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Report on surveys of the distribution, abundance and migrations of the Norwegian spring-spawning herring, other pelagic fish and the environment of the Norwegian Sea and adjacent waters in late winter, spring and summer of 1999

by

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Introduction

The Norwegian spring-spawning herring reoccupied the Norwegian Sea as its main feeding area in the early 1990s, after nearly 25 years of absence. The herring stock is now a typical straddling and highly migratory stock, and its migration route crosses the borders of several national EEZs (exclusive economic zones) and international waters. From 1994, an international fishery has taken place during summer in the area. The total catch of Norwegian spring spawning herring in the Norwegian Sea and along the Norwegian Coast in 1998 exceeded 1.2 million tonnes.

Since 1995, the Faroes, Iceland, Norway, and Russia, and since 1997 also the EU, have coordinated their survey effort on this and other pelagic fish stocks in the Norwegian Sea. The co-ordination of the surveys has strongly enhanced the possibility to assess and describe the distribution of the pelagic resources, and their general biology and behaviour in relation to the physical and biological environment (Table 1). Based on an ICES recommendation in 1948, similar surveys were conducted under the auspices of ICES from 1950 to the late 70´s. National surveys were continued after this time. At the 1996 Annual Science Conference, the Pelagic Committee recommended that the ICES cooperation should be reintroduced on the planing and conducting of future surveys on herring and the environment in the Norwegian Sea. For the survey efforts to be carried out in 1999, a planing meeting was held in Lysekil in August 1998 (Holst et al., 1998), and a series of 10 surveys to be carried out by Faeroese, Icelandic, Norwegian, Russian, and EU-research vessels in spring and summer 1999 were coordinated (Table 1). The main objectives of the coordinated surveys were to map the distribution and migration of the herring and other pelagic fish, to assess their biomass, and to monitor environmental conditions of the Norwegian Sea and the quantity of available food in the sea for herring.

The 1999 coordinated survey results were evaluated during a meeting in Hamburg in August 1999 (Table 1). The limited time available for the analysis allows only for a brief overview of the main findings of these surveys with respect to herring distribution and migration, environmental conditions (sea temperature, zooplankton biomass), herring abundance, and blue whiting distribution.

Materials and Methods

A total of 9 surveys were conducted to map the distribution and migrations of herring and other pelagic fishes, and to monitor environmental conditions of the Norwegian Sea in spring and summer 1999 (Table 2, figure 1-9). In addition one survey on young herring in the Barents Sea is reported here. A brief overview of the applied sampling procedures follows below. For a more precise description, confer the survey reports of the different surveys.

Hydrography

Oceanographic data were sampled along the transect lines of the hydro-acoustic surveys of the EU (Walther Herwig III, 25 April-17 May, 1999), the Faroe Islands (Magnus Heinason, 1-25 May, 1999), Iceland (Bjarni Saemundsson, May/June 1999), Norway (J.Hjort, 1-29 July 1998; G.O.SARS, 28 April-30 May, 1999; G.O.Sars, August 1999), and the Russian Federation (F. Nansen, 3 June-5 July, 1999). The observations were made using CTD-Systems. Prior to the workshop the majority of these data were sent to the Institut für Seefischerei in Hamburg, Germany to be preprocessed, and prepared in a suitable data format. Considerable time had to be allocated for the conversion of the incoming data, both prior and during the workshop. A total of **728** stations were compiled in the workshop oceanographic data base. The most recent version (July 1999) of the OCEAN-DATA-VIEW 4.0 software (ODV 4.0.11), as provided by R. Schlitzer from the Alfred-Wegener-Institute for Polar and Marine Research, Bremerhaven, Germany through the INTERNET (http://www.awi-bremerhaven.de/GPH/ODV), was used for a quality check of the data, and for preparation of graphic presentations of station maps, and of the vertical and horizontal distributions of temperature, salinity and density.

Plankton

Zooplankton was sampled in vertical hauls from 200-0, 50-0 m by standard WP-2 net with a 180 µm mesh (*Walther Herwig, G.O. Sars, Arni Fridriksson* & *Magnus Heinason* (only 50-0 m)) and in oblique hauls with a 1 m^2 MOCNESS gear from 50 - 25 m and 25 - 0 m, also with 180 µm mesh (*G.O. Sars*). Russian zooplankton samples were collected in vertical hauls from 0-50m using a Djedy and Nansen net with a 160 µm mesh (*F. Nansen*). The biomasses in 50-0m taken by the Icelandic vessel “Bjarni Saemundsson” were converted to biomasses in 200-0 m using a conversion factor of 1.98 established from simultaneous 50-0 m and 200-0 m net hauls on “Bjarni Saemundsson” in 1998.

Fish sampling

Fish traces identified on the echosounder were sampled by pelagic trawl (vertical openings of 25 - 40 m). With ordinary rigging the trawls could be used to catch deep fish schools. The trawls could also be rigged to catch fish near the surface by removing the weights, extending the upper bridles and attaching two buoys to each upper.

Subsamples of up to 100 specimens of herring and blue whiting were taken from the trawl catches. The length, weight, sex, maturity stage and stomach contents were recorded. Scales were taken for age reading of herring and ototliths from blue whiting. From each cruise, the data on echo integration recordings of herring, length distribution, zooplankton abundance and temperature, were provided in an agreed format as described above.

Acoustics

During the surveys, continuous acoustic recordings of fish and plankton were collected using calibrated echo integration systems (38 kHz Simrad EK500 working at a range of 10 - 500 m). The recordings of area back scattering strength (S_A) per nautical mile were averaged over five nautical miles, and the allocation of area backscattering strengths to species was made by comparison of the appearance of the echo recordings to trawl catches. To record schools near the surface, a horizontal guided sonar was operated from some of the vessels.

The equipment of the research vessels were calibrated directly before or during the surveys against a standard calibration spheres. Intercalibrations were also done between the R/V "Walther Herwig III" and R/V " G.O. Sars" during the May cruise.

Acoustic estimation of herring abundance was carried out during the surveys. This was done, either by visual scrutiny of the echo recordings directly from the echograms or by post-processing using the BEI-system. The allocation of s_A-values to herring was based on the composition of the trawl catches and the appearance of the echo recordings. To estimate the abundance of herring, the allocated s_A-values were averaged for statistical squares measuring 0.5^o of latitude by 1^o of longitude. For each statistical square, the unit area density of herring (ρ_A) in number per square nautical mile (N n.mile^{-2}) was calculated using the standard equations (Foote 1987).

To estimate the total abundance of herring, the unit area abundance for each statistical square was multiplied by the number of square nautical miles in each statistical square and then summed for all the statistical squares within defined sub-areas and for the total area. The biomass was calculated by multiplying abundance in numbers by the average weight of the herring in each statistical square and then summing for all squares within defined subareas and the total area. Furthermore, the average length, weight, area density and biomass of each year class were also estimated for each statistical square, for defined sub-areas and for the total area.

Results and discussion

Hydrography

Two main features of the circulation in the Norwegian Sea, where the herring stock is grazing, are the Norwegian Atlantic Current (NWAC) and the East Icelandic Current (EIC). The NWAC with its offshoots forms the northern limb of the North Atlantic current system and carries relatively warm and salty water from the North Atlantic into the Nordic Seas. The EIC, on the other hand, carries Arctic waters. To a large extent this water derives from the East Greenland Current, but to a varying extent, some of its waters may also have been formed in the Iceland and Greenland Seas. The EIC flows into the south western Norwegian Sea where its waters subduct under the Atlantic waters to form an intermediate Arctic layer. While such a layer has long been known in the area north of the Faroes and in the Faroe-Shetland Channel, it is only in the last two to three decades that a similar layer has been observed all over the Norwegian Sea.

This circulation pattern creates a water mass structure with warm Atlantic Water in the eastern part of the area and more Arctic conditions in the western part. Due to the influence from the EIC, the NWAC is rather narrow in the southern Norwegian Sea, but when meeting the Vøring Plateau off Mid Norway it is deflected westward, its western branch often reaching the area of Jan Mayen at about 71°N. Further northward in the Lofoten Basin the lateral extent of the Atlantic water gradually narrows again, apparently under topographic influence of the mid-ocean ridge.

Variability

It has been shown that the distribution of the water masses in the Nordic Seas is largely controlled by atmospheric forcing. Hence, the lateral extent of the NwAC, and consequently the position of the Arctic Front in the Norwegian Basin, is closely correlated with the large scale distribution of the atmospheric sea level pressure. This is clearly indicated for example by the correlation with the winter index of the North Atlantic Oscillation. As a result, the Atlantic water now has a far more easterly distribution than it had during the 1950s and 1960s. The temperatures in the narrower NwAC have, however, shown an overall increase during the same period. Accordingly, in the 1950s and 1960s the herring had a more westward distribution during the feeding season than the distribution which has been observed during the 1990s.

The observations from May 1999 indicated a large influence from the EIC. This was indicated by relatively large volumes of the intermediate water of Arctic origin, lying under the Atlantic Water in the NwAC. In the Svinøy Section a core of water with salinities ranging below 34.85 represented a clear signal of the strong Arctic influence and similar conditions had not been observed since 1978. In July 1999 this had developed into a large volume of Arctic water and as shown in Figs 10 and 11, the body of Arctic intermediate water of salinity below 34.88 was much larger in July 1999 than in July 1998. Further, this strong Arctic influence was indicated by a narrower NwAC in 1999 than in 1998.

Three sections across the area along 69°20'N are shown in Figs 12, 13 and 14. The observations were from July 1998, May 1999 and July 1999. The section from May 1999 shows the conditions before the seasonal warming had started in this area. Upper layer temperatures were generally close to 6°C and the upper 300 to 400 m of the water column were relatively homogeneous. The sections from July show the summer situation when a warm, mixed surface layer has developed. There was a clear difference in mixed layer conditions between the two years with considerably higher temperatures near the surface in 1999 than in 1998. The seasonal thermocline, and in particular the pycnocline were considerably sharper in 1999 than in 1998. Hence, the near surface temperatures in the area where the herring was grazing in July 1999 were about 1°C higher than in July 1998.

Figs 15, 16, 17, 18, 19 and 20 show horizontal temperature and salinity distributions at 20, 50, 100, 200, 300 and 400 m depth in April - June 1999. These maps show the water mass characteristics typical for the end of the winter season as even the figure for 20 m depth shows temperatures yet undisturbed by seasonal warming.

The distribution of the waters carried into the Norwegian Sea by the EIC is clearly indicated at all four depths by a body of relatively cold and fresh water extending eastward from Iceland. These Arctic waters are separated from the Atlantic waters in the eastern part of the area by the Arctic Front which is indicated by closely spaced isotherms. At 20 m depth the front extends eastward from Iceland (here known as the Faroe Front) and turns north at around the Prime Meridian. The maps for the deeper layers show that its position is gradually moving eastward with increasing depth.

To the east of the Arctic front the Atlantic water formed an area with relatively homogeneous condition in both temperature and salinity. In this area which broadened toward north, coincided with the densest concentrations of both herring and blue whiting.

Zooplankton

April-June

The comparison of figures 21 and 22 shows that both in 1998 and 1999 the coverage with plankton samples has been high. The total number of plankton stations in 1998 was 268 (including the samples of the Faeroes shelf region), and in 1999 it was 342. The total number of stations was considerably higher in 1999 and also there was a shift from west to east in the distribution and density of stations in 1999 compared with 1998. This uneven spacing of stations may have influenced the obtained horizontal distributions as demonstrated in the maps (Figs. 21 and 22) and to a lesser extent the estimated average biomass per area (Table 3).

Taking these uncertainties into account there is a general decline of biomass in 1999 as compared to 1998 (approximately -21%). The 1999 values are still above the 1997 biomasses. However, the 1997 values are known to be exceptionally low (Anon. 1999).

Table 3, Total Zooplankton biomass [g dw*m^{-2}] arithmetic mean. The 1998 data on the Faeroes shelf were omitted to allow comparison with the 1999 data.

Year	1997	1998	1999
Total area	8.2	13.4	10.6
Region W of 2°W	9.1	13.4	13.5
Region E of 2°W	7.5	14.4	10.2

The decrease of the total biomass from 1998 to 1999 is taking place in the area east of 2°W (-29.2%).

Figures 23-25 show the distribution of zooplankton biomass separated in different size fractions (g dw m^{-2}) in 200-0 m in May 1999 in the survey area covered by Walther Herwig III. The total zooplankton biomass was generally higher in the north-eastern part of the Walther Herwig III investigated area (Fig. 22). At most of these stations the smallest size fractions (180 – 1000µm) formed the main part of the biomass (Fig. 23). At stations between 64° and 68°N and east of 4°E plankton of the small size class as well as plankton of 1000-2000 µm contributed to the relatively high biomass values (Figs. 23 and 24). When higher biomass values were found at stations in the west and the southwest they consisted mainly of plankton of the bigger size classes, >1000 µm, (Fig. 24 and 25).

July-August

The Norwegian July-August cruise with R/V "G.O. Sars" was still not finished at the time of the PGSPEN meeting. However, the zooplankton data from the first part of the cruise, covering the southern regions, were available. It is clear from this preliminary data set that the total zooplankton biomass in 1999 was much higher than in 1998 (Figs. 26 and 27). Average total zooplankton biomass, calculated for the area south of 70^{o}N both years, was estimated at 5.3 g dw m^{-2} in 1998 and 10.1 g dw m^{-2} in 1999. The stations with the highest biomass in 1999 were from the frontal region between Atlantic water and the Arctic water of the East Iceland Current.

Herring

April/May

The international co-ordinated herring survey took place under generally favourable weather conditions during the period 23/4 to 2/6 1999. The EU and Norwegian vessel covered the eastern parts of the Norwegian Sea, while the Icelandic and Faroese vessels covered the western parts (Table 2, Fig. 1,2,3).

The RV Walther Herwig III and RV G.O.Sars surveyed the area from 62° N to 72° N, 2°W to 18°E during the period 26/4 to 30/5. Only small registrations of herring were made south of 66°N, while large concentrations were observed from 67°N to 70°N, between 2°W and 5°E (Fig. 28). Relatively large concentrations were also observed between 69°N to 71°N, 5°E to 16°E. The zero line was not reached in the northern part, and it is not possible to judge whether significant amounts of herring were left out of the acoustic estimate due to this. In the eastern parts the herring was observed as small schools near the surface and herring may have been lost from the echo integration in the surface layer.

During 6-22 May the area from 63°15'N to 69°N was surveyed by *Magnus Heinason* and *Árni Fridriksson* (Fig. 3, 28), between about 8°W and the zero medridian south of 67°N, while reaching east to 3°E to the north of that. There appeared to be two maxima within the area covered, one at about 67°30'N between 0° and 1°W, where there were mostly large schools at variable depth, and another farther to the northeast between about 68°30'-69°N and 0°-3°E, where the herring were mostly scattered and in part above transducer range. In addition, single schools were recorded along a transect at 69°55'N between 1°W and 3°30'W. While the western limit of herring distribution was reached by these two vessels the northern limit was not determined.

On her return journey in the 3rd week of May, *Magnus Heinason* recorded herring considerably farther to the south and west than previously, i.e. at about 66°N, 3°W. Obviously, these were the herring that had been recorded a week earlier near 67°30'N, 0°30'W, since they had been followed continuously by the fishing fleet. However, these concentrations soon scattered and the fishery shifted to north of 68°N.

Based on the combined acoustic results of all the four vessels an acoustic estimate of the herring stock was run. The total biomass was estimated at 6.39 million tonnes (Table 4).

The RV F.Nansen surveyed the southern parts of the Barents Sea for young herring during the period 20.05-02.06 (Tab. 2, Fig. 5). Herring was observed throughout the surveyed area. The acoustic estimate is presented in table 5.

June/July

During the period 3 June –22 June the RV F.Nansen surveyed the area 61°-66°N, 10°W-10°E (Fig. 8). Only insignificant amounts of herring were observed within the surveyed area, while larger concentrations were observed off the Lofoten Isles/Vesterålen, northern Norway on a transport transect passing this area (Fig. 29).

The RV Johan Hjort carried out a hydrographic survey in the northern parts of the Norwegian Sea and the Greenland Sea (66°-74.50°N, 14°W-20°E) during the period 15 June-9July (Fig.7). The target species during this survey was salmon, but large catches of herring were made in some of the surface trawl hauls carried out (Fig. 30). From the catches it is indicated concentrations of herring from 71°N to 74°30N, 0° to 10°E. The largest catches were, however, taken close to the Norwegian coast, off Finmark at 71°N to 72°N, along 20°E, and off Vesterålen at 69°N, 12°E. The concentrations observed off Finmark is consistent with a summer fishery which took place in this area in June.

In the period 21 June-6 July the *Árni Fridriksson* surveyed the area north and east of Iceland as shown in figure 6. No herring were found east of Iceland, but concentrations of large herring were located in the northeastern part of the Icelandic EEZ as well as in the southwesternmost part of the Jan Mayen zone. Furthermore, concentrations of very large herring were located north of Iceland, between approximately 67°45'-68°20'N and 14°-16°W. At that time Iceland had taken her TAC, but a few Faroese boats fished herring north of Iceland for a while.

July/August

The G.O Sars covered the Norwegian Sea from 62°-74.50°N, 10°W-18°E during the period 21.07-22.08 (Table 2, Fig. 9). The main herring concentrations during this period were observed north of 71°N, from 0° to 16°E (Fig.31). The northern zero line was not observed and herring may well have been distributed even further north than 74°30'N which was the northernmost transect sailed. However, it seems clear that by this period the bulk of the stock had a more north-eastern distribution than observed during the same period last year (Anon., 1998). Nor acoustic estimate of herring was carried out during this survey.

The fishery and herring migrations

The changes in the position of the Icelandic and Faroese fishing fleets probably roughly reflect the migration pattern of the bulk of the herring stock in May and June (Fig.32).

The fishery began in early May in the area between 67°N and 68°N, 0°-1°W. During the 2nd and 3rd weeks of May the fishing area gradually shifted south-west and around 20 May was located near 66°15N, 3°W. Schools were usually too deep during the day and often scattered on approaching the surface layer at night resulting in generally low catch rates during this period.

In the beginning of the 4th week of May, the fishing fleet shifted to just north of 68°N, around 4°W. During the next few days the fishery shifted westward and from 25 May until 10 June took place in the area from 68°05'N to 70°40N, between about 6°W and 8°W.

Judging by the movements of the main fishing fleet, the herring began migrating fairly rapidly to the east or eastnortheast around 10 June. They had reached the zero meridian at about 71°N-72°N on 20 June and 5°-6°E towards the end of the month.

However, as described in an earlier section, part of the stock did remain longer in the Jan Mayen EEZ and migrate farther west to where Faroese boats made good catches for a short time in early July near 68°N, 15°W. The westernmost record in 1999 is from an Icelandic capelin boat, which caught some herring among capelin at 68°10'N, 18°W on 10 July.

Herring migrations in 1999

The inferred migration paths of herring in 1999 are shown in figures 33 and 34, which represent a synopsis of the data collected during 1999. The basis for each is discussed below as well as supplementary information from the location of catches (Fig. 32).

In March it is assumed that the herring are still largely on or near to their spawning grounds along the Norwegian coast. In late April there are few fish left in coastal areas and relatively little within 20-30 nautical miles. It is assumed that the herring migrated away from the Norwegian coast in a northwesterly direction

The observed distribution in May is shown in Figure 28. The main difference as compared to last year is a northward shift of large part of the total biomass by about 150 nautical miles and a greater distance from the coast of Norway, south of the Lofoten area. While no herring was observed in the Jan Mayen zone in May in 1998, the herring had all ready protruded into this area in May 1999. The northwards shift in herring distribution in 1999 is probably associated with an unusually low temperature in the eastern Norwegian Sea in spring 1999 (further discussed in the hydrography section).

Around mid-May, the herring located near 67°30'N, 0°-1°W began to migrate in a southwesterly direction. This probably was only a small fraction of the stock. The movement of these herring was observed by *Magnus Heinason* and is also demonstrated by the movement of the fishing fleet.

A much larger part of the stock, however, migrated west and northwest during the last week of May and the first 10 days of June, into the Jan Mayen zone, at least to 8°W and 70°40'N as judged by the operations of the fishing fleet. After that most of these herring began retracing their route back east and had reached 72°40'N, 6°E by the end of the month.

During the same period a fishery took place off the coast of northern Norway where approx. 4000 tonnes were caught. These concentrations were also observed by the F/F “Johan Hjort” who made good trawl catches of up to 28 thousand individuals north west of Finmark in early July. These concentrations has not been observed in the foregoing years and represents s new tendency in the herring migration during this period. Herring was also observed off Vesterålen during summer both by the RV F.Nansen and the RV Johan Hjort. In this area the so called

"fat-herring" (adolescent herring) normally feeds and concentrations of herring in this area is quite normal during summer.

As described in an earlier section, surveying by *Árni Fridriksson* during during 22 June-6 July located concentrations of herring in an area near the borderline between the EEZs of Iceland and Jan Mayen, as well as in deep waters off the eastern north coast of Iceland. Due to the irregular behaviour of these herring, a valid abundance estimate could not be made. However, the total abundance was possibly in the order of 400-500 thousand tonnes, about equally much in each area. Whether these herring derive from the component which was observed on a southwest migration in mid-May, or an offshoot from the main migration to the Jan Mayen area later in the month cannot be determined on the available evidence.

In July the herring had migrated further to the north-east and was observed in the area from 71°N to 75°N, 0°-18°E. The G.O.Sars survey in July-August did, however, not find the northerly zero-line and some herring may very well have been situated further to the north at that time.

By the end of August the herring had started its migration towards the Norwegian coast, and Norwegian fishing vessels were taking good catches around 72°N, 13°E. The herring was found in very large schools that migrated S and SW at approx. 20 n.miles per day. Based on the observed autumn migration during the 1990's the herring is expected to enter the wintering areas in the Vestfjord-Tysfjord-Ofotfjord area in September-October.

The herring migrations in 1999 must be considered the most northerly one during the period the PGSPFN group has carried out its analysis (1995-1999). As discussed in the hydrography section this may partly be due to the cooling of the southern part of the Norwegian Sea and the warming of the northern parts.

Blue whiting

May

In early May the adult stock of blue whiting was situated south of the Faroes, and the post spawning migration had only barely entered into the Faroe zone in the first week of May (Fig.35). However, not conclusive the distribution of the concentrations of post spawning fish indicated a significant migration to the North through the Faroe Bank Channel and less through the Faroe Shetland Cannel. The international fishery in the Faeroe area in May, which to a large extent took place in the Faroe Bank channel, would support this migration pattern. There were only small concentrations of blue whiting recorded in the northern parts of the Faroes Shetland channel and north of the Faroes. However in the eastern and central parts of the Norwegian Sea blue whiting was distributed over a wide area from the 0^0 and to the East to the Norwegian shelf. (Figure 35). Blue whiting was also observed in the Jan Mayen zone in May. The highest recordings were observed in the south at the entrance into the Norwegian Deep, in which blue whiting most likely also were found in May.

The age distribution in the samples of blue whiting both south of the Faroes and in the Norwegian Sea were dominated by the 1996 year class (Apr. 50%), however, with significant contributions from the year classes of 1997 and 1998 (Each Apr. 20%).

July

A survey of the distribution and abundance of blue whiting within the Icelandic EEZ to the east-southeast and south of Iceland was carried out by *Árni Fridriksson* during 14-28 July. Cruise tracks and the relative distribution (S_A-values) of blue whiting is shown in Figure 6. In most of the area covered, the fish occurred in fairly scattered concentrations. The total abundance estimate was about 1.8 million tonnes, comprising 27.6 billion fish by number. The most numerous by far was the 1999 year class (0-group) which amounted to 14.9 billion or 54% of the total. The contribution of the year classes of 1994-1998 was 4.9%, 21%, 6.4%, 4.9% and 7.6%, respectively. Details of the abundance estimate are given in Table 6

The 0-group blue whiting were mainly found between 63°N and 63°30´N, 11°W to 14°W, but also in a limited area at the shelf edge off the south-east coast. Other year classes were more or less evenly distributed throughout the survey area. The blue whiting were usually

distributed from 150-300 m depth, but the 0-group also occurred as dense schools at 50-100 m depth and of which the largest part were 3-4 year olds with a length distribution mostly between 24-29 cm. In addition the survey recorded 14.1 billion 0-group fish within a relatively restricted area in deep waters to the south-east of Iceland as compared to only about 1.5 billion in 1998.

July-August

During the survey by the RV G.O.Sars in July-August blue whiting was found distributed over wide areas in the Norwegian Sea (Fig.36). An acoustic estimate indicated a biomass of blue whiting in the area surveyed of 4.2 million tonne (Table 7). Again the samples were dominated by the year classes of 1996, 1997 and 1998.

Evaluation of blue whiting data

None of the surveys reported in this document were designed at obtaining a total estimate and general distribution of blue whiting during summer in the Norwegian Sea and adjacent areas. It is therefore not possible to base any conclusions on zonal attachments on these alone.

The blue whiting stock is presently dominated by the year classes of 1996,1997 and 1998. The maturity ogive for blue whiting is not very well known and it is therefore not certain what proportion of these year classes matured to spawn this spring.

The May samples have not been fully analysed yet, and it was not possible for the study group to analyse weather there were age or maturity differences between the blue whiting caught in the Norwegian Sea in the area south of the Faroes. The length distribution, however, was very similar indicating the same age distribution. The discontinuous distribution of blue whiting between the Faroe Shetland Channel and the Norwegian Sea may, therefore have been caused by immature blue whiting distributed in the feeding areas.

The nursery areas for blue whiting are mainly along the shelf edges in the north east Atlantic. Large year-classes have a very wide distribution extending from off East Greenland to the Barents Sea, which has clearly been demonstrated since 1996. Similar distributions were also observed when the strong of 1982 and 1989 recruited. The nursery areas for smaller year

classes have a more restricted distribution mainly along the Faroe shelf, along the shelf edge west of Scotland, and in the Norwegian Deep.

The post spawning migration to the feeding areas in the Norwegian Sea past the Faroes and the distribution of feeding blue whiting is very much influenced by the hydrography. The strong influx of East Icelandic Water in to the southern Norwegian Sea in 1999 compared to previous years may have favoured a migration to north trough the Faroe Bank Channel into the areas between Faroes and Iceland (Hansen and Jákupsstovu, 1993)

Mackerel, Horse mackerel, Salmon

Due to low catches the group will not comment on these species in 1999.

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Tables

Table 1. Organisational frame of the coordinated herring investigations in the Norwegian Sea, 1995-1999.

Year	Participants	Surveys	Planning meeting	Evaluation meeting
1995	Faroe Islands, Iceland Norway, Russia	11	Bergen, (Anon, 1995a)	Reykjavík (Anon, 1995b)
1996	Faroe Islands, Iceland Norway, Russia	13	Tórshavn, (Anon, 1996a)	Reykjavík (Anon, 1996b)
1997	Faroe Islands, Iceland Norway, Russia, EU	11	Bergen (Anon, 1997a)	Reykjavík (Anon, 1997b)
1998	Faroe Islands, Iceland Norway, Russia, EU	11	Reykjavík (Anon, 1997b)	Lysekil (Anon, 1998)
1999	Faroe Islands, Iceland Norway, Russia, EU	10	Lysekil (Anon, 1998)	Hamburg (this report)

Table 2. Surveys conducted in spring and summer 1999 by Faroes, EU, Icelandic, Norwegian and Russian vessels in the North Atlantic and the Barents Sea, which are related to the Norwegian Spring Spawning Herring

Vessel		**Survey area**	**Period**	**Herring samples**	**Plankton samples**	**CTD stations**
>>Walther Herwig III<<	EU	61.25°-69°N, 1.5°W-14°E	23.04-21.05	0	102	110
>>G.O.Sars<<	NOR	62°-72°N, 7°W-17°E	28.04-02.06	32	89	88
>>Magnus Heinason<<	FAR	59.5°-68.5°N, 7.5°W-3°W	30.04-25.05	20	117	143
>>Árni Fridriksson<<	ISL	65°69.75°N, 17.5°-6°W	05.05-22.05	3	75	75 (*)
>>Bjarni Saemundsson<<	ISL	62°-68°N, 35°W-09°W	17.05-03.06	0	95	72
>>F. Nansen<<	RUS	69°-72.5°N, 29°-38.5°W	20.05-02.06.	13	37	39 (*)
>>F. Nansen<<	RUS	61°-70.5°N, 14°W-10°E	03.06-22.06	8	85	66 (*)
>>Johan Hjort<<	NOR	66°-74.50°N, 14°W-20°E	15.06-09.07	17	65	93
>>Árni Fridriksson<<	ISL	62.5°-68.75°N, 12°W-3°E	21.06-06.07	20	60	60 (*)
>>G.O.Sars<<	NOR	62°-74.50°N, 10°W-18°E	21.07-22.08	10	93	131

(*) Data are not yet included in the combined hydrographic data set.

Table 4. Age stratified estimate of Norwegian spring spawning herring in the Norwegian Sea, RV Árni Fridriksson, RV G.O.Sars, RV Magnus Heinason and RV Walther Herwig III, May, 1999. Numbers in millions, weight in thousand tonnes, length in cm, mean weight in grams.

Norwegian spring spawning herring in the Norwegian Sea, May 1999.

Age	2	3	4	5	6	7	8	9	10	11	12	14	15	Total
Numbers	212	2191	322	965	3067	11763	6077	853	258	5	14	158	128	26013
Percent	0.8	8.4	1.2	3.7	11.8	45.2	23.4	3.28	1.0	0	0	0.6	0.5	100
Mean length	20.93	26.37	29.95	32.11	32.54	33.25	33.90	35.05	35.70	36.25	36.68	37.59	38.33	32.69
Weight	15.0	319.0	65.9	230.4	737.1	2964.6	1627.3	243.9	81.4	1.5	4.9	55.2	46.4	6392.9
Mean weight	71	146	205	239	240	252	268	286	315	298	351	350	363	246

Table 5. Age stratified estimate of Norwegian spring spawning herring in the Barents Sea, RV F.Nansen, May-June, 1999. Numbers in millions, weight in thousand tonnes, length in cm, mean weight in grams.

Norwegian spring spawning herring in the Barents Sea

Age	1	2	Total
Numbers	49462	4889	54351
Percent			
Mean length	9.5	14.7	9.8
Weight	234	96	330
Mean weight	5.5	19.7	6.2

Table 6. Age stratified estimate of blue whiting in the Icelandic EEZ, Árni Fridriksson, July, 1999. Numbers in millions, weight in thousand tonnes, length in cm, mean weight in grams.

Blue whiting: (Árni Fridriksson), July, in the Icelandic EEZ

Age	0	1	2	3	4	5	6	7	8	9	10	Total
Numbers	14869	2100.4	1356.8	1772.2	5789.6	1343.8	316.4	50.1	15.4	33.1	8.6	27655.8
Percent	53.8	7.6	4.9	6.4	20.9	4.9	1.1	0.2	0.1	0.1	0.0	100.0
Mean length	13.5	23.5	25.6	26.3	27.6	29.0	30.3	33.7	35.5	36.5	37.8	19.7
Weight	265.4	162.6	127.3	201.0	764.3	211.7	54.9	12.7	3.8	10.2	3.3	1817.2
Mean weight	17.8	77.4	93.8	113.4	132.0	157.6	173.6	254.1	247.5	307.1	380.2	65.7

Table 7. Age stratified estimate of blue whiting in the Norwegian Sea,G.O.Sars, July, 1999. Numbers in millions, weight in thousand tonnes, length in cm, mean weight in grams.

Blue whiting: (G.O.Sars), July-August, in the Norwegian Sea

Age	0	1	2	3	4	5	6	7	8	9	10	Total
Numbers	185	12267	8393	21929	3964	389	150	29	33	58	25	47422
Percent	0.4	25.9	17.7	46.1	8.4	0.8	0.3	0.1	0.1	0.1	0.1	100.0
Mean length	17.1	22.1	24.8	26.0	27.8	30.5	32.2	32.6	36.1	35.3	37.3	25.0
Weight	5.8	723.4	722.5	2185.2	472.9	58.4	26.0	5.4	8.1	13.6	6.5	4227.9
Mean weight	31.5	59.0	86.1	99.6	119.3	150.1	173.5	187.0	245.3	234.9	259.0	89.2

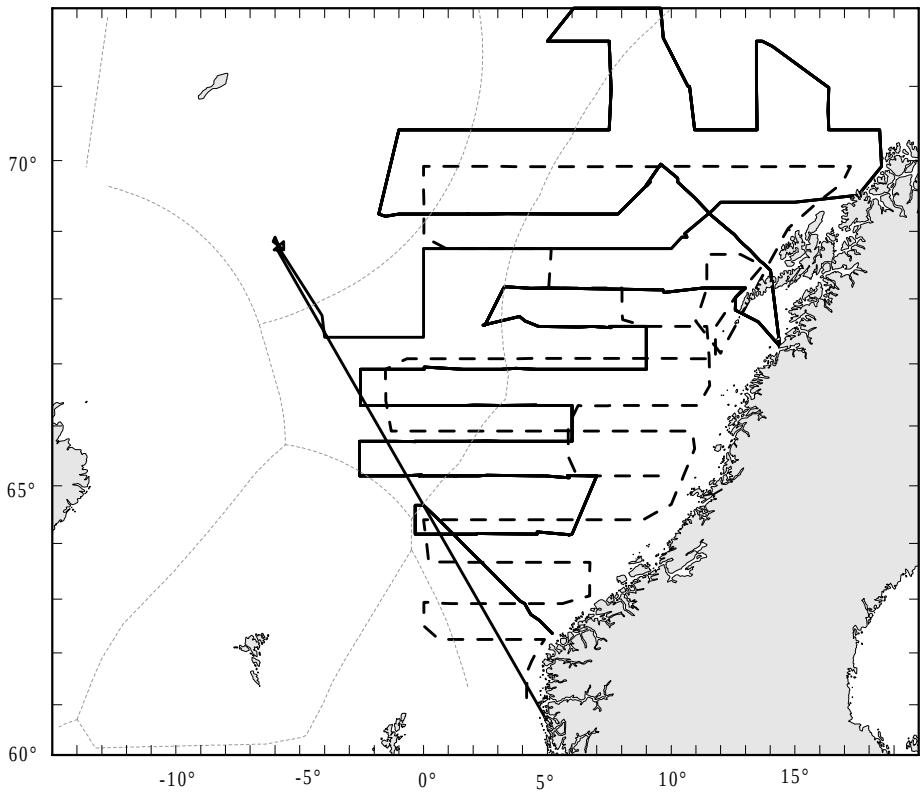


Figure 1. Cruise tracks of the RV G.O Sars (whole line) and the FRV Walther Herwig III (stipled line) during the international acoustic survey on Norwegian spring spawning herring in April-May 1999.

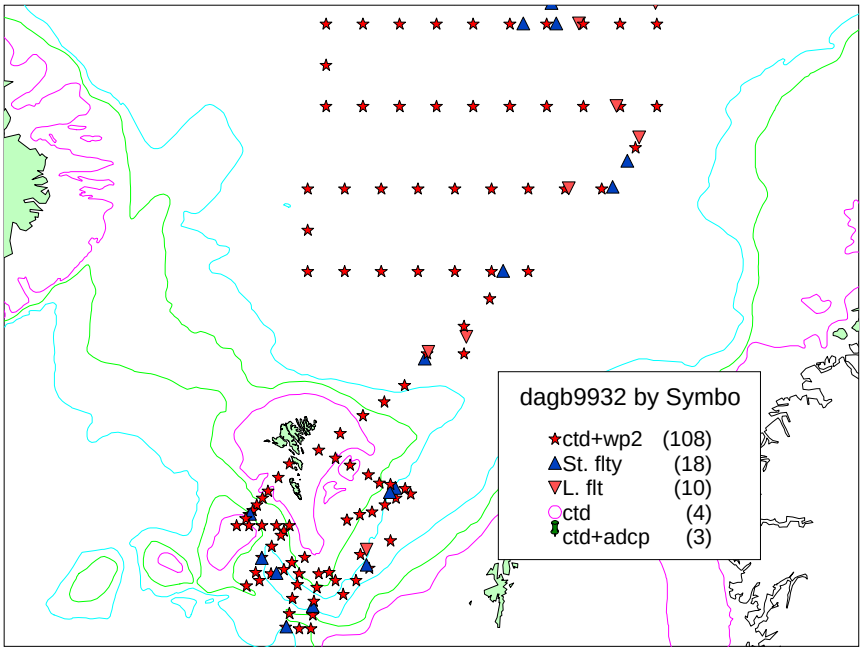


Figure 2. Cruise tracks of RV Magnus Heinasson during the international acoustic survey on Norwegian spring spawning herring in April-May 1999.

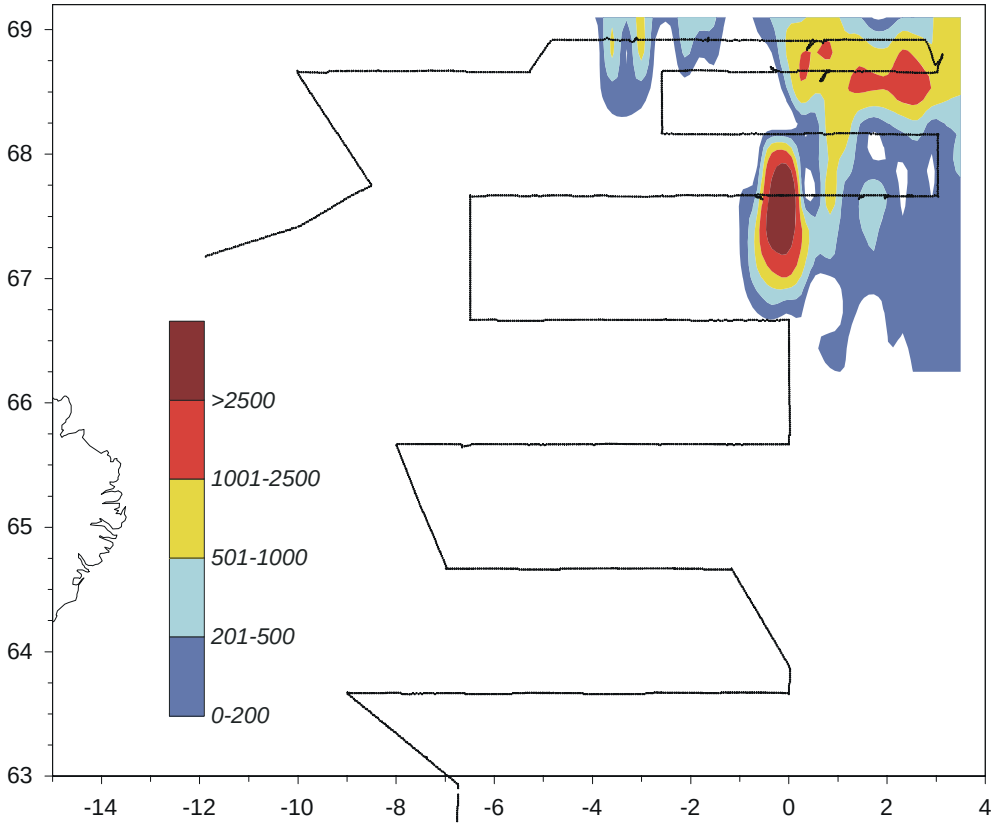


Figure 3. Cruise tracks of the RV Árni Fridriksson during the international acoustic survey on Norwegian spring spawning herring in April-May 1999. Isolines are Sa values of herring.

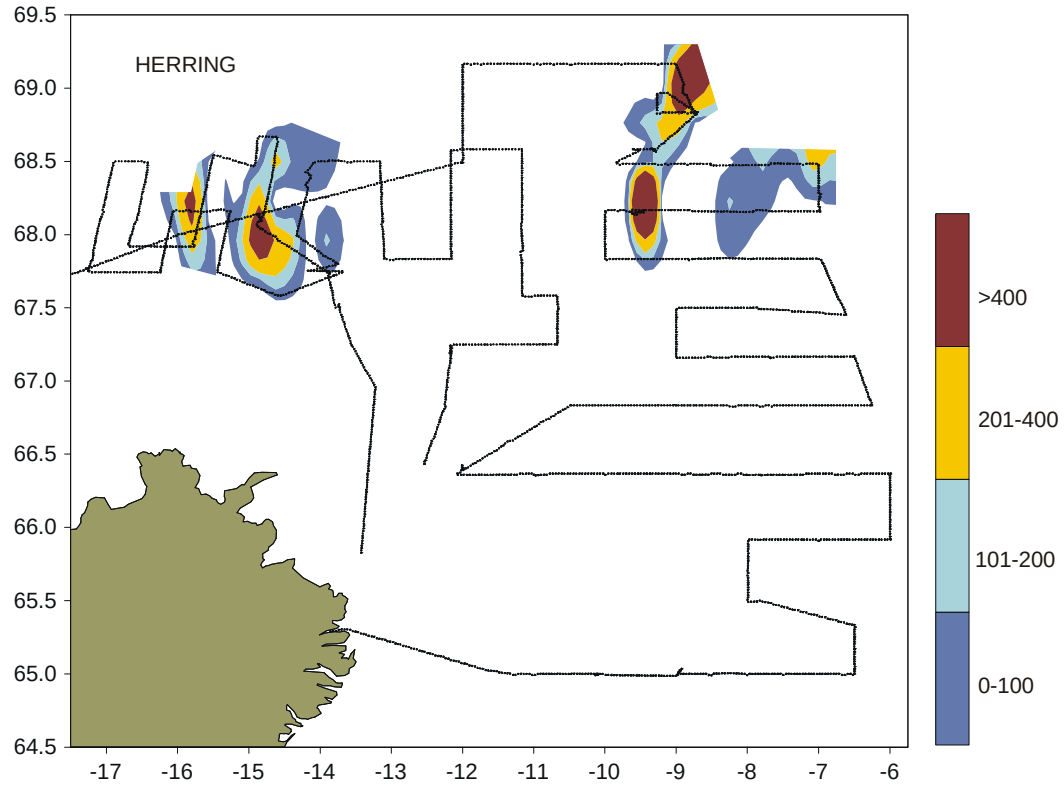


Figure 4. The observed distribution and relative density (S_A-values) of herring during 22 June - 06 July 1999.

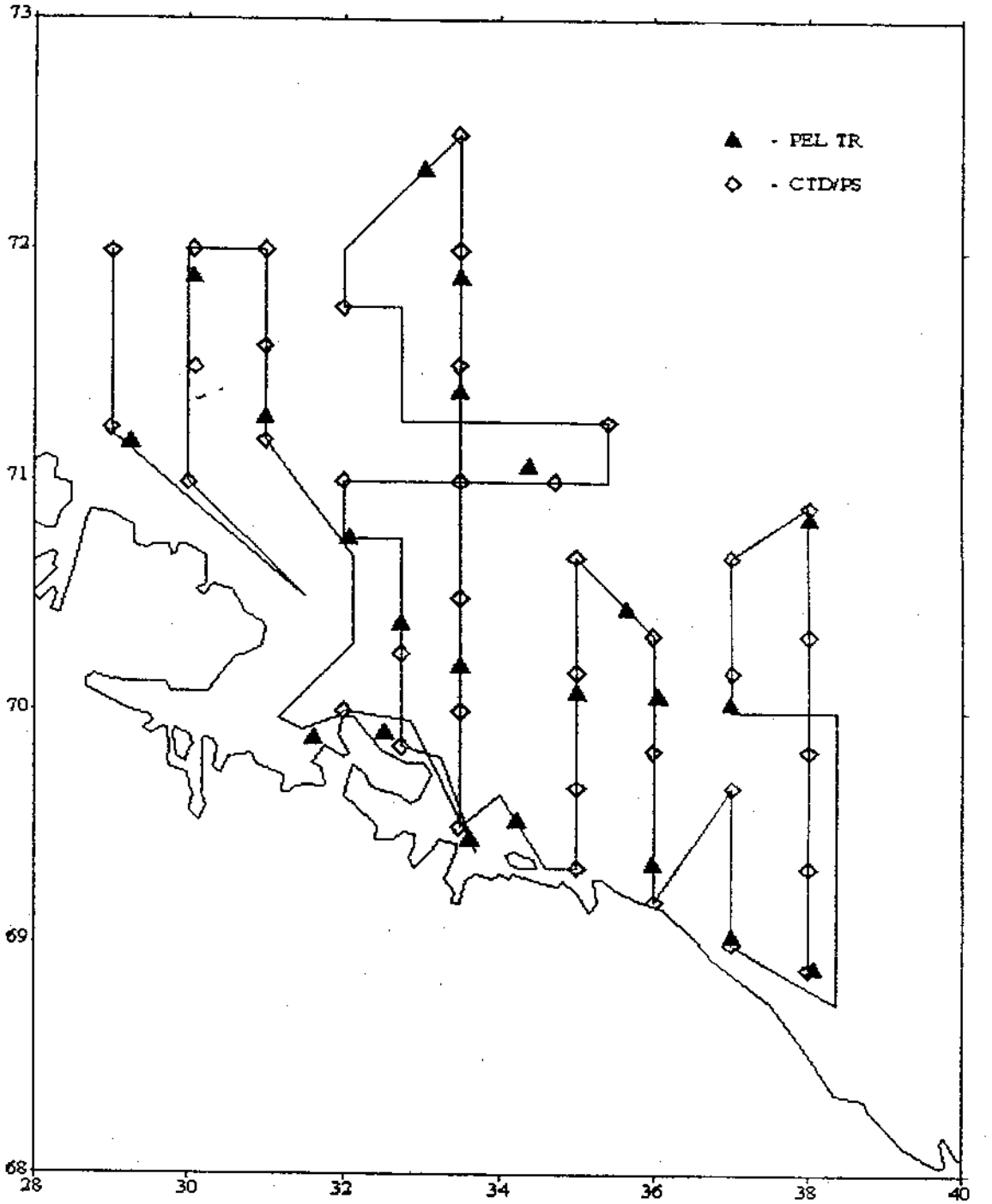


Fig. 5. Cruise track with fishing and CTD stations, R/V "F. Nansen" in the Barents Sea, 20/5-02/6 1999.

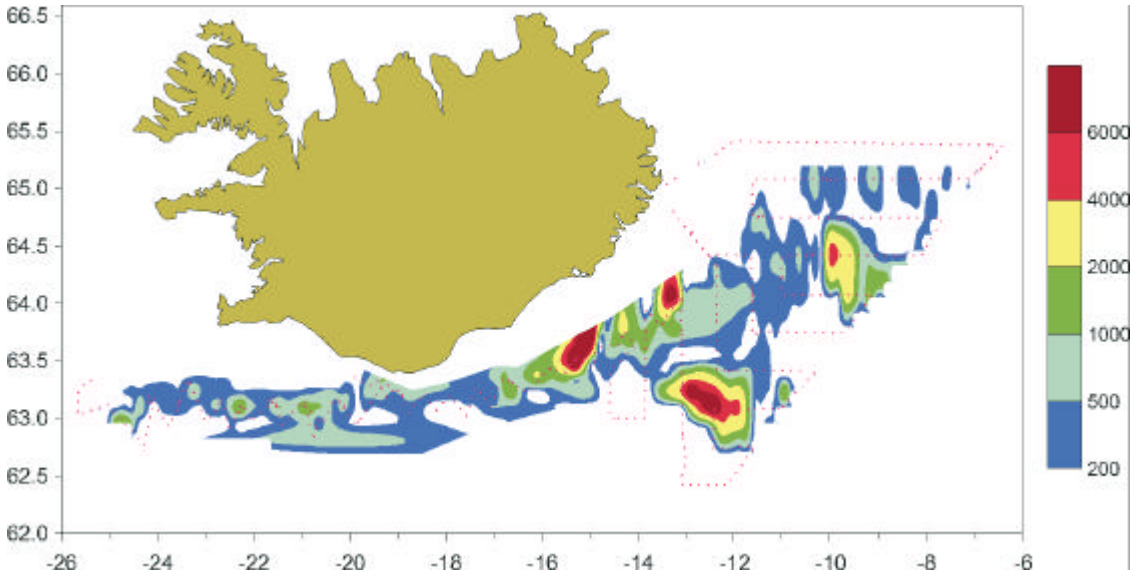


Figure 6. Cruise track of RV Árni Fridriksson 21.06-06.07, 1999. Isolines are distribution of blue whiting represented by Sa values.

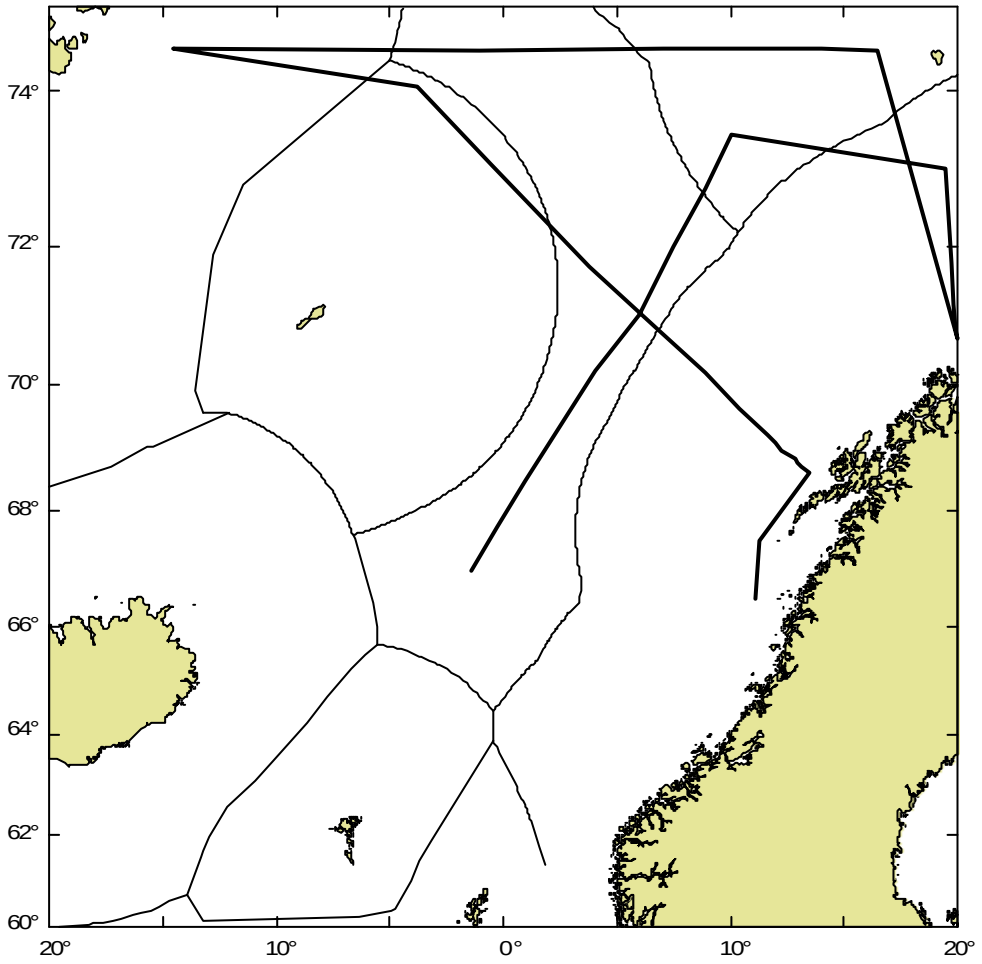


Figure 7. Cruise track of RV Johan Hjort 15.06-09.07, 1999.

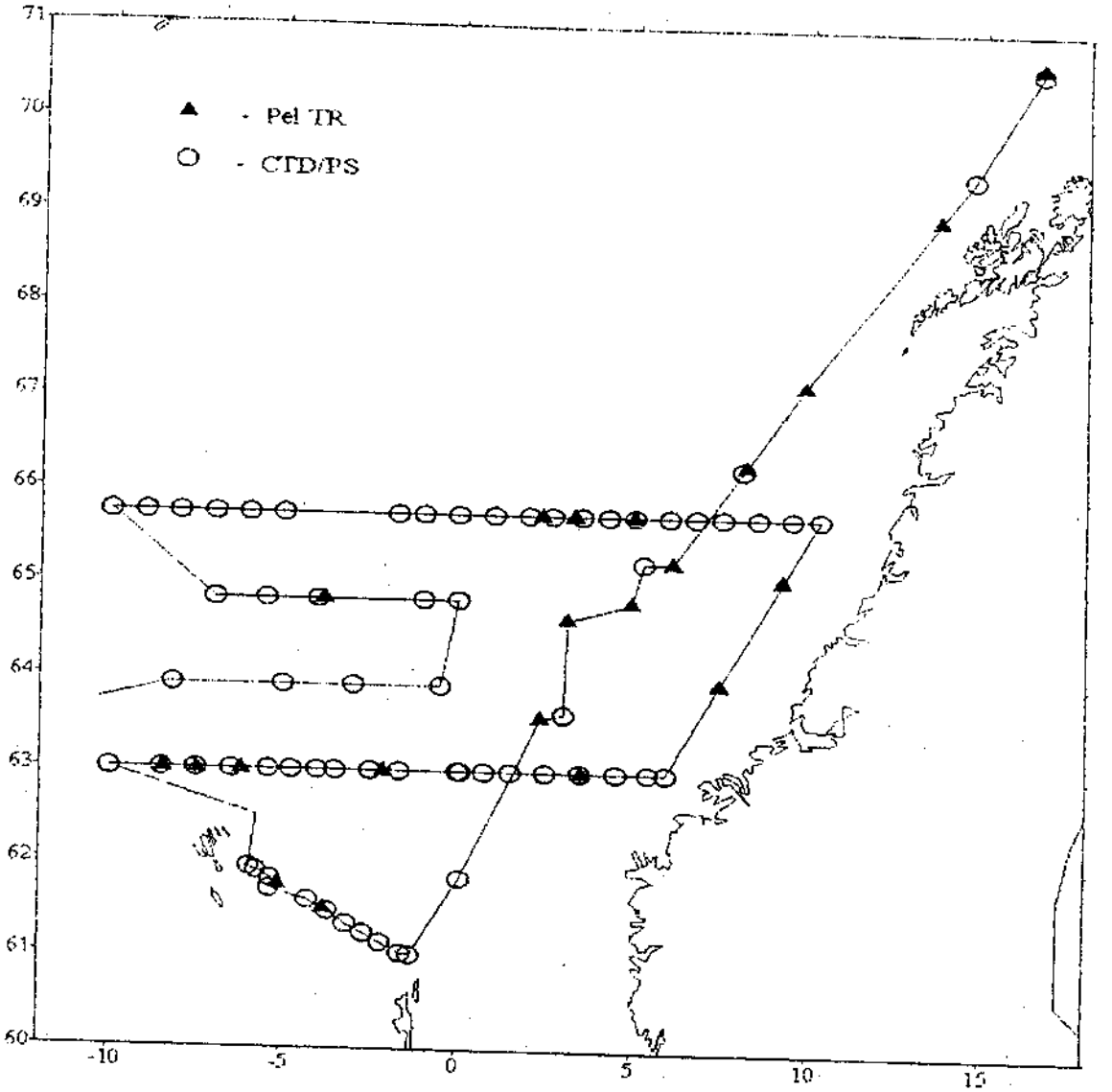


Fig. ßSurvey transects, trawl and CTD stations R?V ""Fr. Nansen" during 03.06-22.06.1999.

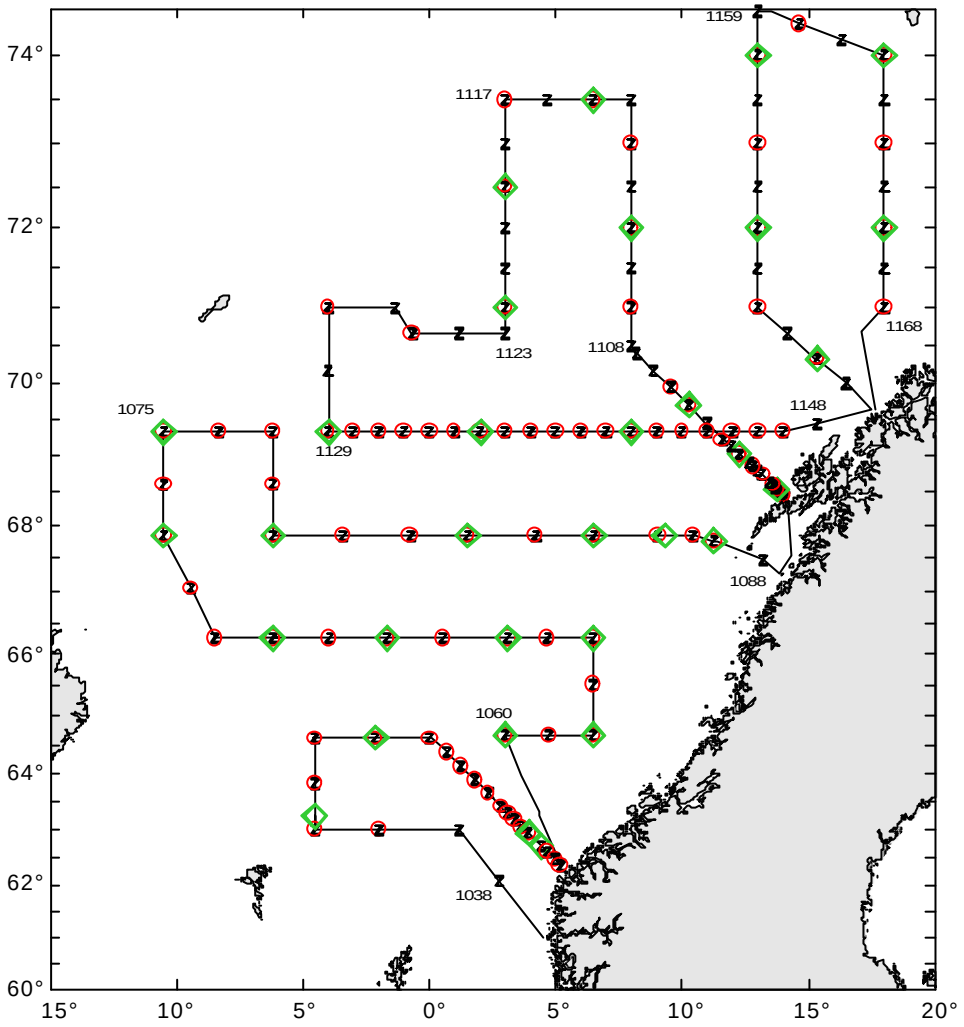


Figure 9. Cruise track of RV G.O.Sars 21.07-22.08, 1999. Z = CTD, = WP-2, square = Mocness.

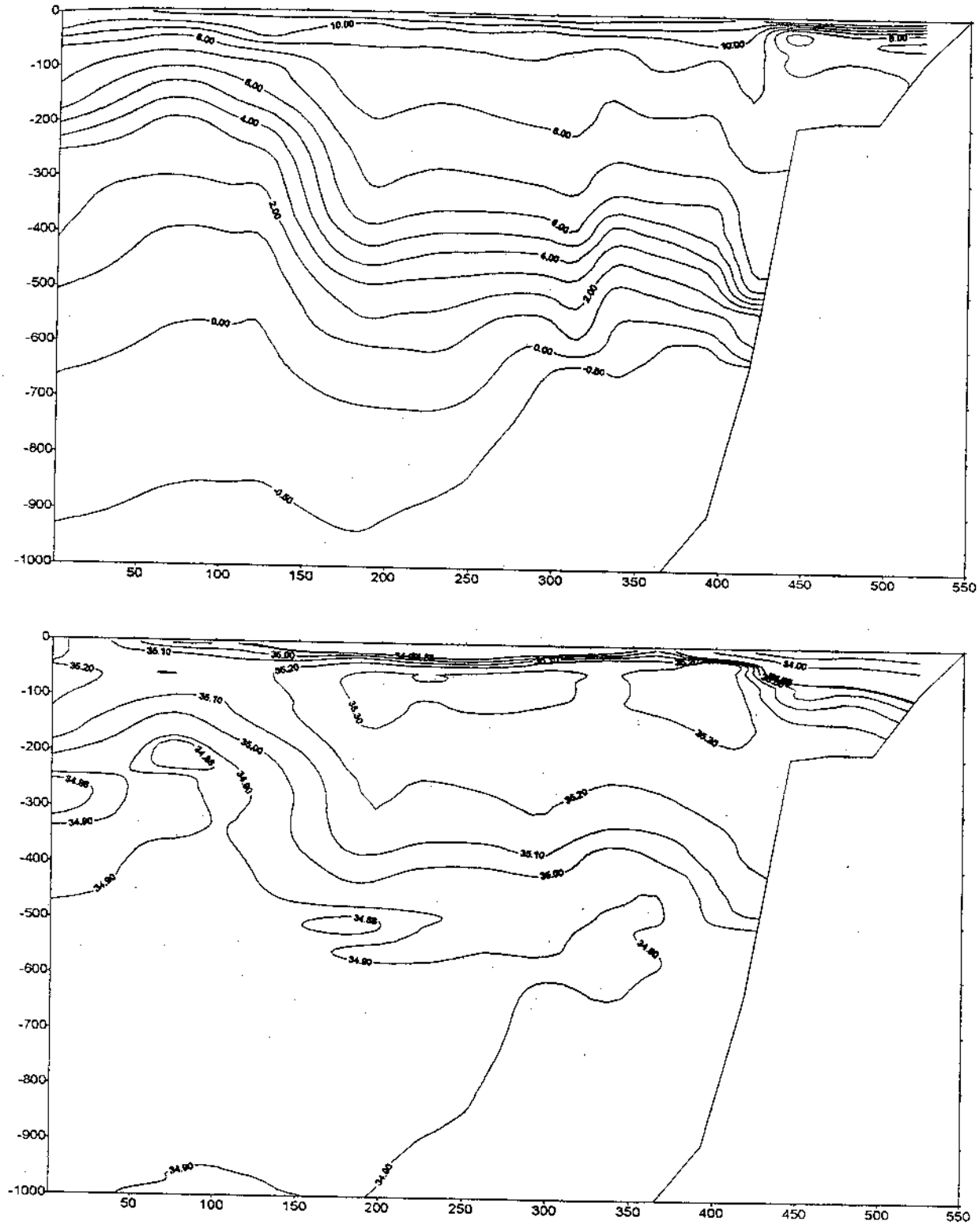


Fig. 10. Temperature and salinity in the section Svinøy - NW, July 1998

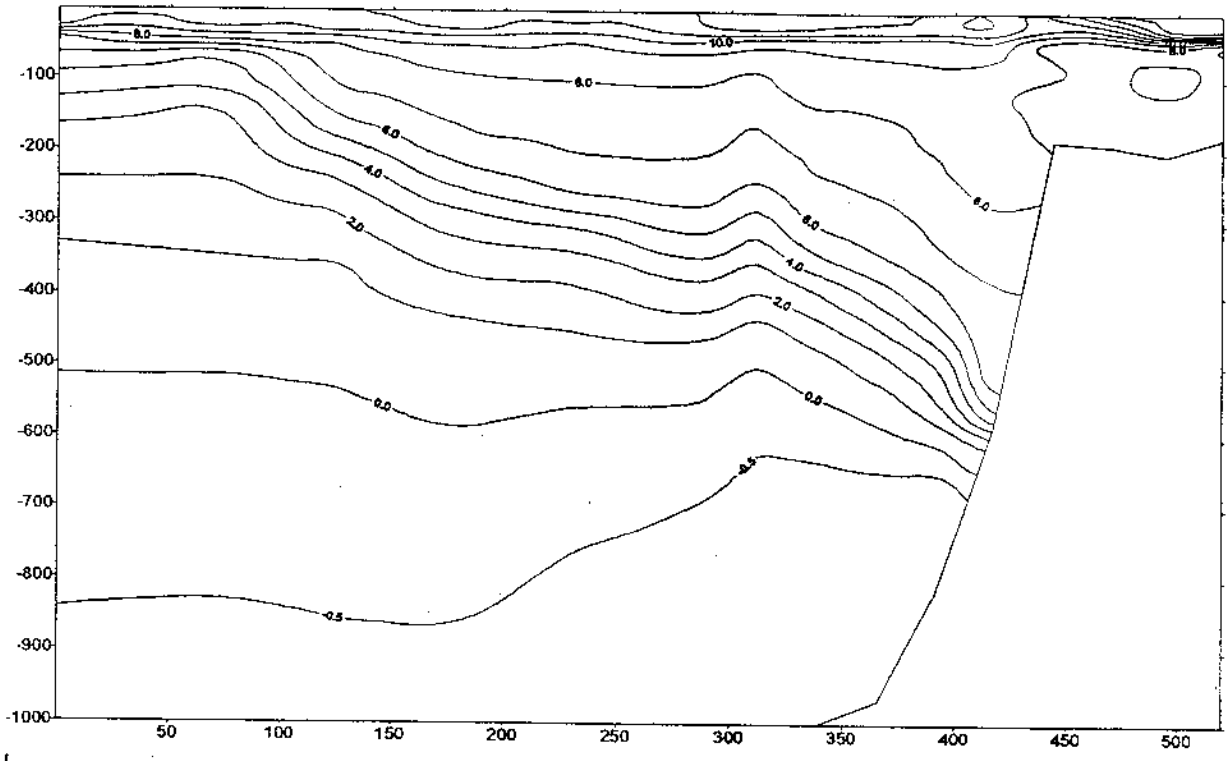


Fig. 11

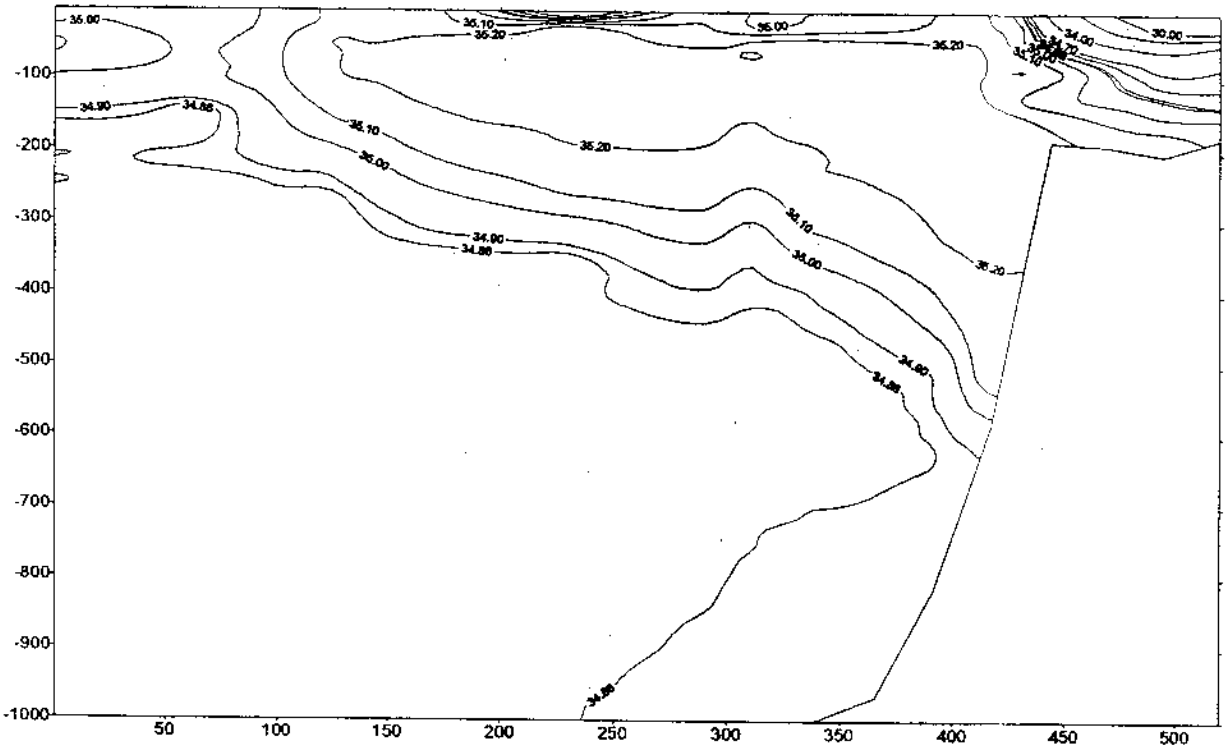
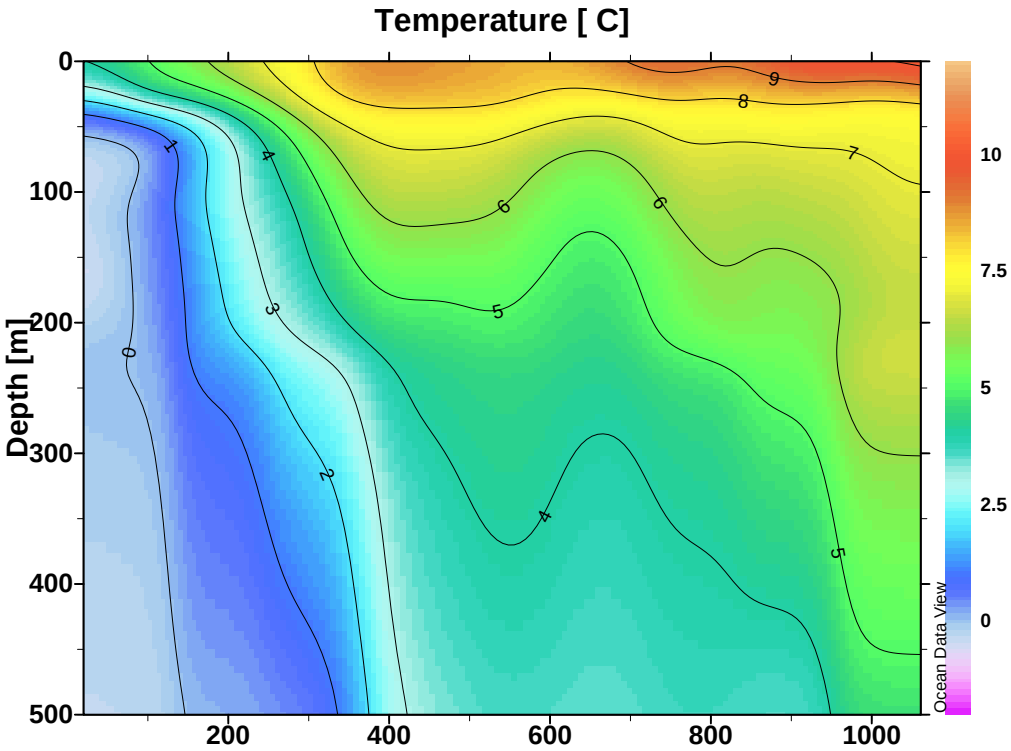
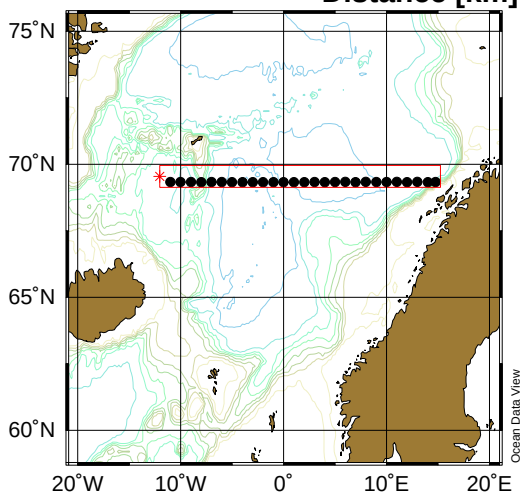
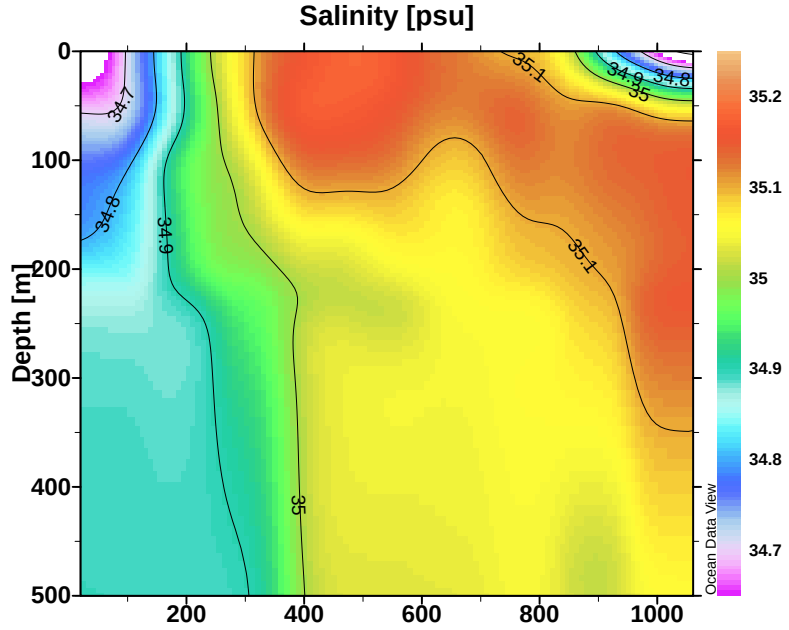
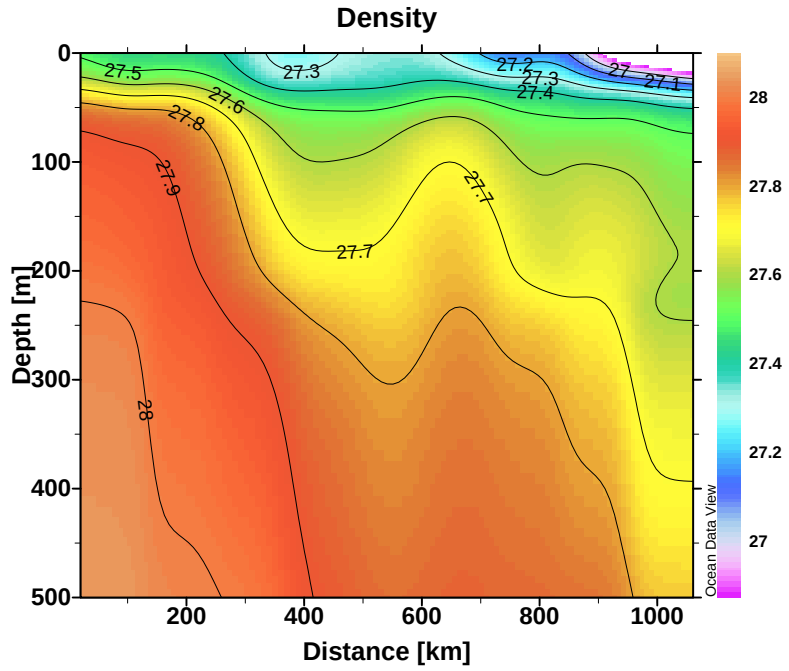


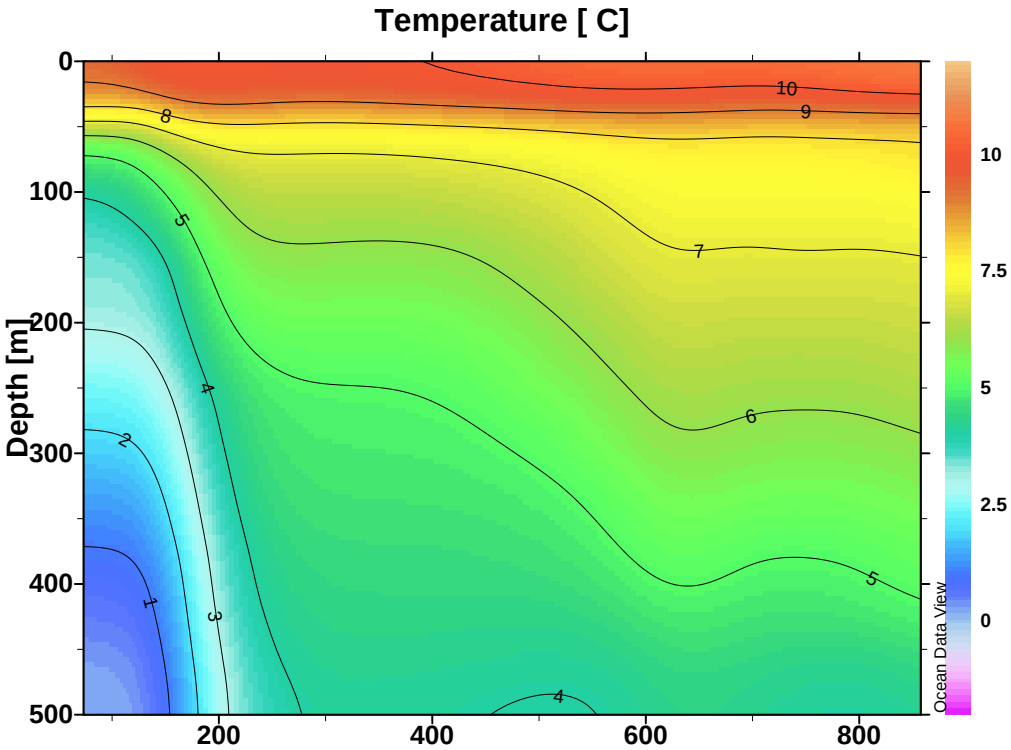
Fig 12 Temperature and salinity in the section Svinøy - NW. G.O. Sars, August 1999.

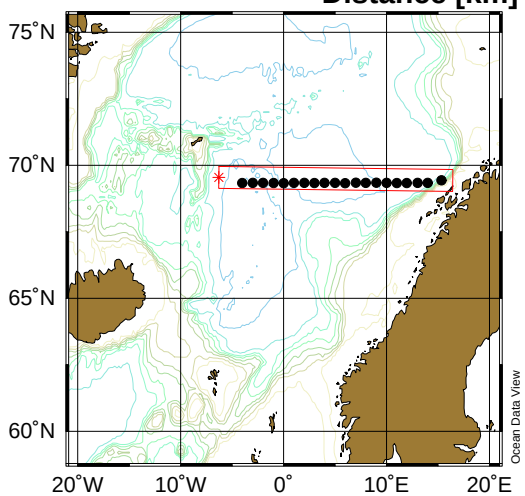

Temperature [C]
Depth [m]
Distance [km]
Ocean Data View

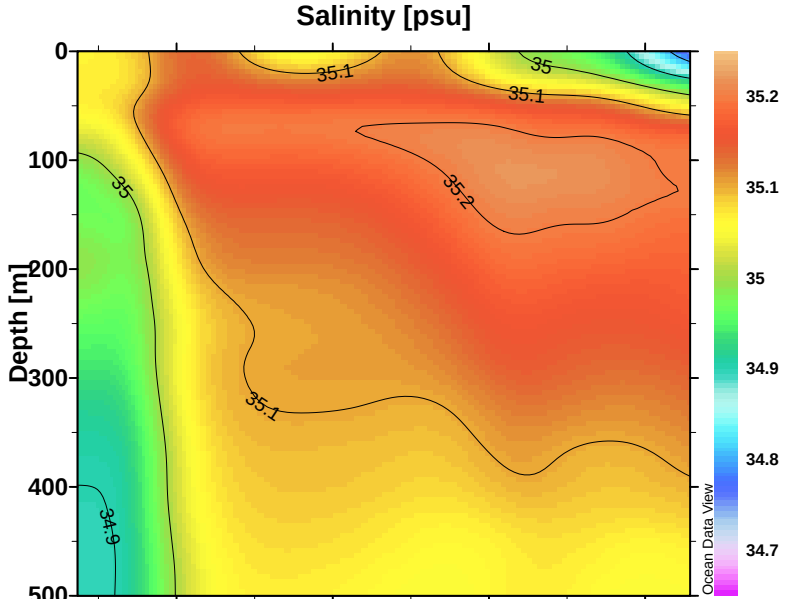

75°N
70°N
65°N
60°N
20°W
10°W
0°
10°E
20°E
Ocean Data View

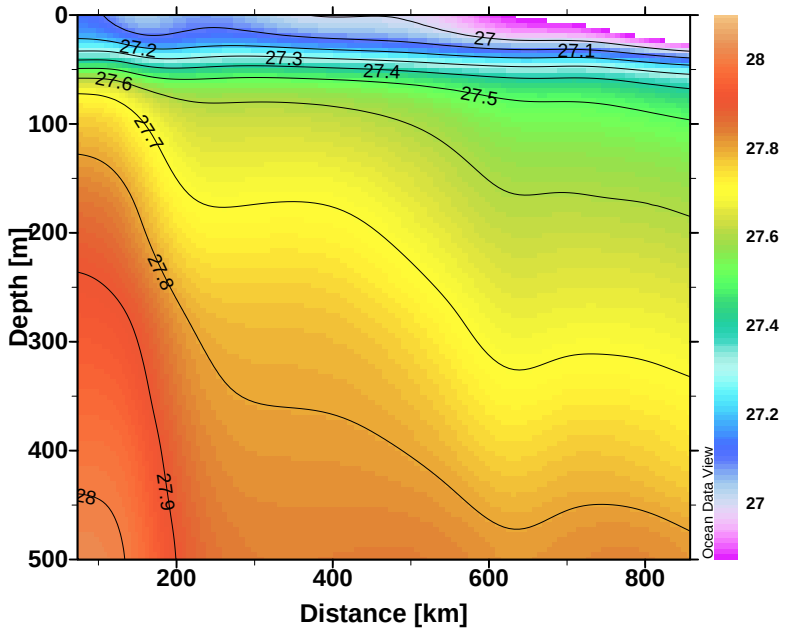

Salinity [psu]
Depth [m]
Ocean Data View

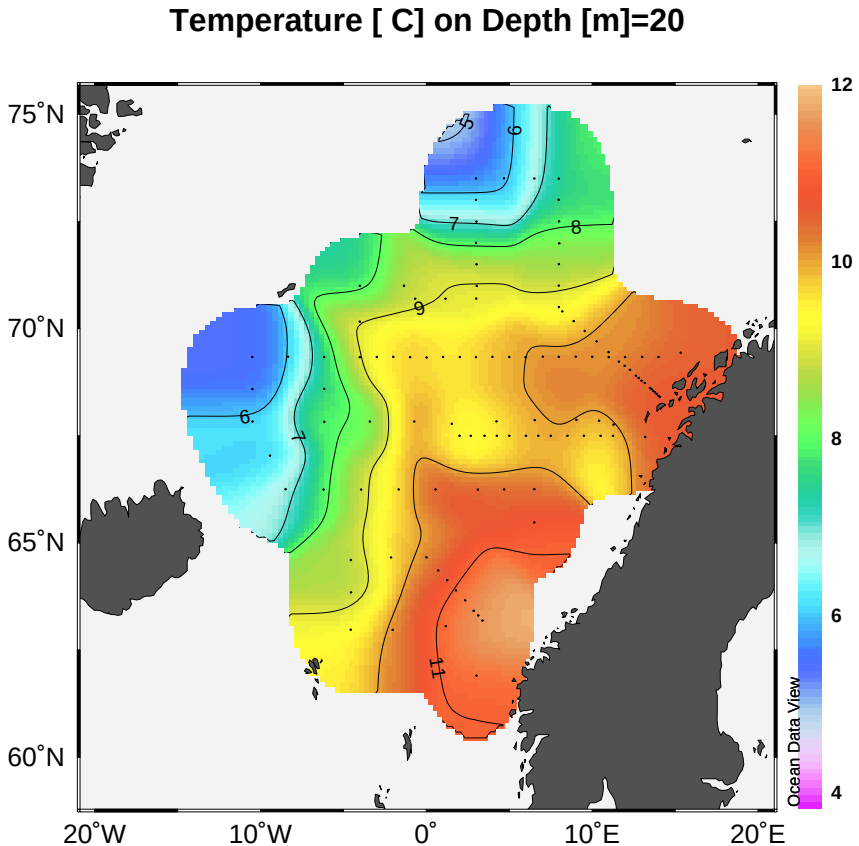

Density
Depth [m]
Distance [km]
Ocean Data View


Temperature [C]
Depth [m]
Distance [km]
Ocean Data View


75°N
70°N
65°N
60°N
20°W
10°W
0°
10°E
20°E
Ocean Data View


Salinity [psu]
Depth [m]
Density
Ocean Data View


Depth [m]
Distance [km]
Ocean Data View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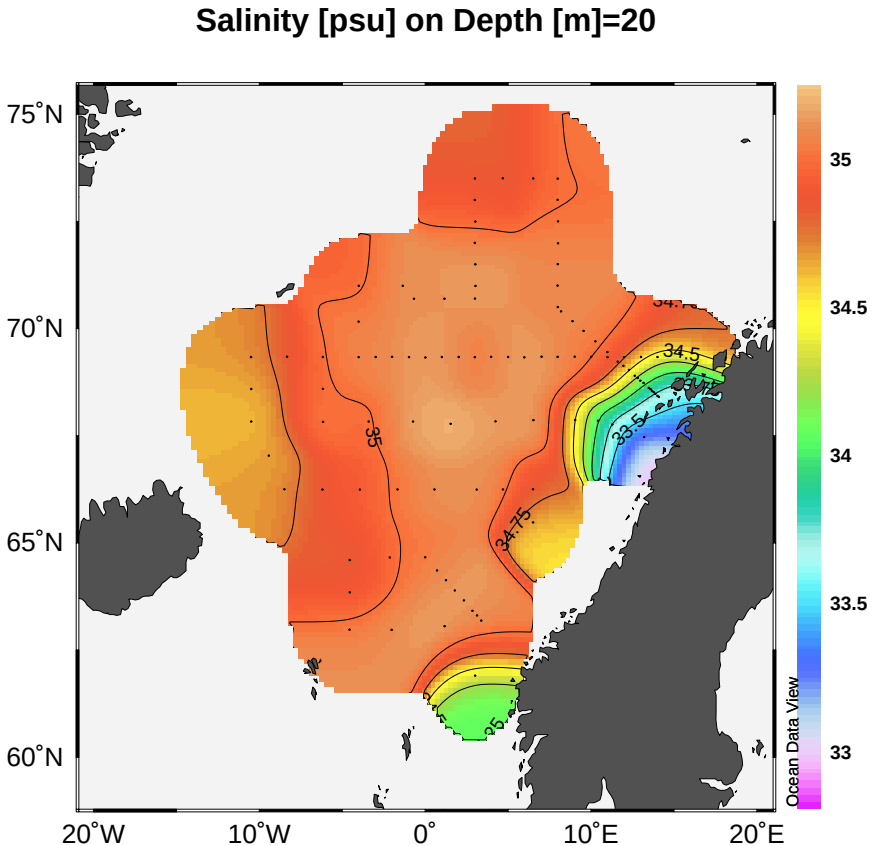
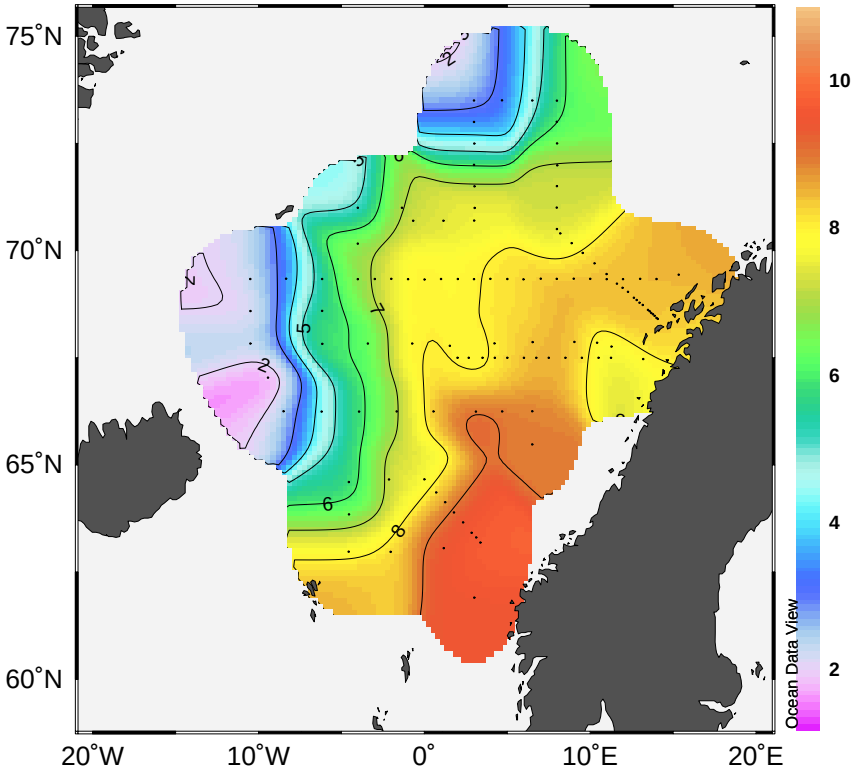
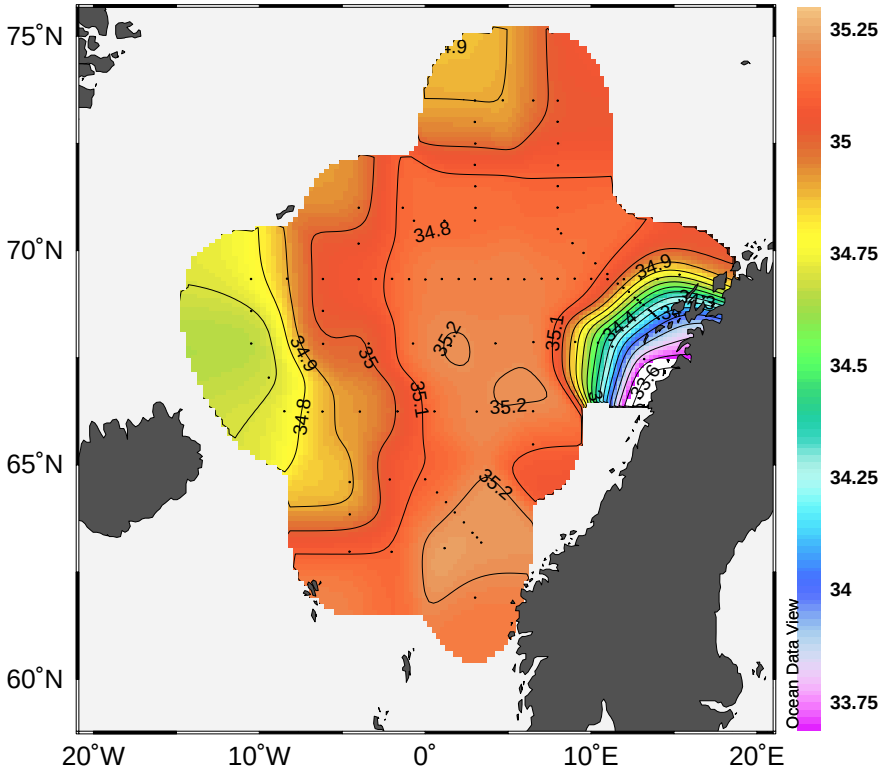
70°N
65°N
60°N
20°W
10°W
0°
10°E
20°E
12
10
8
6
4
Ocean Data View

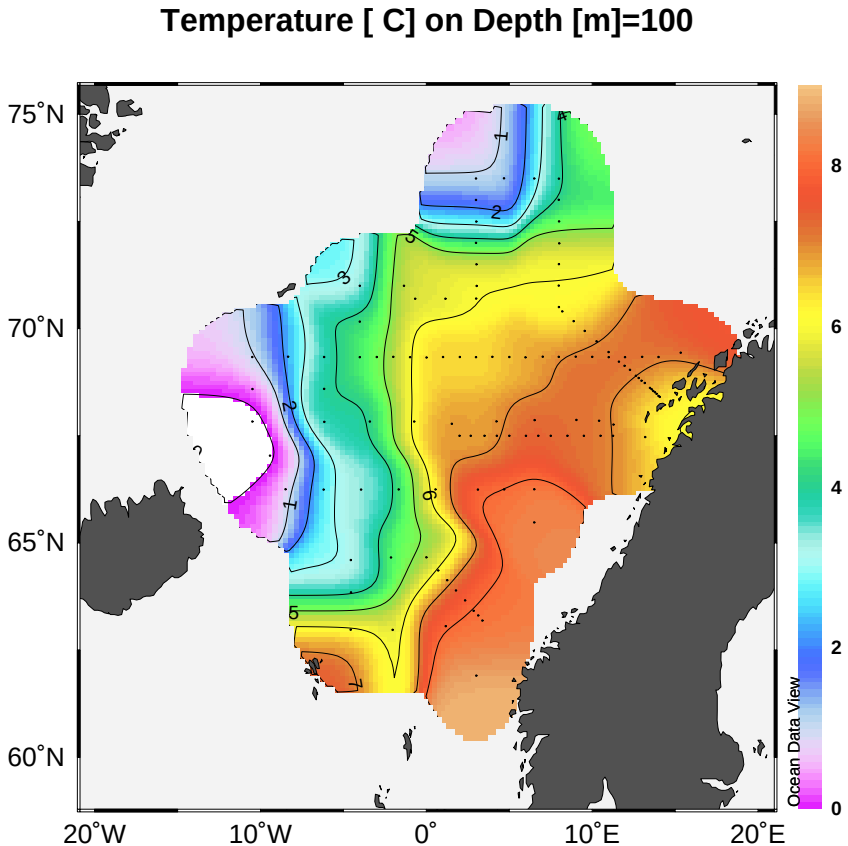

Salinity [psu] on Depth [m]=20
75°N
70°N
65°N
60°N
20°W
10°W
0°
10°E
20°E
35
34.5
34
33.5
33
Ocean Data View

Temperature [C] on Depth [m]=50



Salinity [psu] on Depth [m]=50

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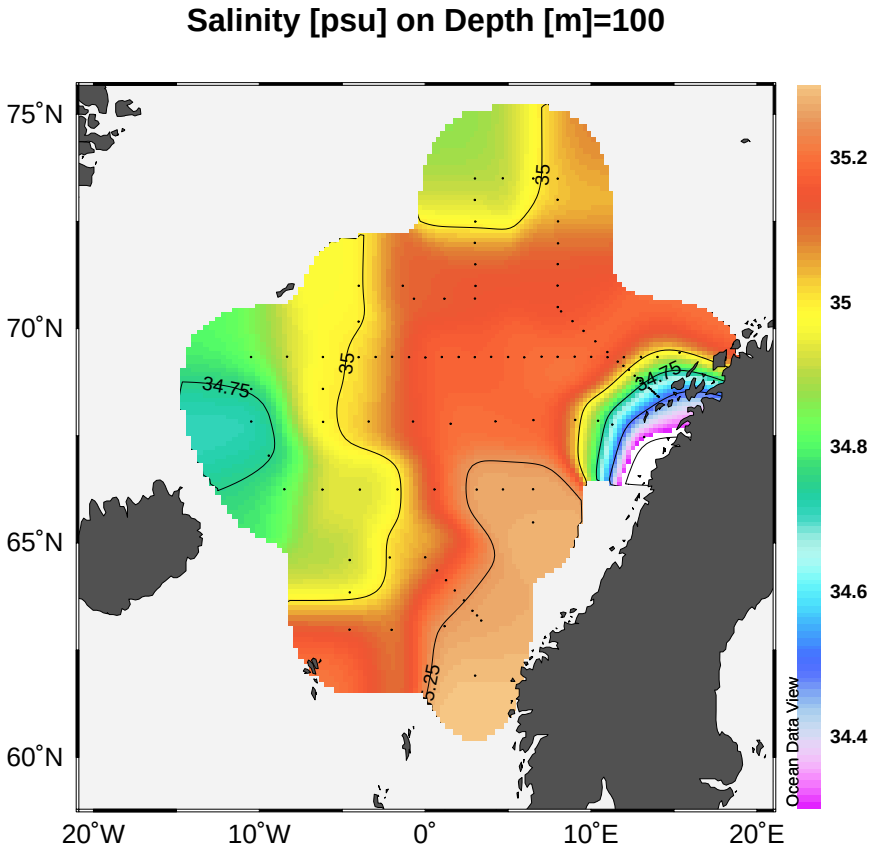
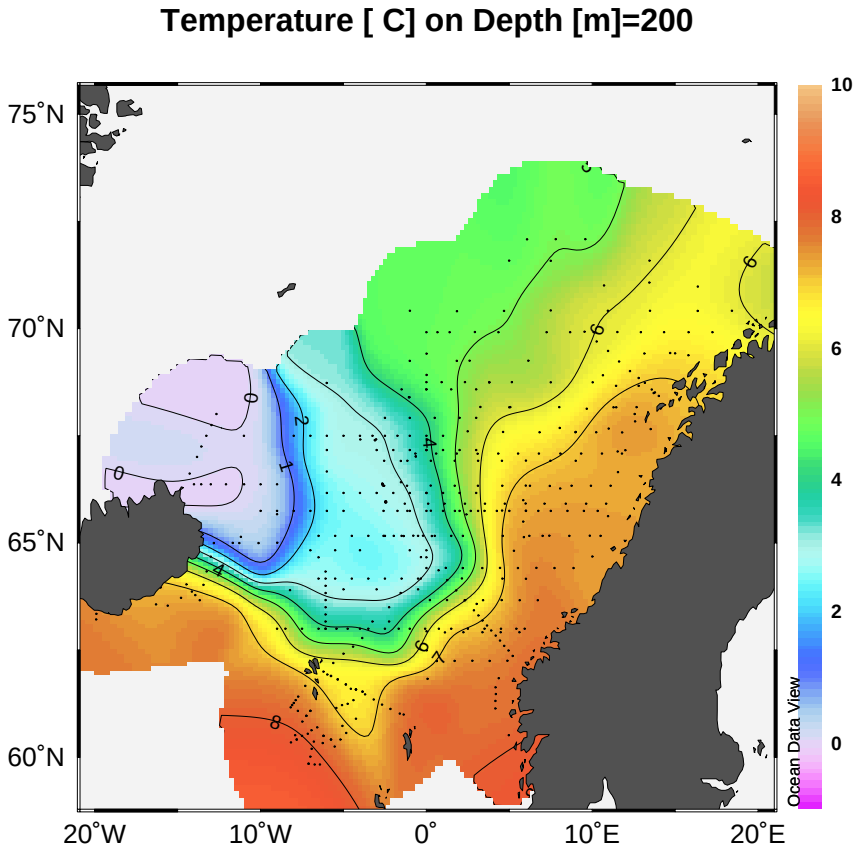
10°W
0°
10°E
20°E
8
6
4
2
0
Ocean Data View


Salinity [psu] on Depth [m]=100
75°N
70°N
65°N
60°N
20°W
10°W
0°
10°E
20°E
35.2
35
34.8
34.6
34.4
Ocean Data View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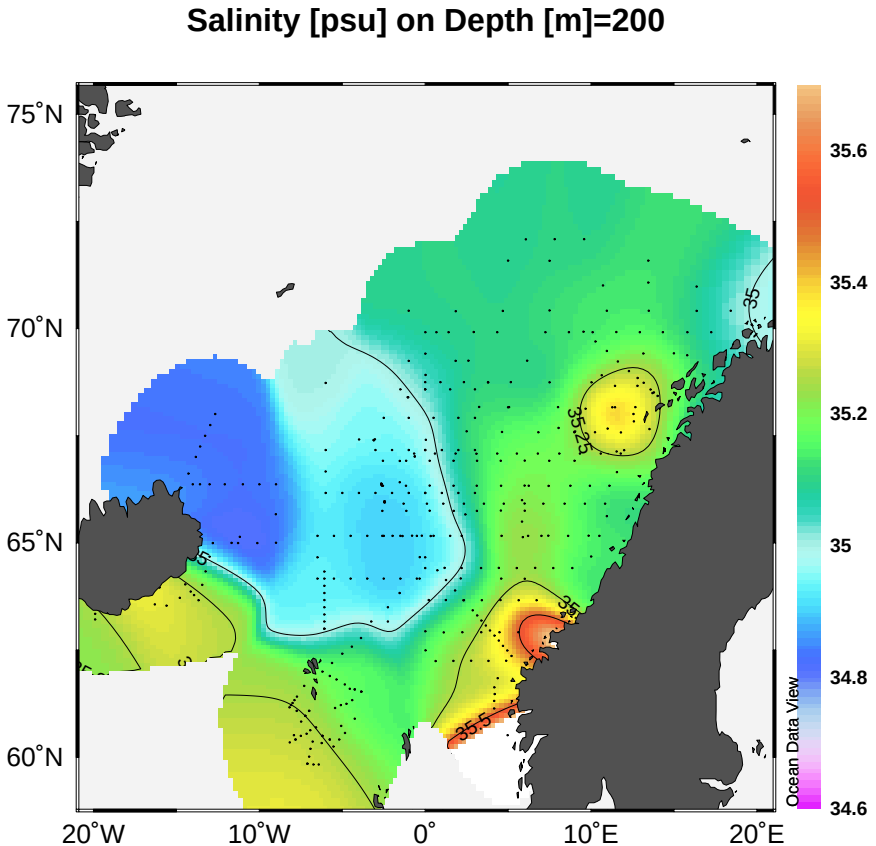
0°
10°E
20°E
10
8
6
4
2
0
Ocean Data View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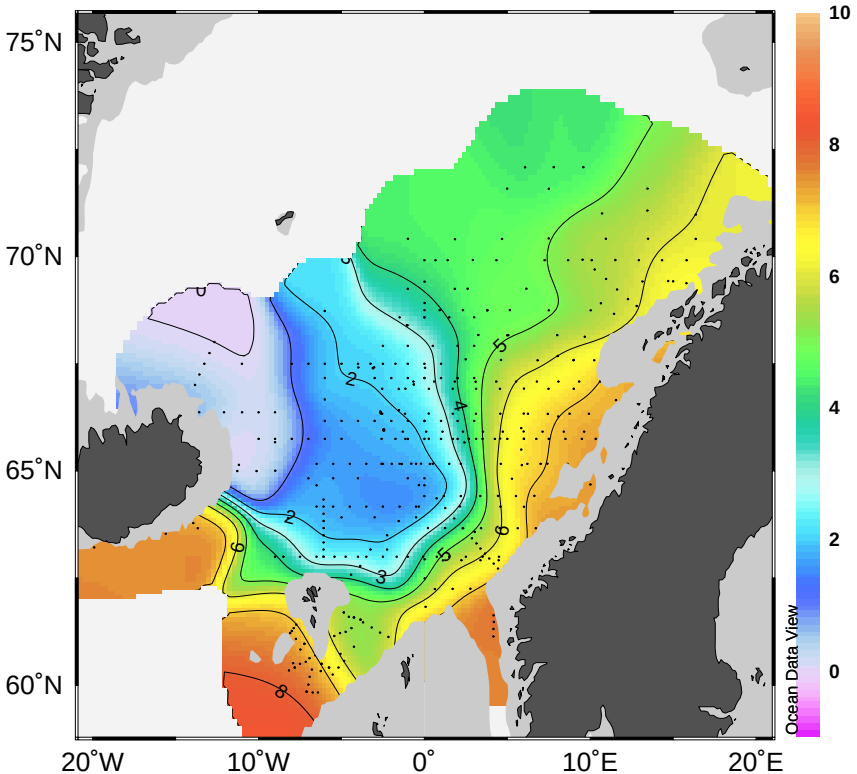
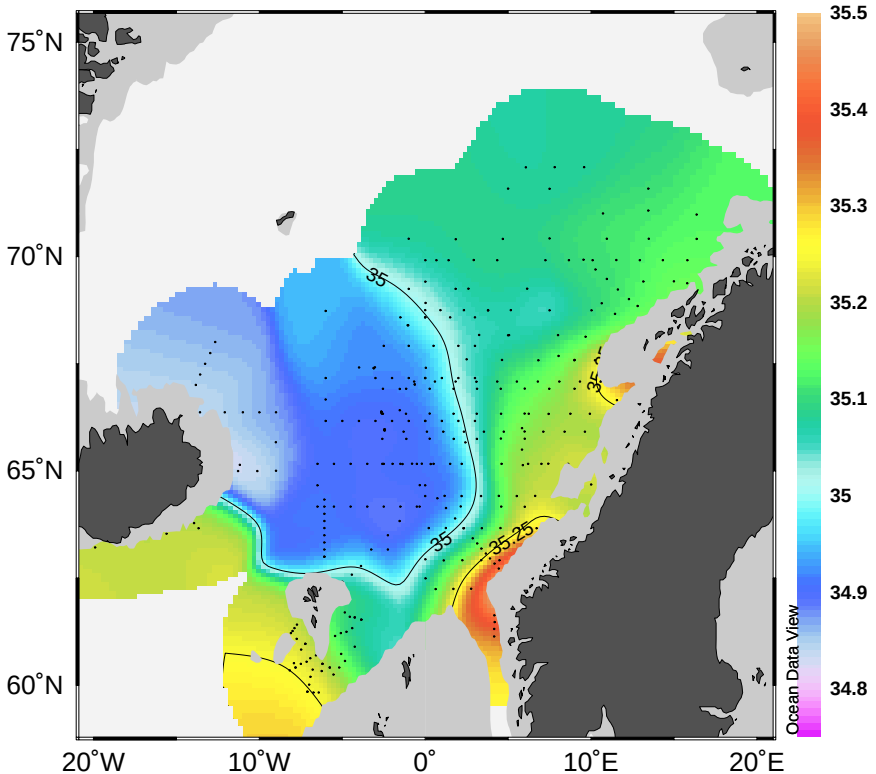
35.6
35.4
35.2
35
34.8
34.6
Ocean Data View

Temperature [C] on Depth [m]=300



Salinity [psu] on Depth [m]=300



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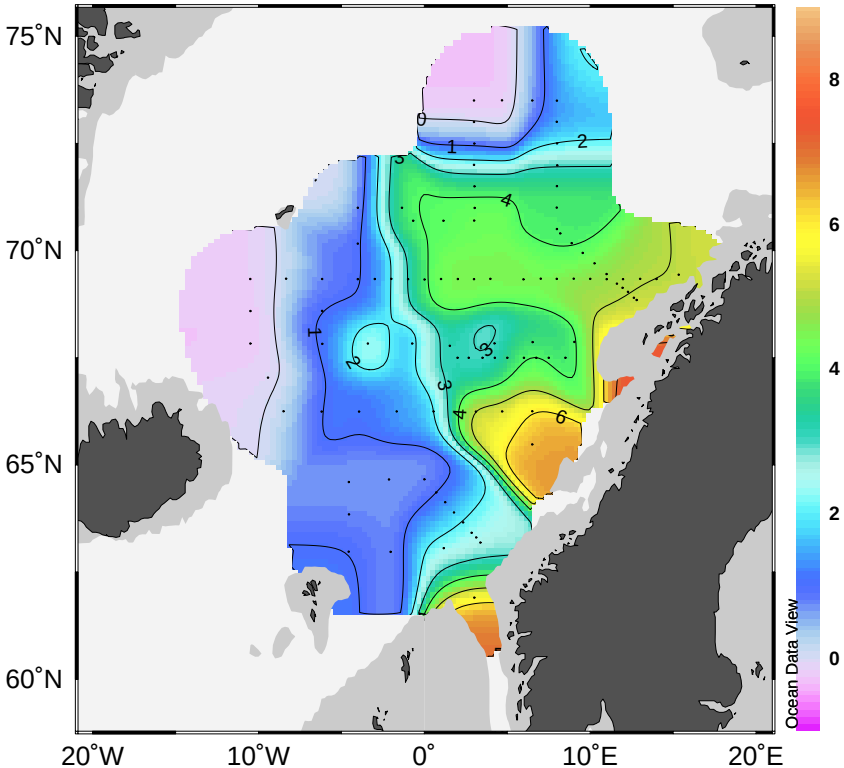

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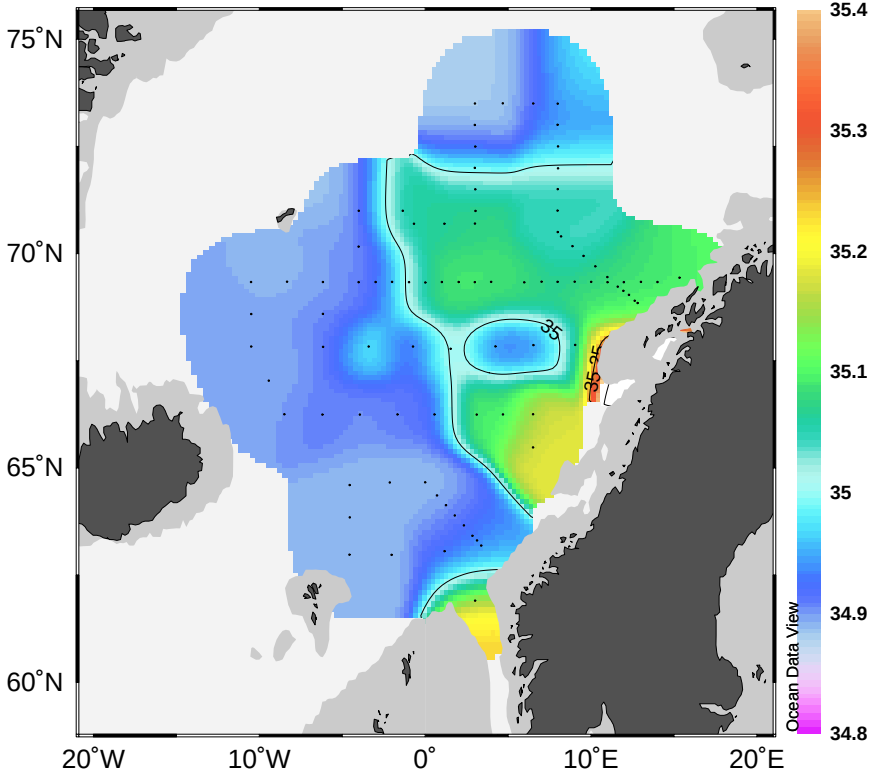

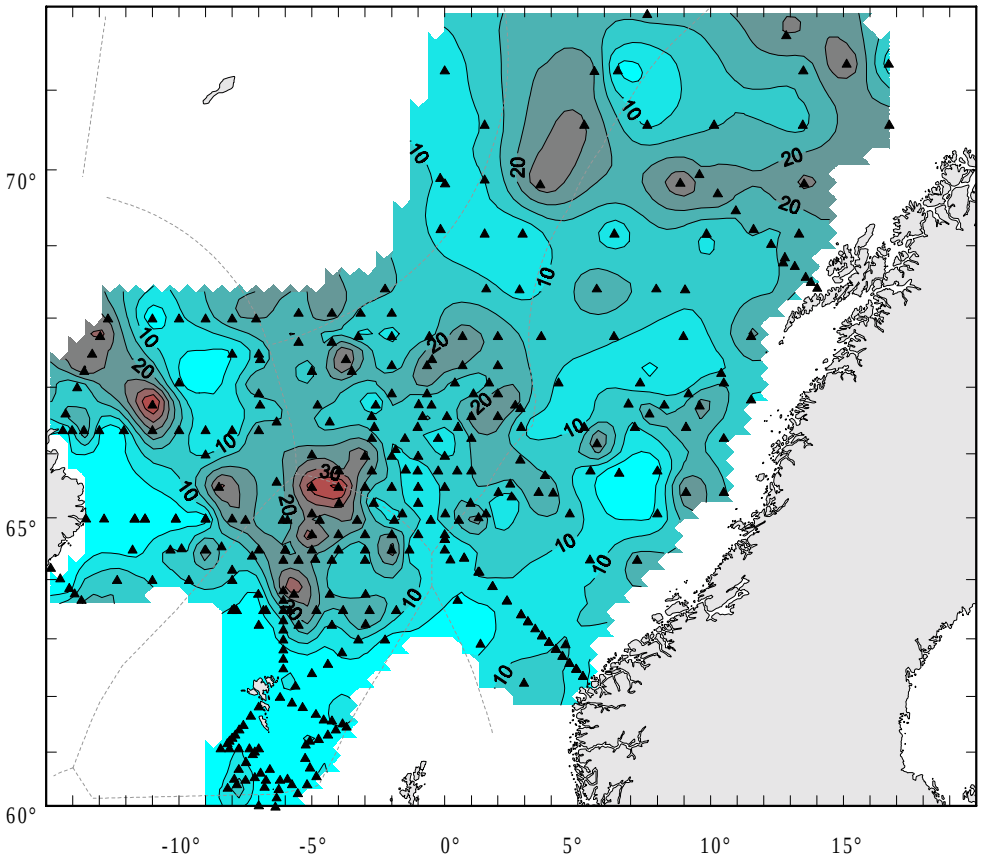

Figure 21. Zooplankton biomass [g dw*m^{-2}] (200-0m) April-June 1998

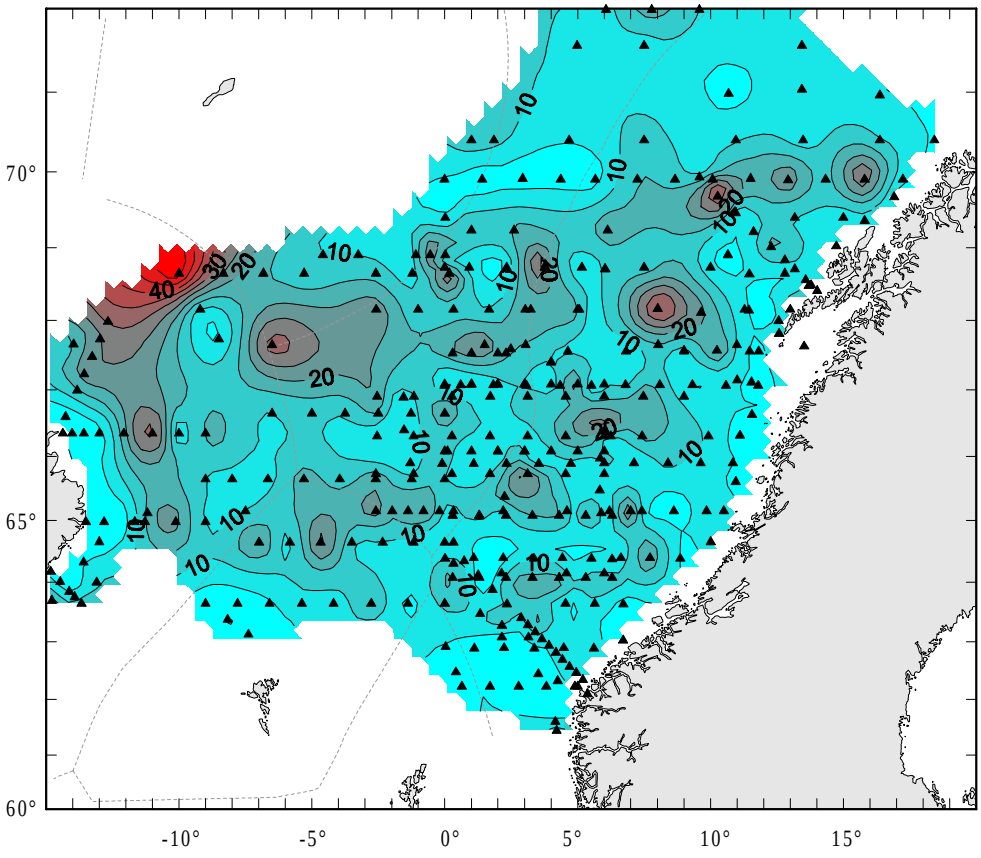

Figure 22. Zooplankton biomass [g dw*m^{-2}] (200-0m) April-June 1999.

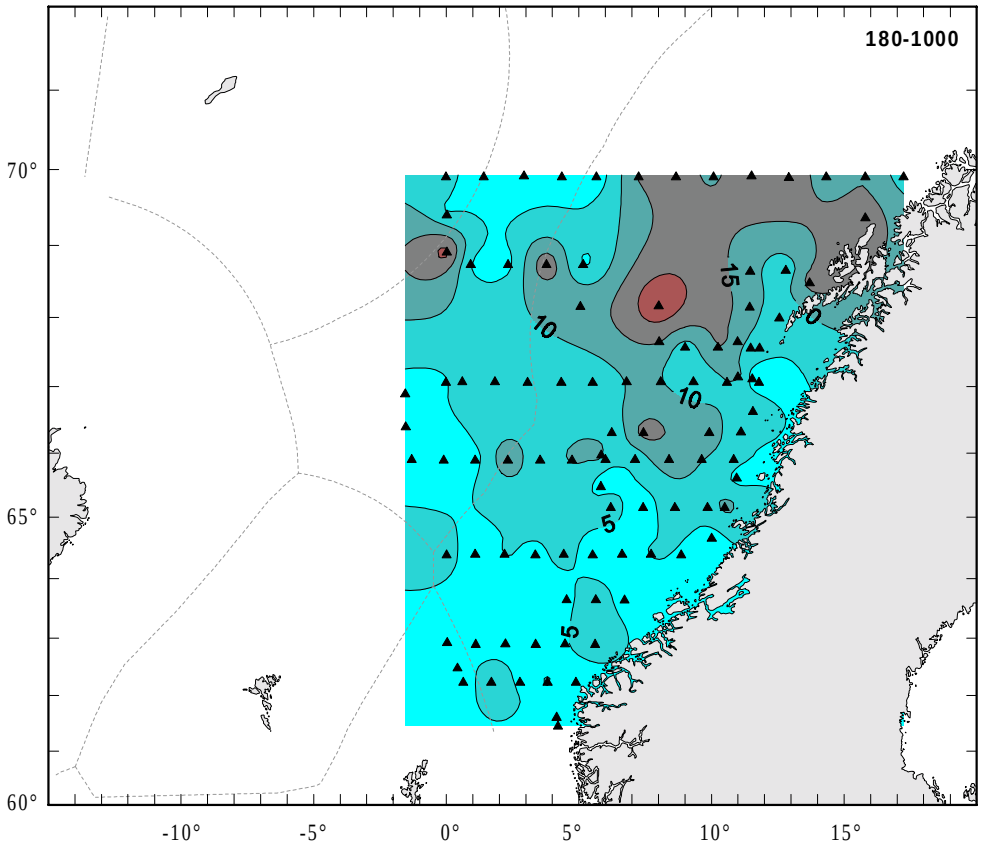

Figure 23. Zooplankton biomass in size fraction 180-1000 µm [g dw*m^{-2}] (200-0m) April-June 1999.

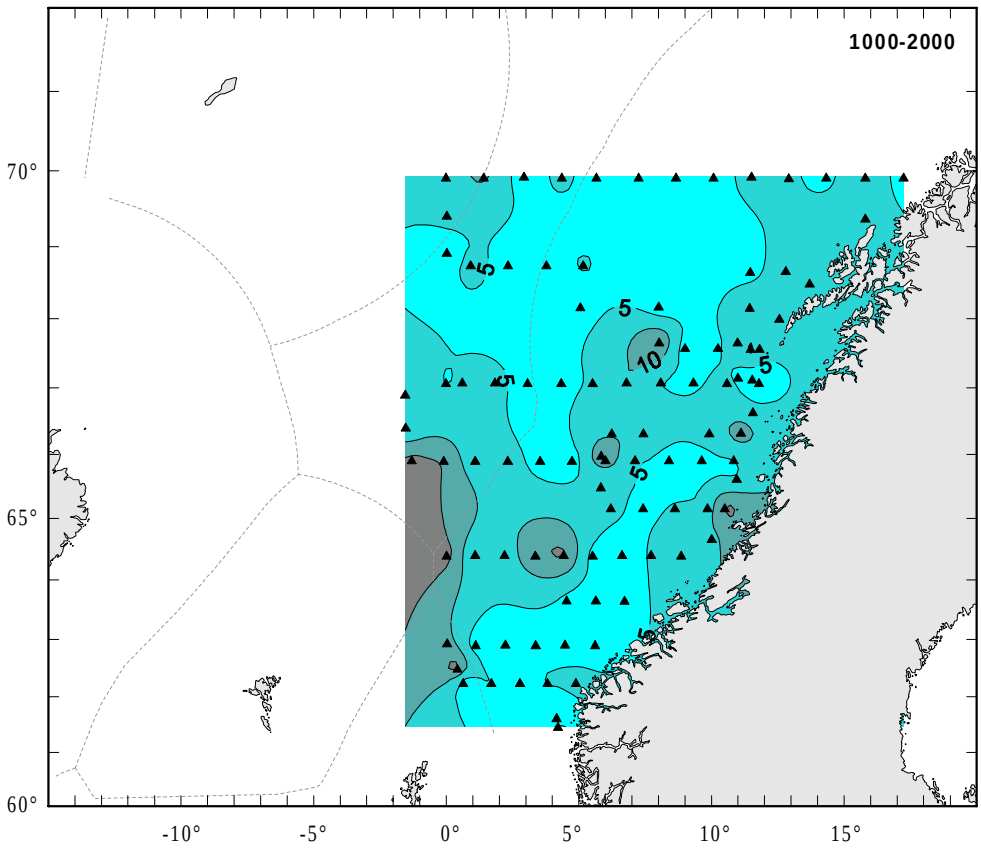

Figure 24. Zooplankton biomass in size fraction 1000-2000 µy [g dw*m^{-2}] (200-0m) April-June 1999.

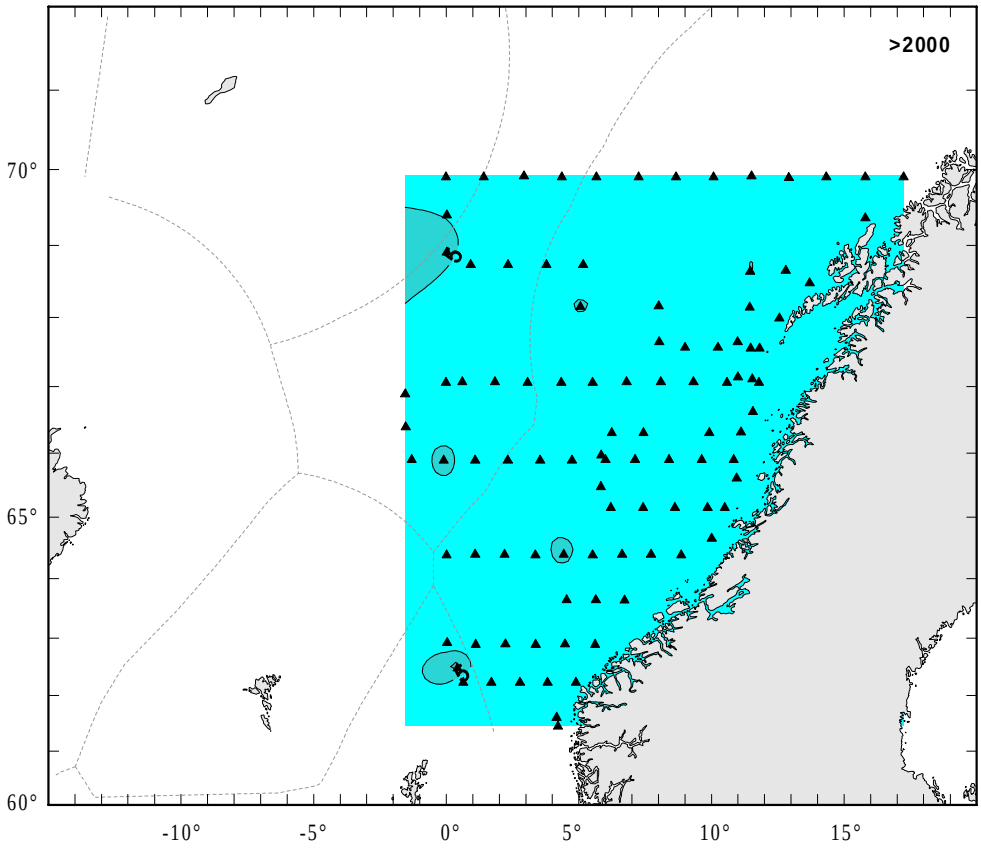

Figure 25. Zooplankton biomass in size fraction >2000 µm [g dw*m^{-2}] (200-0m) April-June 1999.

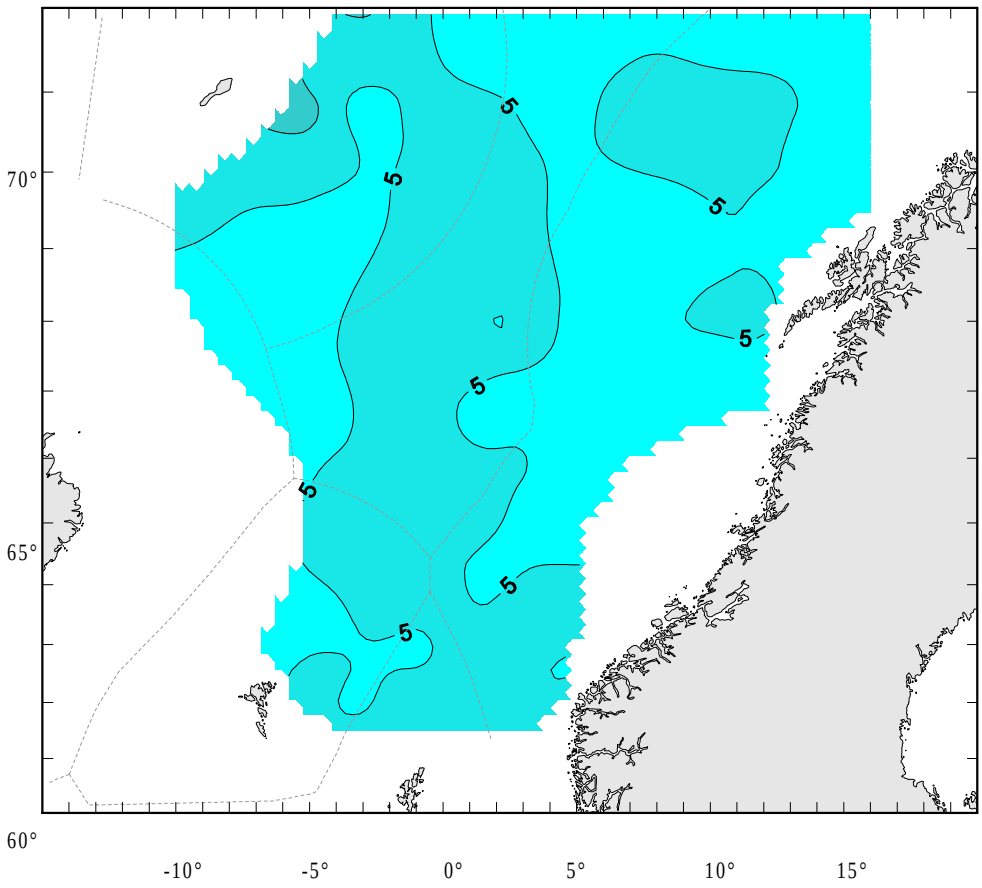

Figure 26. Zooplankton biomass [g dw*m-2] (200-0m) July-August 1998.

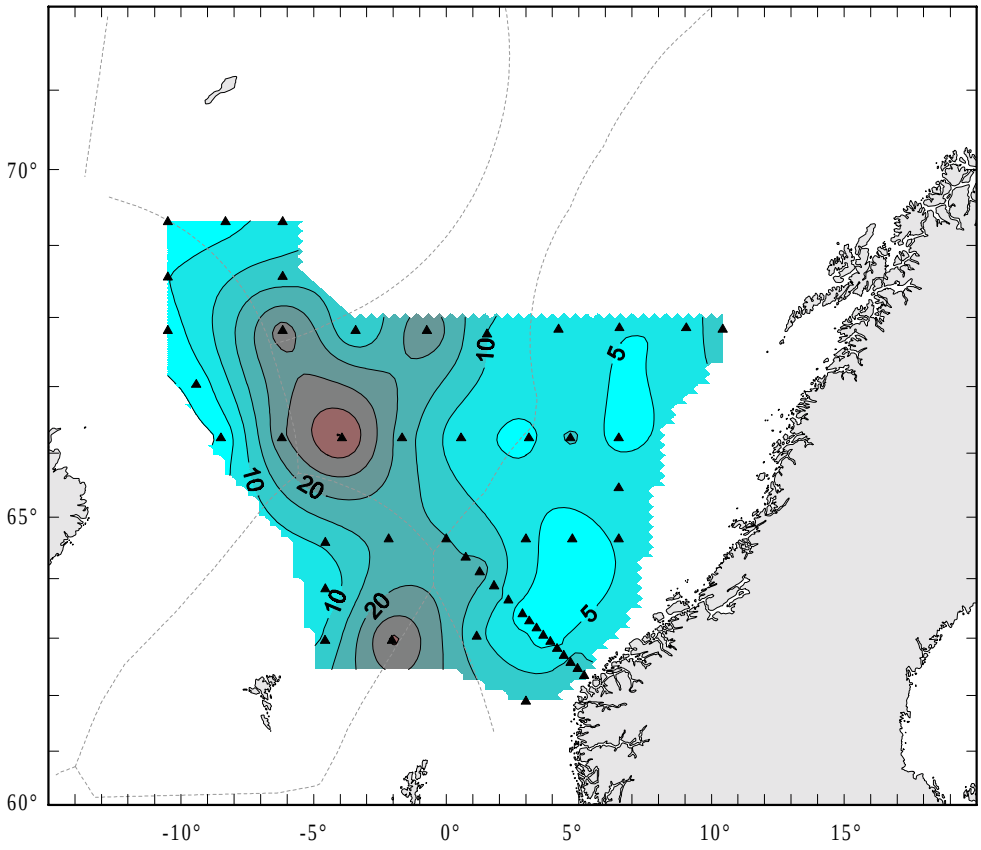

Figure 27. Zooplankton biomass [g dw*m-2] (200-0m) July-August 1999.

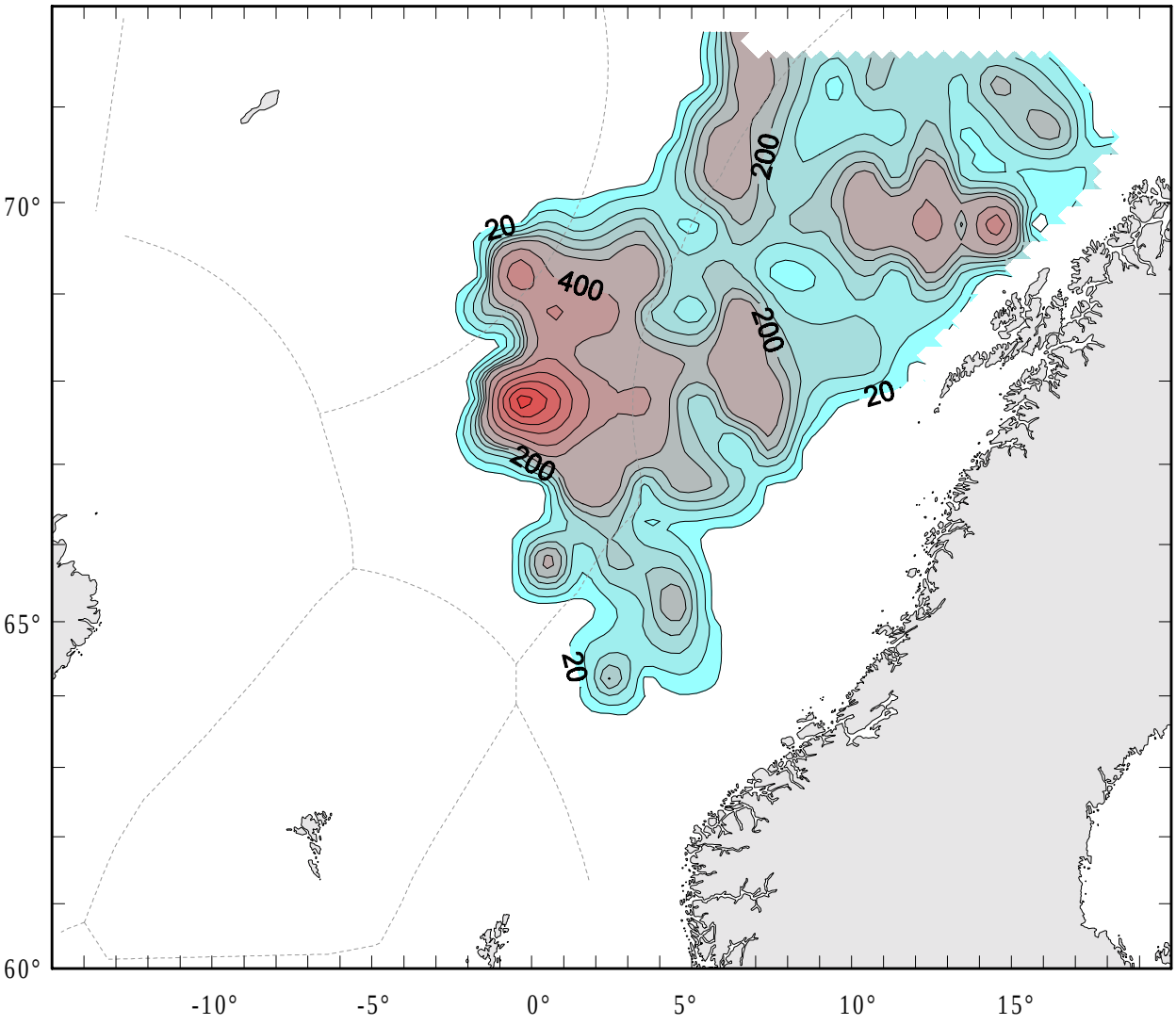

Figure 28. Distribution of Norwegian spring spawning herring in May 1999 as measured by RV Arni Fridriksson, the RV G.O. Sars, the RV Magnus Heinasson and the RV Walther Herwig III during the international coordinated herring survey.

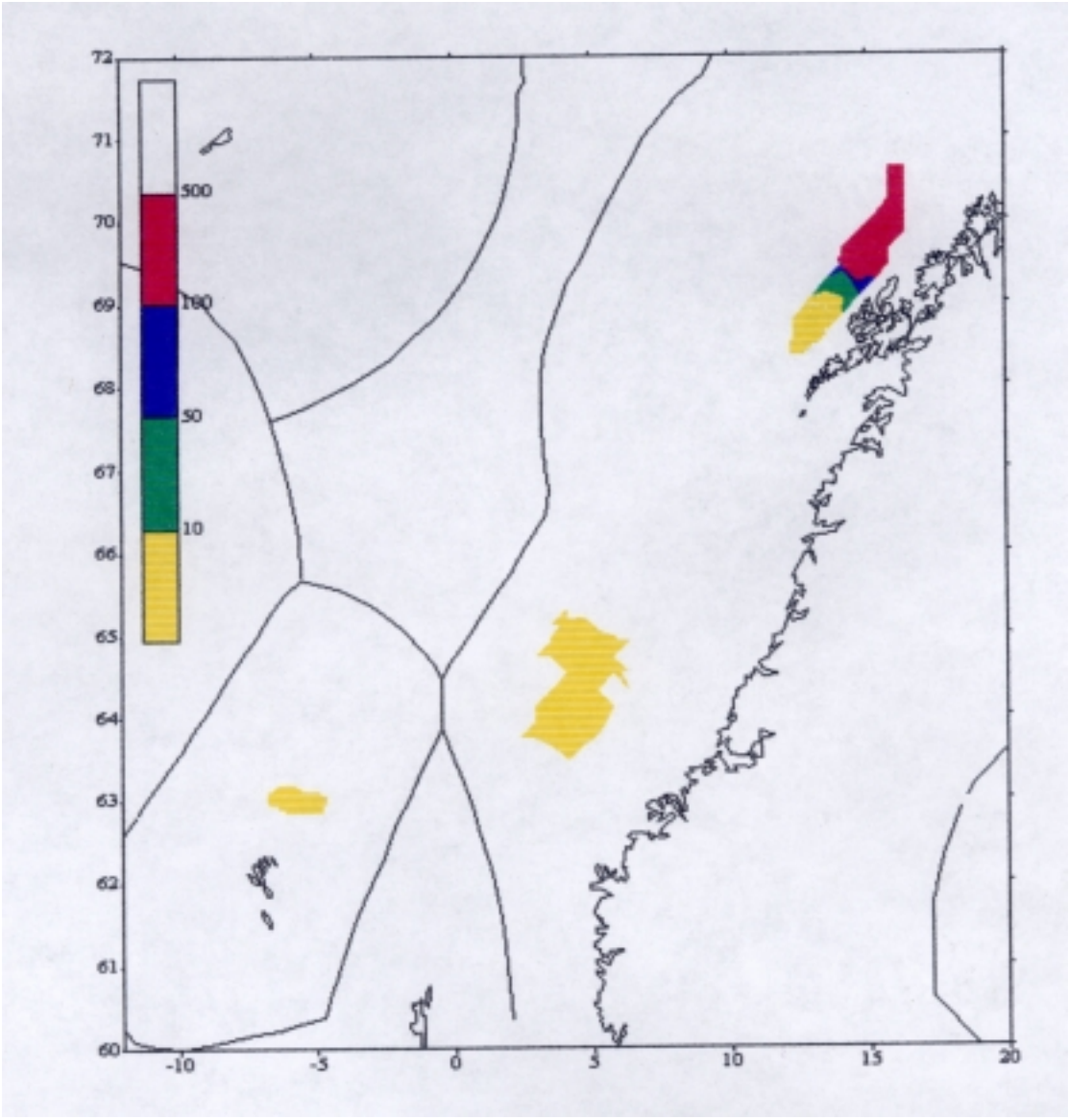

Fig. 29. Distribution of herring in the Norwegian Sea, map of Sa values, FF “F.Nansen” 03.06-22.06. 1999,

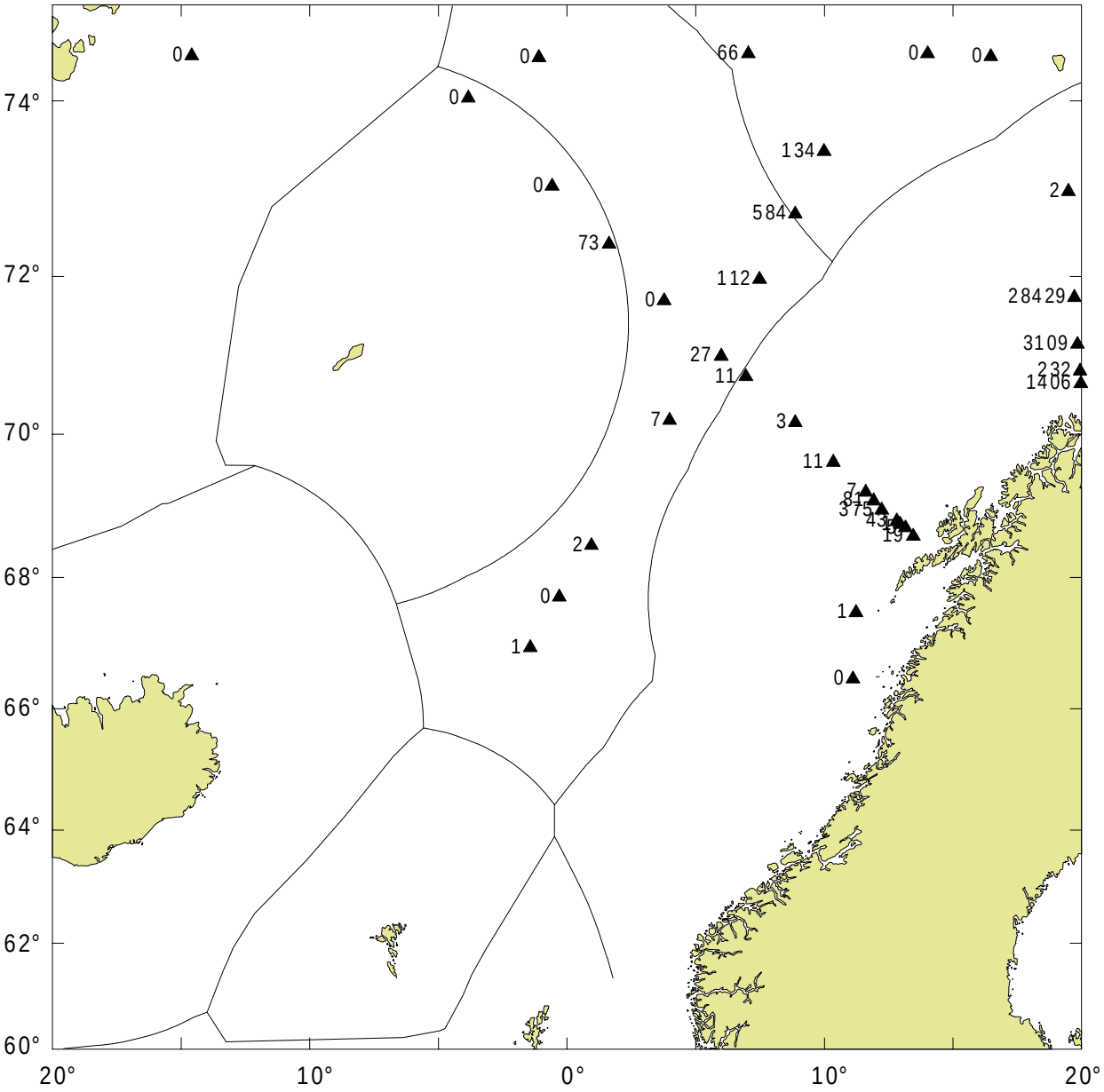

Figure 30. Herring catch in numbers taken by the RV Johan Hjort during the period 15.06-06.07, 1999.

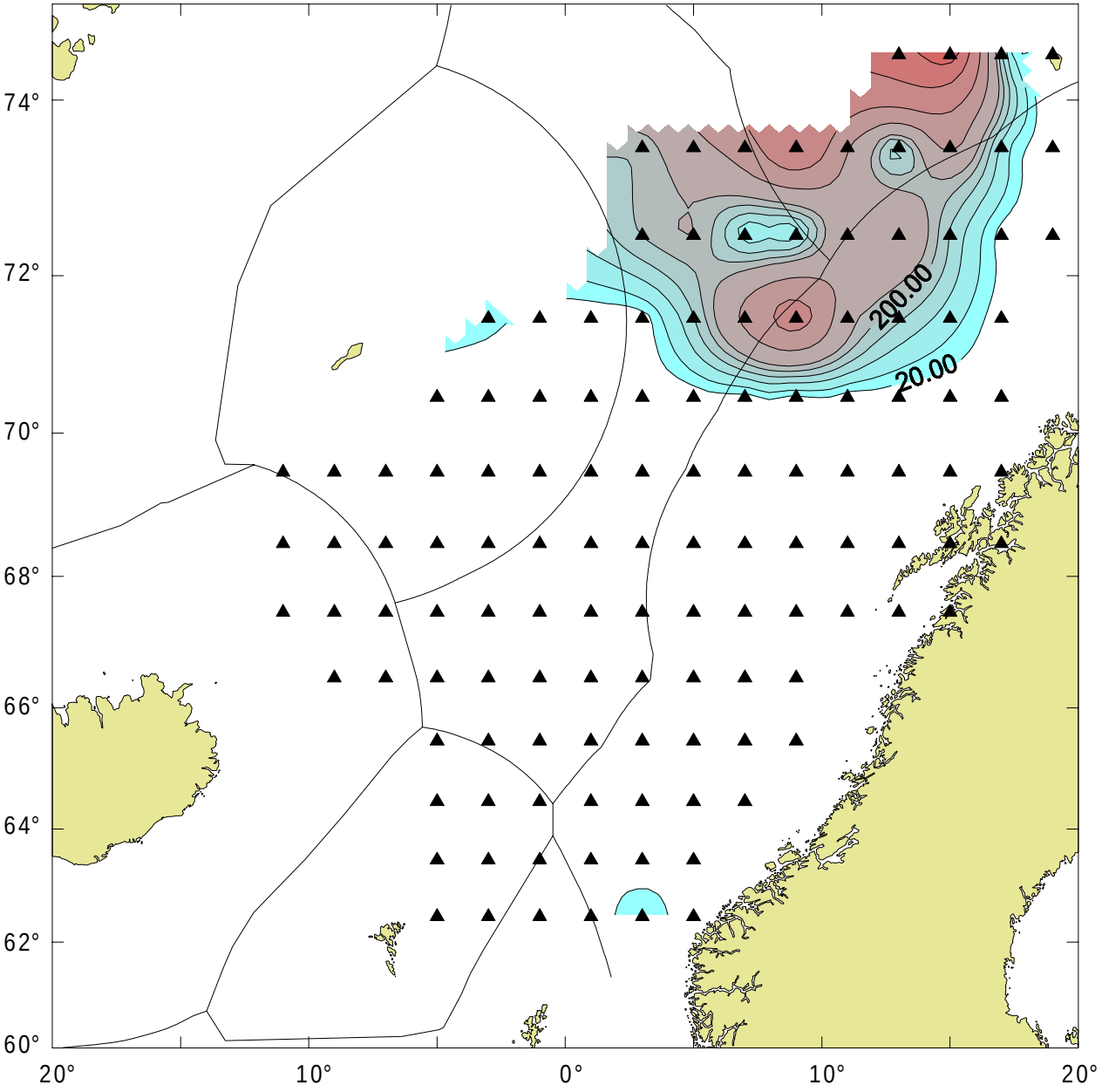

Figure 31. Herring distribution as observed by the RV G.Osars during the period 21.07-22.08 1999. Black triangles indicate squares with Sa values.

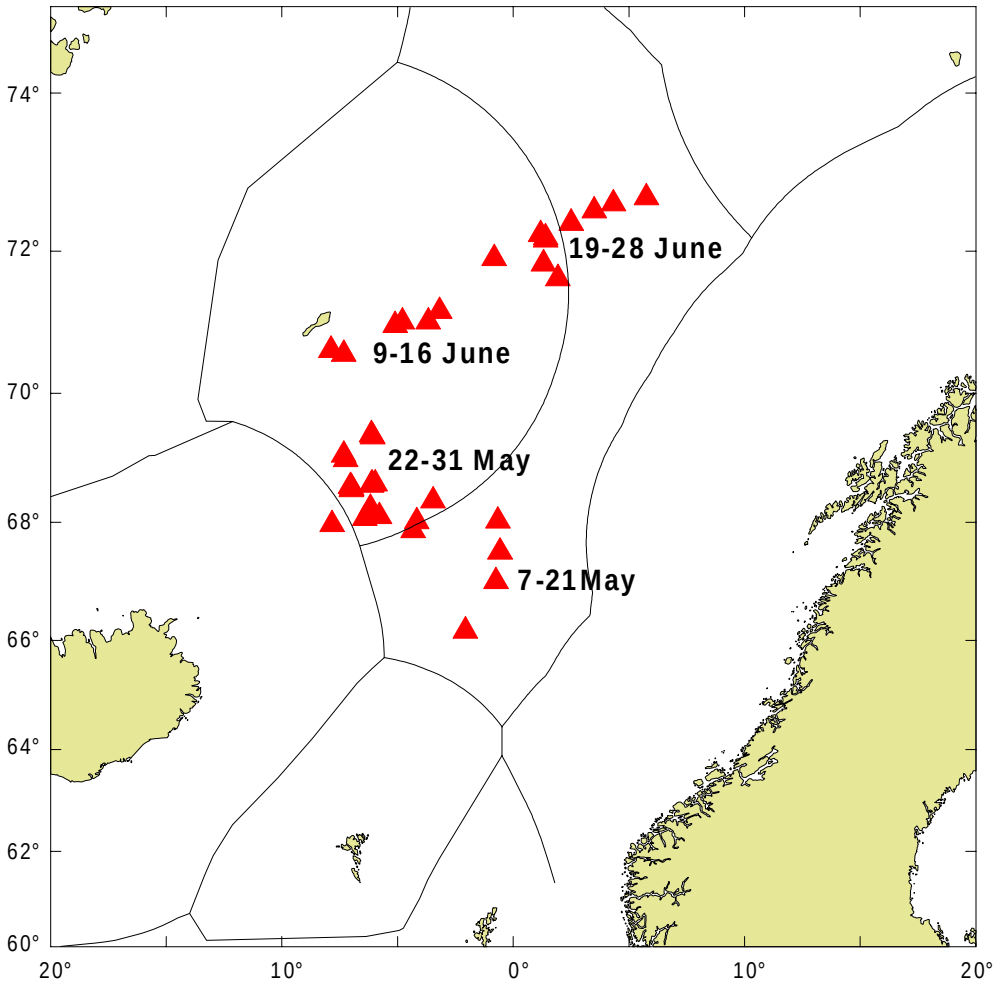

Figure 32. Positions and dates of herring samples obtained from Faroese and Icelandic fishing vessels.

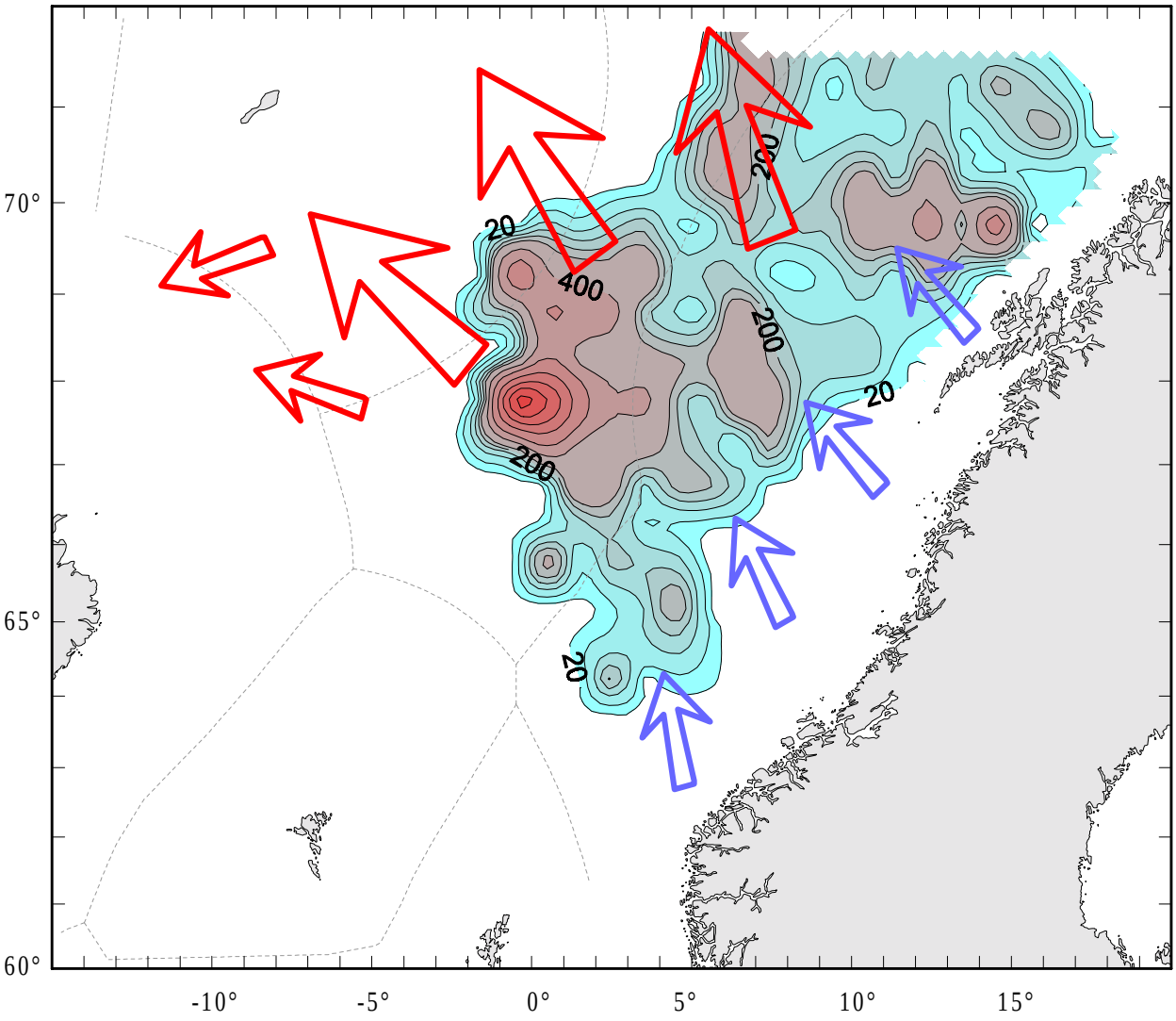

Figure 33. Inferred migration pattern of the Norwegian spring spawning herring in march-april (blue arrows, near coast) and May-June (red arrows, NW. Distribution by isolines is as measured during the international survey in May.

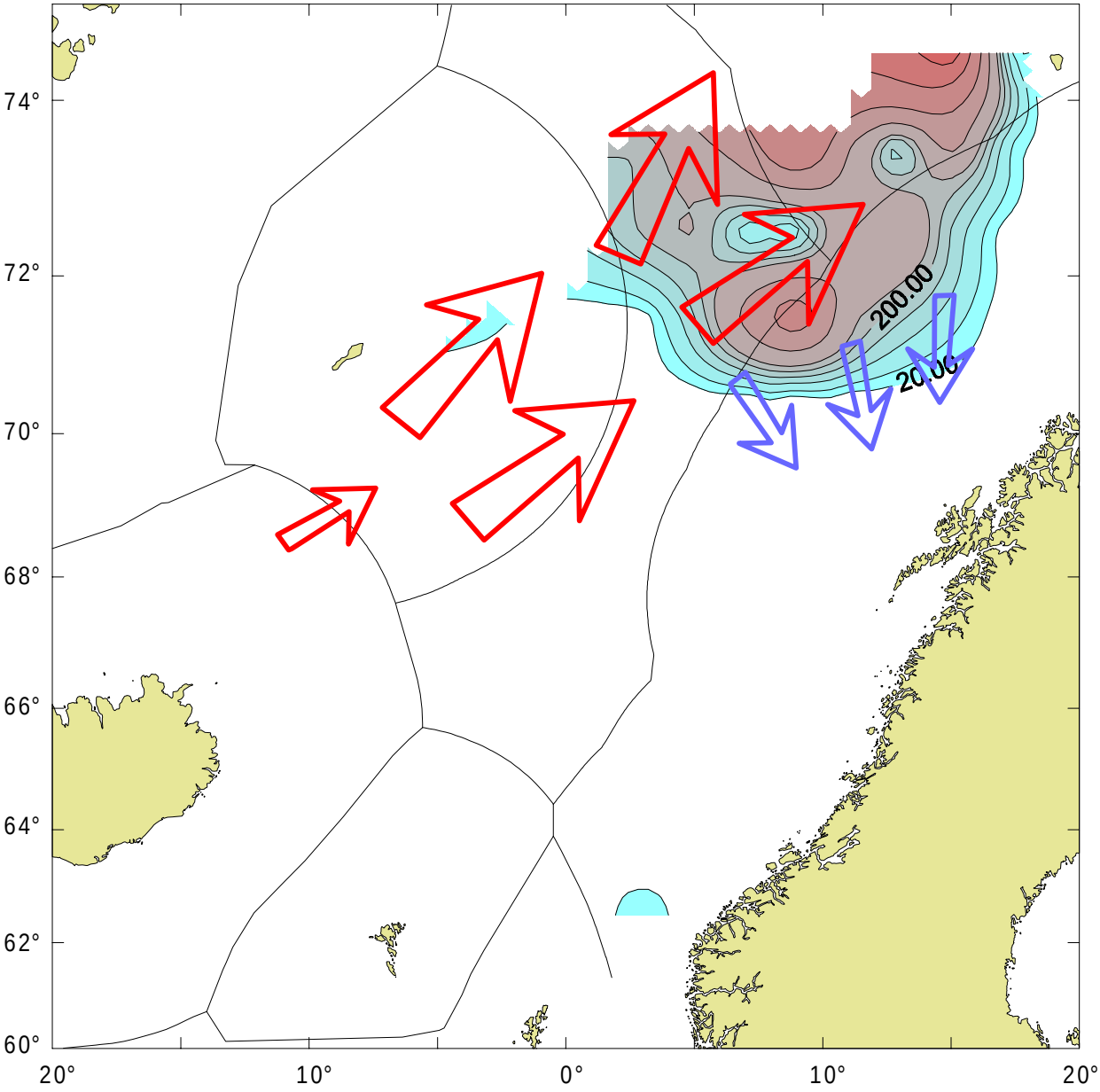

Figure 34. Inferred migration pattern of the Norwegian spring spawning herring in July(red arrows) and August-September (blue arrows, small near coast) 1999. Distribution by isolines is as measured by the RV G.O.Sars during 21.July-22 August.

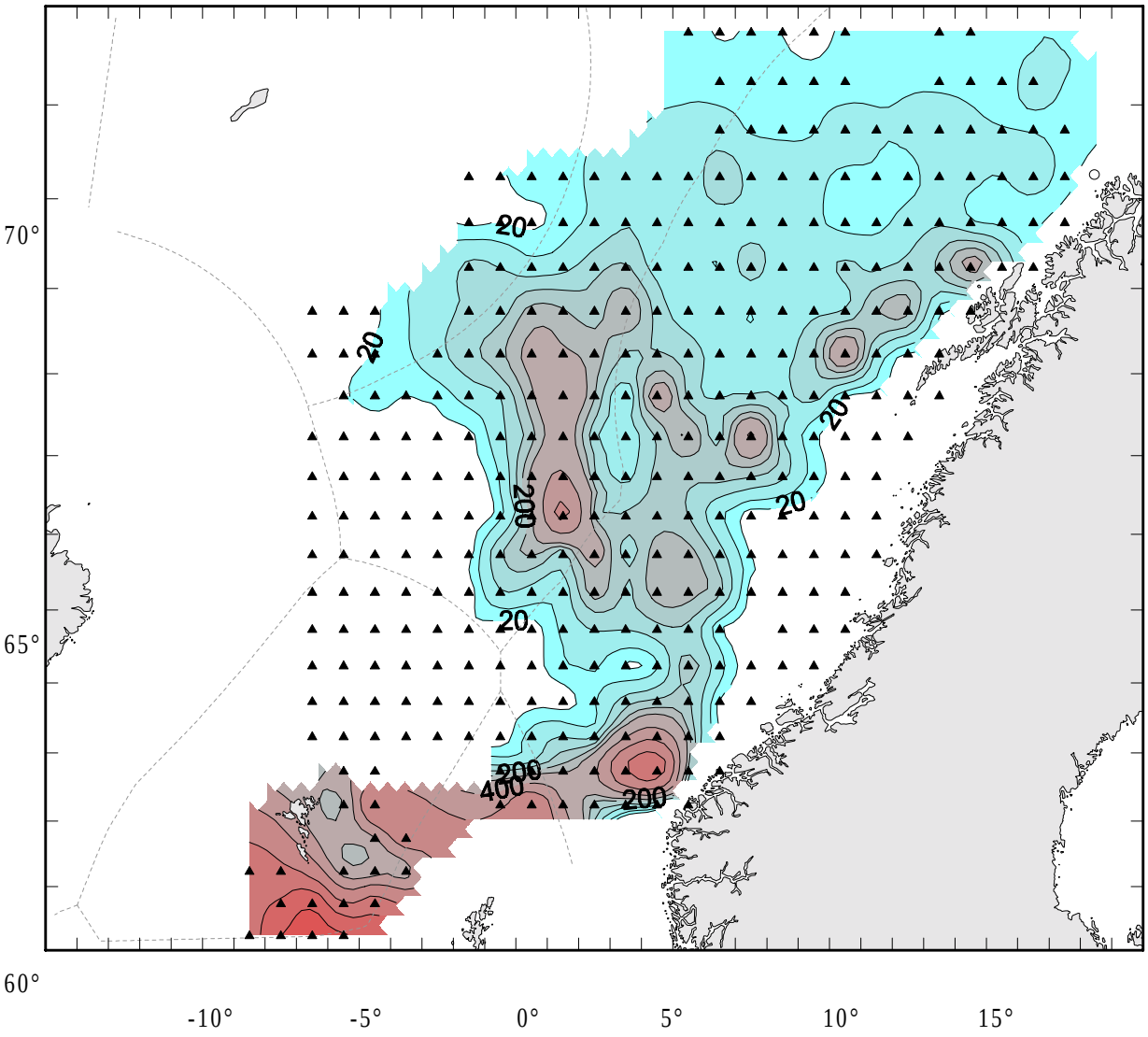

Figure 35. Distribution of blue whiting in May 1999 as measured by the RV Árni Fridriksson, the RV G.O.Sars, the RV Magnus Heinason and the RV Walther Herwig III during the international coordinated herring survey.

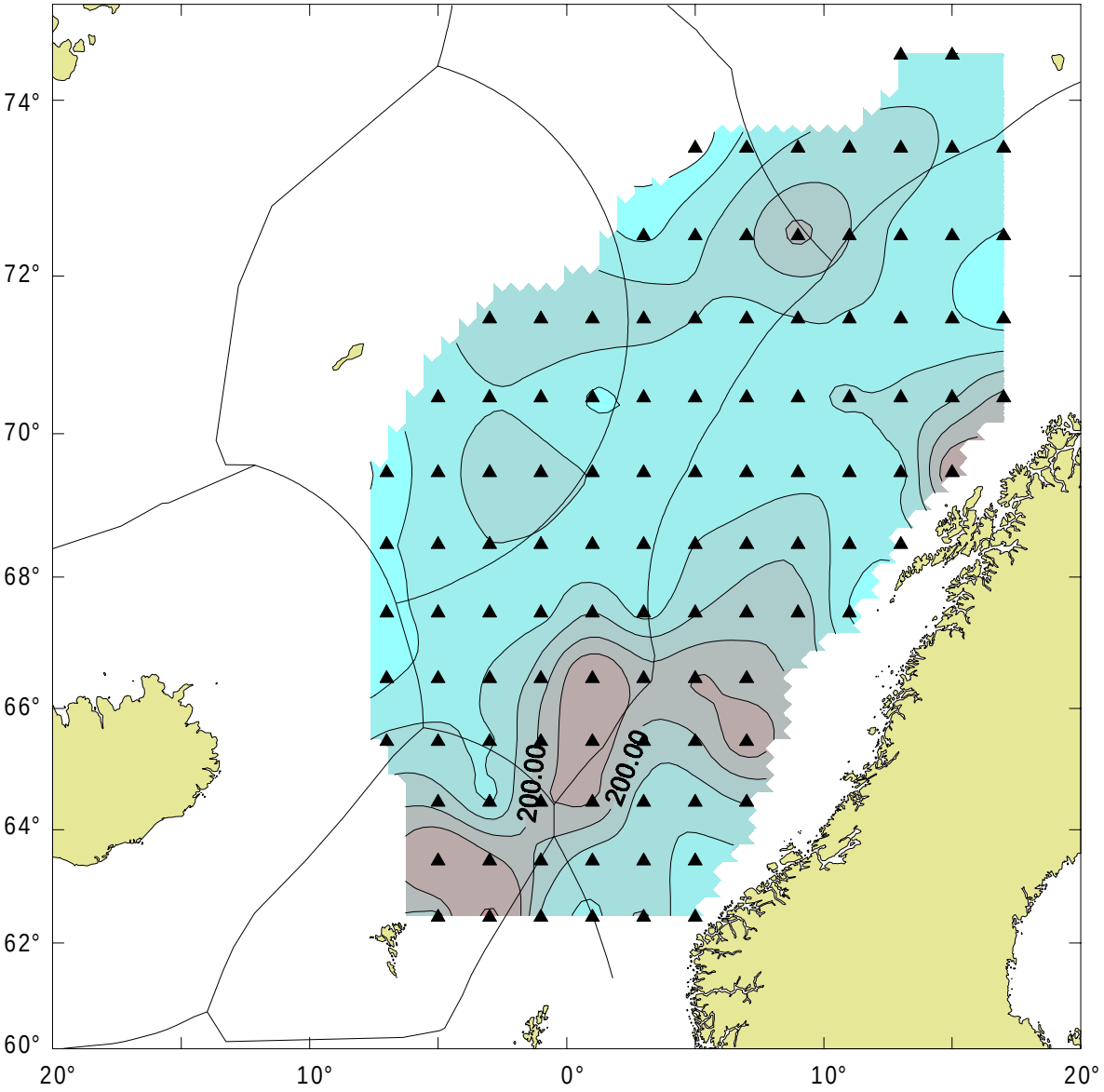

Figure 36. Distribution of blue whiting in July-August 1999 as measured by the RV G.O.Sars.