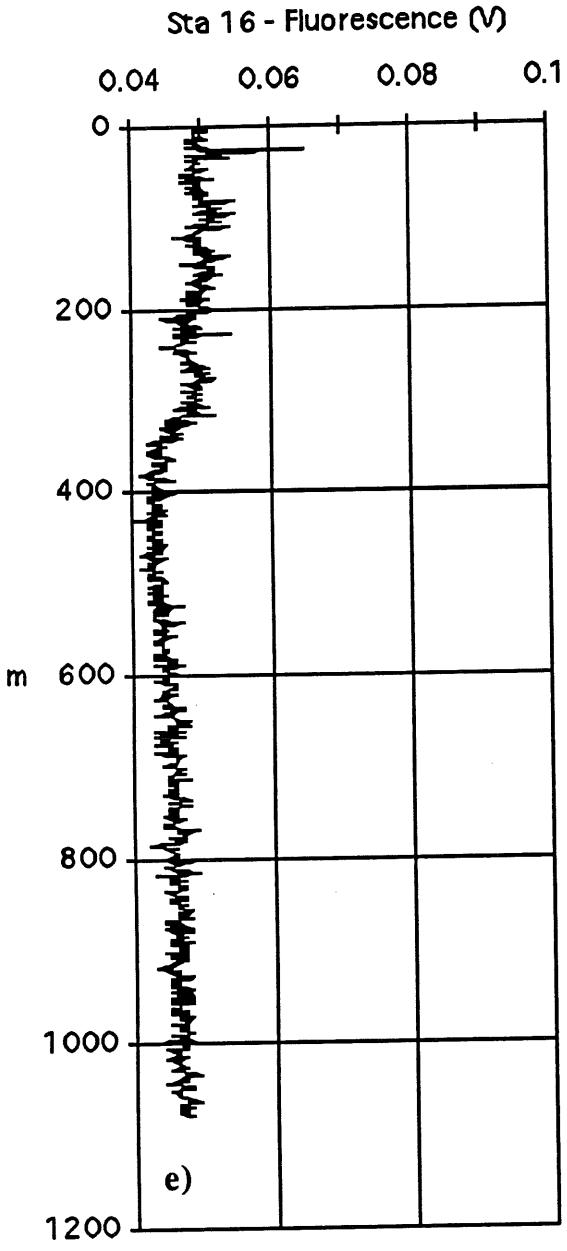

Figure 8 continued.

RESULTS - EXPERIMENTATION

Results from the experiments on metabolic activity are presented in Table 2. It should be noted, however, that these values are only preliminary and expressed as oxygen consumption per individual ($\mu l * individ^{-1} * h^{-1}$). These calculations will later be corrected for average body weight.

Table 2. Preliminary results of metabolic activity for krill and copepods.

Experiment	Sampl. depth (m)	Parall. (#)	Incubation time (h,min) average	#Ind. per bottle average	Oxygen consumption ($\mu l*ind.^{-1}*h^{-1}$) average	min	max
Meganyctiphanes norvegica							
Krill 1	30	5	9,35	2,2	63,26	38,81	112,43
Krill 2	10	5	26,15	4,8	16,39	7,54	20,91
Krill 4	20-0	5	13,56	4,0	57,03	47,30	67,47
Krill 5	20+10	5	13,53	5,8	16,28	7,69	28,55
Thyssanoëssa inermis							
Krill 3	20+10	5	14,05	4,4	19,96	17,06	22,99
Calanus finmarchicus							
Cop. 1 surface	200-0	4	29,16	23,0	0,158	0,058	0,261
deep	400-300	4	27,08	41,8	0,102	0,093	0,119
Cop. 2	190-0	2	18,23	30,0	0,130	0,115	0,145
Cop. 3 surface	100-30	1	14,54	22,0	0,202	no parallels	
deep	450-250	5	13,02	32,2	0,081	0,044	0,117
Cop. 5	100-50	1	12,21	13,0	0,065	no parallels	
Metridia longa							
Cop. 2	190-0	3	18,31	23,0	0,096	0,051	0,142
Cop. 4	335-0	5	12,24	37,2	0,074	0,002	0,137
Cop. 5	100-50	2	12,16	23,0	0,189	0,184	0,194
Pleuromamma robusta							
Cop. 5	100-50	2	12,17	21,0	0,282	0,250	0,315

ASSESSMENT OF EQUIPMENT AND RECOMMENDATIONS

The following is a brief assessment of the performance of equipment used during this cruise. Recommendations for future cruises are presented.

1. *Winches, boom and cable*

A. Inadequacies of the present winch system -- The present array of winches and cable is inadequate to properly sample plankton at depths below about 600 m, e.g. in deep fjords and open-ocean regions of the Norwegian and Greenland Seas. Presently the depth of deployment of the MOCNESS is limited by the length of the wire used to carry the load of deployment. Further, the necessity to connect an additional coaxial cable to the MOCNESS to transmit signals makes the procedure unduly complicated. This cable is liable to entanglement with the net and/or the carrying wire which can result in damage during deployment as well as on deck. Especially the operation of the trawl doors and sharp edges of the ships hull was damaging the cable. It was necessary to repair this cable several times during the cruise, whereby the cable was shortened by about 250 m.

Moreover, with the introduction of the Multinet to routine sampling, it was necessary to install a small, portable CTD winch equipped with approximately 1500m of coaxial cable. Notably, the winch does not have the capacity to carry the MOCNESS. As the same boom must be used to deploy the MOCNESS, Multinet (and Isaac-Kidd, etc.), it is considerably inconvenient, very slow and probably damaging to the cables and connectors to change from one piece of equipment to another. This is especially true as the "strekkavlaster" on the cables must be mounted and removed during each change. This is a major problem.

As we feel that it is of primary importance to be able to sample the deep ocean, to do this efficiently and to protect the cables as well as possible, we strongly recommend the purchase of a large winch outfitted with at least 3500 m of cable to accommodate the MOCNESS, Multinet and possible other pieces of equipment requiring telemetric communication with shipboard units.

B. Performance -- Performance of the winches was generally satisfactory, although they are not designed for the deployment of our equipment at depths of greater than about 400 m (see point 1) However, especially but not only under poor weather

conditions, the following problems were encountered:
- The boom used in running the MOCNESS and Isaac-Kidd trawl apparently cannot withstand the added tension caused by a rocking ship. This problem prevented the deployment of these two pieces of equipment on several occasions.
- The "slipring" on the winch used for the MOCNESS wire as well as the "slipring" on the winch for the trawl-sonde-cable did not operate 100 %. The latter winch was repaired. It is noted that the housing for the "slipring" on this winch is not equipped with a heater to prevent oxidation of parts due to moisture. The "slipring" on the other winch was not repaired during the cruise.

2) The Isaac-Kidd-Trawl proved to be a good surface sampling device for krill which were to be used in experimentation. However, as it cannot be closed during deployment, we could not use it to sample discrete subsurface layers of plankton. We suggest using the MOCNESS fitted with one (or more) net of coarse mesh (≥1000 µm) for sampling subsurface layers of krill. In addition, a large closed cod-end should be constructed for collection of "live samples".

3) The large ring net (fitted with a large cod-end) used for collecting copepods for experimentation was a good device in calm weather. With strong winds and currents, however, it was difficult or impossible to use. Moreover, estimating the actual depth of the net was occasionally difficult. Use of additional weight (a total of ca. 30 to 40 kg) below the net and mounting a Scanmar pinger for detecting depth may resolve this problem.

2. *Laboratory facilities*

The laboratory facilities on board F/F G.O. Sars are in general satisfactory. However, with the increasing interest in performing shipboard experiments with live zooplankton and/or phytoplankton, we feel that a temperature and light regulated room or small laboratory is worth considering.

Permanent storage of formalin in one of the laboratories should not be permitted, as this chemical is damaging both to people and the live animals treated on board the ship. Both the heat cabinet and fridge in one of the laboratories should be replaced as they did not function.

Thomas Noji

Jens Nejstgaard

Tor Knutsen