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HAVFORSKNINGSINSTITUTTET
MILJØ - RESSURS - HAVBRUK

Nordnesparken 2 Postboks 1870 5024 Bergen
Tlf.: 55 23 85 00 Fax: 55 23 85 31

Forskningsstasjonen	Austevoll	Matre
Flødevigen	Havbruksstasjon	Havbruksstasjon
4817 His	5392 Storebø	5198 Matredal
Tlf.: 37 01 05 80	Tlf.: 56 18 03 42	Tlf.: 56 36 60 40
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MICRONEKTON AND PELAGIC FISHES IN FJORDS ON THE NORWEGIAN SKAGERRAK COAST IN WINTER

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Forfatter(e):

Odd Aksel Bergstad, Else Torstensen and Bjørn Bøhle

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Sammendrag:

Resultater fra akustiske sild- og brislingsurvey i februar-mars 1993-95 og detalj-undersøkelser i fjordene ved Kristiansand og Risør i 1995 er benyttet til å beskrive det pelagiske fiske- og mikronektonsamfunnet i fjorder og bukter på Skagerrakkysten om vinteren. Sild og brisling er karakteristiske fiskearter i alle undersøkte områder, forøvrig varierer forekomstene av fisk og mikronekton mellom ulike fjorder, trolig p.g.a. ulike fysiske betingelser som bl.a. har betydning for utveksling av vann og organismer med havet utenfor.

Emneord - norsk:
1. Skagerrakkysten
2. Pelagiske samfunn
3. Sild, brisling, fjorder

Emneord - engelsk:
1. Skagerrak,
2. Coastal fish communities
3. Herring, sprat, micronekton

Odd Aksel Bergstad
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Prosjektleder

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Seksjonsleder

MICRONEKTON AND PELAGIC FISHES IN FJORDS ON THE NORWEGIAN SKAGERRAK COAST IN WINTER

Av

Odd Aksel Bergstad, Else Torstensen and Bjørn Bøhle

SAMMENDRAG

Arbeidet summerer opp resultater fra akustiske sild- og brislingundersøkelser foretatt i februar-mars langs kysten fra Kristiansand til Svenskegrensen i årene 1993-95, og spesielt mer detaljerte undersøkelser utført vinteren 1995 i Kristiansandsfjorden og Nordfjorden ved Risør.

Kristiansandsfjorden, som er relativt åpen og har dyp terskel, hadde et mer artsrikt pelagisk samfunn enn Risørfjorden som har grunn terskel og lavt oksygeninnhold i dypvannet i fjordbassenget. Sild og brisling var karakteristiske arter i begge fjorder som langs Skagerrak-kysten generelt, i Kristiansandsfjorden også dyp-pelagisk. I Kristiansandsfjorden forekom også en rekke torskefisk pelagisk. I Risørfjorden var krill eneste tallrike pelagiske krepsdyr. I Kristiansandsfjorden er også krill dominerende i antall, men dyp-pelagisk var *Pasiphaea* sp. og *Pandalus borealis* tallrike.

Kristiansandsfjorden er, mer enn Risørfjorden, å regne som en dyp havbukt med en pelagisk fauna lik den en finner i havet utenfor. Erfaringene fra sild- og brislingundersøkelsene tyder på at de pelagiske samfunnene observert i Kristiansand og Risør er representative for h.h.v. relativt åpne og lukkede fjorder på Skagerrakkysten. Interaksjoner mellom hav og fjord er trolig av stor, men varierende betydning for sammensetning og dynamikk i dyresamfunnene i disse relativt små fjordene.

ABSTRACT

Information on the species composition, distribution patterns and food-web of micronekton and pelagic fish communities of fjords on the Norwegian Skagerrak coast is assembled based on data from February 1993-1995 herring-sprat surveys and detailed studies in the Kristiansand and Risørfjords in 1995.

Herring *(Clupea harengus)* and sprat *(Sprattus sprattus)* were characteristic species in many fjords, and also in the Kristiansand and Risør fjords. In addition, several gadoid fishes occurred. Euphausiids dominated among the invertebrates, but in the deeper open Kristiansand-fjord, *Pasiphaea* sp. and *Pandalus borealis* were abundant in the deeper layers. The community in the Kristiansandfjord resembled that found in the adjacent Skagerrak deep-water.

It is suggested that ocean-fjord interactions are relativeley pronounced in the rather small fjords along the Norwegian Skagerrak coast, and because advective and migratory exchanges across the sill are supposedly important processes, sill depth is important in determining the dynamics and structure of the pelagic communities.

1. INTRODUCTION

Both short-term investigations and monitoring programmes which focused on fishes on the Norwegian Skagerrak coast primarily concerned demersal species or communities, e.g. cod (Dannevig 1906; Dahl 1906; Ruud 1939; Danielssen 1969; Tveite 1971, 1984, 1992; Hop *et al.* 1992, 1994), fishes in the sublittoral zone (Løversen 1946; Dannevig 1959; Gjøsæter and Danielssen 1990; Gjøsæter *et al.* 1993; Johannessen and Tveite 1989; Johannessen and Sollie 1994) and fishes of the coastal deep-water shrimp grounds (Hjort and Dahl 1900; Stålesen 1963; Lid 1967; Ruud 1968; Hjort and Ruud 1938; Nash 1985). In addition, relatively extensive early studies on pelagic fish eggs and larvae were made (Dannevig 1922, 1940, 1945; Myrberget 1965; Ellingsen 1979), also a few population studies of herring (Danielssen 1969) and sprat (Dannevig 1954; Brunvoll 1979; Torstensen 1992; Torstensen and Gjøsæter 1995). Descriptive pelagic community studies with emphasis on hydrography, phyto- and zooplankton were conducted in the Oslofjord (Wiborg 1940; Ruud 1968; Beyer 1968; Dahl *et al.* 1974, 1976, 1979a,b), the Langesund area (Molvær *et al.* 1979; Dahl *et al.* 1983) and the Kristiansandfjord (e.g. Molvær 1986). Overall, however, very little information is available on pelagic fishes, even less on the pelagic communities as such. This contrasts with the extensive community and ecosystem studies made in several of the fjords of western and northern Norway (e.g. Matthews and Heimdal 1980; Hopkins *et al.* 1989; Aksnes *et al.* 1989; Giske *et al.* 1990; Balino and Aksnes 1993; Kaartvedt and Svendsen 1995).

In an attempt to begin filling this gap this paper presents results of recent studies on the occurrence, distribution patterns and food-web relations of the micronekton and fish in fjords and bays of the Norwegian Skagerrak coast. The study was motivated by the need for a greater understanding of structure of the fjord and bay communities and their relation to the open Skagerrak communities. Enhanced knowledge on community structure is needed as basis of both process studies and for applied research such as fish surveys and pollution monitoring programmes.

The fjords on the Norwegian Skagerrak coast are relatively small, short and shallow. Some have wide and deep openings and are more or less continuously flushed by coastal water and Norwegian Deep Water. Others have shallow sills and narrow connections with the open sea and show a more classical fjordic circulation and hydrography (e.g. Strøm 1936; Dannevig 1940; Gade 1968; Aure and Danielssen 1993). The deep-water of many of the fjords is intermittently or permanently hypoxic or anoxic (e.g. Strøm 1936; Bøhle 1989, 1990). In contrast with the fjords of western and northern Norway, the Skagerrak fjords have openings facing south- or southeastwards and higher summer surface temperatures and lower winter temperatures. Most inner parts of the fjords have ice-cover in winter.

In 1991 Bøhle initiated extensive studies of euphausiids both in coastal waters and the open sea (Bøhle and Moksness 1991), and since 1993 annual acoustic surveys of coastal herring and sprat were conducted in February-March by the Institute of Marine Research along the coast from about Kristiansand to the Swedish border. The present paper is based on two sources of information, i.e. the coastal acoustic surveys and some detailed studies of two fjords, the Kristiansand and Risør fjords carried out in February 1995.

2. MATERIAL AND METHODS

2.1 Acoustic surveys in the winters 1993-95

The surveys were conducted in the periods 3-12 February 1993, 7-26 February 1994 and 13 February - 2 March 1995, with the R/V "G.M.Dannevig". The target species were herring and sprat.

Fjords and coastal grounds east of Kristiansand (Fig. 1) were surveyed, in 1994 also some fjords further west. Information from fishermen on the location of traditional winter herring grounds was used as background when defining the survey track. In 1993, the sampling of the inner Oslofjord and most of the eastern coastal areas, was restricted due to fog and in 1994 and 1995 several fjord areas were inaccessible due to extensive ice-cover (i.e. in 1994 Bonnefjord, Holmestrandfjord, Fossingfjord, the inner fjords near Risør and Kragerø, and the inner parts of Langangsfjord, Eidangerfjord and Lyngdalsfjord; in 1995 the inner parts of Topdalsfjord (Kristiansand), the inner fjord areas near Kragerø, Tønsbergfjord and Bonnefjord near Oslo).

In winter, both herring and sprat tend to occur as schools by day and scattering layers by night. Therefore, most of the surveying was conducted during the dark period of the day. The Simrad Echo Sounder System EK500, with settings and accessories given in Table 1, was used for mapping of fish distribution and to estimate abundance.

Table 1. Echo sounder (Simrad EK500) data and settings.

Frequency	38 KHz
Transducer type	ES 38b
Pulse duration	1.0 ms
Bandwidth	3.8 KHz
TVG	20 log R
2-way beam angle	-21.0 dB

Integrator values (S_a) per 0.5 or 1.0 nm were allocated to the following groups; herring, sprat, plankton and demersal fish (i.e gadoids in mid-water). The allocation of integrator values was based on the species composition in trawl catches considered representative for mixed fish recordings and visual inspection of the recordings on the echogram. Herring often occurred in well-defined schools of a characteristic shape and could be recognised rather consistently on the echogram.

The S_a values were plottet along the survey track, and the arithmetic mean calculated for geographical sub-areas as basis for estimating the abundance in each sub-area. For both herring and sprat the following target strength (TS) vs. fish length (TL) function was applied to convert the S_a-values to number of fish (N) in a selected area (A) (Anon. 1982):

$$TS = 20 \text{ Log } TL-71.2 \text{ dB}$$

and

$$N= ((S_a/4^1)10-0.10TS)A$$

A modified Harstad trawl (8 x 8 fathoms opening) with a 11 mm mesh size liner in the cod end was used for identification of echo traces and for sampling the scattering layers. The fishing depth of the trawl was adjusted according to readings from a SCANMAR depth sensor except when trawling at the surface. The trawl was towed on two warps using four trawl doors and trawling speed was 1.8-2.3 knots.

For each trawl haul, overall total weight of the catch and total weight and number of each species were recorded. Samples of individual fish were examined for length and weight. Otoliths were collected for age determinaton of herring and sprat. For herring fat content, sex, stage of maturity and number of vertebrae were recorded according to Fotland *et al.* (1995).

Routinely, stomach contents were sorted and the frequency of occurrence of different prey in non-empty stomachs recorded.

2.2 Studies in the Kristiansand and Risør fjords 1995

In 1995 two fjords were selected for detailed studies using acoustics, pelagic trawl and micronecton samplers. The procedures applied for acoustics and pelagfic trawling were as decribed above. Micronecton was sampled by a Modified Isaacs-Kidd's Midwater Trawl (MIK-net) (Munk 1993) which is a 10 m long net with 1.6 mm mesh size, fastened to a 2 m diameter steel ring hinged diametrically with two 5 m long sweeps forward to the towing wire. At the end of the net was a bucket with 500 µm mesh size net. The MIK-net, which has no closing mechanism, was equipped with a flow meter in the center of the ring and a SCANMAR depth sensor. The MIK-net was towed for 20 min. at desired depth at a speed of 3 knots.

Large jellyfish were sorted from the catch before the remaining organisms were divided repeatedly in a splitting box until a suitable subsample was achieved. One subsample was sorted out for later examination of the euphausiids and conserved in 4 % neutralized formol. In the laboratory the sample was sorted to species and all individuals were measured to the nearest mm (total length, i.e. from the eye-front to telson (Boysen and Buchholz 1984)).

The activities in the two fjords included the following:

2.2.1 Kristiansandfjord (13-17 February 1995)

1. *Hydrographical transects with CTD and water samples for O_2 analysis at standard depth.* The Topdalsfjord was covered by ice during the first part of the survey. The two inner stations were therefore worked 5 days later than the other.

2. *Depth-stratified day and night fishing with the pelagic trawl.* To describe the abundance of fish in the water column, trawling at a fixed station at different depths was performed. The fishing depth were 10, 50 and 150 m, and towing time was 45 min. The echo depth in the area was 180-240 m. In total, 7 hauls were taken, 4 in daytime and 3 at night.

3. *Acoustic day and night surveys.* The entire fjord except the inner areas covered by ice were surveyed in the morning and a few hours after dusk on 14 February. Integrator data were recorded per 0.5 nm, and the procedures were the same as used during the coastal survey described above.

4. *Depth-stratified day and night sampling with a Modified Isaacs-Kidd's Midwater Trawl (MIK).* A total of 7 hauls were made in the same area as worked during the midwater trawling. Sampling depths were 10, 50, 75 and 150 m. Towing time at the pre-determined depth was 20 min. One of the hauls was considered unsuccessful and not included in the analysis.

5. *Gill-net fishing for herring.* In the inner fjord, midwater trawling was impossible due to the topographical conditions and gill-nets were set to catch herring. A chain of 3 square-meshed nets (lenght of mesh side 27 mm) were set 5 m off the bottom at a depth of 30 m. The nets were set in the afternoon and hauled the following morning (soaking time approx. 12 hours).

2.2.2 Risør (20-21 February 1995)

The work at Risør was concentrated in the Nordfjord (outer Søndeledfjord), here denoted Risørfjord.

1. *Hydrographical transects with CTD and water samples for O_2 analysis at standard depths.*

2. *Acoustic day and night surveys.* The fjord was surveyed in the morning and at night following the same procedures as decribed previously.

3. *Pelagic trawling and MIK-sampling.* Pelagic trawling was only possible in the outer central basin of the Nordfjord and only 4 tows were made, two by day and 2 at night. MIK-samples were collected in the same outer basin. Day and night samples were obtained from

10, 50 and 75 m according to the procedures described above. The greatest observed depth at the site was 183 m.

3. RESULTS

3.1 The pelagic community in the Kristiansandfjord

The depth profile and hydrographical conditions of the Kristiansandsfjord are shown in Fig 2. A thin surface layer of cold brackish water was found in the inner fjord. The warmest water (7-7.5°C) occurred in an intermediate layer in the inner fjord, in deeper layers the watermass was homogeneous and had the same temperature and salinity as the deep-water in the Norwegian Deep outside the fjord (St. 17). All parts of the fjord were well oxygenated.

In daytime, dense but not very large herring (*Clupea harengus*) schools were observed in deeper parts of the rather narrow sounds of the outer fjord (Fig 3a,b). The innermost part of the fjord (named the Topdalsfjord) was not surveyed due to ice-cover. In the night, the herring appeared to rise and disperse but were only abundant in the mouth of the inner fjord (Fig. 3a, b). In the inner area, gill-net catches of 23 - 33 cm TL herring aged 2-6 years were made (Fig. 4). The mature fish had mostly ripening gonads, none were spent. Pelagic trawling in different depth layers of the outer fjord (Table 2, Fig. 5) showed that also small herring (Fig. 4) occurred in the fjord but were scattered over wider areas and depth ranges than the larger fish. The nighttime abundance estimate based on the acoustic survey was 106 tonnes.

Sprat (*Sprattus sprattus*) occurred in the pelagic trawl and was most abundant in the 150 m trawls both during the day and night (Fig. 5). No near-surface schools identified as sprat were recorded during the acoustic survey. The sprat caught by trawl were mostly I-group of 7-10 cm TL.

The species composition in the overall very small pelagic trawl catches from the outer fjord showed that the number of species was twice as high in the 150 m as in the near-surface trawls (Fig. 6). Whiting (*Merlangius merlangus*) was a characteristic species at all depths, and in the deep-water juvenile hake (*Merluccius merluccius*) was relatively abundant. For the larger and presumably most mobile species (e.g. whiting, hake, haddock (*Melanogrammus aeglefinus*)), nighttime catches appeared to be higher than daytime catches. There were no indications of pronounced day-night differences in depth distribution. Exceptions are the hake which occurred in the 50 m hauls in the night but only in the 150 m trawls during the day, and perhaps the small herring which appeared to be more abundant in the shallower hauls during the day (Fig. 5).

The fish catch was generally only a small fraction of the total catch in terms of weight (Fig. 7) and even more so by numbers. Crustaceans such as shrimps and euphausiids dominated the catches, and there were pronounced changes by depth in the species composition of the invertebrate catch. In the 10 and 50 m trawls, euphausiids were most abundant, and much more abundant in the night than the day hauls (Fig. 8). A characteristic species in the surface layer was *Pleurobrachia pileus,* and a few cephalopods occurred at all depths. In the 150 m catches *Pasiphaea* sp. and *Pandalus borealis* were the abundant species in addition to the euphausiids. Both were more abundant and occurred in shallower hauls by night than by day.

Euphausiids and *Pasiphaea* sp. dominated the catches in the MIK net (Fig. 9), the latter particularly at 150 m depth. The catch of euphausiids was much higher by night than by day, probably due to net avoidance during the day. Mysids occurred in the deepest tows and *Pleurobrachia pileus* was a characteristic species at many depths. The catch also contained some small fish, primarily the gobid *Aphia minuta*.

Four species of euphausiids occurred (Fig. 10) and *Thysanoessa inermis* and *Meganyctiphanes norvegica* were the prominent species in terms of numbers and biomass. Both were most abundant in the night catches from the upper 50 m of the water column.

The stomach contents of the fish species were examined and the frequency of occurrence of different prey recorded. The rather large herring which occurred in the inner fjord had eaten fish (probably mainly gobids) and euphausiids (Fig. 11) while the small herring in the outer fjord had eaten euphausiids (%Frequency of occurrence=42, number examined=36, number with contents=24) and fish (probably gobids, %F=54). Other fishes in the outer fjord, i.e. whiting, hake, Norway pout (*Trisopterus esmarki*) and horse mackerel (*Trachurus trachurus)* had typically consumed euphausiids, but many stomachs were empty. The few haddock caught had more diverse stomach contents, i.e. polychaets, bivalves, gobids and euphausiids.

3.2 The pelagic community in the Risørfjord

The depth profile, i.e. along the series of CTD stations, and hydrographical profiles are shown in Fig. 12. The sill depth is about 40 m. Dissolved oxygen was measured at Stns. 28, 32, 33 and 38 and showed that the major deep-water basin of the fjord, where all the community studies were made, had low oxygen content (< 2.0 ml/l) deeper than about 75 m. The salinity in the deep-water was similar to that in the water at corresponding depth outside the fjord, the temperature slightly lower (Stn. 28).

Echograms from the acoustic day and night survey showed that scatterers were restricted to the water column shallower than the poorly oxygenated deep-water, i.e. shallower than 75 m. In daytime, a major herring school was found near the mouth of the fjord and only minor schools elsewhere. In darkness, this school dispersed in the upper 30 m of the water column over large parts of the deepest basin (Fig 13). The herring caught by pelagic trawl from this major school were immature or ripening adults in the size-range 22-35 cm TL. The age distribution is given in Fig. 14. The abundance estimate for the entire fjord was 90 tonnes.

No catches of small herring were made. Sprat was relatively abundant (Fig. 15) and occurred in the upper 75 m only. The catches were dominated by I-group fish of TL 7-10 cm, and the acoustic abundance estimate was 43 tonnes.

Only scattered catches of other fishes occurred in the pelagic trawl (Table 3). The species were cod, saithe and whiting. Euphausiids were abundant, particularly in the night haul at 20 m.

In the MIK net, euphausiids dominated the catches at all depths (Fig. 16) except in the upper 50 m during the day. The night catches were much higher than the day catches. Euphausiids were also caught in the tows at depths below 75 m, hence they appeared to also occur in the poorly oxygenated water. Among the euphausiids *Meganyctiphanes norvegica* was the most abundant species (Fig. 17). In the surface layer, *Pleurobrachia pileus* was abundant.

The herring in the Risør fjord had mostly empty stomachs, and the few stomachs with prey contained euphausiids (Fig. 11). All the whiting had eaten euphausiids, some also sprat and unidentified fish (Fig. 11). The two saithe (*Pollachius virens*) and the single cod (*Gadus morhua*) caught had eaten sprat.

3.3 Herring and sprat and other fishes in the survey area Kristiansand-Oslofjord

Detailed results from the 1993-1995 acoustic surveys has been presented previously as cruise reports. Here, selected distribution maps for 1995 are presented as examples as they represent the most complete coverage of the areas (Fig. 18-20).

3.3.1 Herring

Kragerø area

Herring occurred every year in the Kragerø fjords (Fig. 1, 18), and the highest concentrations were observed in the outer part of the fjords. Characteristic schools were observed close to the bottom during daytime and as scattering layers in the upper 25 m at night.

In the Fossingfjord, to the northeast of Kragerø, schools of herring were distributed at 40-60 m depth in daytime. At night, the herring schools ascended to the upper 15-20 m layer and dispersed to form a scattering layer together with sprat.

Langesund area

Herring was mainly distributed in and near the narrow sounds between the open Langesund Bay and the inner fjord areas (Fig. 19), but were also observed on the grounds to the south and southwest of Langesund.

Oslofjord

The entire Oslofjord was surveyed all years except in 1993 when the sampling was restricted to southern areas due to fog. Herring was found in the same areas in all three years (Fig. 20); typically south and west of Horten, south of Tønsberg and at the entrance to the Larviksfjord. These locations are all considered traditional herring spawning grounds. In 1995, herring was also abundant in the inner Oslofjord. Also in these areas the herring formed layers at 5-20 m depth at night, and dense schools near or close to the bottom during the day.

The estimated abundances of herring in weight and numbers, are presented in Table 4. By no means all fjords and bays were surveyed, and the sum of the local estimates should not be used as estimates of the total abundance in the region.

Table 4. Herring. Abundance estimates by numbers (10^6) and weight (tonnes), February 1993-1995.

Area	1993 Biomass (tonnes)	1994 Numbers (mill.)	1994 Biomass (tonnes)	1995 Numbers (mill.)	1995 Biomass (tonnes)
Inner Oslofj.	- 1)	22.9	1035	38.8	1990
Outer Oslofj.	3807	138.0	7385	62.0	5718
Langesund	1462	3.0	350	17.3	346
Kragerø	223	- 1)	-	1.9	379

1) Not surveyed

3.3.2 Sprat

Kragerø area

In the Kragerø area, sprat was observed every year in the inner, more enclosed fjord areas (Fig. 18). Also in the Fossingfjord, northeast of Kragerø, sprat was abundant. During the day, sprat occurred in a layer of small schools at 45-55 m depth, rising to the surface at dusk.

Langesund area

Sprat was mainly observed in the innermost fjords; the Frierfjord and Eidangerfjord (Fig. 19). In 1995, sprat was also distributed on the grounds in the inner part of the open Langesund Bay where it occurred dispersed in the upper 20 m at night. In the Frierfjord, sprat occurred in small schools at 50-60 metres depth during the day.

Oslofjord

Sprat was distributed in the southwestern part of the Oslofjord during the three surveys, in the Larviksfjord, Sandefjord and south of Tønsberg. In general, sprat occurred in small schools at 40-60 m depth in daytime, and in the upper 20 m at night.

In 1994 and 1995 in the inner Oslofjord, high concentrations of sprat were observed in northeastern areas. Sprat was also observed near Holmestrand and Horten (in Breidangen); in 1995 also along the east coast at about 60 m depth during the day.

The estimated abundances of sprat in weight and number are presented in Table 5. Again, the sum of the estimates across sub-areas does not represent a total regional estimate.

Table 5. Sprat. Abundance estimates by numbers (millions) and weight (tonnes), in February 1993-1995.

Area	1993 Biomass (tonnes)	1994 Numbers (mill.)	1994 Biomass (tonnes)	1995 Numbers (mill.)	1995 Biomass (tonnes)
Inner Oslofj.	- 1)	3.0	30	34.3	350
Oouter Oslofj.	141	68.3	623	82.5	628
Langesund	78	6.4	57	32.8	144
Kragerø	74	- 1)	-	8.5	88

1) Not surveyed

3.3.4 Other fishes

1993-1995 pelagic trawl catches of fishes and euphausiids in and outside the sub-areas considered above are given in Table 6. Most of the catches were aimed at echo recordings of herring and sprat which typically occured in all the fjords. Sixteen fish species were represented in the catches, but many were sporadic. The characteristic by-catch species which occurred in most fjords were whiting, cod, and Norway pout. Stomach contents were recorded for most species, and data for the more abundant species are summarised in Fig. 11.

4. DISCUSSION

The 1993-1995 winter surveys of the fjords and bays of the Norwegian Skagerrak coast have confirmed the assumed widespread occurrence of herring and sprat. In all three years the highest abundance of both species was found in the northeastern areas. Observed recordings were frequently difficult to sample because the topographical conditions made trawling difficult or impossible. The topographical constraints and ice cover also restricted the survey area, and the abundance estimates are not total estimates for the entire coast, only rough estimates for the sub-areas actually surveyed.

Herring was observed at many locations pointed to by senior fishermen as traditional spawning grounds but also elsewhere, particularly in the narrow sounds near the open coast. During the day herring was observed both as characteristic schools close to the bottom and in small schools mixed with sprat at different depths in the water column. The major schools showed a classical diurnal vertical migration and concentration-dispersal cycle. The herring was wintering or maturing and probably belongs to local groups of spring-spawners which were studied in detail in Langesund by Danielssen (1969). Spring-spawners spawn at many locations scattered along the Norwegian and Swedish Skagerrak coasts but are not abundant compared with other herring groups occurring in the Skagerrak-Kattegat (Bakken *et al.* 1991).

The sprat was characteristically found in inner fjord areas and enclosed waters where it seemed to be the numerically dominant fish species. In general, 90-100% of the catches were I-group sprat, and only scattered older individuals occurred. It is assumed that the stocks are primarily sustained by annual advective influx of eggs and larvae, but to some extent supplemented by local reproduction (Dannevig 1954; Ellingsen 1979).

The survey and the pelagic trawling in many areas showed that herring and sprat are abundant members of the pelagic winter communities in the fjords and bays. This was also the case in the Kristiansand and Risør fjords which were studied in somewhat greater detail in 1995. The impressions gained from those areas are summarised diagramatically in Fig. 21 and 22. The Kristiansandfjord had a pelagic fish and micronekton community with many more species than the Risør fjord. In both fjords, the fish catches were rather small compared with the catch of invertebrates, especially euphausiids. In Risør, the euphausiids and *Pleurobrachia pileus* were the only abundant invertebrates, whereas in Kristiansand other groups, such as decapod shrimps, were also abundant.

The most obvious topographical difference between the two fjords is the sill depth which is considerably deeper in Kristiansand than in Risør. The Risør fjord is more enclosed and the hypoxic conditions observed below 75 m depth shows that deep-water exchange is restricted or intermittent. Fish will probably not penetrate the poorly oxygenated water and be restricted to the upper layers as was also observed on the echograms. In Kristiansand the entire deep-water basin appeared well oxygenated and the physical conditions were similar to those observed in the Norwegian Deep outside the fjord. The topographical and hydrographical conditions would therefore seem to favour exchange of organisms across the sill to a greater extent in Kristiansand than in Risør. This is probably also what is reflected in the differences in the species composition of the pelagic communities in the two fjords. In Kristiansand a pelagic fish and invertebrate assemblage resembling that found at similar depth in the Norwegian Deep (Bergstad 1991) was found. In Risør only the epipelagic herring, sprat and a few gadoids occurred and were restricted to the upper layers of the water column.

Euphausiids were abundant in both fjords but the species composition was different. In Risør *Meganyctiphanes norvegica* dominated greatly, while *Thysanoëssa inermis* was the most abundant species in Kristiansand. It is not known whether the two species reproduce in the fjords to the extent that local populations are sustained. In the Kristiansandfjord, the sill is so deep that the euphausiids may probably be transported relatively freely in and out of the fjord and the existence of local fjord populations seems unlikely. The apparent penetration of the generally oceanic *M. norvegica* into the poorly oxygenated layers in Risør was surprising. Given that the MIK net has no closing mechanism, it cannot be ruled out that the euphausiids were actually caught above the low-oxygen layers during hauling.

The euphausiids seemed very important in the food-web of the fjords studied, and are probably prominent winter prey for several fish species, including the herring, yet in some areas small fish were the most common prey. To the more abundant pelagic gadoids such as whiting and Norway pout, euphausiids was the most common prey and also deep-water species which were sometimes abundant, e.g. hake in the Kristiansandfjord, had eaten euphausiids. The food of the sprat was not observed systematically, but the work of Brunvoll (1979) from the Oslofjord showed that copepods and *Oikopleura* sp. were typical winter prey. The large cod and saithe are piscivorous and had eaten sprat and small herring.

The results gathered from Kristiansand and Risør show that sampling of different depth zones and times of day are essential to obtain data on structure and dynamics. There is a pronounced vertical and temporal variation in species composition and distribution. Using micronekton and plankton samplers with opening-closing devices would be beneficial in further studies.

Based on observations from the surveys and the detailed studies in 1995, we believe that the results from Kristiansand and Risør are relatively representative for the winter conditions of many fjords and bays of the Skagerrak coast. As demonstrated for the Kristiansand and Risør fjords, the community structure may differ between fjords, and we suggest that the physical conditions are the most important in structuring the communities in the fjords on the Norwegian Skagerrak coast as in the west-Norwegian fjords (Matthews and Heimdal 1980; Aksnes *et al.* 1989; Balino and Aksnes 1993).We hypothesise that exchange of organisms by migration and advection with the open sea must be relatively strong in these rather small fjords. The relative significance of such exchanges may depend on topography and circulation patterns which are to a large extent governed by sill depth (Strøm 1936; Gade 1968; Aure and Danielssen 1993). Temporal patterns in the advective and migratory exchange across the sills may influence what species composition will be sustained in different fjords. Further studies of seasonal changes in the fjord communities, well supported by hydrographical observations and current measurements, are required to test these hypotheses.

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Table 2. Pelagic trawl catches (kg/45 min tow) from the Kristiansandfjord, February 1995

Station Number	5	8	4	1 (13.2.)	7	2	3	6
Depth, time	10m day	10m night	40m day	50m day	50m night	150m day	150m day	150m night
Argentina silus					0.015	0.01	0.00	
Müller´s pearlside						0.01	0.00	0.01
Herring	0.11	0.06	0.36	0.834	0.032	0.025	0.068	0.28
Sprat	0.11	0.07	0.015		0.25	1.11	0.836	1.3
Whiting	0.2	0.85			0.04	0.48	0,00	1.346
Haddock					0.432			0.994
Norway pout		0.01			0.045	0.095	0.022	0.03
Silvery pout							0.002	
Hake					0.1	0.5	0.362	0.674
Aphia minuta			0.005			0.005	0.005	
Pomatoschistus minutus		0.005						
Trachurus trachurus						0.00	0.132	0.07
Limanda limanda					0.005			0.108
Pleurobrachia	5.87	0.553	1.01		0.255	0.228	0.38	
Euphausids		20.94	0.02	6.50	4.386	0.02	0.38	4.95
Pasiphaea sp.		0.553			0.255	1.38	3.04	4.95
Pandalus borealis			0.01		0.204	0.34	0.67	1.10
Cephalopods		0.01	0.01		0.024	0.02	0.03	0.01

Table 3. Pelagic trawl catches (kg/45 min tow) from the Risørfjord, February 1995

Station Number	17	18	19	20
Depth, time	50m day	75m day	20m night	75m day
Herring	0.60	0.06	1.15	280.00
Sprat	47.00	2.21	0.84	
Cod		0.88		
Saithe		2.40		
Whiting			0.76	1.60
Euphausids		6.77	47.59	

Table 6. Pelagic trawl catches (kg/tow) from fjords and bays of the Norwegian Skagerrak coast 1993 - 1995.

Year	**Station Number**	**Location**	**Depth (m)**	**Fishing depth (m)**	**Tow duration (min)**	Müller´s pearlside	Herring	Sprat	Salmon	Mackerel	Cod	Haddock	Saithe	Whiting
1993	52	Kilsfjord	85	60	15		0.10	60.00			1.20		3.70	6.00
1993	53	Kragerøfjord	130	27	10		23.66	2.60			9.00			1.50
1993	54	Stavern	50	10 - 40	30		60.00	20.00						
1993	56	Frierfjord	90	60	20			14.00					16.50	15.50
1994	14	Inner Oslofjord	60	20	14		.32	.04						1.19
1994	15	Outer Oslofjord	150	0-15	30	0.002	0.01							0.10
1994	16	Outer Oslofjord	50	0-10	30			0.01						
1994	17	Hvaler	135	70-80	25	0.03	0.31	0.13			5.00			0.72
1994	18	Tjøme	34	16	10	0.005	23.40	6.55			18.00	0.53		0.81
1994	19	Sandefjord	55	18-28	30	0.004	2.30	3.50						1.60
1994	20	Larviksfjord	80	18-33	20		0.60	0.06						2.60
1994	21	Eidangerfjord	100	15-30	28	0.04	10.53					0.43	0.54	1.02
1994	22	Topdalsfjord	39	25-30	15		87.00	0.16					5.50	
1994	23	Ny Hellesund	100	45	15			0.02						
1995	29	Fossingfjord	88	25-50	24		13.30	6.26			0.88			1.34
1995	30	Kragerøfjord	130	10	23		342.00				9.96			
1995	31	Langesund bay	30	10	30		4.54	15.09			31.7			3.45
1995	32	Frierfjord	90	57	20		0.18	6.04						1.77
1995	33	Larviksfjord	100	10	34		45.57	4.74			1.57			5.73
1995	34	Tønsbergfjord	54	0	46		37.73	02.28						
1995	35	Singlefjord	84	4	58		0.59	0.45						
1995	36	Outer Oslofjord	70	10	22		198.09	7.18			4.67			1.58
1995	37	Outer Oslofjord	140	50-55	30		0.37	77.43						
1995	38	Inner Oslofjord	60	10	25		44.00	16.10	5.90		20.82			0.70
1995	39	Holmestrand	67	10	30		2.00	1.89		0.44				3.52

Continued on next page

Table 6. Continued

Year	Station Number	Location	Pollack	Norway pout	Blue whiting	Hake	Lumpfish	Grey gurnard	*Syngnathus acus*	3-spined stickleback	Dab	Flounder	Euphausids
1993	52	Kilsfjord											
1993	53	Kragerøfjord											
1993	54	Stavern											
1993	56	Frierfjord		0.13									
1994	14	Inner Oslofjord											1.80
1994	15	Outer Oslofjord										0.346	8.20
1994	16	Outer Oslofjord											
1994	17	Hvaler		0.05									0.30
1994	18	Tjøme		0.15		0.43						0.19	
1994	19	Sandefjord		0.05		0.01							
1994	20	Larviksfjord		0.27									10.22
1994	21	Eidangerfjord		0.39	1.06								4.00
1994	22	Topdalsfjord	0.90										
1994	23	Ny Hellesund											
1995	29	Fossingfjord											
1995	30	Kragerøfjord											
1995	31	Langesund bay	0.21	0.04			1.76	0.25	0.002		0.35	0.26	
1995	32	Frierfjord											
1995	33	Larviksfjord		0.18								0.48	
1995	34	Tønsbergfjord											
1995	35	Singlefjord								25.81			
1995	36	Outer Oslofjord				0.02							
1995	37	Outer Oslofjord											
1995	38	Inner Oslofjord										0.26	
1995	39	Holmestrand		1.96									

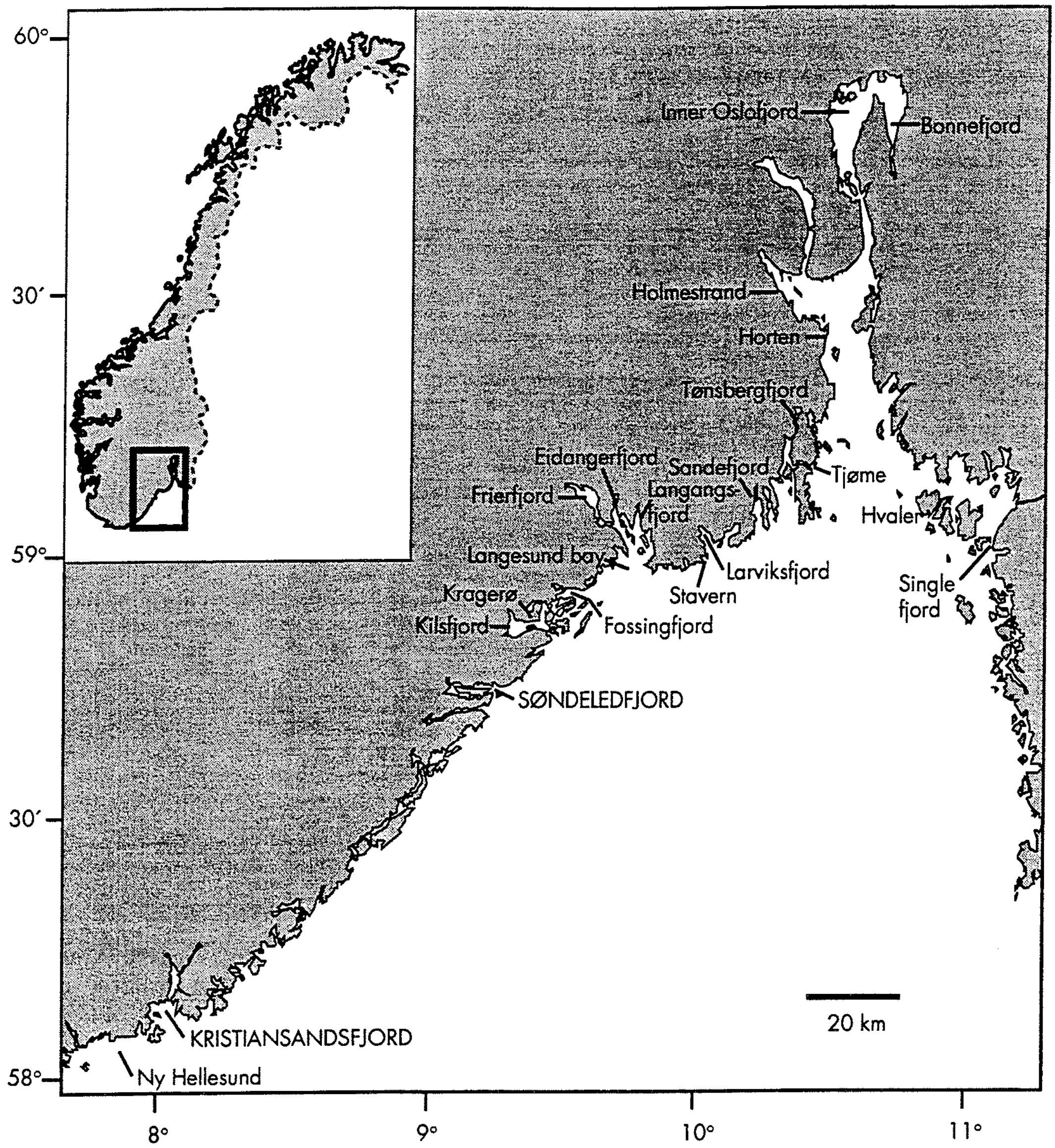


Fig. 1. The Norwegian Skagerrak coast and the fjords and bays studied.

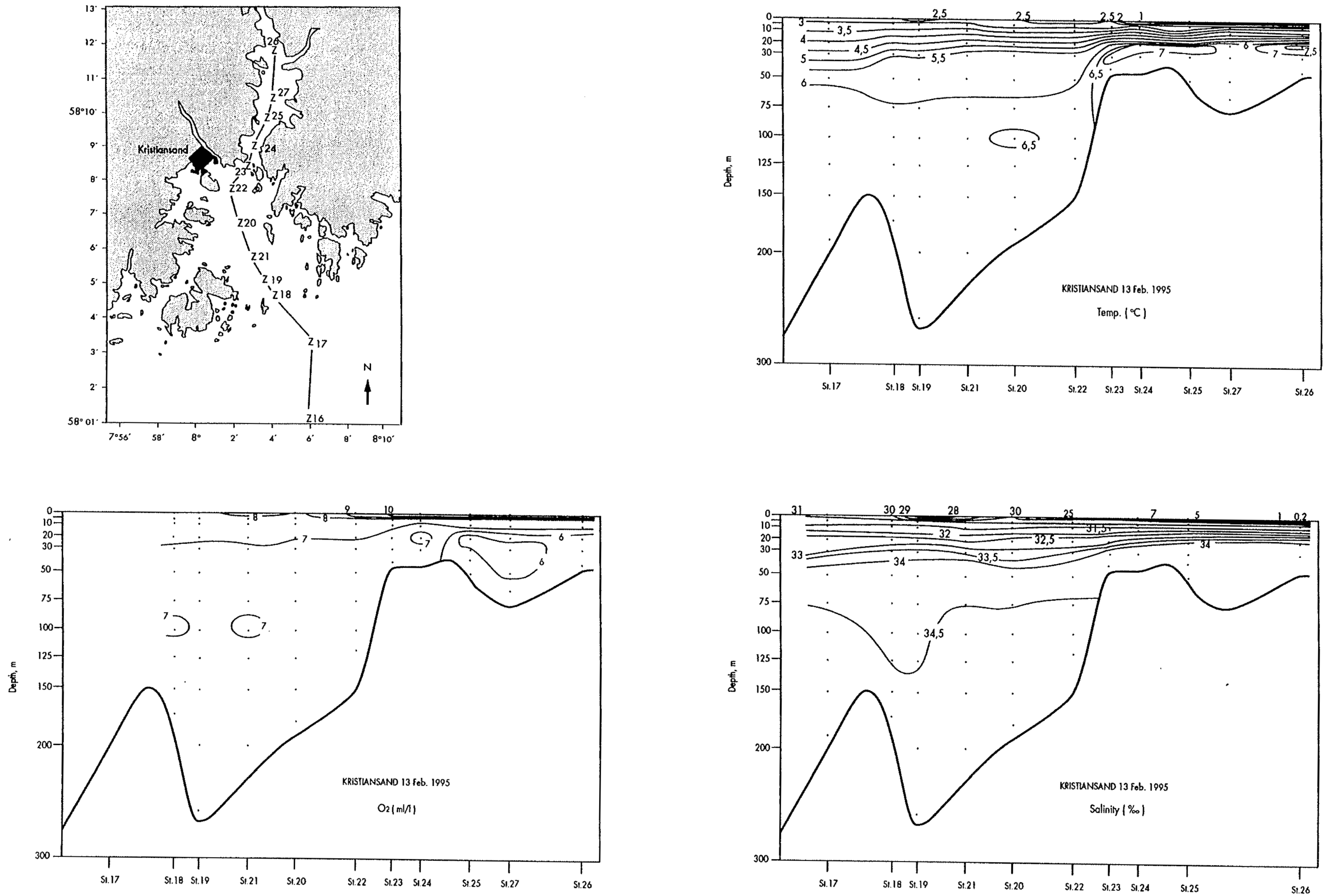


Fig. 2, CTD stations and hydrographic observations from Kristiansandsfjord

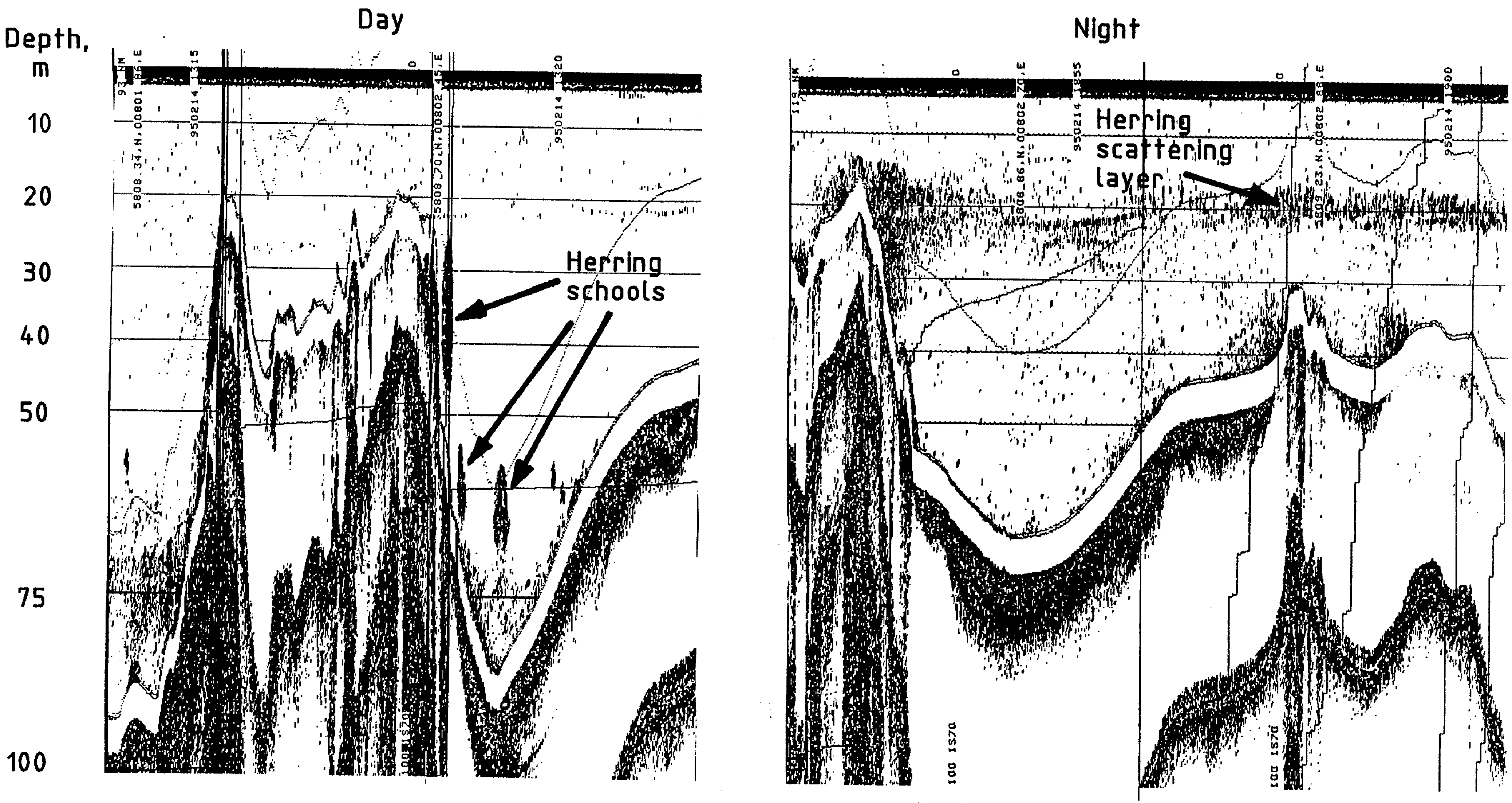
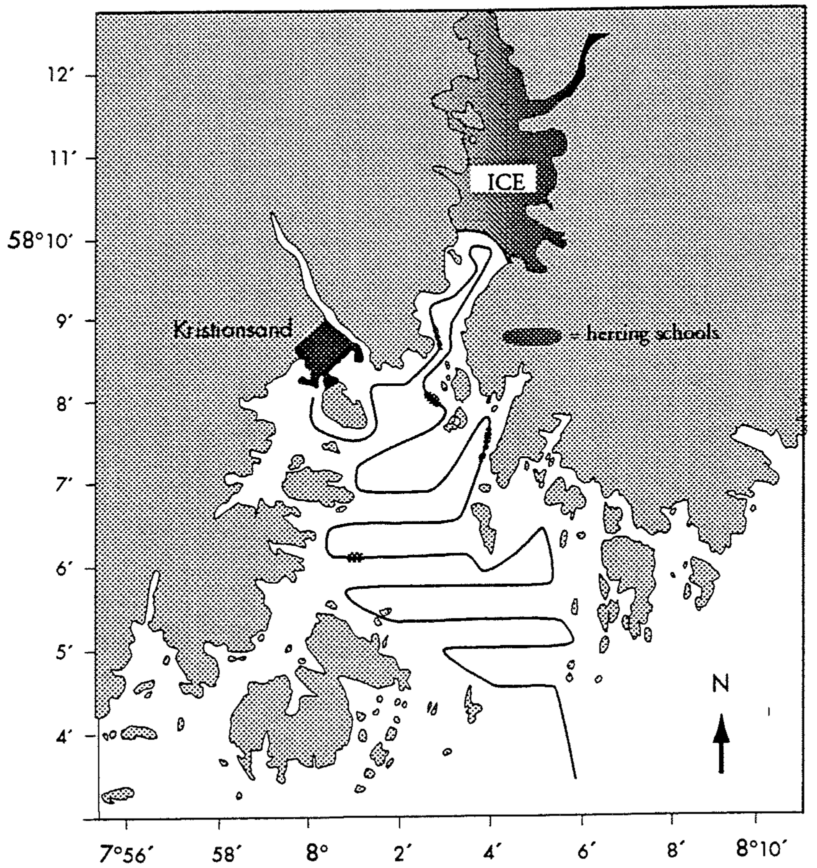
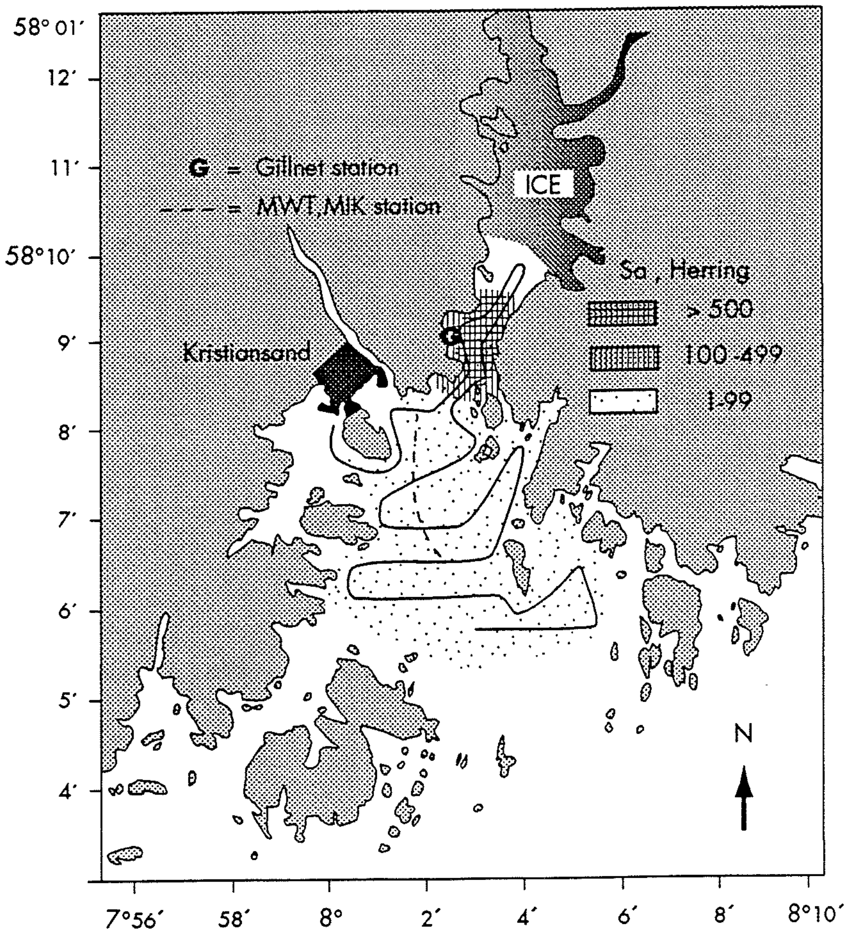


Fig. 3. Echograms showing schooling and dispersed herring (a) and the results of the acoustic day and night survey of the Kristiansandsfjord (b).



Day



Night

Fig. 3b

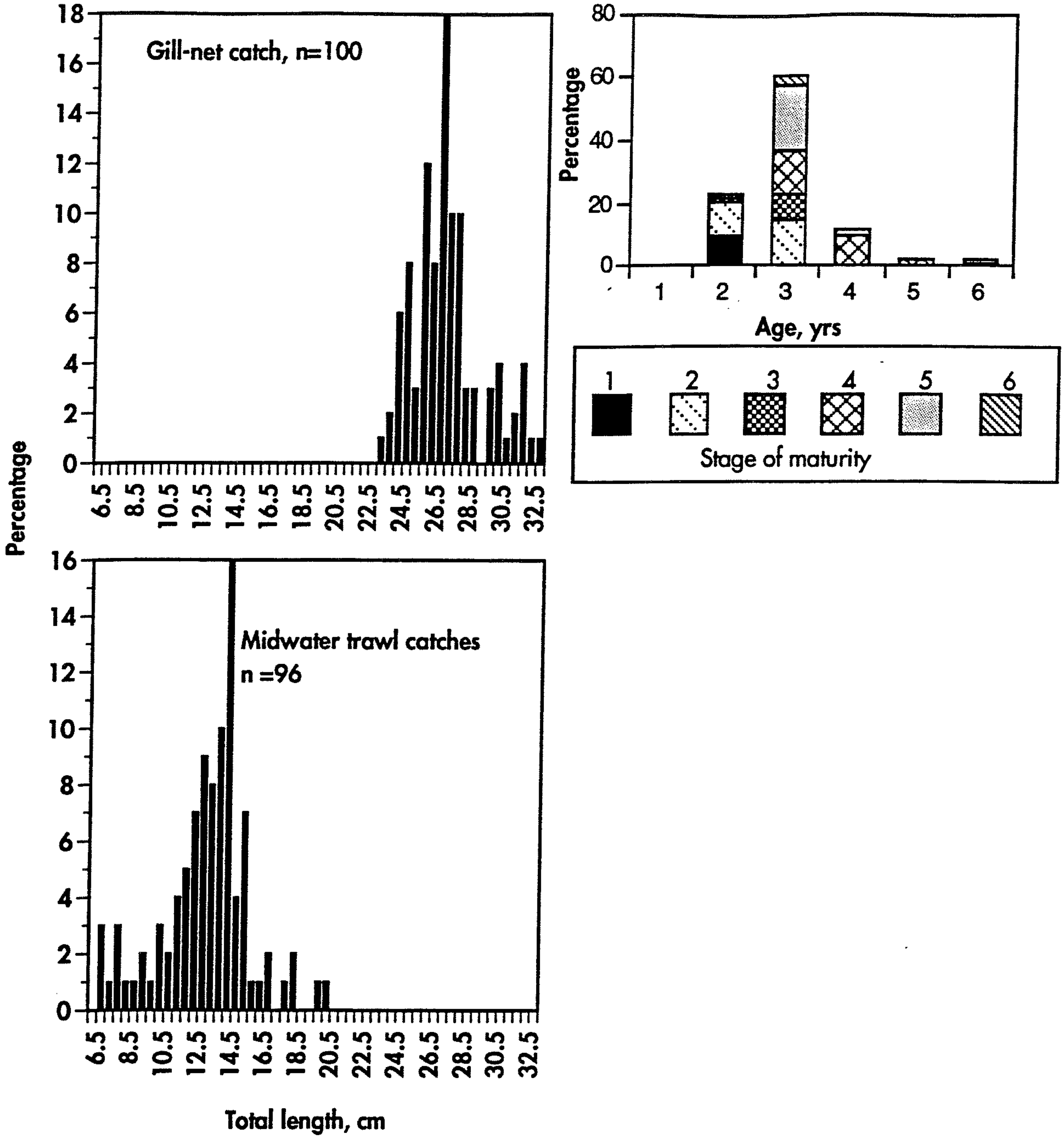


Figure 4. Length frequency distributions of herring from gill-net and mid-water trawls (left) and age composition and maturity stages of the gill-net catch (right, upper). Kristiansandsfjord,Feb 1995.

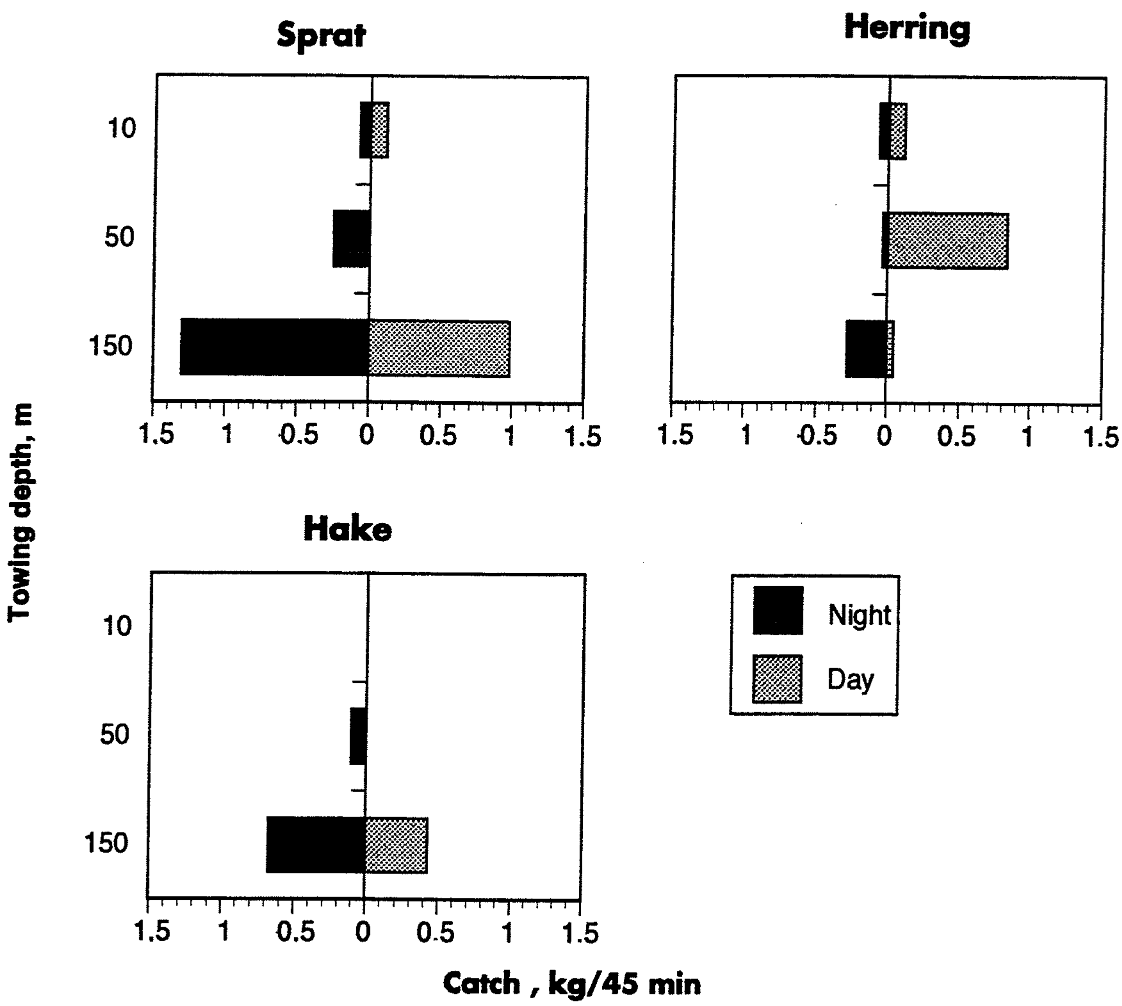


Figure 5. Day and night catches of selected fishes in the Kristiansandsfjord, 14 Feb 1995

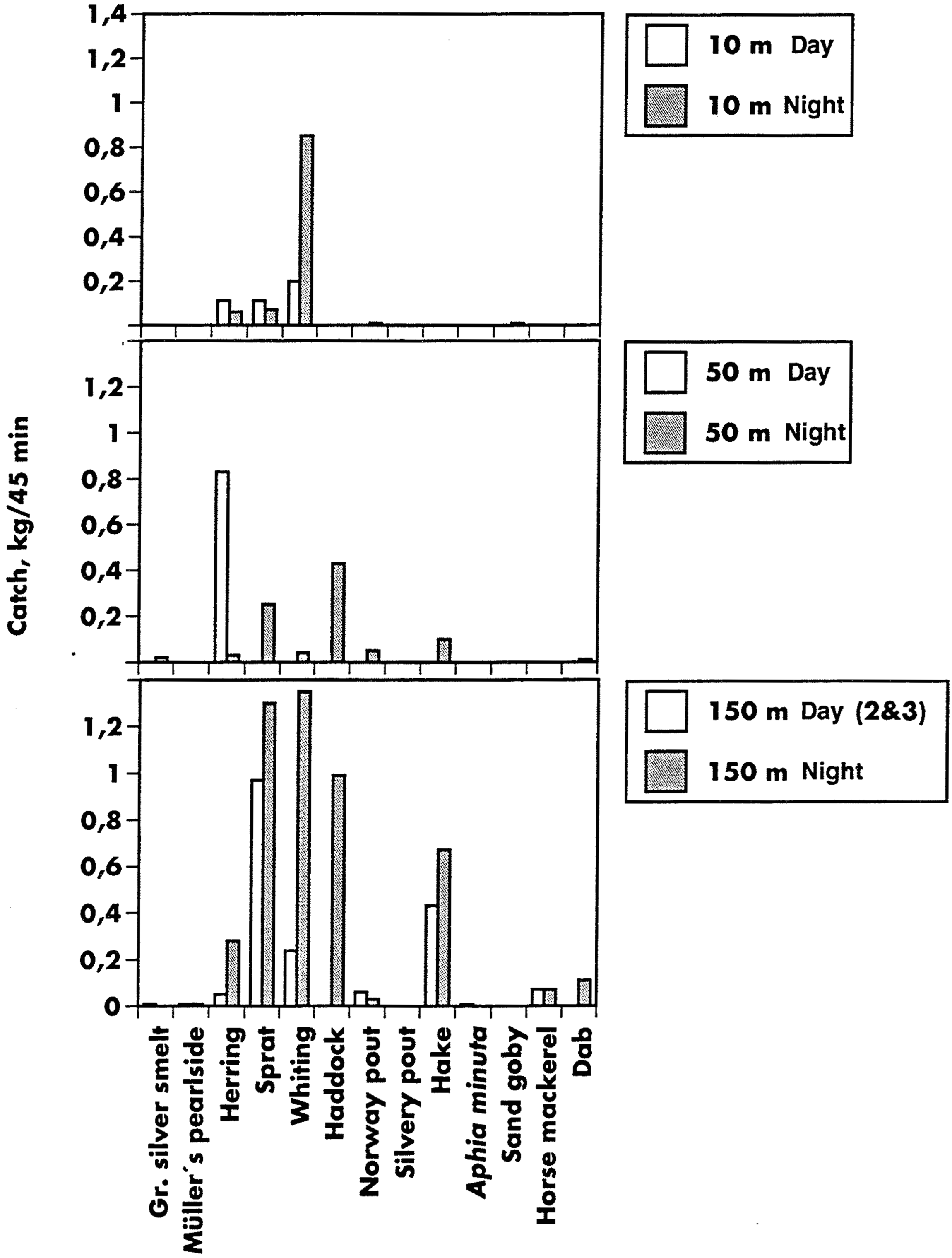


Figure 6. Catches of fish by depth and time of day. Kristiansandsfjord, 14 Feb 1995

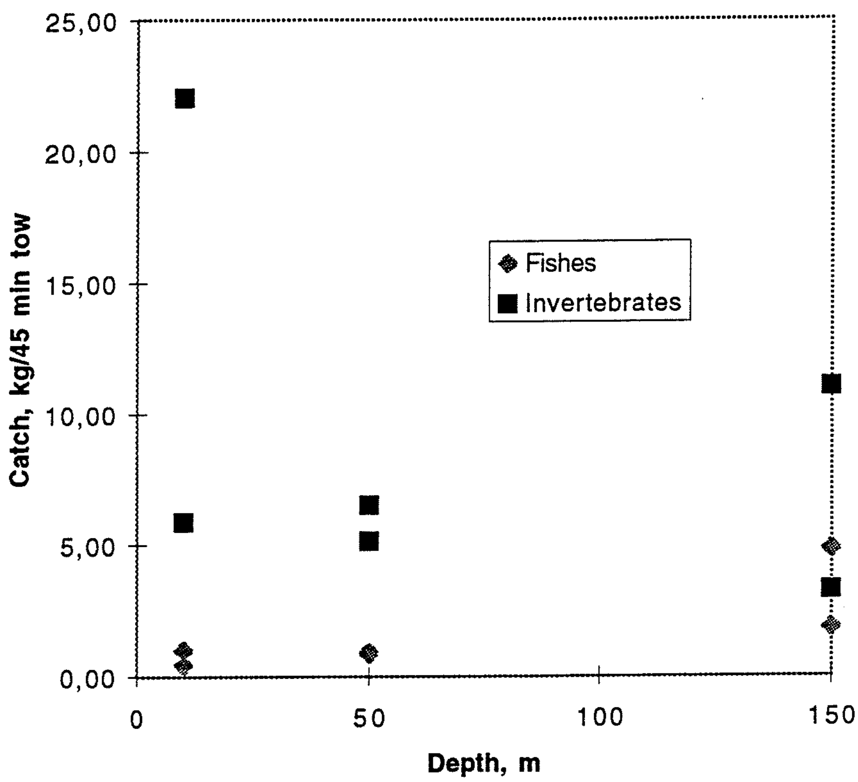


Figure 7. Kristiansandsfjord, Midwater trawl catch by depth zone

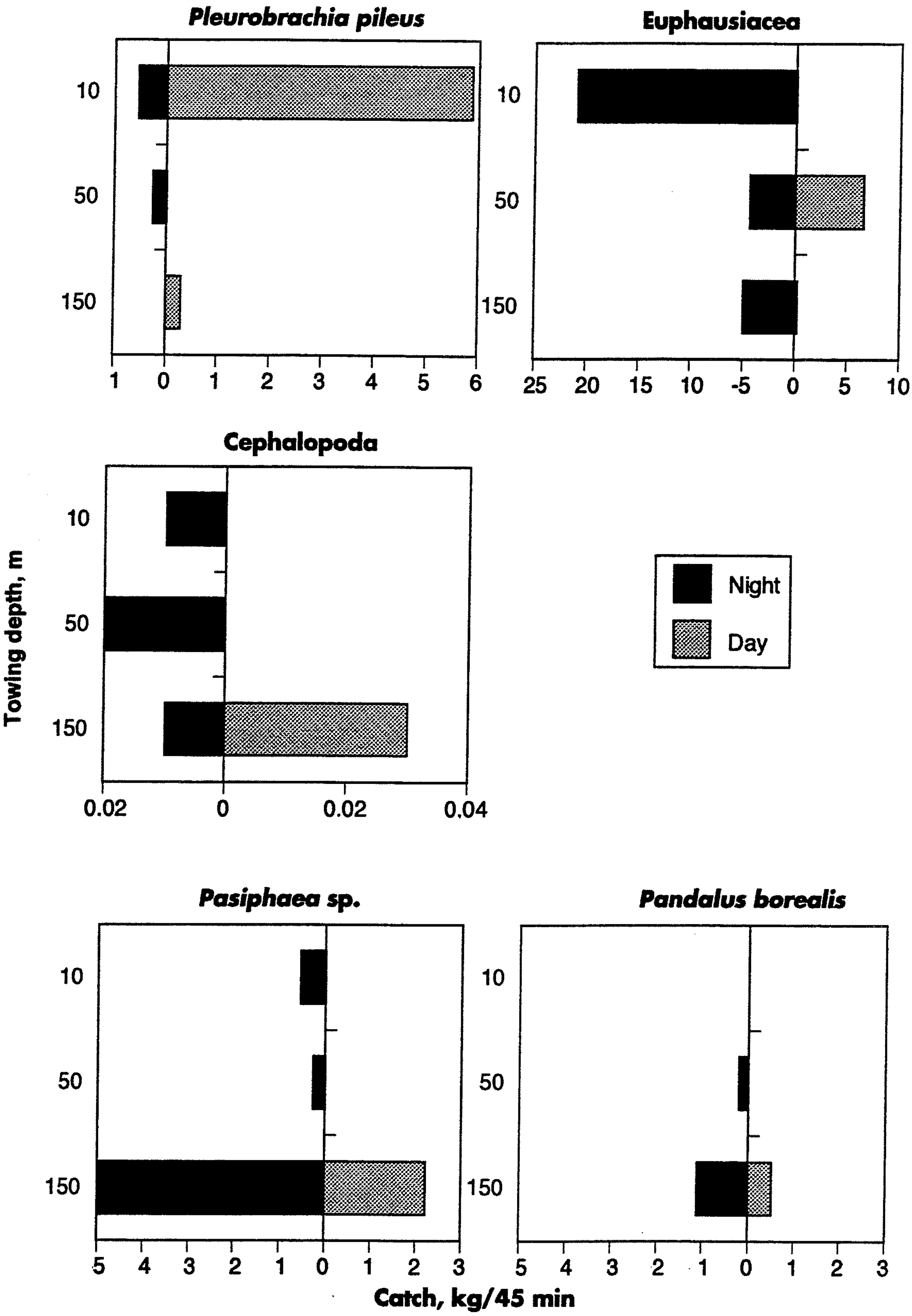


Figure 8. Day and night catches of major invertebrates. Kristiansandsfjord, 14 Feb 1995

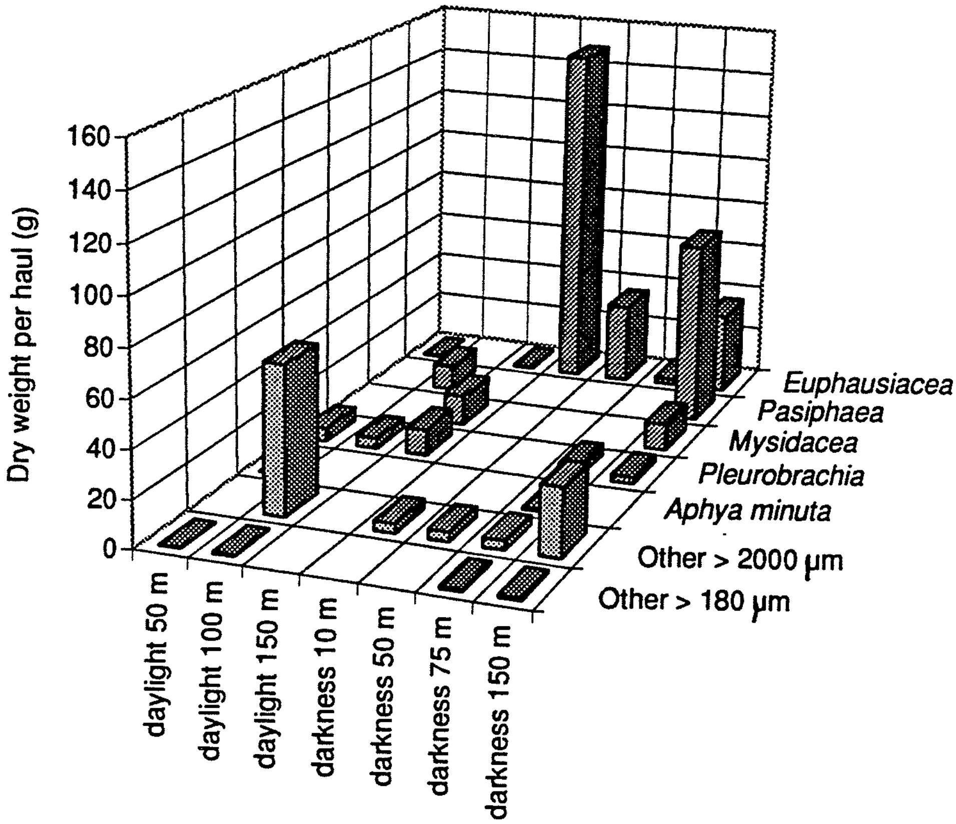


Fig. 9. Dry weight of organisms per haul in the MIK net in the Kristiansandfjord

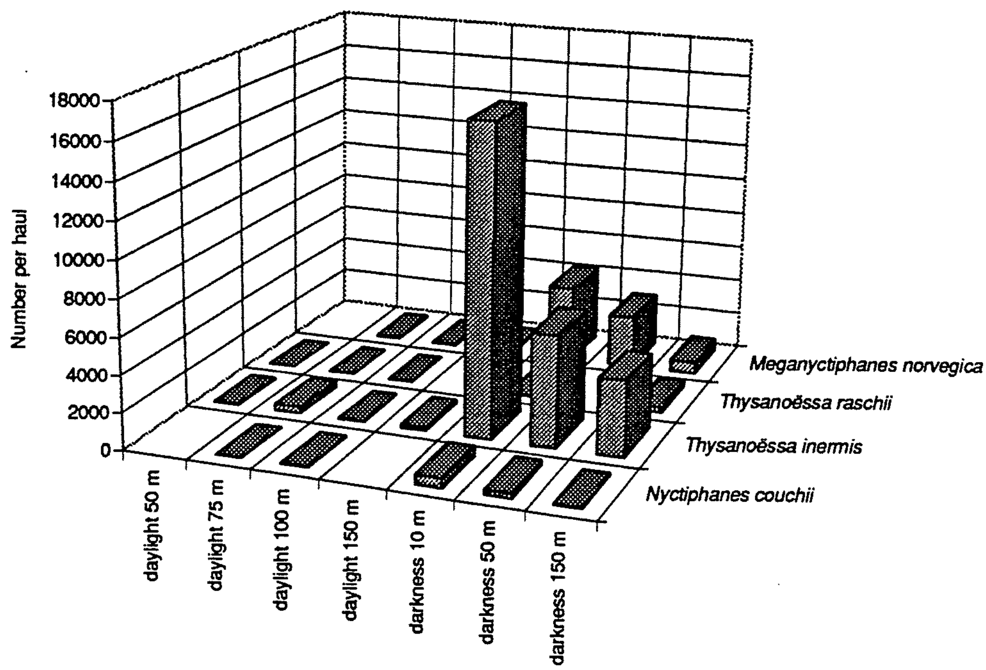


Fig. 10. Number per haul of different euphausiids in the MIK net in the Kristiansandfjord

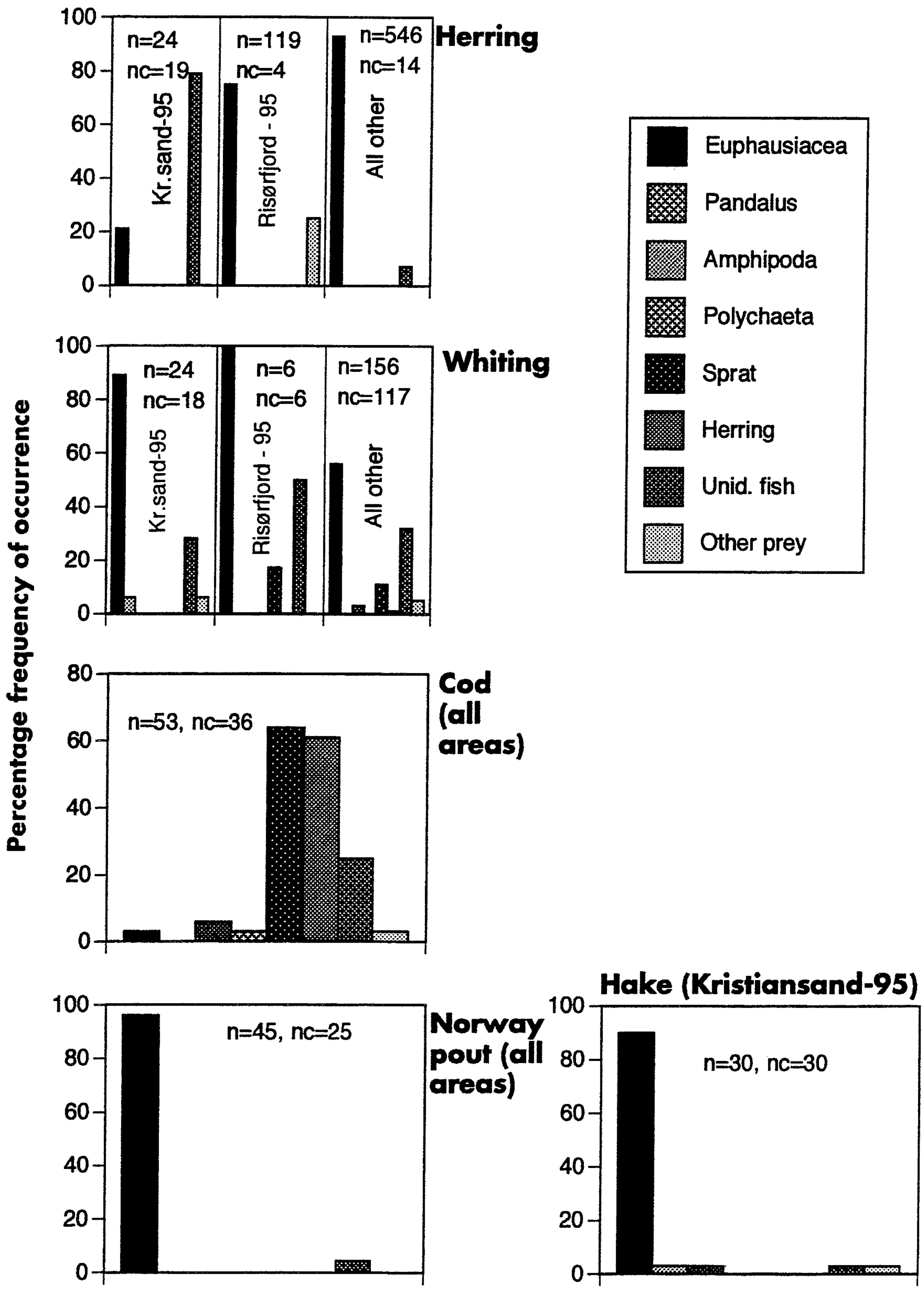


Fig. 11. Summary of stomach contents of fishes caught by midwater trawl in fjords and bays of the Norwegian Skagerrak coast.n- number of stomachs examined, nc- numbers with food.

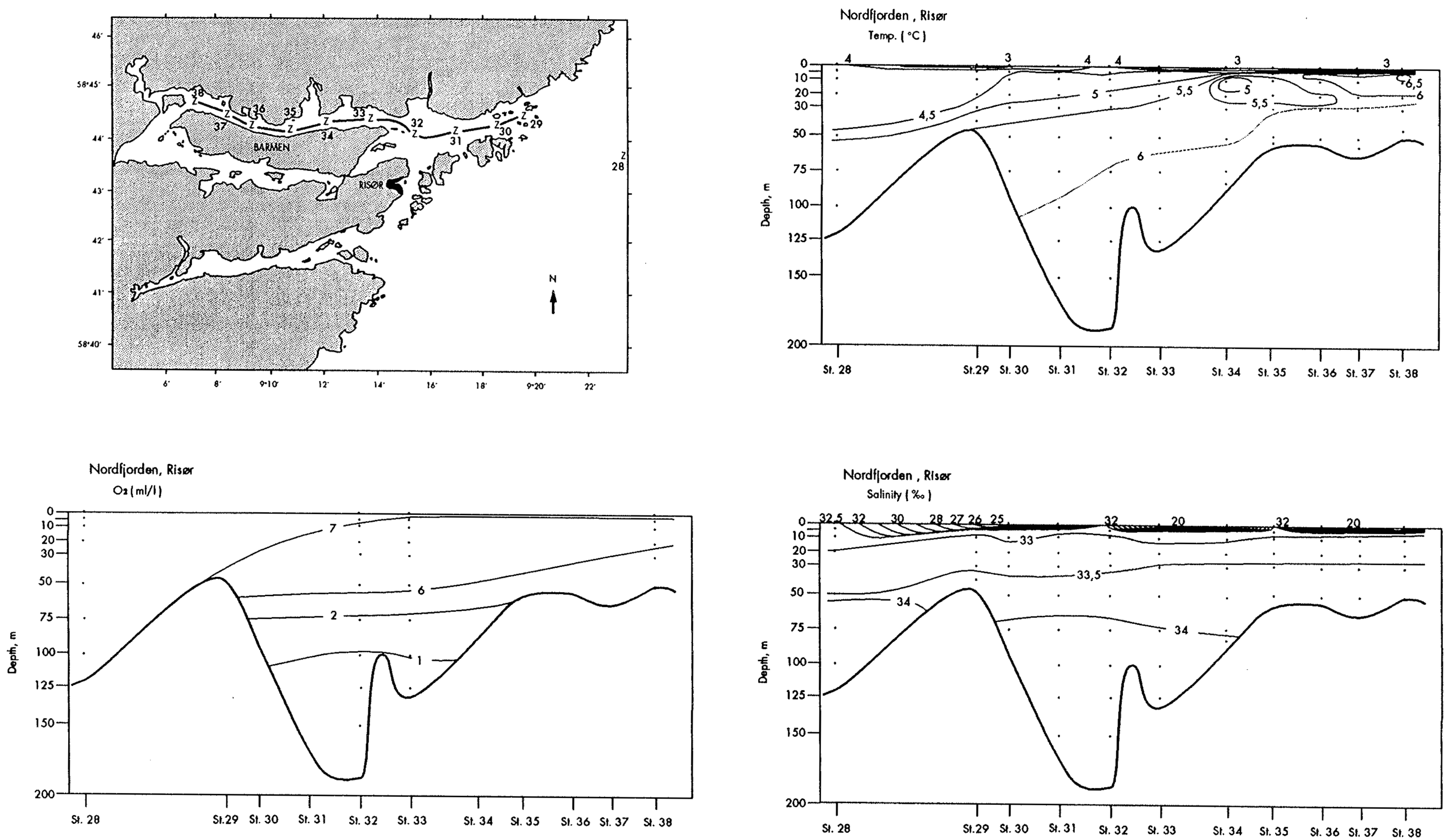


Fig. 12. CTD stations (upper left) and hydrographic observations from the Risørfjord

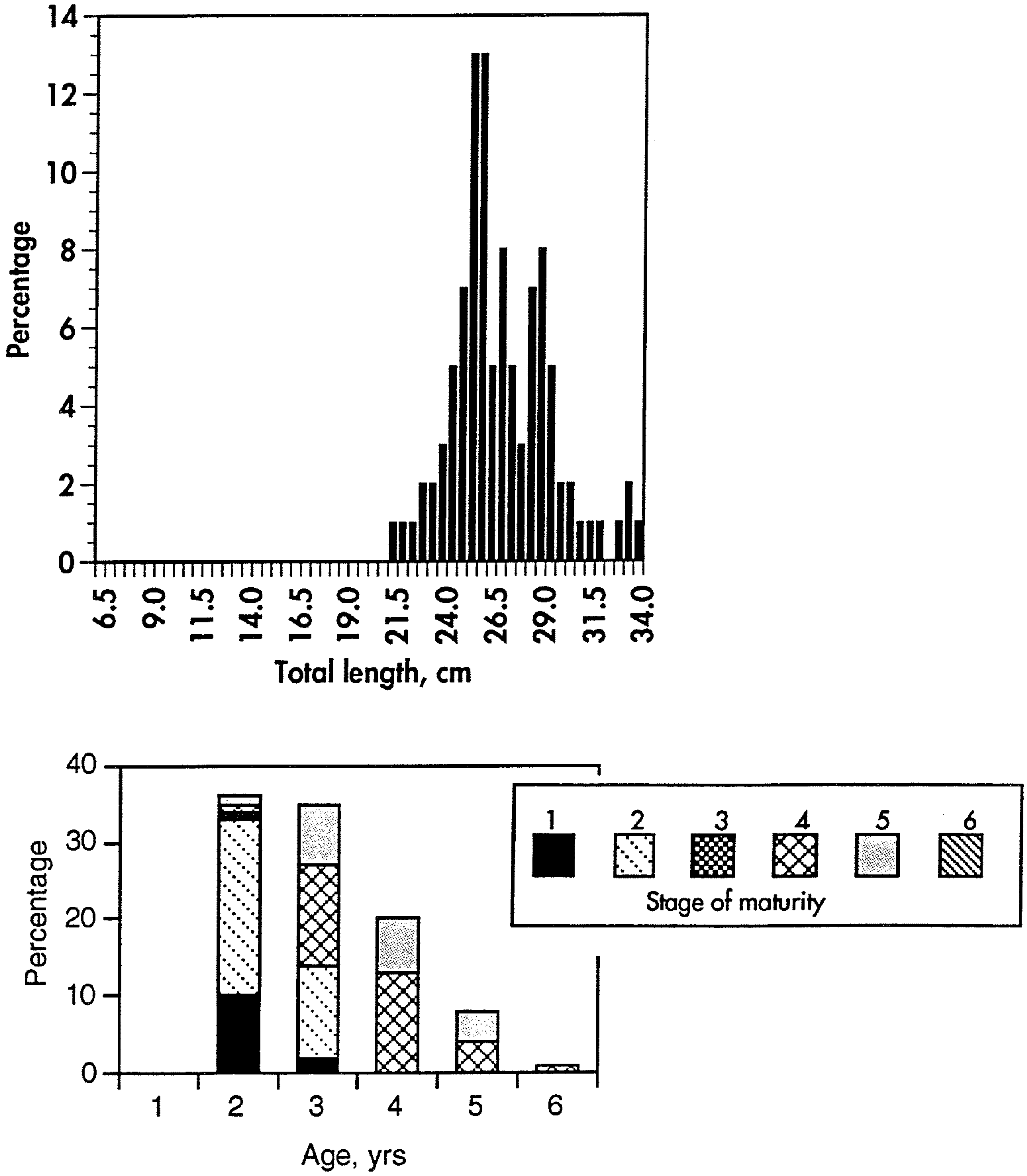
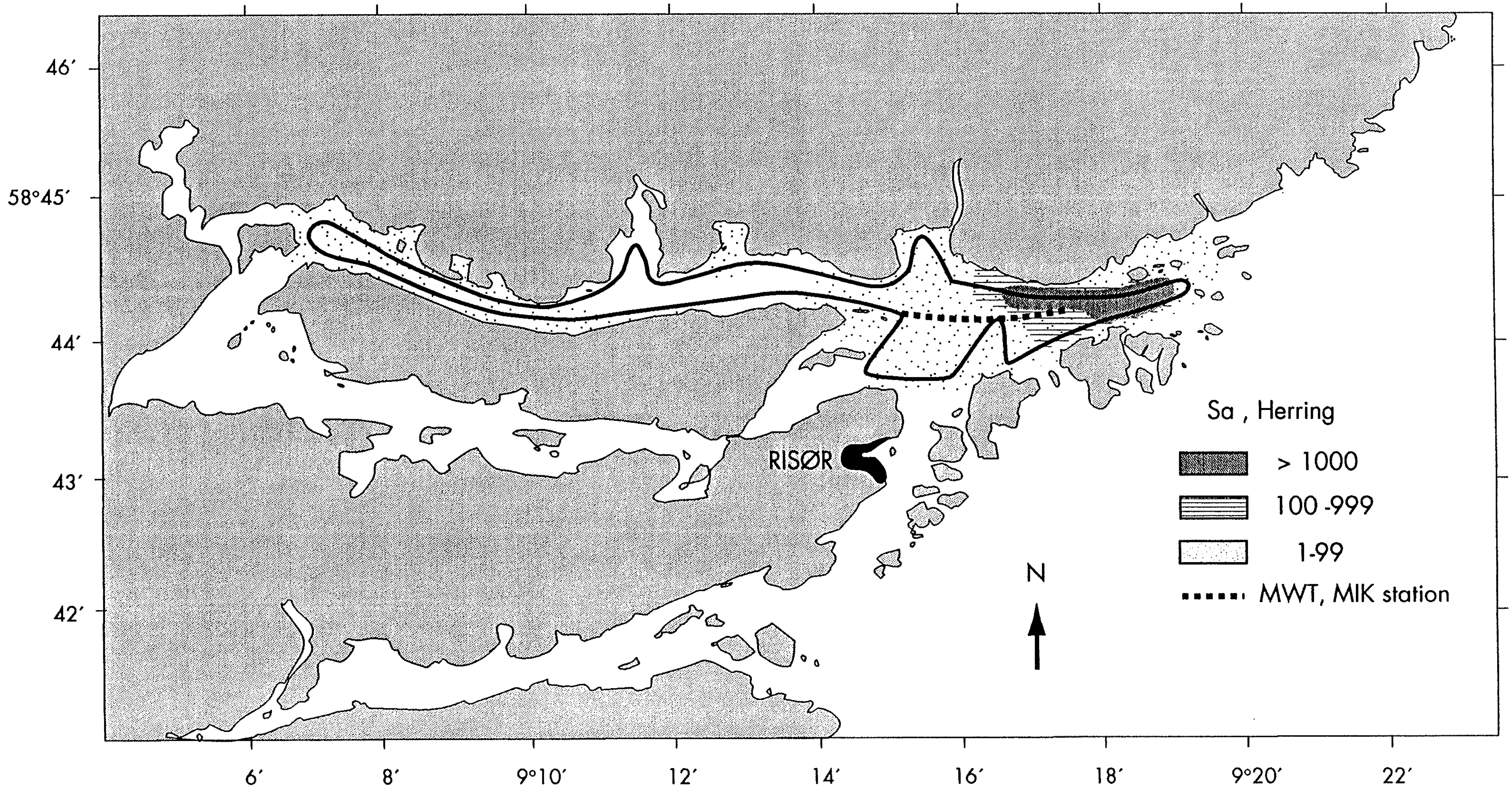
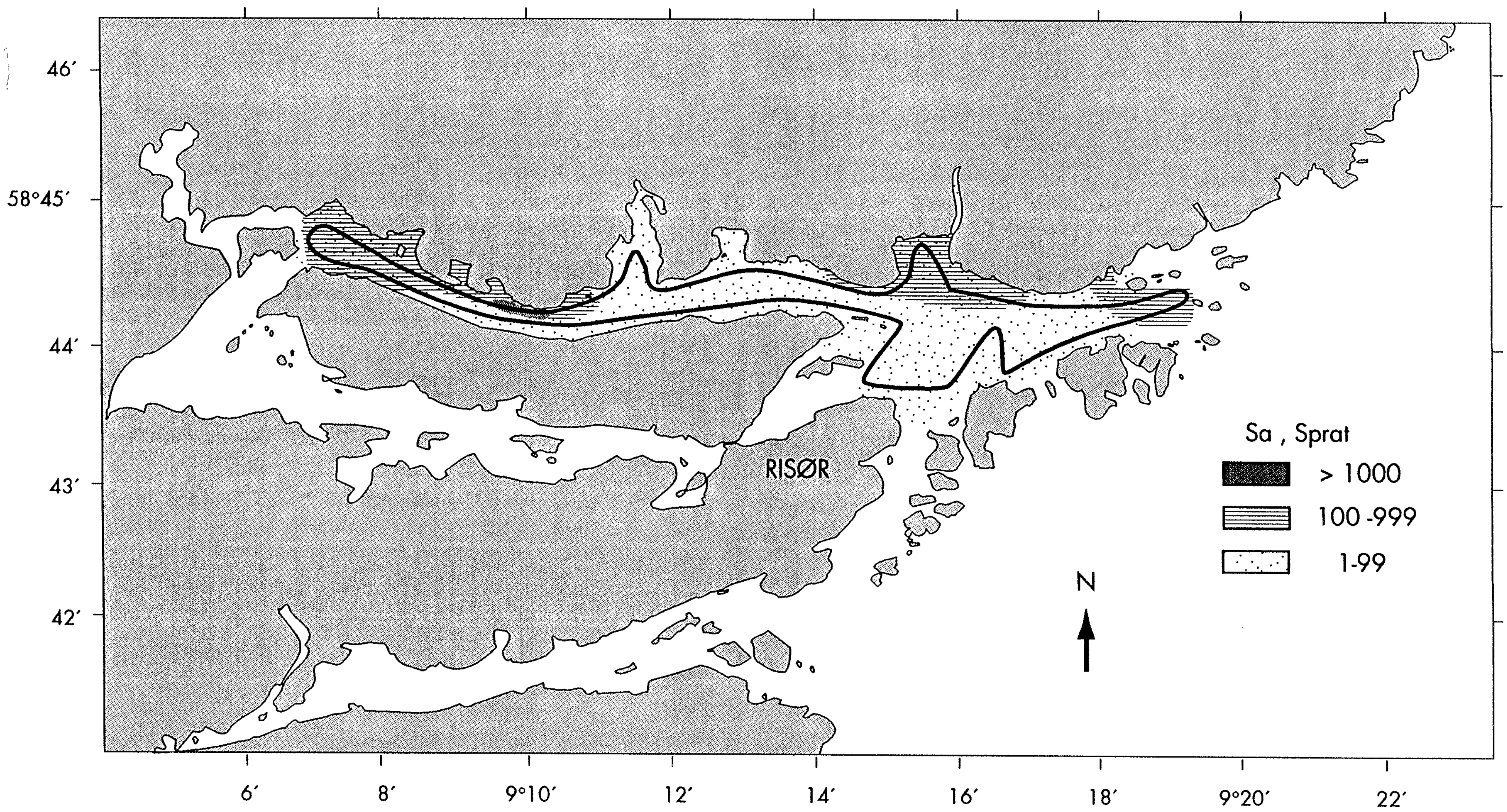


Figure 14. Length frequency distribution (upper) and age composition and maturity of herring caught by midwater trawl in the Risørfjord, Feb 1995



Fig, 13. Distribution of herring in the Risørfjord. Nighttime survey 21 February 1995



Fig, 15. Distribution of sprat in the Risørfjord. Nighttime survey 21 February 1995

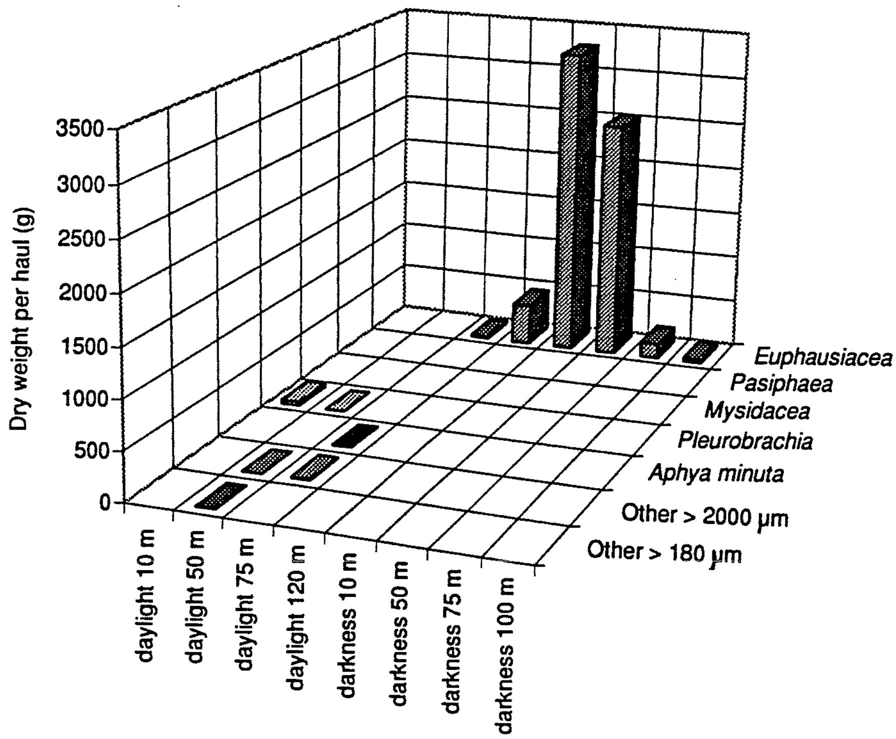


Fig. 16. Dry weight of organisms per haul in the MIK net in the Risørfjord.

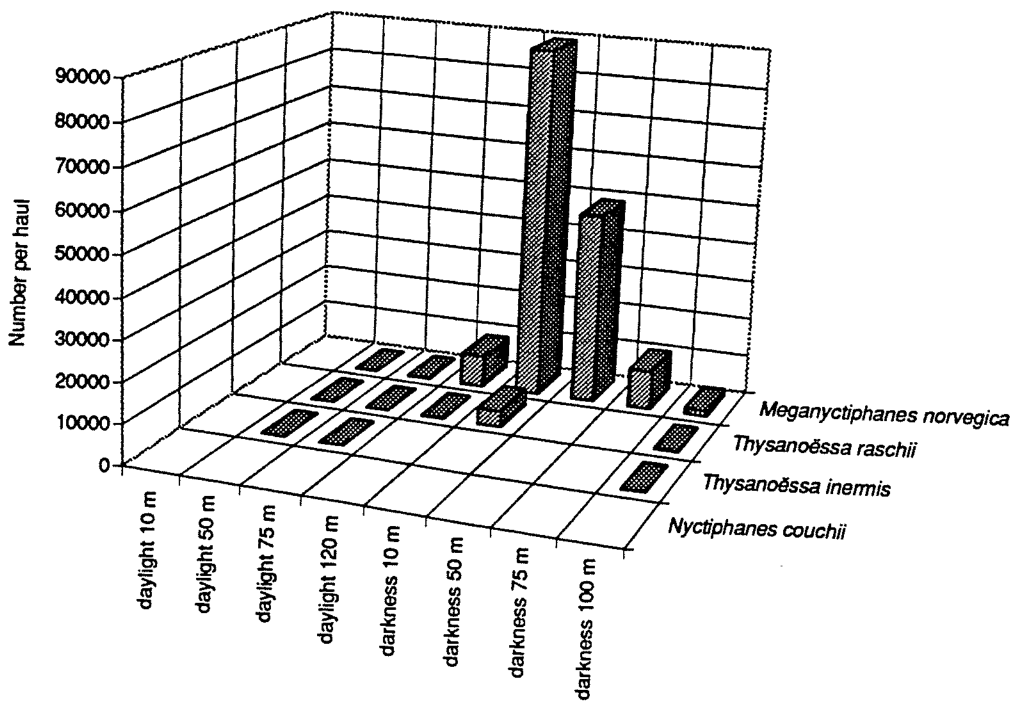
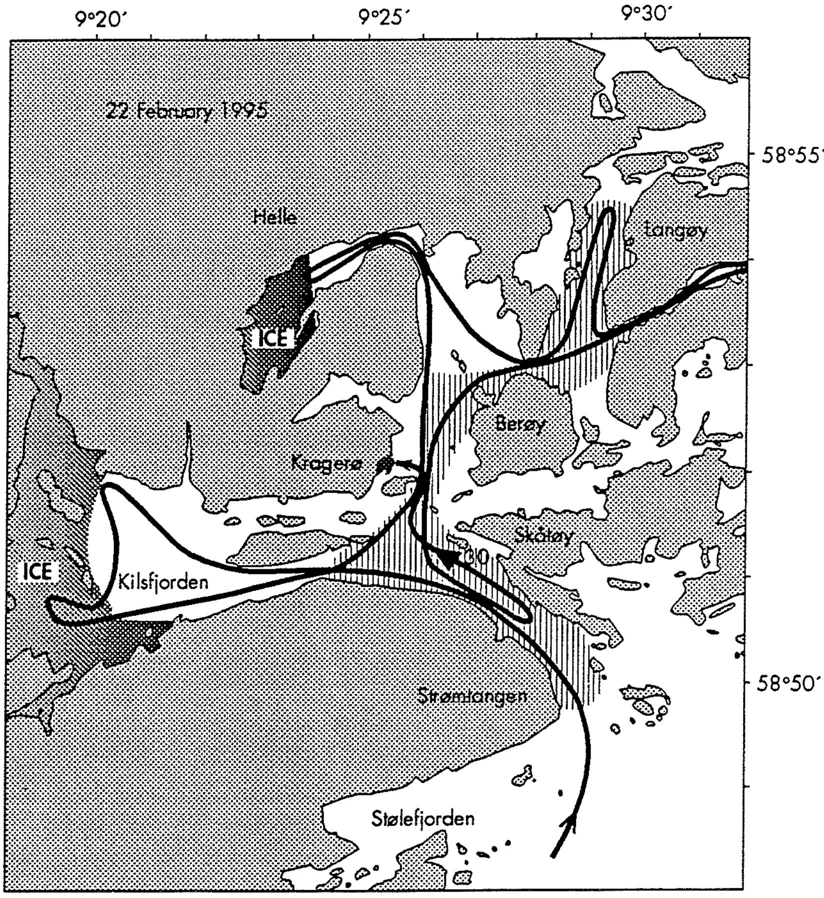


Fig. 17. Number per haul of different euphausiids in the MIK net in the Risørfjord.

HERRING



SPRAT

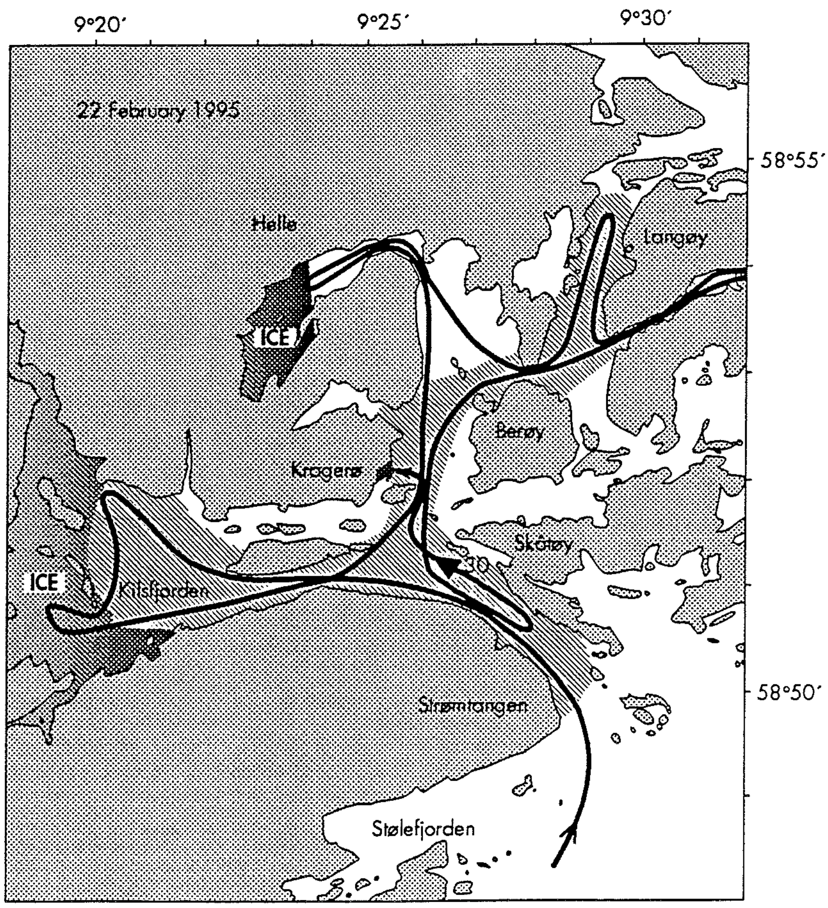
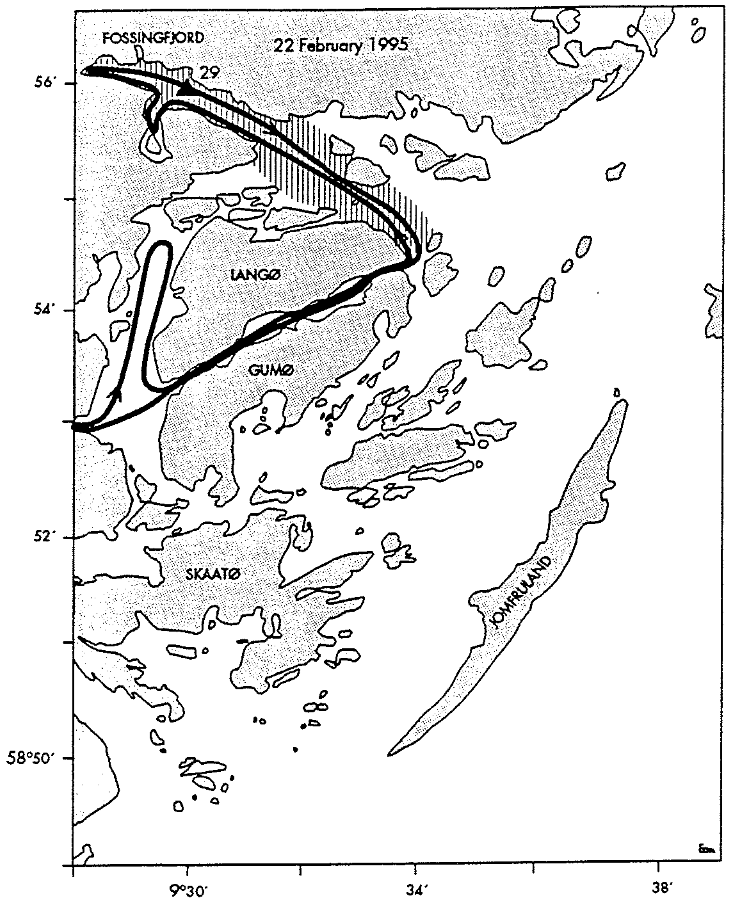


Fig. 18. Distribution of herring and sprat in the Kragerø area, 22 February 1995

HERRING



SPRAT

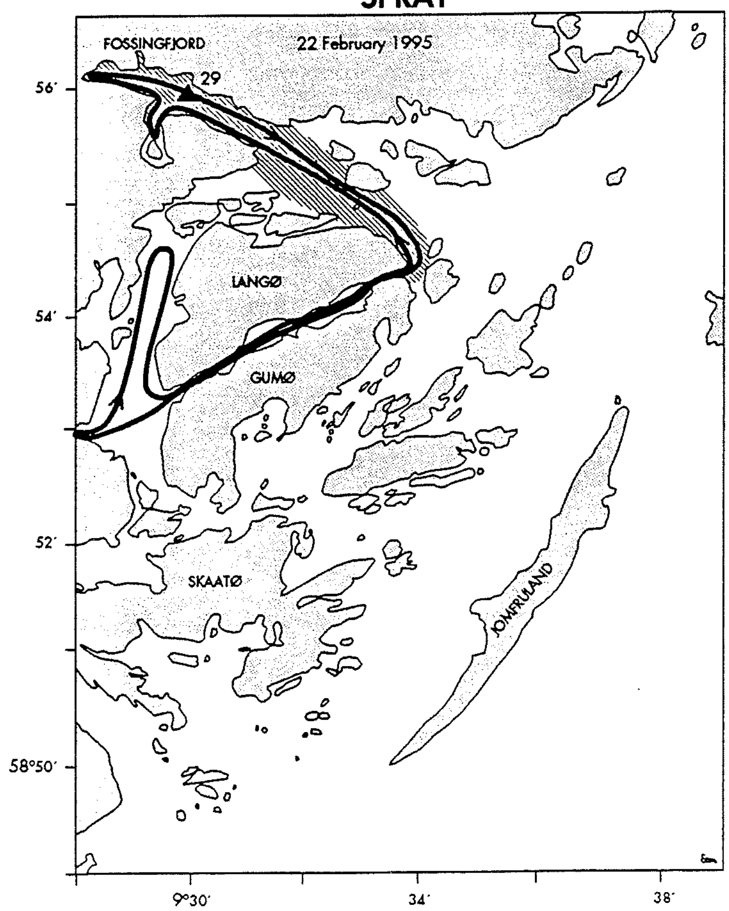
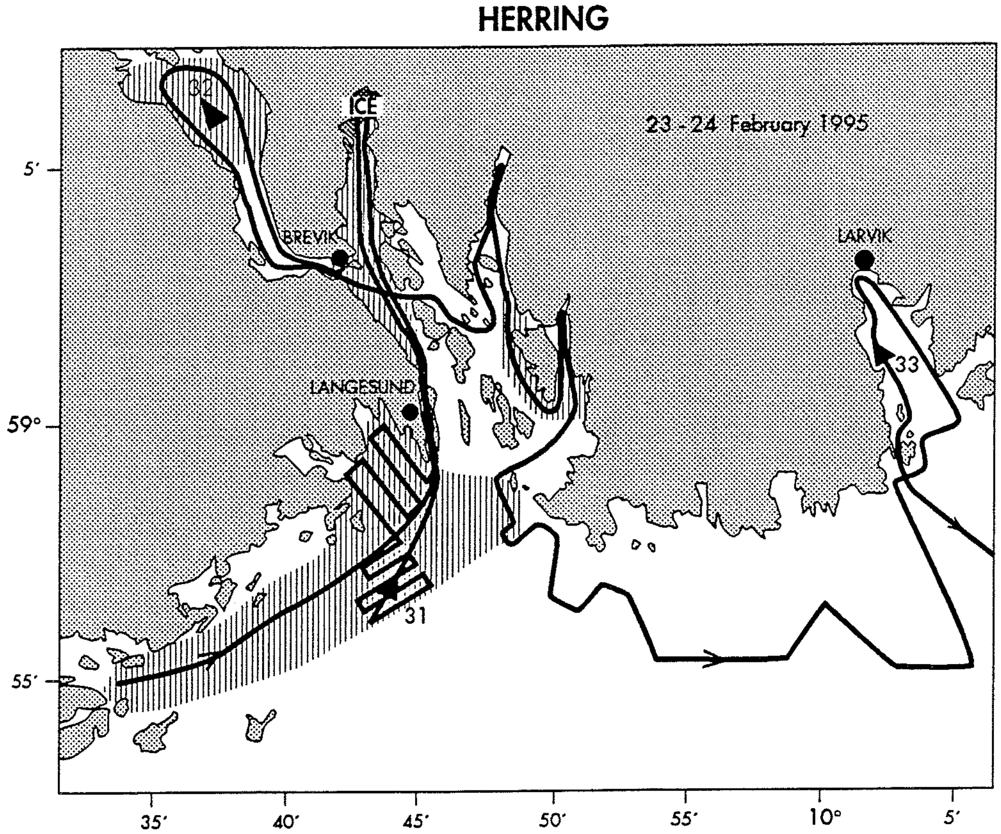


Fig. 18. Contd.



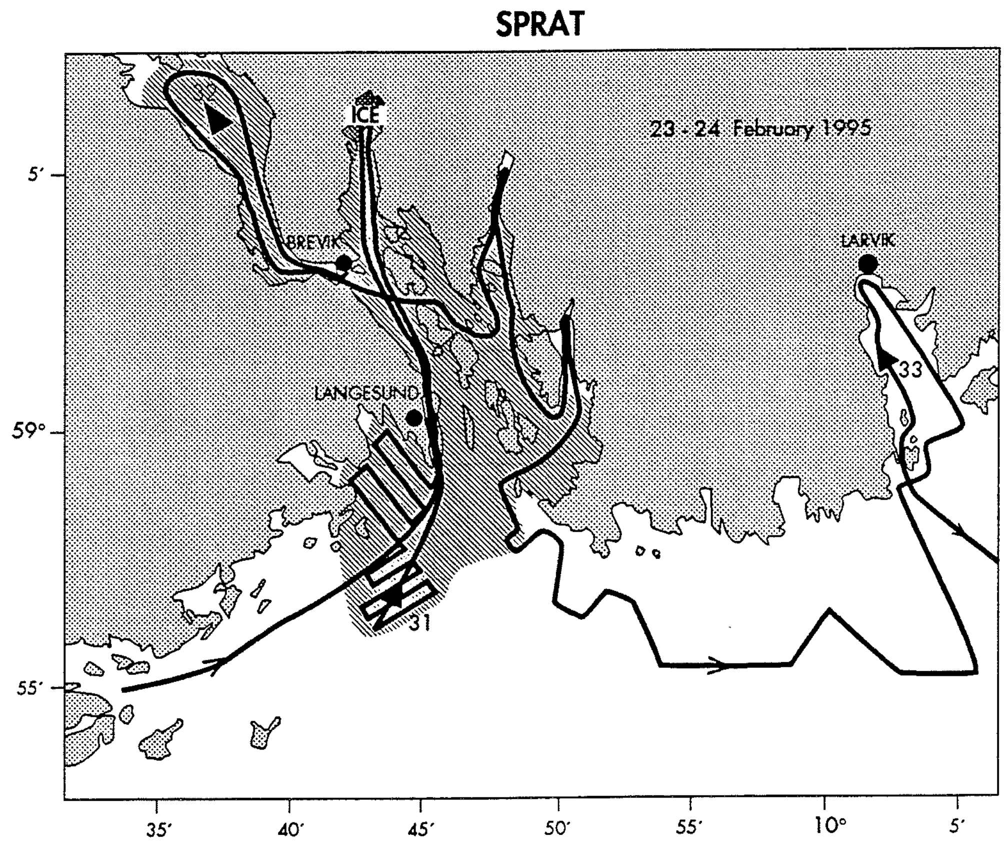


Fig. 19. Distribution of herring and sprat in the Langesund area, 23 - 24 February 1995

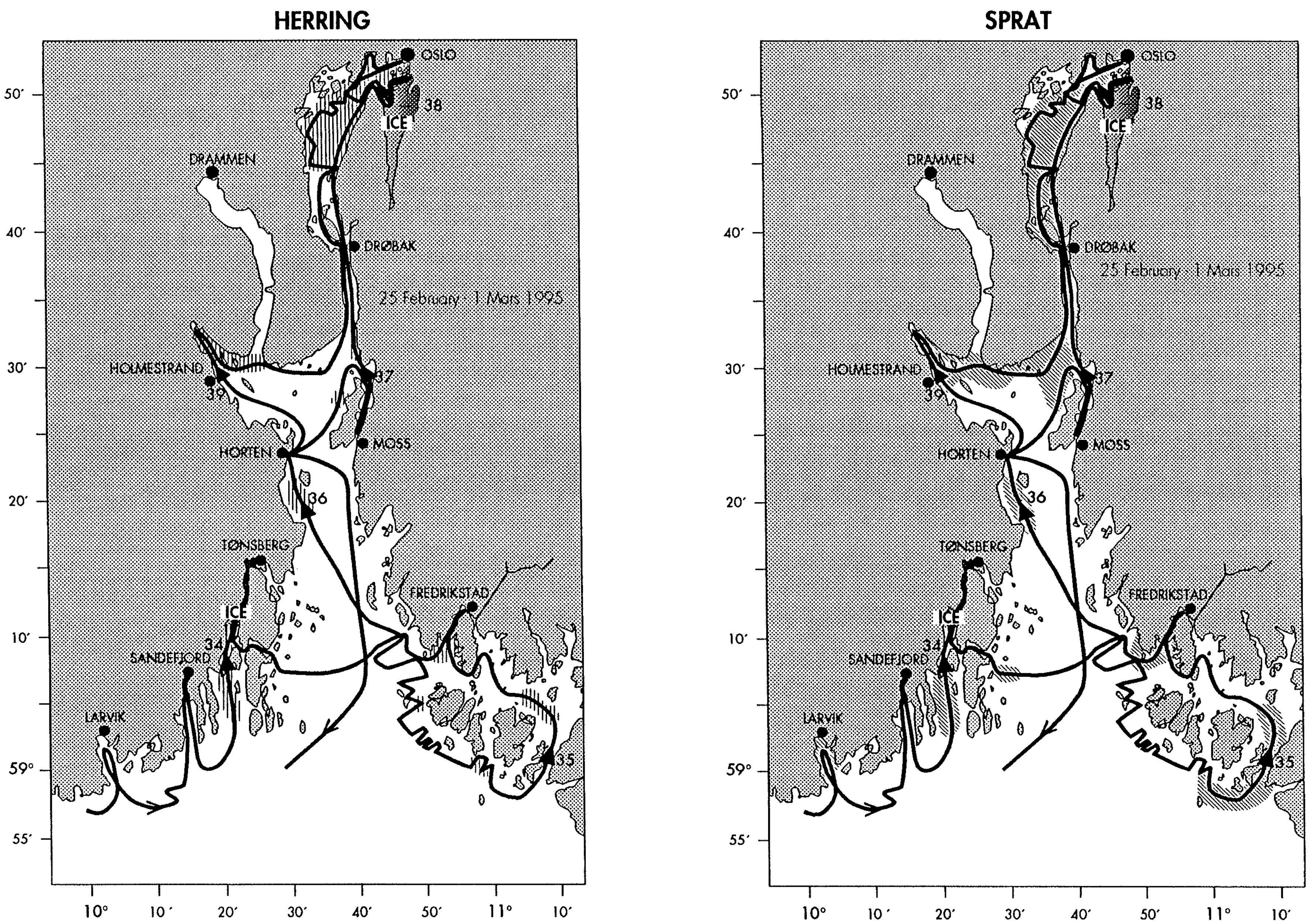


Fig.20. Distribution of herring and sprat in the Oslofjord, 25 February - 1 March 1995.

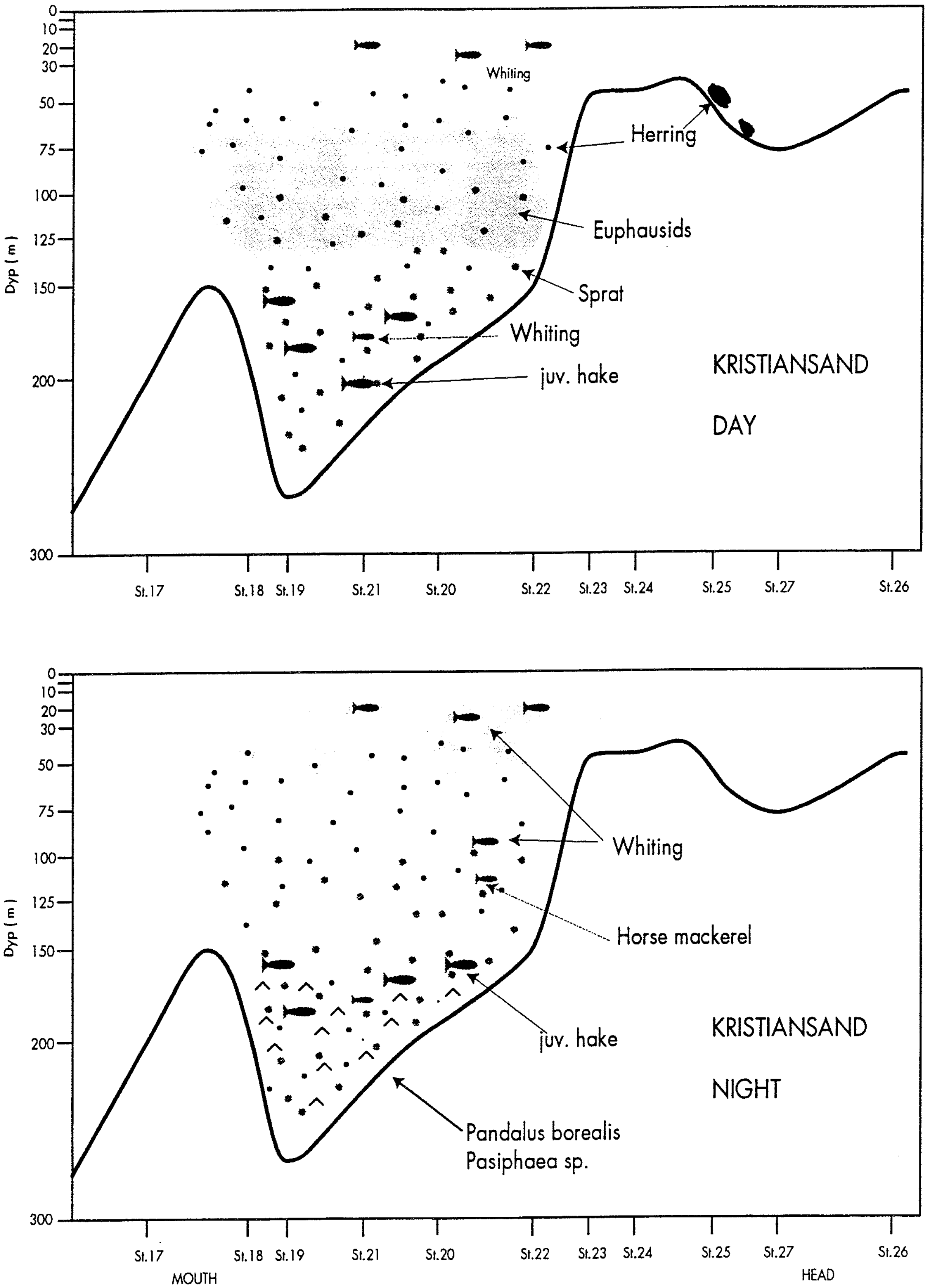


Fig. 21. The pelagic winter community of the Kristiansandsfjord.

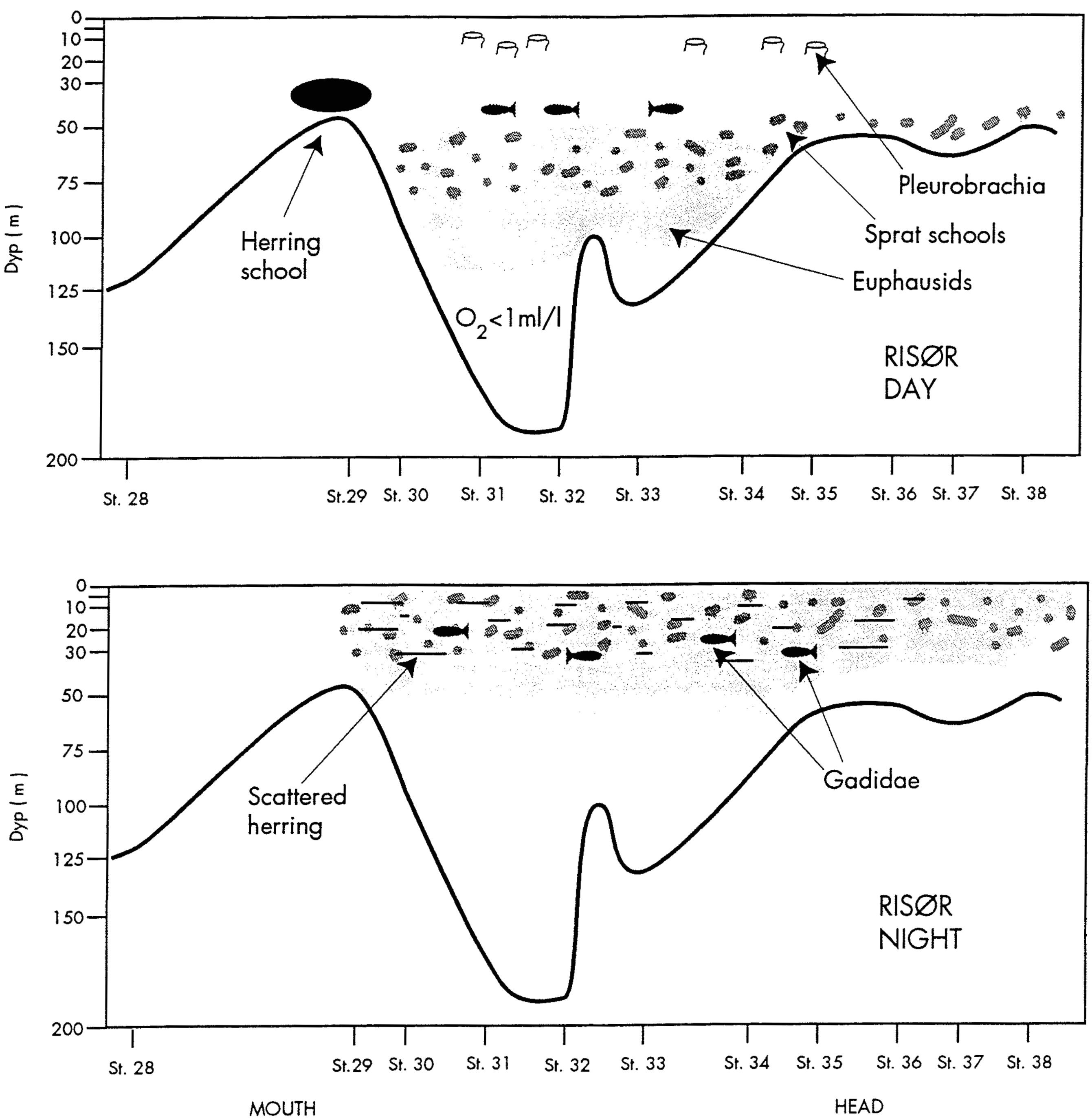


Fig. 22. The pelagic winter community of the Risørfjord.