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REPORT OF THE

Joint Icelandic/German/Russian Trawl-Acoustic Survey On Pelagic Redfish in the Irminger Sea and Adjacent Waters in June/July 1999

By

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1 INTRODUCTION

Several acoustic surveys have been conducted on the oceanic redfish in the Irminger Sea and adjacent waters. During the period of commercial fishery in the area which commenced in 1982 the former Soviet Union and later Russia, carried out acoustic surveys annually until 1993. These surveys provided valuable information on the distribution and relative abundance of oceanic redfish and on the biology of the species as well as on the oceanographical conditions of the area surveyed (e.g. Pedchenko *et al.,* 1995). The acoustic measurements were, however, not considered sufficient for stock assessment purposes (Anon. 1991).

In 1991, Iceland conducted a pilot acoustic survey (Magnússon *et al.,*1992a). The same year, Iceland and Russia decided to conduct an acoustic survey on the oceanic redfish in the Irminger Sea in 1992, in accordance with an agreement between the two countries. One of the main aims of the ICES Study Group on Redfish Stocks (SGRS), in May, 1992, was therefore to co-ordinate the ongoing research on the stock (Anon.1992). The Icelandic and Russsian acoustic surveys were not carried out as anticipated. Therefore, the results of these surveys were presented at the ICES Statutory Meeting 1992, (Magnússon *et al.,* 1992b) in a combined paper containing two separate survey reports.

It became obvious from the surveys in 1992 that for an acoustic assessment, two vessels were hardly sufficient to cover the whole area of distribution within a reasonable time period (Anon. 1994).

In 1993, Russia conducted a survey in the Irminger Sea, in the summer time and Iceland, a short survey in September, the same year. (Anon.1994a,1994b), with no reliable stock size estimate, as the area coverage was limited.

In 1994, Russia, Iceland and Norway announced their readiness to participate in the combined survey to be conducted in June/July 1994. Some other nations considered participation but were not able to provide vessel time in June-July, 1994. The Russians withdrew from the survey, hence it was carried out by only two vessels, one from Iceland and one from Norway. A report was presented at the ICES Statutory Meeting (Magnússon *et al.,* 1994), resulting in a stock size estimate of about 2.2 million tonnes. In the report from the survey, the view of the ICES Study Group on Redfish Stocks, that the entire area of distribution could not be covered sufficiently by only two vessels (Anon. 1993.) was supported.

In 1995, Russia carried out a single vessel survey for redfish, covering the main distribution area at depths down to 500 m layer. The stock was estimated to be 2,5 million tonnes and 4,1 billion individuals (Shibanov *et al.*, 1996). As the survey was only covered by one vessel, the NWWG meeting in 1996 (Anon, 1996), considered the results to be unreliable.At the 82nd ICES Statutory Meeting (1994) it was decided that the Study Group on Redfish stocks should meet, to: "Explore the possibility of carrying out a joint international survey on oceanic redfish in the Irminger Sea and adjacent waters in 1996 and, if appropriate, plan the necessary co-ordination." Iceland, Germany and Russia carried out the survey in June/July 1996. Approximately 250,000 nm^2 were covered. The acoustic assessment yielded a stock size of about 1.6 million tonnes or 2.6 billions individuals at depths down to 500 m. This estimate was considered to be an underestimation of the stock due to mixture of the redfish towards depths below 500 m. The oceanic redfish concentrations were densest in 200-300 m depth, mainly within temperature range of 3.5°C to 5°C. The temperatures recorded during the survey were somewhat higher than observed during previous acoustic surveys.

In 1997, Russia carried out a single vessel survey in June/July resulting in a stock estimate of 1.2 mill. tonnes down to 500 m depth (Melnikov *et al.,* 1998).

During all of the surveys mentioned above, oceanic redfish has been measured by acoustics down to approximately 500 m depth. Attempts have been made to measure below that depth, but basically without success in obtaining any stock size estimate. The reason is mainly due to a "scattering layer", which is a mixture of many vertebrate and invertebrate species, mingled with the redfish (Magnússon, 1996).

During it's acoustic survey in 1995, Russia tried to map the distribution area of redfish at depths below 500 m, and the results were presented to the ICES NWWG in 1996 (WD in Anon. 1996). The results shows that redfish below 500 m depths was widely distributed but with highest concentration in the NE part of the investigation area.

An attempt to map the distribution of redfish in and below the scattering layer was made in the autumn of 1996 when the Marine Research Institute in Reykjavík (MRI) hired a commercial trawler for that purpose for two weeks. Due to spells of bad weather during the survey only 17 hauls were made. Redfish was caught in every haul, both west and east of the Reykjanes Ridge, but the catch rate was very low indicating a very low density and a nearly even distribution in the survey area (unpublished data).

Preliminary results from a Russian trawl-acoustic survey, conducted in 1997, (WP 22 in Anon. 1998a) indicate a peak in abundance in the upper layer (above 500 m) far to the south-west of the investigation area, whereas the highest concentration observed in the lower layer (below 500 m) where observed in the NE part of the area. During the survey, estimated biomass of redfish below 500 m depth was in the order of 500,000t. This value must be treated with caution (Anon, 1998b).

In 1998, Iceland conducted a survey where the main purpose was to map the deeper layer of oceanic redfish (at depth below 500-600 m) i.e. that part of the stock which is the target of commercial fishing during spring-early summer (Sigurðsson and Reynisson, 1998). The results indicate an even distribution with low density of redfish except for two small areas where fishing fleet was concentrated, the vessels catching 2-3 tonnes of redfish per hour.

None of these surveys conducted in the last years have yielded a abundance estimate from the lower layer, but have however been important for mapping of the spatial distribution of redfish in and below the scattering layer.

At the 86th ICES Statutory Meeting it was decided (C.Res 1998/2:57) that the Study Group on Redfish Stocks should met to plan an international acoustic survey of oceanic redfish, to be carried out in the Irminger Sea and adjacent waters in June/July 1999 (ICES C.M. 1999/G9). The main objective was a trawl-acoustic assessment of the oceanic redfish stock in the area. The basic area coverage was determined to be as defined in the Report of the Study Group on Redfish Stocks (Anon. 1995). As the fishery has changed towards greater depths during the latest years it was considered important to expand the vertical coverage and assess the stock below the scattering layer (below 500 m depth). Therefore, the area had to be limited and modified somewhat as the available vessel time was not sufficient to cover the whole area as set out in the report of the Study Group in 1995. The results of this survey is given here.

A long with the acoustic measurements mentioned above, hydrographic data were obtained during all the surveys. The results indicates relationship between the hydrography and distribution of redfish in the survey area. Shibanov *et al*., (1996b) found that the main concentration of redfish in the upper 500 m during June/July were found in the Subarctic Water mass (located in the central parts of the Irminger Sea). They further postulate that the determining role in the redfish distribution during June/July is the hydrographic (thermohaline) conditions.

During the last years there has been discussion on the stock structure of redfish in the Northwest Atlantic. In this report, no attempt was made to distinguish between different stocks of *S.mentella* in the survey area, as only one of the nations participating distinguished catches to different stocks. Therefore, reference is only made to depths, above and below 500 m.

2 MATERIAL AND METHODS

2.1 Acoustic assessment of redfish above 500 m depth

The primary material consists of acoustic and biological data collected on pelagic redfish in the Irminger Sea. The Icelandic part of the survey was carried out by the Marine Research Institute (MRI), Reykjavík, with the research vessel "Bjarni Sæmundsson" during the time period 18 June to 10 July, with 19 days in the field. The German part was carried out by the Federal Research Centre for Fisheries, Institute for Sea Fisheries, Hamburg, with the research vessel "Walther Herwig III" during the time period 18 June to 10 July, with 12 days in the field, instead of 14 days as was planed. The Russian part was carried out by PINRO, the Marine Research Institute in Murmansk, with the research vessel "Atlantniro" during the time period 08 June to 26 July, with 22 days in the field. The vessels covered an area of approximately 300,000 square miles within the boundaries of about 54° N to 65 °N and 27° W to 49° W, mostly on transects 45 N.M. apart (Figure 1). The time schedule for the cruises, the distribution of the areas and the technical settings were discussed and agreed at a planning meeting in February 1999 in Reykjavík (Anon. 1999). However, some of the planned transects were altered and rescheduled during the survey due to occasional “bad” weather, reduced time in field by the German vessel and because of ice in the area near to Cape Farewell.

A 38 kHz Simrad EK500 split-beam echo sounder and integrator was used for the acoustic data collection on all three ships (Bodholt *et al.,* 1989), and a BI500 post-processing system (Foote *et al.* 1991). Prior to the survey the acoustic equipment on all three vessels was calibrated with the standard sphere method (Foote *et al.,* 1987). The settings of the acoustic equipment used during the survey are given in **Table 1**.

In order to verify that the acoustic data from the ships were comparable, an inter-calibration of the hydroacoustic equipment was planned to take place between all three vessels during the survey. However planned inter-calibration between "Atlantniro" and "Bjarni Sæmundsson" had, to be cancelled due to bad weather and different arrival time at the scheduled calibration area. On July 2, the intercalibration between “AtlantNIRO” and “Walther Herwig III” took place.

The vessels simultaneously recorded the hydroacoustic measurements along a parallel course over a distance of 25 N.M. at a speed of 8 knots. “AtlantNIRO” acted as the master vessel and was followed by “Walther Herwig III” sailing 0.15 N.M. behind with a distance of 0.3 N.M.. The echo recordings consisted mainly of redfish at the depth range 100-300 m and of deep scattering layer at depths between 300 and 500m. The scrutinised acoustic values from redfish and from the scattering layer were averaged over the distance of one nautical mile. The redfish registrations of “Walther Herwig III” exceeded the values measured by “AtlantNIRO” by about 20-40 %. This might partly be explained by an avoidance reaction of the redfish from the noise created by the Russian research vessel. Avoidance reaction of redfish was recorded during the intercalibration by “Walther Herwig III” as indicated from the shape of single redfish echoes. The values measured from the deep scattering layer at depths from 300 to 550 m were almost identical for the two vessels involved in the intercalibration (**Figures 2 and 3**). However, the comparison between the acoustic values of both vessels resulted in a poor fit (r^2=0.43) with a high part of the variation remaining unexplained. It was therefore impossible to apply the maximum likelihood method and to determine the confidence interval to describe the relationship between the two vessels as outlined by MacLennan and Pope (1983). Despite the high variation between the acoustic values recorded during the intercalibration, it was concluded that there was no conversion factor needed to correct the hydroacoustic measurements obtained from the two echo integration systems.

During the survey, the post-processing systems onboard all the vessels were used for scrutinising the echograms. Mean integrated values of redfish per 1 N.M. were recorded. In the “Detailed” programme report mean integrated values are shown disaggregated to 5 N.M. sailed and 50 m depth.

Earlier investigations (Magnússon *et al.*, 1994; Magnússon *et al.*, 1996; Reynisson and Sigurðsson, 1997) have shown that the acoustic values obtained from oceanic redfish exhibit a clear diurnal variation, due to a different degree of mixing with smaller scatter as well as changes in target strength. In order to compensate for these effects to some degree, it was decided to discard the acoustic data obtained during periods of the most pronounced mixing, *i.e*. during the darkest hours of the night, and to estimate the values within the missing sections by interpolation.

In further data processing the number of fish were calculated for statistical rectangles, the size of which were 45 N.M. in latitude and 1 degree in longitude. A single fish target strength of -40.0 dB (Reynisson, 1992) was used for the whole area. The total number of fish within sub-areas was then obtained by summation of the individual rectangles. The sub-areas are those agreed upon in the report on the SGRS as shown in **Figure 4** (Anon. 1993), but the limits where shifted to fit the squares used. The acoustic results at depths down to 500 m were further divided into numbers and biomass based on the biological samples representative for each sub-area.

For the entire survey area, single-fish echoes from redfish were expected to be detectable down to at least 200-250 m. In order to include all echoes of interest, a low integration threshold was chosen. As shown in **Table 1**, the integration threshold was set at -80 dB//1 m^2 / m^3 on all instruments. Based on the depth distribution of oceanic redfish observed during the survey and the expected target strength distribution, the method outlined by Reynisson (1996) was used to estimate the expected bias due to thresholding. The results of the biomass calculations were adjusted accordingly.

Earlier investigations on "Walther Herwig III" and on “AtlantNIRO” indicated that when using low integration threshold noise could possibly be a problem. In order to increase signal-to-noise ratio it was decided to use the long pulse length and narrow bandwidth on the above mention vessels, in order to be able to detect redfish at greater depths than about 500 m. On "Bjarni Sæmundsson" and “AtlantNIRO” the transducers are hull-mounted, but a towed body was used on "Walther Herwig III".

The net used on "Bjarni Sæmundsson" was a Gloria type #896 with a vertical opening of approximately 47 m. The net employed on “Walther Herwig III“ was a Gloria type #1024, with a vertical opening of approximately 50 m. On AtlantNIRO a Russian pelagic trawl (design 75/448) with a circumference of 448 m and a vertical opening of 47-50 m was used.

At the planing meeting at Reykjavík, in February 1999, it was decided to restrict trawling in the upper 500 m to the minimum needed for the acoustic assessment. It was also decided to take the hauls mainly during the hours of darkness when acoustic measurements are difficult (Reynisson, 1996). This was done although catches at night are generally poorer.

2.2 Experimental redfish abundance estimation below 500 m depth

The classic method of continuous echo-integration beyond 500 m depth along survey tracks is applicable only under specific conditions, mainly because of the increased influence of the vessel’s noise, as well as the mixing of redfish with various components of sound scattering layer. An additional difficulty is due to decrease of the effective angle of the transducer beam pattern during single fish registration at high depths. The last one, in particular, demands to decrease the Sv-threshold up to (-85) – (-90) dB for correct echo-integration, which is not always possible.

During the preparatory meeting, a Russian proposal on the experimental redfish abundance estimation at depths below 500 m was discussed (WD3 in Anon. 1999a). The method is based on a combination of standardised survey catches and the acoustic data, where the correlation between catch and acoustic values during trawling in the upper layer is used to obtain acoustic values for the lower layer, based on catches in the lower layer. During the survey, the vessels made a total of 77 deep trawl hauls in the depths range 450–1050 m which were relatively evenly distributed all over the survey area (**Figure 1**). Each trawl haul of 6 nautical miles (about 150 min duration) was taken at three depth intervals, 450-600 m, 600-750 m and 750-900 m, 2 N.M. at each depth. The catches were standardised to one nautical mile and converted into echo acoustic values using a linear relationship between catches and acoustic values at depth above 500 m. The data for the correlation calculations were obtained during trawling only. In addition scrutinised acoustic values where only taken from exactly the same position and depth range as the trawl covered. The linear regression between acoustic values and catches recorded above 500 m is given in **Figure 5** and resulted in a 49 % explanation of the observed variation. Catches and hydroacoustic measurements reported by R/V Bjarni Sæmundsson above 500 m were excluded because of their extremely low numeric values. Mamylov (WD3 in Anon., 1999) proposes to use the following equation:

$$Satr = \frac{W(kg/nm) \times 4\pi \times 10^{0.1<TSkg>} \times 1852 \times dH}{K \times Ltr \times Htr} \qquad (1),$$

where Satr = equivalent acoustic back scattering strength, converted from catches (m^2*nm^{-2})
W = catch of redfish (kg/nautical mile);
<TSkg> = -38.3 dB/kg, the mean target strength per 1 kg of redfish;
Ltr and Htr = horizontal and vertical trawl opening (m);
K = coefficient of trawl efficiency.
dH = vertical coverage of the trawl (ratio).

This formula says that the abundance is the amount caught by the trawl divided by the volume swept times the efficiency of the trawl. Mamylov suggest using the value 0.5 for the trawl efficiency (K), based on Russian experience both from the Barents Sea and the Irminger Sea. The results using this equation will be compared to the results using linear regression between catchrates and acoustic values in the upper layer. The geometric parameters of the trawl mouth trawled by the three vessels were very similar and amounted to approximately Ltr X Htr = 50 X 50 m^2. The catchability of the three different trawls was therefore assumed to be equal. As the assumed depth range of the redfish assessed by this experimental method was fixed from 500 m – 950 m, dH is therefore a constant equal to 9 as the trawl only cover about 11% of the assumed depth range of the redfish.

As all three trawls were assumed to have equal Ltr, Htr, K and dH is also assumed to be equal, only the catchrate is variable. Therefore the formula could be simplified and to convert the catches of each trawl haul to theoretical SA values (SA_{trawl}) to:

$$SA_{trawl} = a + \mathrm{b} * \mathrm{catch} * \mathrm{dH}$$

As stated above, dH is 9 and a and b are the constants in linear regression between catch and SA values at same location and depth range.

The SA_{trawl} values for the depth beyond 500 m were computed based on the linear regression illustrated in **Figure 5** and averaged for a square of 1 degree latitude and 2 degrees longitude.

The corresponding abundance is then calculated by the same method as for the upper layer, applying a target strength of –38.3 dB per kg redfish. TS of –38.3 corresponds to –40 dB for 37 cm specimen. It was considered better to use TS per kg since the fish in the lower layer was in most cases larger.

2.3 Biological and hydrographic measurements

Standard biological observations needed for the acoustic assessment were carried out, as decided at the preparatory meeting in Reykjavík.

In addition otoliths were collected and observations on external and partly muscular melanosis, parasite infestation as well as on stomach contents were recorded, as agreed. Samples for genetic studies were collected onboard the Icelandic and German RVs.

On all vessels, temperature and salinity measurements were made by means of CTD after each haul and at cruise turning points, usually down to 1000m (119 in total). In addition the Russian vessel did measurements on 4 stations along the so-called 3 -K section.

3 RESULTS

3.1 Acoustic assessment of redfish above 500 m depth

The means of integrated values (m^2/nm^2) within the statistical rectangles are given in **Figure 6**. The average S_A value of all rectangles was about 4.6 with standard deviation of the mean of 2.1. As can been seen in **Figure 6** the entire distribution area was not covered, as the values in the southern and southwesternmost part of the surveyed area were relatively high at the turning points of the vessel covering that part. The stock abundance estimate of oceanic redfish within the covered area of 296,000 nm^2 amounts to about 1.2 **billion individuals** or 596 **000 tonnes**. Details are given in **Table 2** and **Table 3** where the number of fish are divided according to the proportion of males and females and the corresponding mean weight obtained from the biological samples within sub-areas (**Tables 4-8**).

The depth distribution and the diurnal distribution of oceanic redfish observed on "Bjarni Sæmundsson" and “AtlantNIRO” is shown in **Figures 7 and 8**. With the threshold used (-80dB), the expected underestimate in the depth intervals indicated in **Figure 7** ranges from 0-28 %, with a weighted mean of about 13 %, which is 4% higher correction than in the 1996 survey, due to higher proportion in deeper water.

3.2 Experimental redfish abundance estimation below 500 m depth

Figures 9 and 10 illustrates the geographical distribution of catches and calculated SA_{trawl} values below 500 m depth. The catches varied between 0 and 25 kg per nautical mile all over the area of investigation. Corresponding mean SA_{trawl} within the statistical rectangles is 3.34 with a standard deviation of the mean of 0.24. The highest catch rates were close to the Icelandic 200 miles EEZ border. The redfish density seems to be low within the Greenland EEZ below 500 m depth (**Figure 9)**.

The results of the experimental estimation of deep redfish abundance and biomass below 500 m depth including the scattering layer are listed in **Table 9**. The abundance and biomass estimations amounted 638 mill. and 497,000 tonnes of redfish (494,000 t according to the Russian method). However, the relatively poor fit between the observed catches and SA values above 500 m (r^2=0.49) on which the estimation below 500 m is based, decreases the reliability of the results given. It is therefore strongly recommended to interpret the magnitude of the redfish abundance below 500 m with care. Good comparison with results using the Russian method described above is on the other hand promising.

3.3 Biology and hydrographic measurements

Length and weight. In the layers above 500 m the males percentage exceeded the females and compiled 63,2%. There has been a trend of increasing proportion of females during this decade. In the layer below 500m the proportions of each sex were similar. Fish length in catches varies from 20 to 52 cm. Mean length of the redfish in the upper layer (above 500 m) was 34.2 cm and the mean weight was 498 g. In the lower layer, the mean length was 38.8 cm and the mean weight was 763.7 g. In general, the mean length of redfish increases with increasing depth (**Tables 4-8**).

The length frequencies from each trawl stations were aggregated by area and depth and scaled to abundance. Those values are listed in **Table 10** and illustrated in **Figure 11**, but it must be noted that the length disaggregated abundance above 500 m are derived from the acoustic estimation while the abundance indices at length below 500 m are based on the experimental trawl-acoustic estimation method. The peak at 35 cm of the length frequency above 500 m has also been observed in previous surveys. However, there are indications of recruitment of fish smaller than 30 cm length which has not been seen before. The redfish distributed below 500 m are significantly larger but display the same peaks, at 28 and 35 cm, respectively.

Food and feeding. Analysis on feeding and food composition is given in **Table 11.** In both the upper and lower layer, great proportion of the redfish stomachs is everted. Of those who were not everted, 70% in the investigated redfish upper layer had food items in the stomachs, as the proportion in the lower layer was 38%. In the upper layer the redfish fed mostly on Amphipods, Copepods, Euphausids and small squids. In the lower layer, the redfish where also eating the above mention items, but in addition shrimps and small fishes were also rather dominant (**Table 11**).

Maturity stage. Table 12 lists the maturity stages by sex and sub-areas A-E above and below 500 m. The stages 1-4 are described in the Report of the Study Group on Redfish Stocks (Anon. 1999a). The great majority of both males and females were identified as ripening (71-87 %, Stage 2) as expected from earlier investigations. In comparison with the 1994 and 1996 surveys, the proportion of juveniles was considerably higher in both depth zones. The only significant area effect is the higher proportion of pre-spawning males in the north-eastern Sub-area A. This area effect might be biased due to the low numbers of fish caught and analysed in that area. There is no significant depth effect on the mature stages of the fish. Relatively high proportion of juvenile oceanic redfish in the catches allowed for the first time to analyse the maturity at length. **Figure 12** displays the maturity ogive by sex and depth zones. In general, all fish at 34 cm length were identified as being mature. 50 % maturity is reached at around 31 cm length for both sexes. Females caught in the lower layer mature larger.

Parasite infestation. The rate of infestation of the redfish by the copepod *Sphyrion lumpi*, as well as muscular melanosis is given in **Table 13.** In the upper layer, about 40% of the males and 66% of the females carried external abnormalities which is a somewhat higher proportion than observed during the 1994 and 1996 international surveys. It is however similar to what has been observed in many surveys during the last years (Bakay, 1988, 1989; Magnússon *et al.*, 1992). The infestation from the lower layer are similar as in the upper layer (36% and 54%). Other muscular abnormalities (muscular melanosis) were not different from what has been observed previously in the upper layer (Bogovski, Bakay, 1989; Magnússon *et al.*, 1996), but there were lower rate of muscular melanosis in the lower layer.

Hydrographic data. A total number of 119 CTD-stations were occupied during the survey (Figure 1) measuring temperature and salinity against depth mostly down to depths of ca. 1000 m. Due to the early stage of processing of the CTD data only temperature will be included in the discussion below. The present hydrographic state observed during the survey is illustrated by the horizontal distribution (**Figures 13-16**) and vertical sections (**Figures 17-21**) of temperature. Two main water masses are present in the survey area: the warm, saline and less dense Subpolar Mode Water (SPMW, by others referred to as Modified North Atlantic Water (MNAW)) found at the eastern and northern rim of the survey area and the colder, fresher and denser SPMW occupying the central and southern parts of the Irminger Sea (hereafter called Subarctic Water (SAW) after Dickson *et al.,* 1988). The circulation of the survey area is reflected by the horizontal distribution of temperature at 200 m depth (**Figure 13**). After passing the Reykjanes Ridge from the Iceland Basin the SPMW participates in the cyclonic circulation in the Irminger Sea as the Irminger Current. After branching in the Denmark Strait the western branch of the SPMW finally joins the East Greenland Current on its southward path. In the central and southern parts of the survey area the SAW participates in the cyclonic circulation of the subpolar gyre of which the circulation of SPMW just mentioned also is part off. The horizontal temperature distribution also suggests the present of a number of eddies in the survey area. A recent comprehensive description of the circulation and water mass distribution of the subpolar gyre is e.g. given by Bersch *et al.,* (1999).

Highest concentrations of redfish above 500 m depth were found in the colder part of the SAW located south of Cape Farewell associated with temperatures around 3.5 to 4°C (e.g. **Figures 13** and **17**).

Below 500 m depth the highest concentrations of redfish were associated with eddies and fronts in the vicinity of the Reykjanes Ridge (e.g. **Figure 21** around station 450) within the temperature range 4.5 to 6°C.

4 DISCUSSION

4.1 Acoustic assessment of redfish above 500 m depth

The 1999 results show that in sub-area A, where the highest concentration of redfish has been observed previously, the biomass recorded was only about 10% of what was measured in 1994 and 1996. In sub-area B only 25% of the 1994 value and 42% of the 1996 value is measured. The survey seems to fail in covering the whole distribution area of redfish in the Irminger Sea and adjacent waters. The boundaries of the horizontal distribution in June/July 1999 were reached to north and east, but not to west and south. It seems from the acoustic results that highest proportion of the acoustically measured redfish in the uppermost 500 m were in the area south and south-west of Cape Farewell. Compared with earlier investigations at this time of year (Magnusson *et al*., 1994, 1996), the redfish were more westerly (and south-westerly) distributed and boundaries of distribution towards west and south were not reached. This stock abundance estimation is therefore an underestimation. It should however been noted that this survey covered nearly 300,000 nautical miles, which is the most extensive acoustic estimation of redfish in the Irminger Sea and adjacent waters.

In this assessment a target strength (TS) of –40 dB was used (Reynisson, 1992). While obtaining this value, the mean length of the fish was about 37 cm in all cases, and the length range from 33-45 cm. In later investigations, the same TS have been measured, with similar length distribution (Reynisson and Sigurðsson, 1996). It is, however, more common to express the target strength as a function of fish length through the standard equation TS= 20 log(length) – b. For a redfish of 37 cm, b is then = -71.3 dB. By applying that length dependent function to the data, the total biomass would between 10 and 15% higher, as the length distribution (range) deviates from earlier length distributions, with higher proportion of small fish.

Even though discarding the acoustic data obtained during the times of the most pronounced mixing with the scattering layer, the diurnal variation of the integration values was evident. In **Figure 8** the mean normalised redfish integrator values during this survey, averaged over every two hours of the day are shown. A comparison to the similarly observed variation in 1994 (Magnússon *et al.*, 1994) as well as in 1996 (Magnússon *et al.*, 1996), shows however, that during the night time (*i.e*. from about 22-06 GMT) the decrease in integration-values was not as pronounced as it has been earlier.

The mixing with the deep scattering layer will certainly affect the results. The observed depth distribution of the redfish in this survey was similar to the observed distribution in 1996 (Magnússon *et al.,* 1996). However, the last surveys do show a deeper distribution compared with the international surveys conducted in 1992, and 1994 (Magnússon *et al.*, 1992a,b and Magnússon *et al.*, 1994, 1996). Whether this indicates that the acoustic measurements of the oceanic redfish were in general more affected by mixing with the scattering layer this year as compared to earlier surveys is difficult to reveal.

Since 1994, the results of the acoustic estimate indicate a drastic decreasing trend (**Table 3 and 4**),. In the same period, the total catches have been about 600, 000 tonnes at the same time as the abundance estimate has decreased by about 1.4 million tonnes. However, it should not be excluded that the results form earlier years might have been an overestimation of the abundance. During the same period, the fishery has also developed towards greater depth. It has been estimated that about 33% of the catches in 1998 were taken above 600 m depth, but in 1994, as an example, about 90% of the Icelandic catches were reported above 600 m depth (Anon. 1999b).

Acoustic measurement at depths below 500 meters.

During the survey, the acoustic data obtained was scrutinised down to 1000 m. Redfish was detected with the acoustic equipment down to about 900 m but the density was very low and it was difficult to distinguish the redfish from other scatters. In previous international surveys in the area, there has not been made an attempt to assess the fish below 500 m depth. During this survey, the redfish occurred in and below the deep scattering layer, of meso-pelagic organisms, but poorer deteriorating S/N ratio of the acoustic signal occurs at those depths. As the uncertainty in the scrutinising, as well as disturbance due to noise, reliable calculation of redfish abundance below 500 m using acoustic abundance results was considered impossible with the equipment used. To be able to measure redfish acoustically below 500 m a towed body lowered to at least 300-400 m is needed. The signal-to-noise ratio would be greatly improved and the resolution of the acoustic beam would also be better.

4.2 Experimental redfish abundance estimation below 500 m depth.

During Russian trawl – acoustic surveys in 1995 and 1997 attempts were made to assess the redfish stock at depth lower than 500 m. According to an expert estimation in 1995 the stock constituted nearly 800 000 tonnes (unpublished data) and in 1997 it was estimated to be 500,000 tonnes (unpublished data). The estimate based on the experimental calculations below 500 m depth, given here, must be considered as a first attempt as the applicability of the applied method can only be verified after replicate measurements. Based on the trawl data below 500 m one can see that although the catch rates are low, the distribution area of the redfish at those depths is very large and exceeds the distribution area of the redfish above 500 m. Relatively good agreement with the Russian swept volume method is encouraging. It is, however, clear and should be kept in mind that all the assumption made in the calculation of the abundance make the calculations unreliable.

4.3 Biology and hydrographic measurements

The observed length distribution of the redfish are similar to previous surveys, with the bigger fish distributed below 500 m. The main difference from earlier surveys is higher proportion of fish <30 cm seen both above and below 500 m depth. Recruiting redfish of that size have been recorded at the East Greenland continental shelves with a decreasing trend in abundance since 1998 (Rätz and Stransky, 1999). The occurrence of small redfish in the Irminger Sea suggests that the oceanic redfish might at least partly recruit from the East Greenland continental shelves, as there have been observed large quantities of redfish in that area (Anon. 1999b).

In recent years, hydrographic conditions in the survey area have been observed to have undergone pronounced changes (e.g. Pedchenko *et al.,* 1997; Bersch *et al.* 1999; Mortensen and Valdimarsson 1999). Comparison with previous joint acoustic surveys on oceanic redfish in the Irminger Sea and adjacent waters in June/July 1994 and 1996 (Magnússon *et al.*, 1994, 1996) also reveals that the hydrography of the area has undergone pronounced changes during the period 1994 to 1999. The changes are seen as a gradual warming over most parts of the Irminger Sea during this period. Horizontal temperature distribution at 200 m depth for the Irminger Sea and adjacent waters obtained during June/July for the years 1994, 1996 and 1999 clearly shows this warming tendency (**Figures 22, 23 and 13**). The progress of the heating can be followed at 200 m depth as a southwestward withdrawal of the 3.5°C isotherm out of the Irminger Sea area between 1994 and 1996, and later the withdrawal of the 4°C isotherm out of the same area between 1996 and 1999. The heating tendency is also reflected in the vertical temperature distribution. Here for example the minimum depth of the 3.5°C isotherm on the section along 60°N has been observed to increase during the same period. In 1994 the depth was ca. 125 m, being ca. 300 m in 1996 and increasing to ca. 660 m in 1999.

During this survey, the highest density of redfish at layer 0-500 m was mainly observed more southwesterly and deeper compared to the surveys in 1994 and 1996, within the temperature range 3.4 to 5.7°C associated with the SAW mass. The relationship between the hydrography and distribution of redfish observed here supports previous results (i.a. Pedchenko *et al.,* 1997) that the distribution of redfish in the Irminger Sea is in many respects governed by oceanographic conditions.

As it has been observed during previous surveys, the highest concentrations of redfish below 500m layer were observed in the vicinity of the Reykjanes Ridge at temperature of and of 3.5°C to 5.6°C.

5 CONCLUDING REMARKS

- A total of about 600.000 t redfish was measured acoustically above 500 m. In addition, about 500.000 t were estimated below 500 m depth by use of trawl data and correlation between catch and acoustic results above 500 m depth. Based on the results given in this report we want to stress that the acoustic abundance estimate given, must be considered as highly uncertain. It is, however, clear that there has been a significant downward trend in the area covered for obtaining the acoustic stock size estimate since 1994.

- The observed decrease in survey abundance is very drastic and exceeds the removed biomass by a factor of 2. This might be due to incomplete coverage of the stock distribution area in vertical and horizontal direction. Another reason might be the deeper distribution of the redfish and their stronger mixing with the deep scattering layer.

- The estimate based on the experimental calculations below 500 m depth must be considered as a first attempt.

- Length distributions indicate recruitment both above and below 500 m depth. This is the first time that any pre-recruits have been seen in this area. The length of these pre-recruits is similar to the length of the abundant juveniles growing up at the shelf of East Greenland. As this is the first time recruitment judging whether this is strong recruitment or not is impossible.

- The stock **above** 500 m is now observed more southwesterly and deeper than it has been during former acoustic surveys in this decade. During the same period, there has been observed gradual increase in temperature in the observation area. This may have influenced the distribution pattern of the redfish in June -July 1999 as the highest concentration were found in the colder part of the survey area.

- **Below** 500 m depth the hydrographic observations indicates that the highest concentrations of redfish are associated with eddies and fronts.

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TABLES

Table 1. Instrument settings of the acoustic equipment settings onboard the participating vessels

Vessel	"Bjarni Sæmundsson"	"AtlantNIRO"	"Walther Herwig III"
Echo sounder/integrator	Simrad EK500/Bi500	Simrad EK500	Simrad EK500/BI500
Frequency	38 kHz	38 kHz	38 kHz
Transmisson power	2000 W	2000 W	2000 W
Absorption coefficient	11 dB/km	10 dB/km	10 dB/km
Pulselength	1.0 ms	3.0 ms	3.0 ms
Bandwidth	Wide	Narrowe	Narrow
Transducer type	ES38-B	ES38-B	ES38-B
2-way beam angle	-20.7 dB	-20.7 dB	-20.9
3 dB beamwidth	7.1	7.1	6.8
TS Transd. Gain	26.0 dB	27.5 dB	25.5 dB
SV Tramsd. Gain	25.75 dB	27.5 dB	25.5 dB
Integration threshold	-80 dB//1 m2/m3	-80 dB// 1 m2/m3	-80 dB//1 m2/m3
Range BI-500	50 - 800 m	0 – 1000 m	0 – 1000 m
Sound speed	1470 m/s	1470 m/s	1470 m/s

Table 2. Abundance computation (in number) and area coverage for redfish at depth down to 500 m for each sub-area. Results for the international surveys conducted in 1994 and 1996 are also given.

		Sub-area					
Year		**A**	**B**	**C**	**D**	**E**	**Total**
1994	Total numbers (millions)	1109	1964	-	95	328	3496
	Total area (nm²)	*75307*	*88132*	-	*7342*	*18348*	*189129*
1996	Total numbers (millions)	1055	1217	-	57	265	2594
	Total area (nm²)	*89198*	*112086*	-	*11409*	*39852*	*252546*
1999	Total numbers (millions)	123	609	27	71	336	1165
	Total area (nm²)	*106688*	*138865*	*6291*	*6291*	*37988*	*296122*

Table 3. Biomass computation (in '000 tonnes) for redfish at depth down to 500 m for each sub-area. Results for the international surveys conducted in 1994 and 1996 are also given.

	Sub-area					
Year	***A***	***B***	***C***	***D***	***E***	***Total***
1994	673	1228	-	63	226	2190
1996	639	749	-	33	155	1576
1999	72	317	16	42	167	614

Table 4a. Redfish trawl data < 500m. **Sub-Area A**. Mean weight (g) by length (cm).

Length (cm)	Males		Females		Total	
	Weight (g)	numbers	weight (g)	numbers	weight (g)	numbers
25						
26	182	1			182	1
27	236	2			236	2
28	248	2			248	2
29						
30	302	2	301	2	302	4
31	342	1			342	1
32	356	4	382	1	361	5
33	392	2	361	1	381	3
34	416	2			416	2
35	512	12	487	6	504	18
36	549	13	542	9	546	22
37	622	15	583	8	608	23
38	681	13	661	5	675	18
39	685	8	717	6	699	14
40	775	1	771	8	772	9
41	814	2	859	3	841	5
42			936	1	936	1
43	963	1			963	1
44	1020	1			1020	1
45	1032	1			1032	1
46						
Total number		83		50		133
Avg. weight	572		621		591	
Avg. length	36.0		37.3		36.5	

Table 4b. Oceanic redfish trawl data > 500m. **Sub-Area A**. Mean weight (g) by length (cm).

Length (cm)	Males		Females		Total	
	weight (g)	numbers	weight (g)	numbers	Weight (g)	numbers
20	95	1			95	1
21						
22						
23						
24						
25	223	1			223	1
26	224	2			224	2
27			220	2	220	2
28	256	2	255	1	256	3
29	280	2	235	1	265	3
30	329	1	318	5	320	6
31	345	5	339	3	343	8
32	369	12	359	4	366	16
33	419	15	406	6	415	21
34	469	20	452	13	462	33
35	514	27	536	9	520	36
36	578	19	585	13	581	32
37	614	24	606	13	611	37
38	675	37	669	14	673	51
39	715	55	737	15	720	70
40	766	81	766	31	766	112
41	826	78	821	43	824	121
42	886	88	930	58	903	146
43	966	78	957	69	962	147
44	992	63	1025	62	1008	125
45	1075	54	1116	53	1095	107
46	1185	25	1141	41	1158	66
47	1168	14	1226	34	1209	48
48	1271	8	1316	13	1299	21
49			1343	7	1343	7
50			1460	1	1460	1
51						
52			1482	1	1482	1
Total number		712		512		1224
Avg. weight	821		925		864	
Avg. length	40.6		42.1		41.2	

Table 5a. Redfish trawl < 500m. **Sub-Area B.** Mean weight (g) by length (cm).

Length (cm)	Males		Females		Total	
	weight (g)	Numbers	weight (g)	numbers	Weight (g)	numbers
23	160	1	168	1	164	2
24	165	1			165	1
25	193	9	184	4	190	13
26	218	22	203	11	214	33
27	260	19	236	18	248	37
28	272	22	260	36	264	58
29	287	41	290	33	289	74
30	321	34	308	33	315	67
31	355	50	352	30	354	80
32	411	64	385	32	404	96
33	444	187	438	33	443	220
34	495	265	507	68	498	333
35	548	271	541	109	546	380
36	598	188	588	145	593	333
37	649	93	637	124	642	217
38	701	69	695	81	698	150
39	732	30	751	53	744	83
40	801	12	802	22	802	34
41	940	2	845	9	859	11
42			1017	1	1017	1
43	1031	1	1010	1	1024	2
44	1035	1	1080	1	1058	1
45						
46	1084	1			1084	1
47						
Total number		1382		845		2227
Avg. weight	513		545		521	
Avg. length	34.1		34.7		34.5	

Table 5b. Oceanic redfish trawl data > 500m. **Sub-Area B**. Mean weight (g) by length (cm).

Length (cm)	Males		Females		Total	
	weight (g)	Numbers	weight (g)	numbers	Weight (g)	numbers
23	150	1			150	1
24			168	1	168	1
25	168	2	190	1	175	3
26	218	2			218	2
27	242	6	227	4	235	10
28	274	12	266	8	370	20
29	292	10	295	7	293	17
30	326	13	311	17	318	30
31	335	15	356	10	343	25
32	416	21	387	14	404	35
33	437	34	419	12	433	46
34	489	54	482	30	487	84
35	531	67	533	21	531	88
36	574	45	594	24	581	69
37	630	50	647	35	636	85
38	689	47	696	32	692	79
39	771	61	769	26	770	87
40	871	55	837	34	857	89
41	918	67	921	34	919	101
42	1002	67	1010	44	1005	111
43	1051	58	1087	56	1069	114
44	1143	56	1148	55	1146	111
45	1182	36	1217	40	1199	76
46	1210	18	1274	16	1239	34
47	1273	2	1317	17	1310	19
48	1355	2	1292	3	1317	5
49			1400	1	1400	1
50						
Total		801		542		1343
Avg. weight	746		827		795	
Avg. length	38.1		39.2		38.5	

Table 6a. Redfish trawl data >500m **Sub-Area C.** Mean weight (g) by length (cm).

Length (cm)	Males		Females		Total	
	weight (g)	numbers	weight (g)	numbers	weight (g)	numbers
30			300	1	300	1
31						
32						
33	410	1			410	1
34						
35	455	1			455	
36			605	1	605	1
37	645	1			645	1
38			760	1	760	1
39						
40	863	2	805	1	834	3
41	903	2			903	2
42	995	1	1040	2	1018	3
43	1040	2			1040	2
44	1178	2	1145	1	1161	3
45	1185	1	1113	2	1149	3
46						
47			1320	2	1320	2
48						
Total number		13		11		24
Avg. weight	853		886		945	
Avg. length	40.6		41.5		41.0	

Table 7a. Redfish trawl data <500m. **Sub-Area D.** Mean weight (g) by length (cm).

Length (cm)	Males		Females		Total	
	weight (g)	numbers	weight (g)	numbers	Weight (g)	numbers
24						
25			192	1	192	1
26						
27			225	1	225	1
28	290	1	275	1	283	2
29	310	1			310	1
30	325	1			325	1
31	388	1	385	1	388	2
32	431	6	470	1	450	7
33	467	13	465	2	466	15
34	516	25	551	7	534	32
35	561	23	572	17	566	40
36	594	17	620	21	607	38
37	640	12	669	20	654	32
38	723	4	750	11	736	15
39	758	2	760	6	759	8
40	790	1	817	2	803	3
41			830	2	830	2
42			910	1	910	1
43						
Total number		106		90		197
Avg. weight	522		566		589	
Avg. length	34.8		36.2		35.4	

Table 7b. Redfish trawl data >500m. **Sub-Area D.** Mean weight (g) by length (cm).

Length (cm)	Males		Females		Total	
	weight (g)	numbers	weight (g)	numbers	Weight (g)	numbers
26	240	2			240	2
27	240	1			240	1
28	285	2	280	1	283	3
29	310	1	300	2	305	3
30	335	2	330	1	333	3
31	350	1	390	1	370	2
32	428	6	410	1	419	7
33	469	15			469	15
34	495	17	487	3	491	20
35	551	16	554	16	553	32
36	593	7	581	20	587	27
37	662	9	625	11	643	20
38	715	4	680	8	698	12
39	720	2	695	2	708	4
40						
41			810	4	810	4
42	1220	1			1220	1
43			900	1	900	1
44						
Total number		86		71		157
Avg. weight	507		542		554	
Avg. length	34.2		36.0		35.0	

Table 8a. Redfish trawl data <500m. **Sub-Area E.** Mean weight (g) by length (cm).

Length (cm)	Males		Females		Total	
	weight (g)	numbers	weight (g)	numbers	Weight (g)	numbers
22			140	1	140	1
23	150	1	150	1	150	2
24	197	4	260	1	228	5
25	281	5	190	4	236	9
26	202	18	218	16	210	34
27	240	26	238	26	239	52
28	257	45	261	40	259	85
29	291	31	282	59	287	90
30	304	38	317	21	310	59
31	345	15	315	6	330	21
32	420	58	358	11	389	69
33	461	122	423	15	442	137
34	503	205	503	48	503	252
35	546	179	540	75	543	253
36	604	141	599	71	602	211
37	654	77	644	62	649	139
38	690	55	688	42	689	97
39	758	27	766	24	762	51
40	823	7	767	6	795	13
41	765	1	868	6	817	7
42			910	4	910	4
43						
Total number		1052		538		1590
Avg. weight	447		449		497	
Avg. length	33.8		33.5		33.7	

Table 8b. Redfish trawl data >500m. **Sub-Area E.** Mean weight (g) by length (cm).

Length (cm)	Males		Females		Total	
	weight (g)	numbers	weight (g)	numbers	Weight (g)	numbers
22	130	1	125	1	128	2
23						
24	145	2			145	2
25	188	2			188	2
26	195	4	215	2	205	6
27	245	4	225	2	235	6
28	252	9	267	8	259	17
29	300	11	295	9	298	20
30	306	16	325	7	316	23
31	371	14	355	3	363	17
32	411	18	370	5	391	23
33	464	30	410	8	437	38
34	487	56	495	14	491	70
35	533	52	548	21	541	73
36	584	25	545	27	564	52
37	674	12	550	20	612	32
38	720	19	699	16	709	35
39	741	8	765	4	753	12
40		1	863	2	863	3
41			861	5	861	5
42	1020	1	880	2	950	3
43	1007	2	940	1	973	3
44	1090	2			1090	2
45	1163	1			1163	1
46						
Total number		290		157		447
Avg. weight	525		512		505	
Avg. length	33.7		34.6		34.1	

Table 9. Results from experimental estimation of redfish at depths between 500 and 950 m.

Area	A	B	C	D	E	Total	Units
Total numbers	217	314	11	25	72	638	Thous.
Area covered	110524	124014	8403	4201	27435	274577	nm^2
Mean weight	864	795	945	554	505		g
Total weight	187	249	10	14	36	497	Thous. tonnes

Table 10. Length distribution by area and depth zone.

Length (cm)	A <450	B <450	C <450	D <450	E <450	A >450	B >450	C >450	D >450	E >450	sum <450	sum >450	sum
20,5	0	0	0	0	0	168	0	0	0	0	0	168	168
21,5	0	0	0	0	0	0	0	0	0	0	0	0	0
22,5	0	0	0	0	211	0	0	0	0	345	211	345	556
23,5	0	547	0	0	422	0	276	0	0	0	969	276	1245
24,5	0	273	0	0	1056	0	276	0	0	345	1329	620	1949
25,5	0	3555	134	353	1901	168	827	0	0	345	5943	1339	7283
26,5	925	9024	0	0	7180	337	551	0	408	1034	17129	2329	19458
27,5	1850	10118	134	353	10982	337	2755	0	204	1034	23437	4329	27766
28,5	1850	15861	269	706	17951	505	5510	0	611	2928	36637	9555	46191
29,5	0	20236	134	353	19007	505	4684	0	611	3445	39731	9245	48976
30,5	3699	18322	134	353	12460	1010	8265	522	611	3962	34969	14370	49339
31,5	925	21877	269	706	4435	1346	6888	0	408	2928	28212	11570	39782
32,5	4624	26252	940	2473	14572	2693	9643	0	1427	3962	48861	17724	66585
33,5	2774	60162	2015	5299	28933	3534	12673	522	3057	6546	99182	26332	125515
34,5	1850	91063	4299	11303	53219	5554	23142	0	4076	12058	161734	44831	206565
35,5	16647	103916	5373	14129	53431	6059	24244	0	6522	12575	193495	49400	242896
36,5	20346	91063	5104	13423	44561	5386	19010	522	5503	8957	174497	39378	213874
37,5	21271	59341	4299	11303	29355	6227	23418	522	4076	5512	125569	39755	165324
38,5	16647	41019	2015	5299	20485	8583	21765	522	2446	6029	85465	39345	124809
39,5	12947	22697	1075	2826	10771	11781	23969	0	815	2067	50316	38632	88948
40,5	8323	9298	403	1060	2745	18850	24520	1565	0	517	21829	45451	67281
41,5	4624	3008	269	706	1478	20364	27826	1043	815	861	10086	50910	60996
42,5	925	273	134	353	845	24572	30581	1565	204	517	2531	57439	59969
43,5	925	547	0	0	0	24740	31407	1043	204	517	1472	57912	59383
44,5	925	273	0	0	0	21038	30581	1565	0	345	1198	53528	54726
45,5	925	0	0	0	0	18008	20938	1565	0	172	925	40684	41609
46,5	0	273	0	0	0	11108	9367	0	0	0	273	20475	20748
47,5	0	0	0	0	0	8078	5235	1043	0	0	0	14356	14356
48,5	0	0	0	0	0	3534	1378	0	0	0	0	4912	4912
49,5	0	0	0	0	0	1178	276	0	0	0	0	1454	1454
50,5	0	0	0	0	0	168	0	0	0	0	0	168	168
51,5	0	0	0	0	0	0	0	0	0	0	0	0	0
52,5	0	0	0	0	0	168	0	0	0	0	0	168	168
53,5	0	0	0	0	0	0	0	0	0	0	0	0	0
54,5	0	0	0	0	0	0	0	0	0	0	0	0	0
55,5	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	123000	609000	27000	71000	336000	206000	370000	12000	32000	77000	1166000	697000	1863000
Mean Length	37,0	34,8	35,9	35,9	34,2	41,7	39,3	41,8	35,5	34,6	35,0	39,4	36,6

Table 11a. Redfish trawl data <500m. Observations on the stomach contents.

	Sub-Area No.	**A** %	Sub-Area No.	B %	Sub-Area No.	C+D %	Sub-Area No.	E %	Total No.	%
Total	133		972		154		324		1583	
everted	79	59.4	532	54.7	98	63.6	241	74.4	950	60.0
empty	31	23.3	131	13.5	21	13.6	6	1.9	189	11.9
w.content	23	17.3	309	31.8	35	22.7	77	23.8	444	28.0
little	17	12.8	73	7.5	5	3.2	42	13.0	137	8.7
medium	6	4.5	155	15.9	20	13.0	28	8.6	209	13.2
high		0.0	68	7.0	10	6.5	7	2.2	85	5.4
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Amphip			174	30.9	30	49.2	21	26.3	225	31.9
Copepods			134	23.8	13	21.3	28	35.0	175	24.8
Euphaus.			106	18.8	2	3.3	16	20.0	124	17.6
Squids.			71	12.6	8	13.1	7	8.8	86	12.2
Chaetogn.			37	6.6	4	6.6	1	1.3	42	6.0
Shrimps			11	2.0	-	0.0	1	1.3	12	1.7
Fish remn.			12	2.1	2	3.3	3	3.8	17	2.4
Other			19	3.4	2	3.3	3	3.8	24	3.4

Table 11b. Redfish trawl data > 500m. Observations on the stomach contents.

	Sub-Area No.	A %	Sub-Area No.	B %	Sub-Area No.	D %	Sub-Area No.	E %	Total No.	%
Total	1386		1287		157		23		2853	
everted	591	42.6	639	49.7	100	63.7	11	47.8	1341	47.0
empty	491	35.4	424	32.9	16	10.2	5	21.7	936	32.8
w.content	304	21.9	224	17.4	41	26.1	7	30.4	576	20.2
little	50	3.6	70	5.4	14	8.9	1	4.3	135	4.7
medium	251	18.1	122	9.5	25	15.9	5	21.7	403	14.1
high	3	0.2	32	2.5	2	1.3	1	4.3	38	1.3
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Amphip	8	13.8	41	12.5	29	34.1	4	30.8	82	16.9
Copepods	25	43.1	52	15.8	24	28.2	4	30.8	105	21.6
Euphaus.	4	6.9	45	13.7	6	7.1		0.0	55	11.3
Squids.	3	5.2	55	16.7	7	8.2		0.0	65	13.4
Chaetogn.		0.0	4	1.2	2	2.4	2	15.4	8	1.6
Shrimps	9	15.5	52	15.8	4	4.7		0.0	65	13.4
Fish remn.	7	12.1	38	11.6	5	5.9	1	7.7	51	10.5
Other	2	3.4	42	12.8	8	9.4	2	15.4	54	11.1

Table 12. Redfish. Maturity stages by sex and Sub-area above and below 500 m depth.

Sub-area (above 500m depth)		maturity stages males				maturity stages females			
		1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
A	No.	4	35	30	1	6	36	0	1
	%	6	50	43	1	14	84	0	2
B	No.	81	54	9	0	68	457	0	2
	%	10	89	1	0	13	87	0	0
C	No.	0	0	0	0	0	0	0	0
	%	0	0	0	0	0	0	0	0
D	No.	3	157	0	0	0	151	0	0
	%	2	98	0	0	0	100	0	0
E	No.	84	494	0	0	77	203	0	0
	%	15	85	0	0	28	73	0	0
Total	No.	172	1440	39	1	151	847	0	3
	%	10	87	2	0	15	85	0	0

Sub-area (below 500m depth)		maturity stages males				maturity stages females			
		1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
A	No.	31	336	347	3	47	456	0	12
	%	4	47	48	0	9	89	0	2
B	No.	85	766	44	0	75	496	0	8
	%	9	86	5	0	13	86	0	1
C	No.	0	13	0	0	1	10	0	0
	%	0	100	0	0	9	91	0	0
D	No.	7	79	0	0	5	66	0	0
	%	8	92	0	0	7	93	0	0
E	No.	17	93	0	0	13	28	0	0
	%	15	85	0	0	32	68	0	0
Total	No.	140	1287	391	3	141	1056	0	20
	%	8	71	21	0	12	87	0	2

Table 13a. Incidence of *Sphyrion lumpi* and pigment abnormalities (depth < 500m).

	Sub-Area A			**Sub- Area B**			**Sub-Area C**			**Sub-Area D**			**Sub-Area E**			**Total**		
External abnormalities																		
	Males	Females	Total	Males	Females	Total	Males	Females	Total	Males	Females	Total	Males	Females	Total	Males	Females	Total
No. of fish examined	83	50	133	502	346	848	ND	ND	ND	74	56	130	133	87	220	792	539	1331
No. of fish with extern. abnorm.	35	32	67	205	237	442	ND	ND	ND	29	37	66	46	50	96	315	356	671
% with external abnormalities	42.2	64.0	50.4	40.8	68.5	52.1	ND	ND	ND	39.2	66.1	50.8	34.6	57.5	43.6	39.8	66.0	50.4
No. with extern. pigment spots	12	15	27	78	106	184	ND	ND	ND	8	18	26	15	20	35	113	159	272
% with extern. pigment spots	14.5	30.0	20.3	15.5	30.6	21.7	ND	ND	ND	10.8	32.1	20.0	11.3	23.0	15.9	14.3	29.5	20.4
No. with *S.lumpi* and/or remn.S.l.	25	23	48	160	184	344	ND	ND	ND	22	31	53	38	38	76	245	276	521
% with *S.lumpi* and/or remn. S.l.	30.1	46.0	36.1	31.9	53.2	40.6	ND	ND	ND	29.7	55.4	40.8	28.6	43.7	34.5	30.9	51.2	39.1
Muskular melanosis*																		
	Males	Females	Total	Males	Females	Total	Males	Females	Total	Males	Females	Total	Males	Females	Total	Males	Females	Total
No. of fish examined	83	50	133	141	98	239	ND	ND	ND	17	8	25	9	17	26	250	173	423
No. of fish w. musc. melanosis	52	26	78	41	28	69	ND	ND	ND	4	2	6	2	4	6	99	60	159
% w. muscular melanosis	62.6	52.0	58.6	29.1	28.6	28.9	ND	ND	ND	23.5	25.0	24.0	22.2	23.5	23.1	39.6	34.7	37.6

***-** Russian and Icelandic data only; ND – no data.

Table 13b. Incidence of *Sphyrion lumpi* end pigment abnormalities (depth > 500m).

	Sub-Area A			Sub- Area B			Sub-Area C			Sub-Area D			Sub-Area E			Total		
External abnormalities																		
	Males	Females	Total	Males	Females	Total	Males	Females	Total	Males	Females	Total	Males	Females	Total	Males	Females	Total
No. of fish examined	646	471	1117	811	547	1358	13	11	24	86	71	157	93	36	129	1649	1136	2785
No. of fish with extern. abnorm.	206	215	421	321	334	655	3	8	11	43	41	84	29	20	49	602	618	1220
% with external abnormalities	31.9	45.6	37.7	39.6	61.1	48.2	23.1	72.7	45.8	50.0	57.7	53.5	31.2	55.6	38.0	36.5	54.4	43.8
No. with extern. Pigment spots	36	51	87	82	102	184	0	0	0	15	22	37	8	7	15	141	182	323
% with extern. Pigment spots	5.6	10.8	7.8	10.1	18.5	13.6	0.0	0.0	0.0	17.4	31.0	23.6	8.6	19.4	11.6	8.6	16.0	11.6
No. with *S.lumpi* and/or remn.S.l	182	169	351	284	262	546	3	8	11	30	30	60	22	17	39	521	486	1007
% with *S.lumpi* and/or remn. S.l	28.2	35.9	31.4	35.0	47.9	40.2	23.1	72.7	45.8	34.9	42.2	38.2	23.7	47.2	30.2	31.6	42.8	36.2
Muscular melanosis																		
	Males	Females	Total	Males	Females	Total	Males	Females	Total	Males	Females	Total	Males	Females	Total	Males	Females	Total
No. of fish examined	611	469	1080	271	153	424	ND	ND	ND	29	21	50	15	8	23	926	651	1577
No. of fish w. musc. Melanosis	99	52	151	44	28	72	ND	ND	ND	10	5	15	2	2	4	155	87	242
% w. muscular melanosis	16.2	11.1	14.0	16.2	18.3	17.0	ND	ND	ND	34.5	23.8	30.0	13.3	25.0	17.4	16.7	13.4	15.3

FIGURES

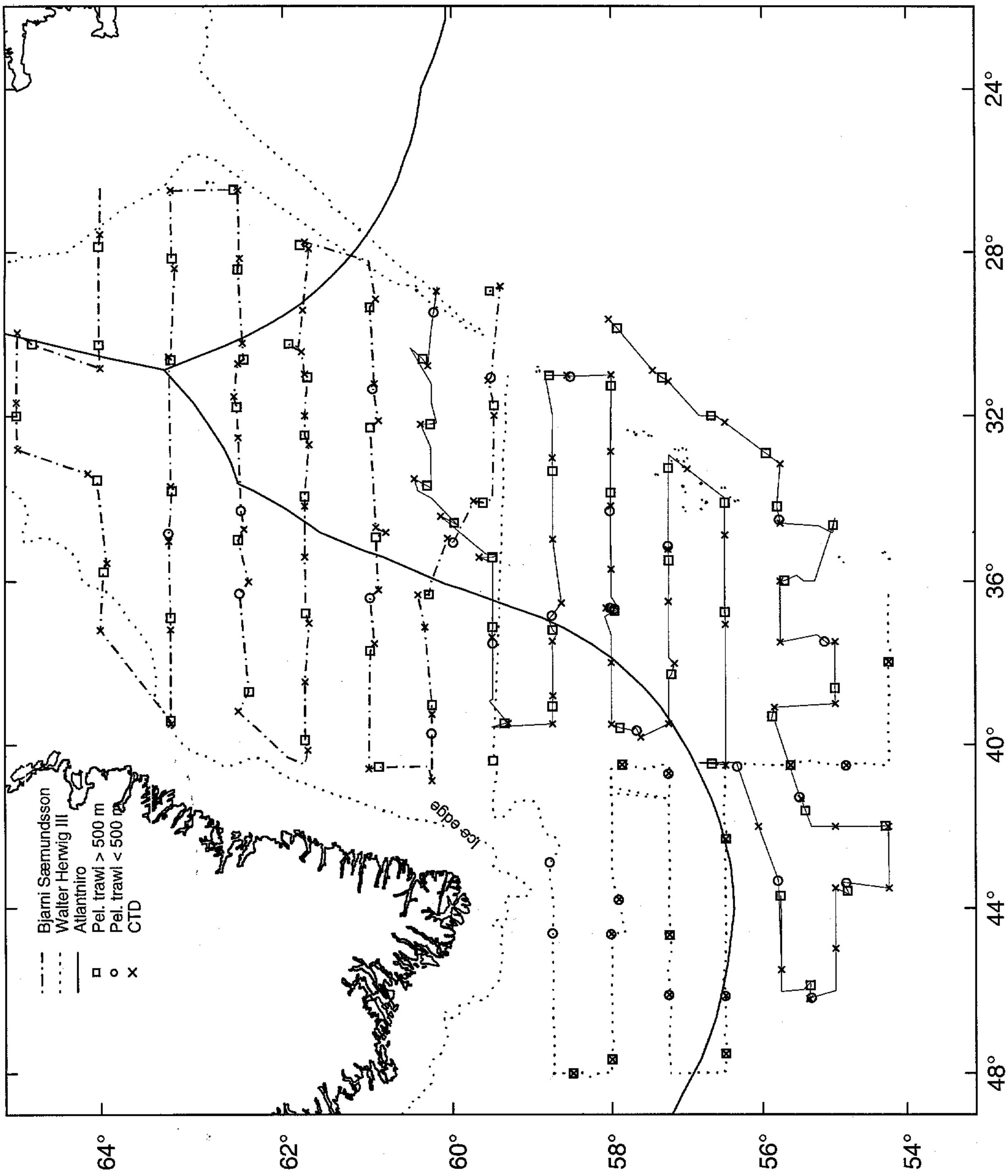

Figure 1. Cruise tracks and stations taken in the joint international redfish survey in June/July 1999.

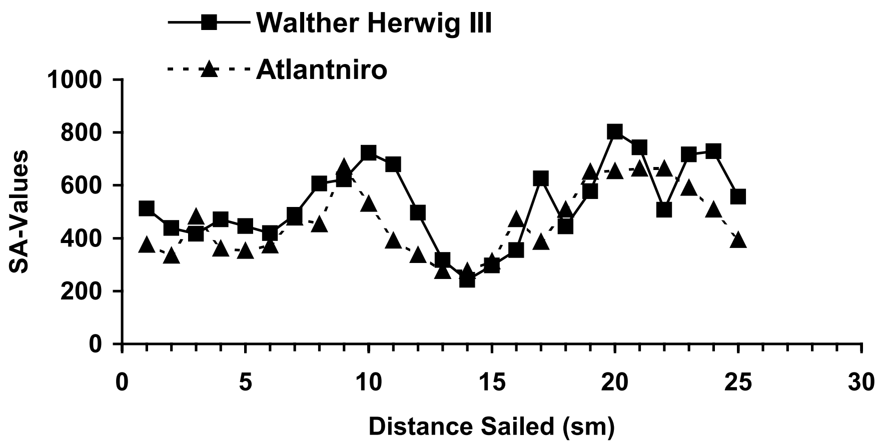

Figure 2. Hydroacoustic SA-values from the two research vessels, "AtlantNIRO" and "Walther Herwig III", measured during the intercalibration excercise at the depth range 300-500 m.

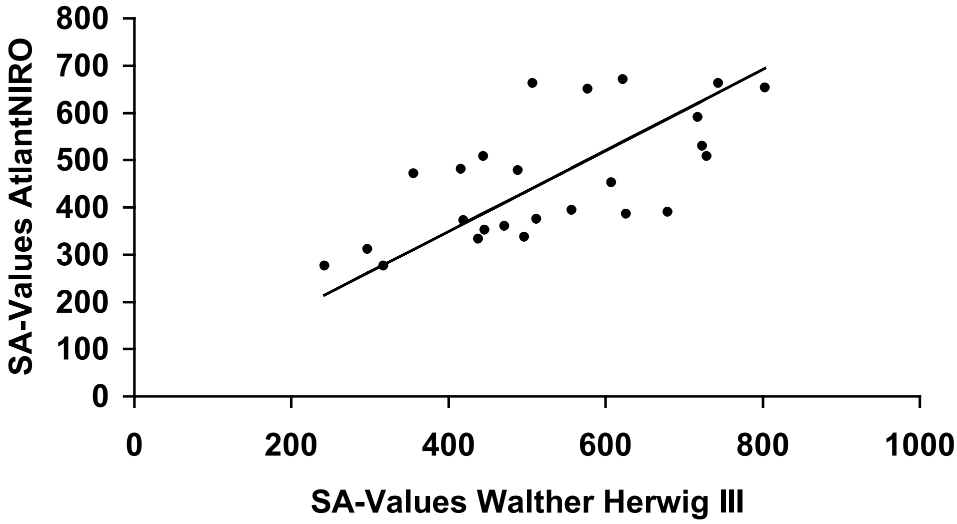

Figure 3. Regression analysis (geometric mean) from the intercalibration analysis between RVs AtlantNIRO and Walther Herwig III. at 300 to 500 m depth. $Sa_{AtlantNIRO}=Sa_{WH3}*0.854+7.85$; $r^2=0.43$.

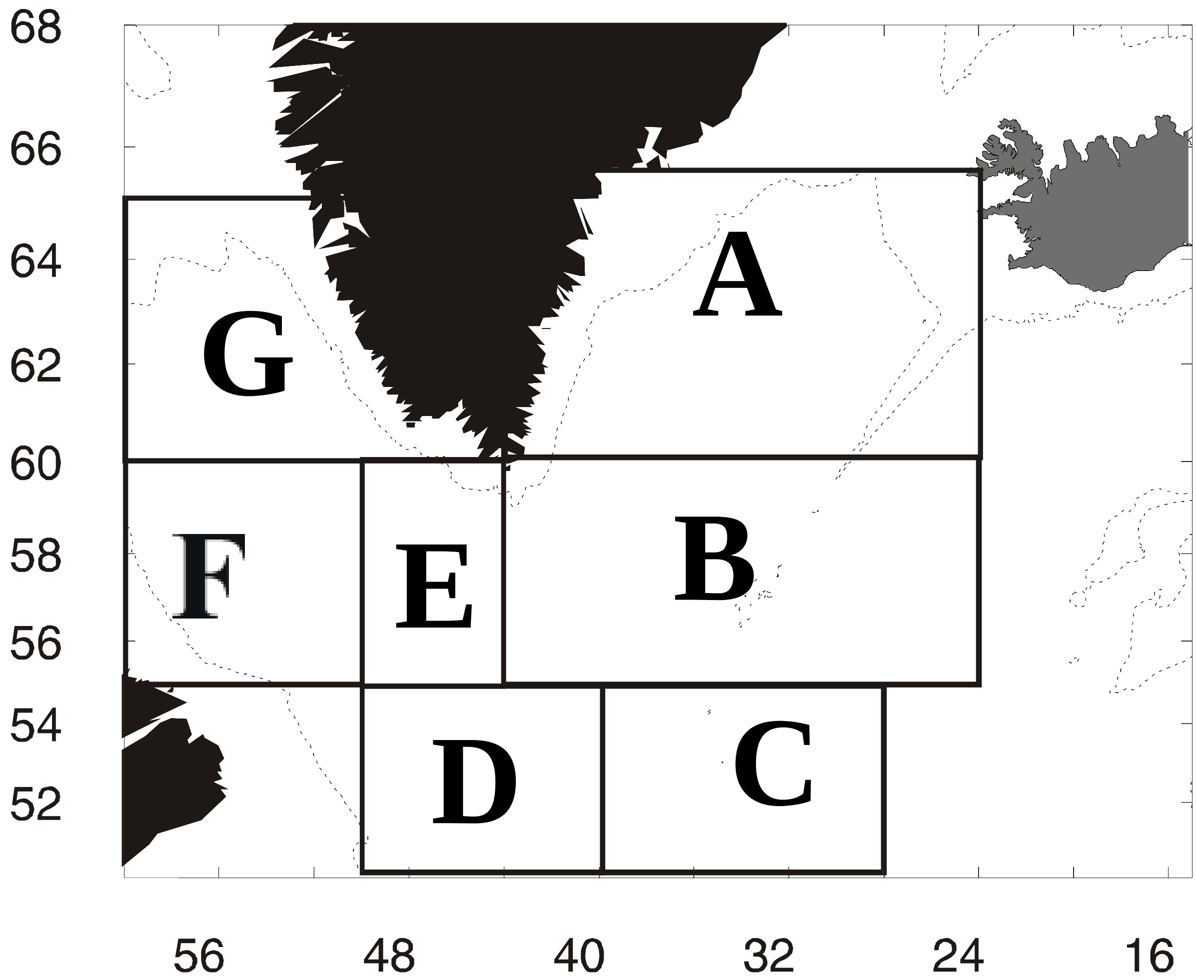

Figure 4. Sub-areas used on international surveys for redfish in the Irminger Sea and ajacent waters.

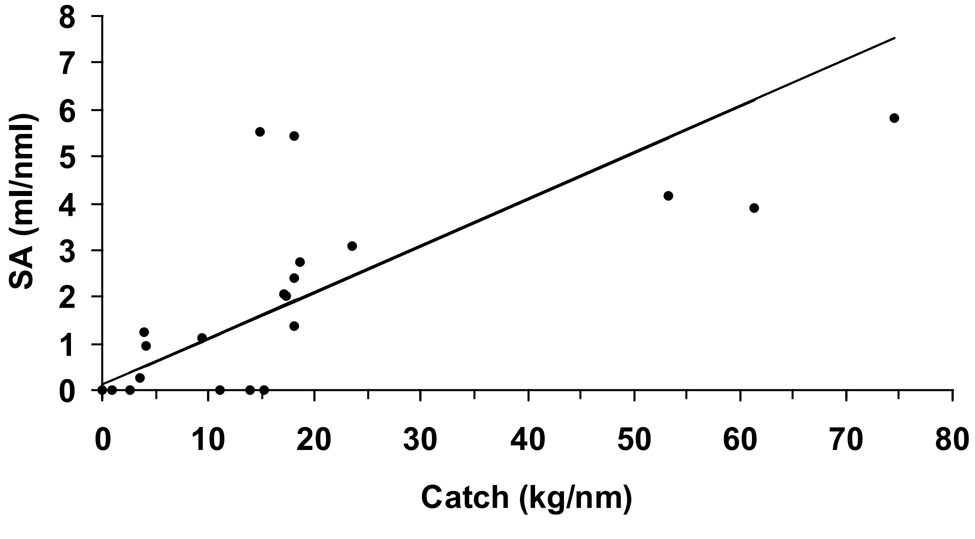

Figure 5 Linear regression (geometric mean) between catches and observed hydroacoustic values SA above 500 m depth (SA=0.11+0.0993*Catch, r^2=0.49).

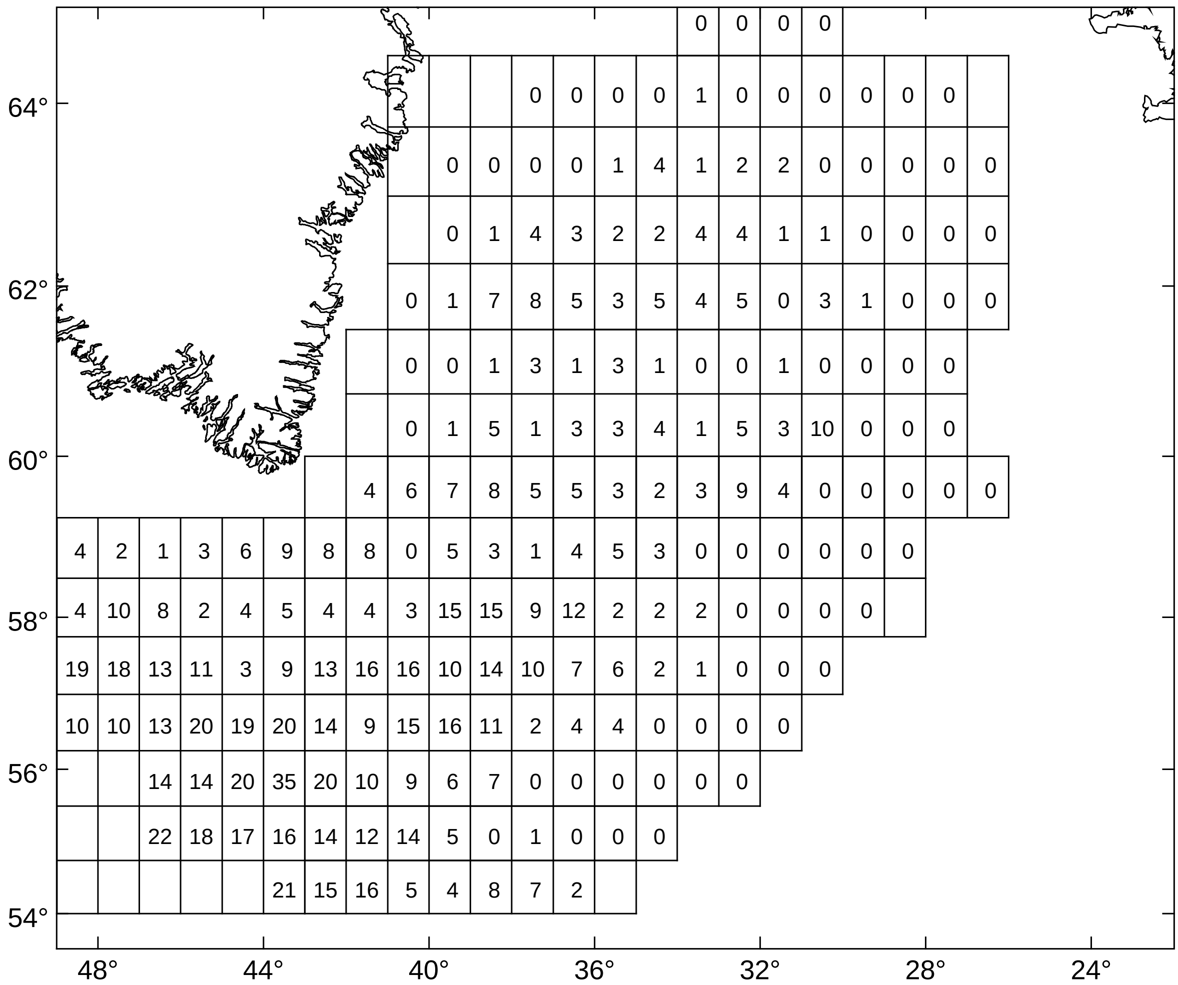

Figure 6. Mean values of area back scattering strength (m^2/nm^2) in June/July 1999 at depths between 0-500 m within statistical rectangles.

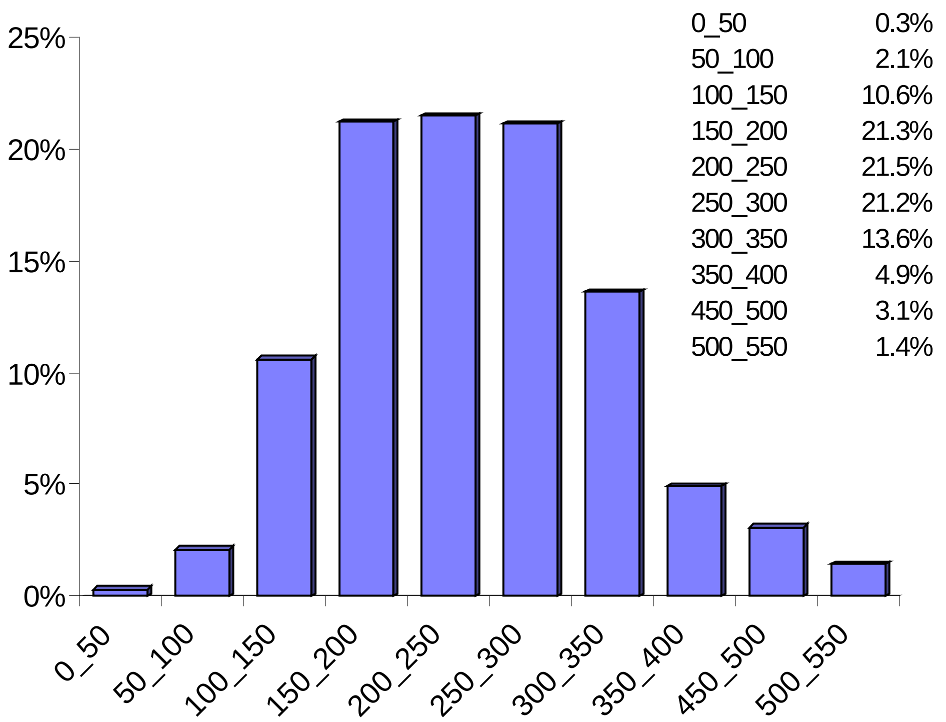

Figure 7. Depth distribution of redfish measured above 500 m depth in the Irminger Sea in June/July 1999.

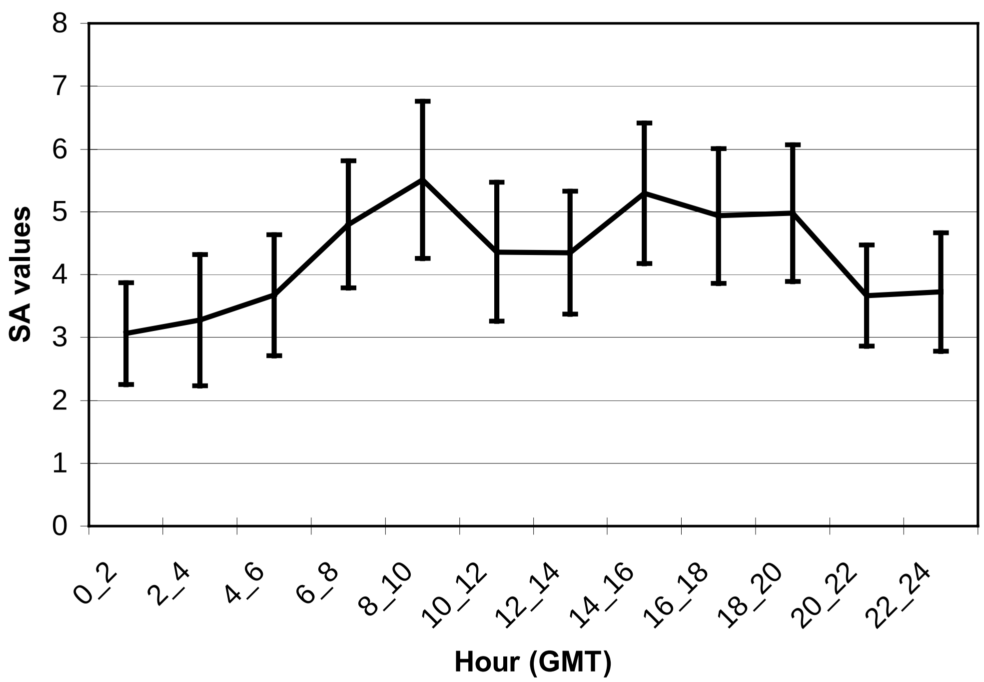

Figure 8. Diurnal variations of intergrator values of redfish in June/July 1999, along with a 95% confidence limits. Data combined for all vessels.

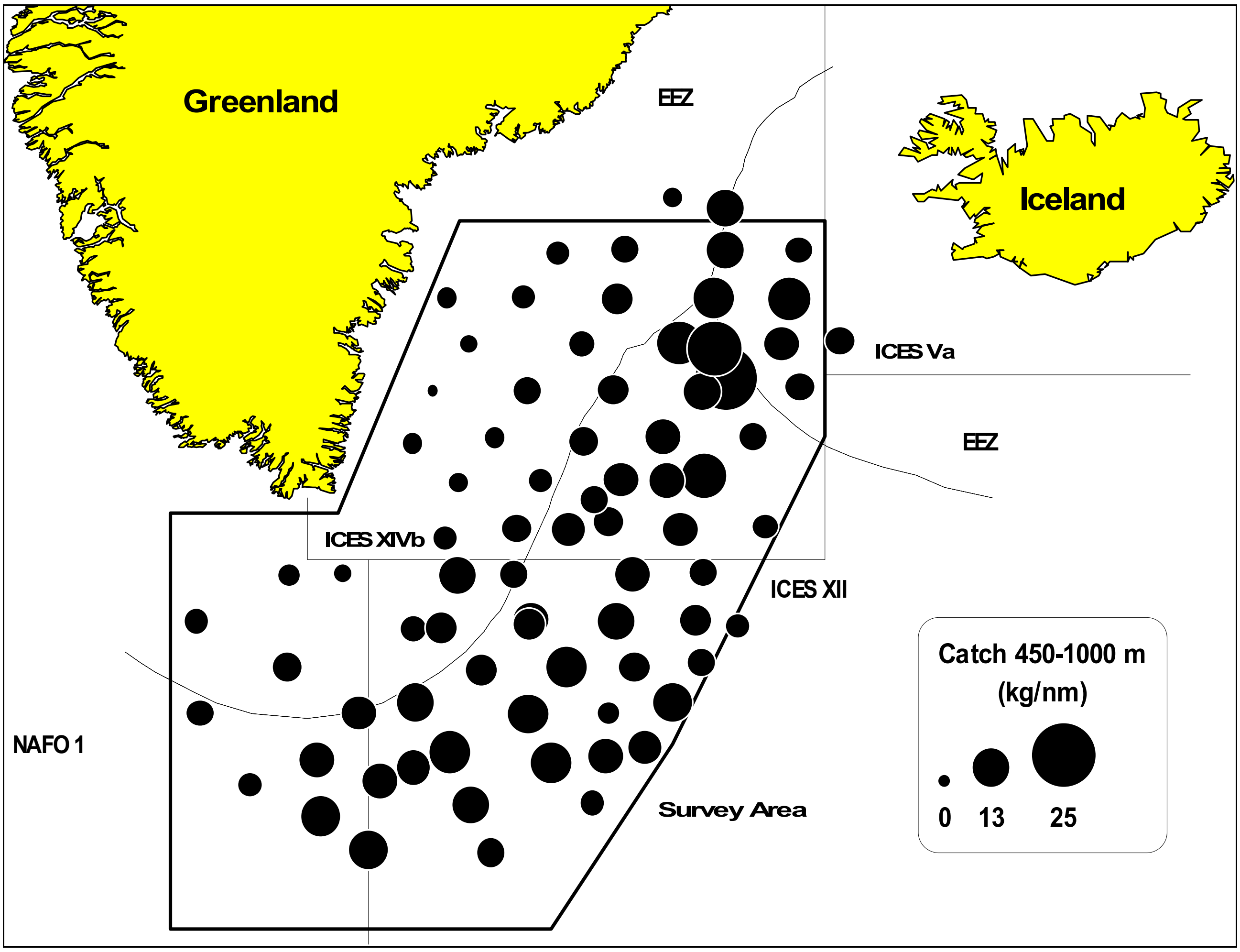

Figure 9. Geographical distribution patterns of standardised redfish catches below 500m depth.

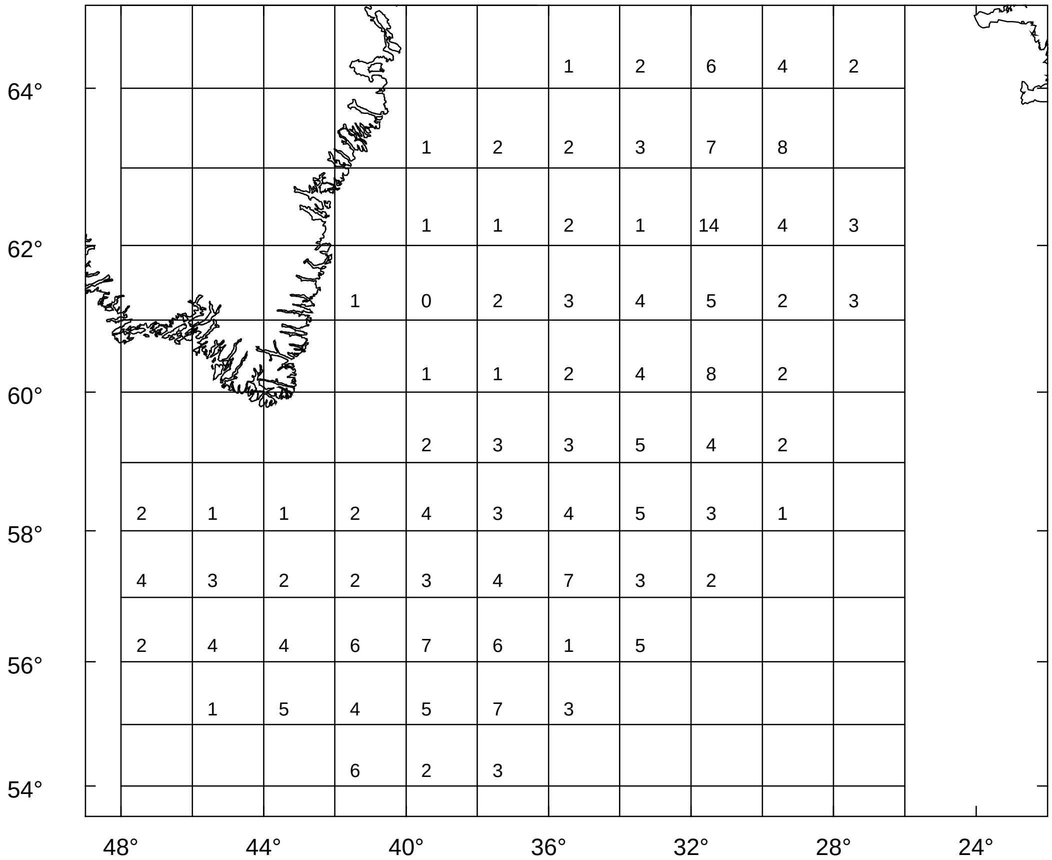

Figure 10. Calculated SA values below 500 m, obtained from correlation between catch and SA values above 500 m. See text for further explanation.

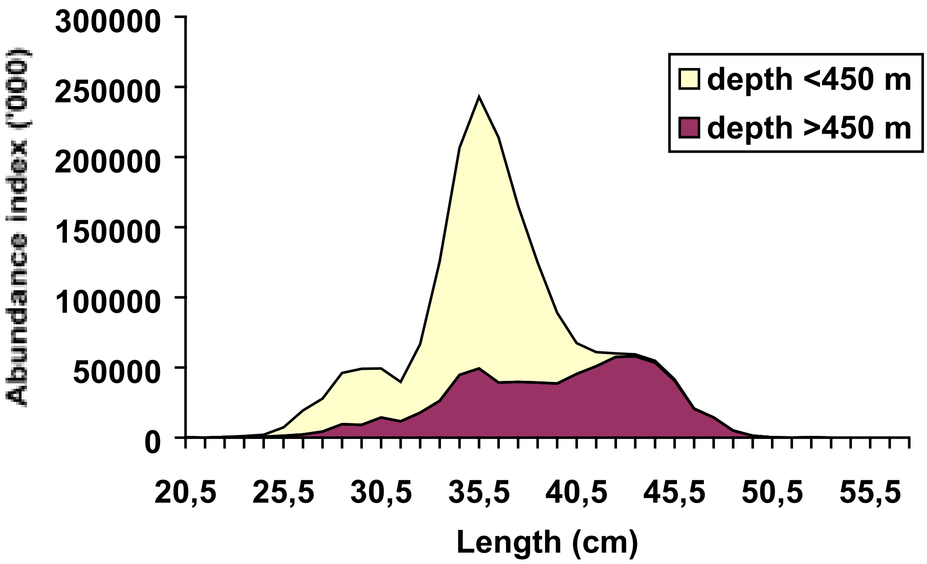

Figure 11. Length distribution of the redfish stock above and below 500 m depth. The values above 500 m are derived from the acoustic abundance estimation while the values below 500 m are based on the described experimental trawl-acoustic method.

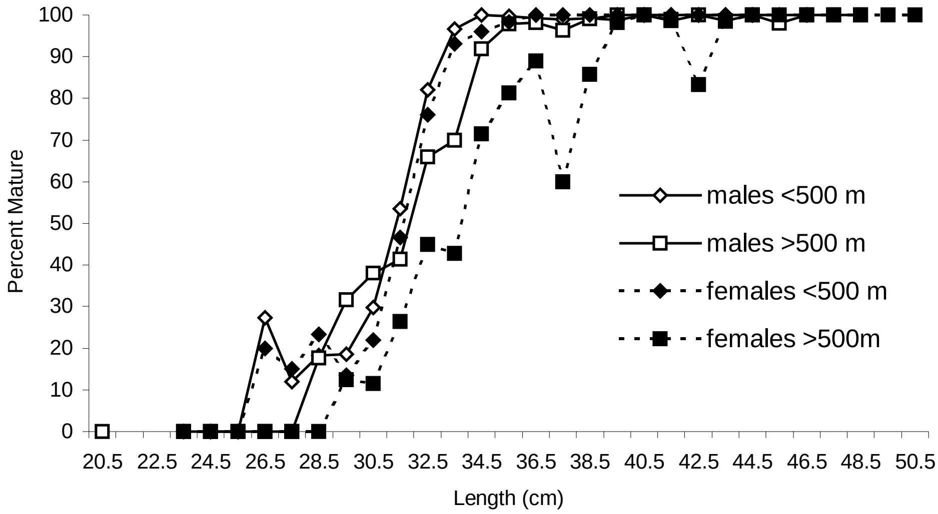

Figure 12. Redfish. Maturity ogives by sex above and below 500 m depth.

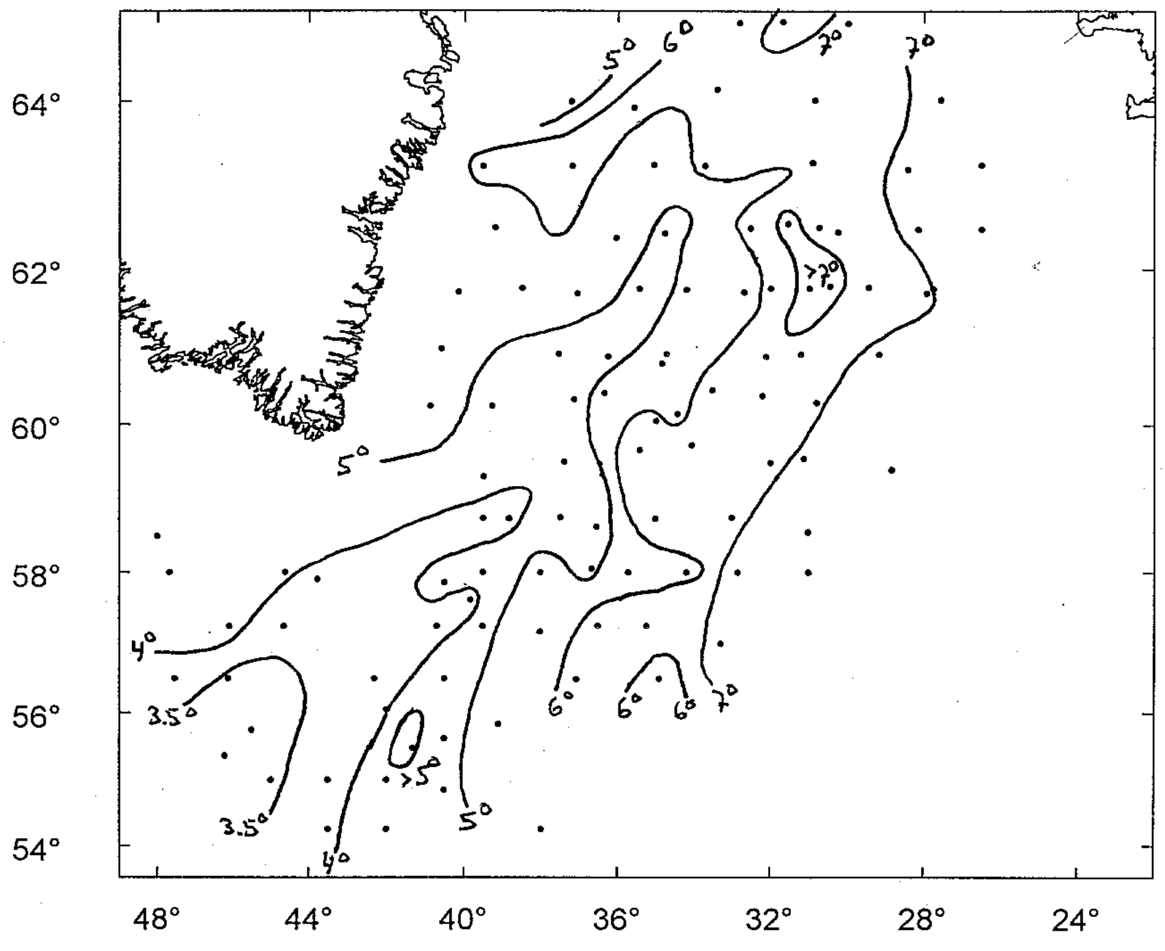

Figure 13. Horizontal temperature (t°C) distribution at 200 m depth in June/July 1999.

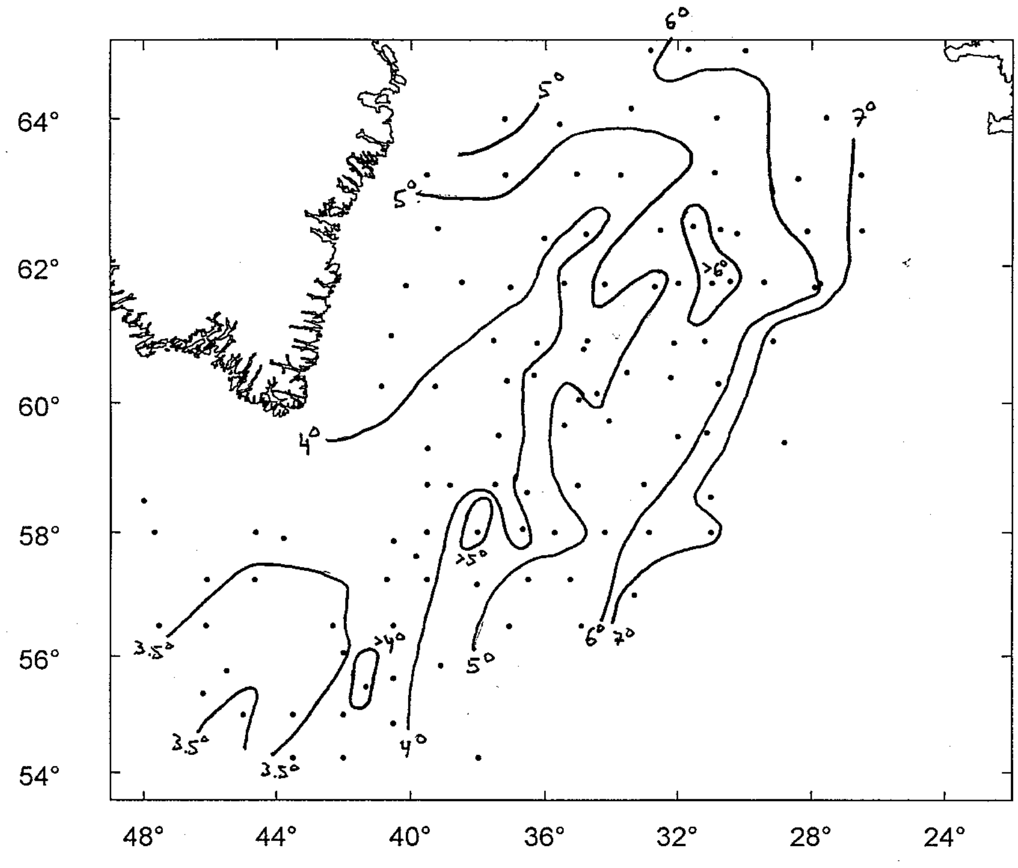

Figure 14. Horizontal temperature (t°C) distribution at 400 m depth in June/July 1999.

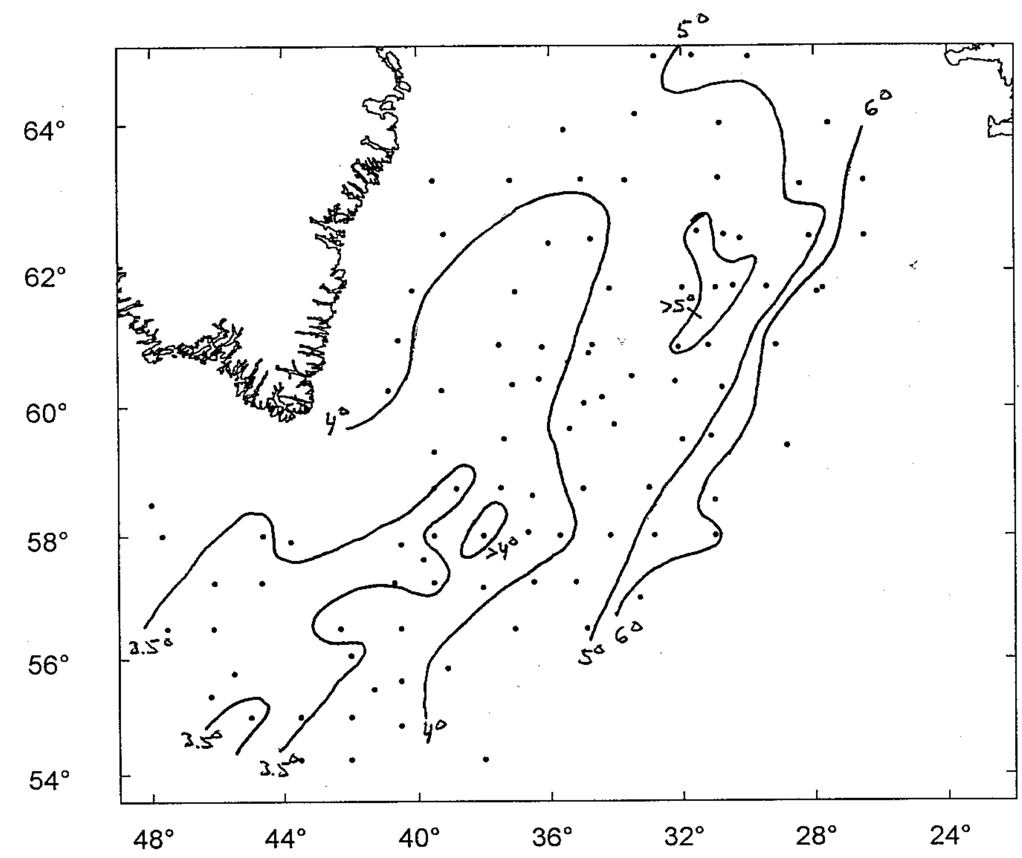

Figure 15. Horizontal temperature (t°C) distribution at 600 m depth in June/July 1999.

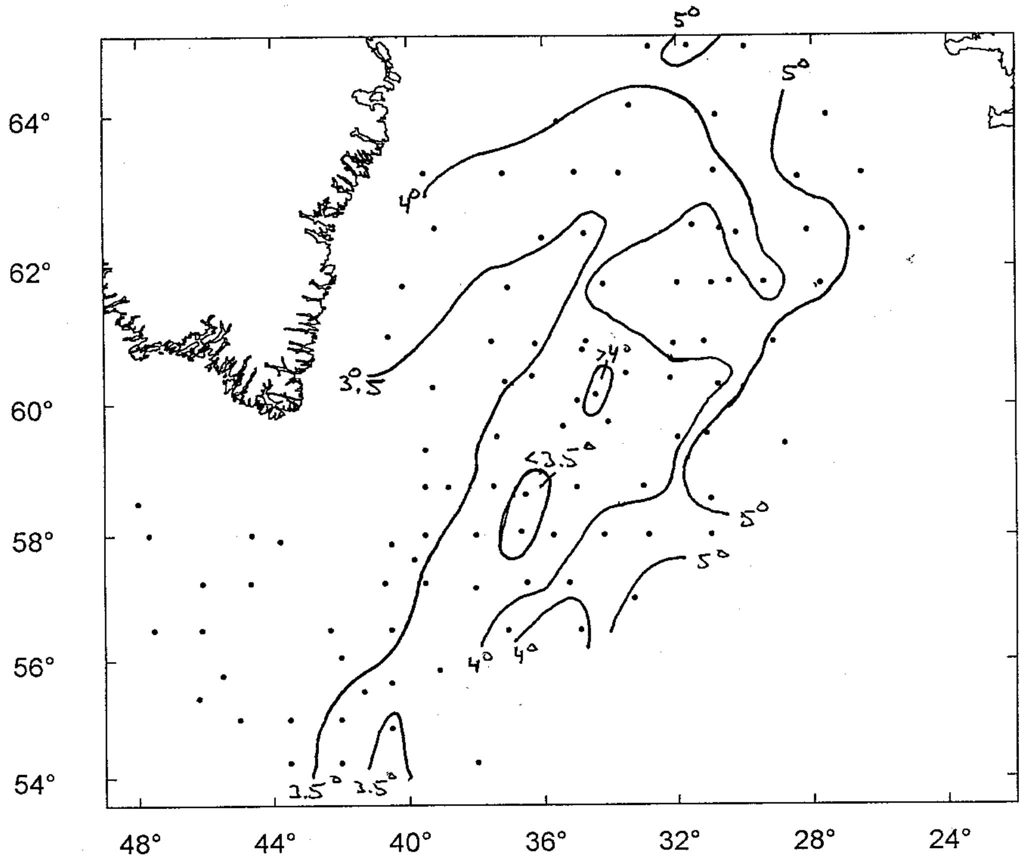

Figure 16. Horizontal temperature (t°C) distribution at 800 m depth in June/July 1999.

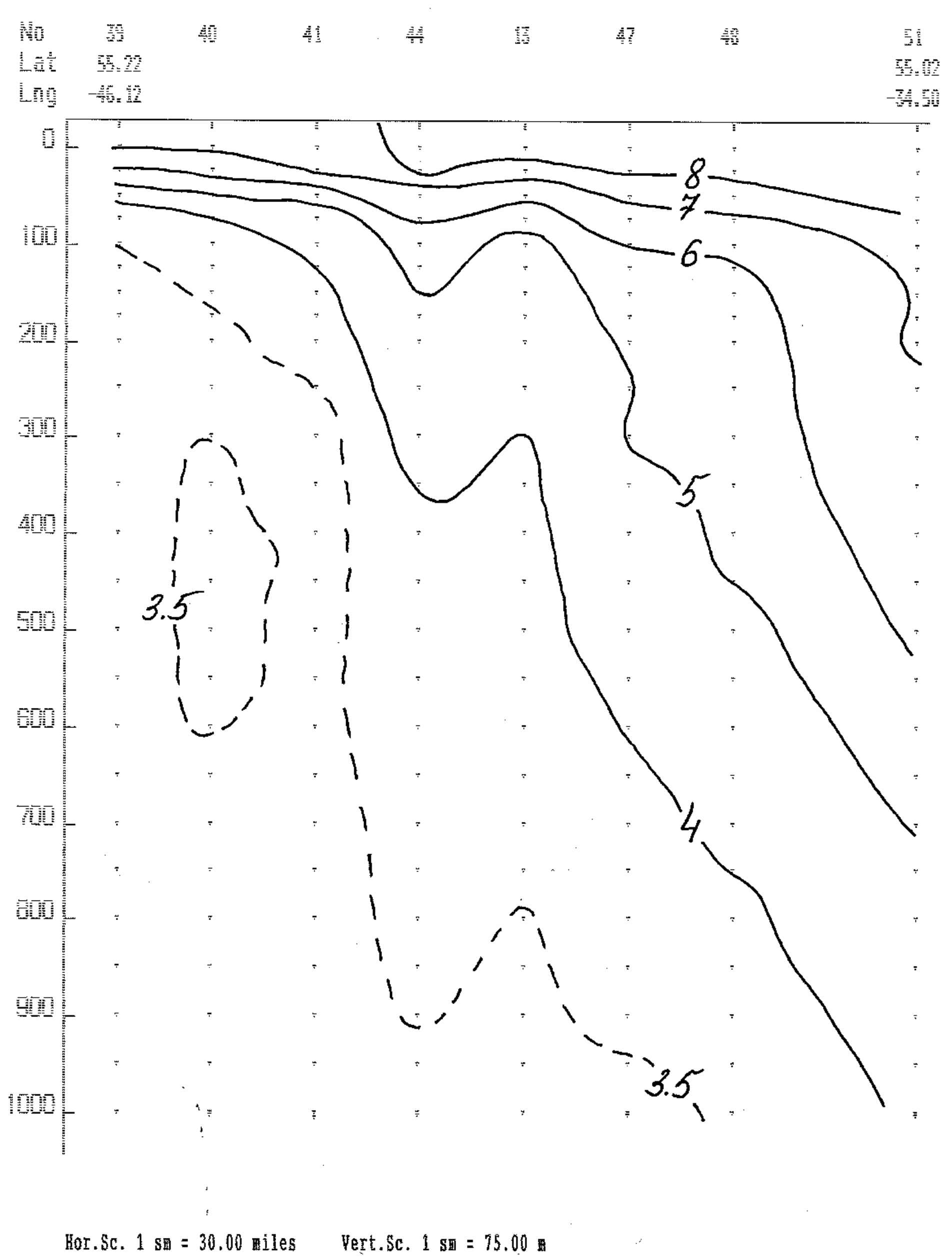

Figure 17. Vertical temperature distribution (tºC) on a section along the 55ºN latitude between 46ºV and 35ºV.

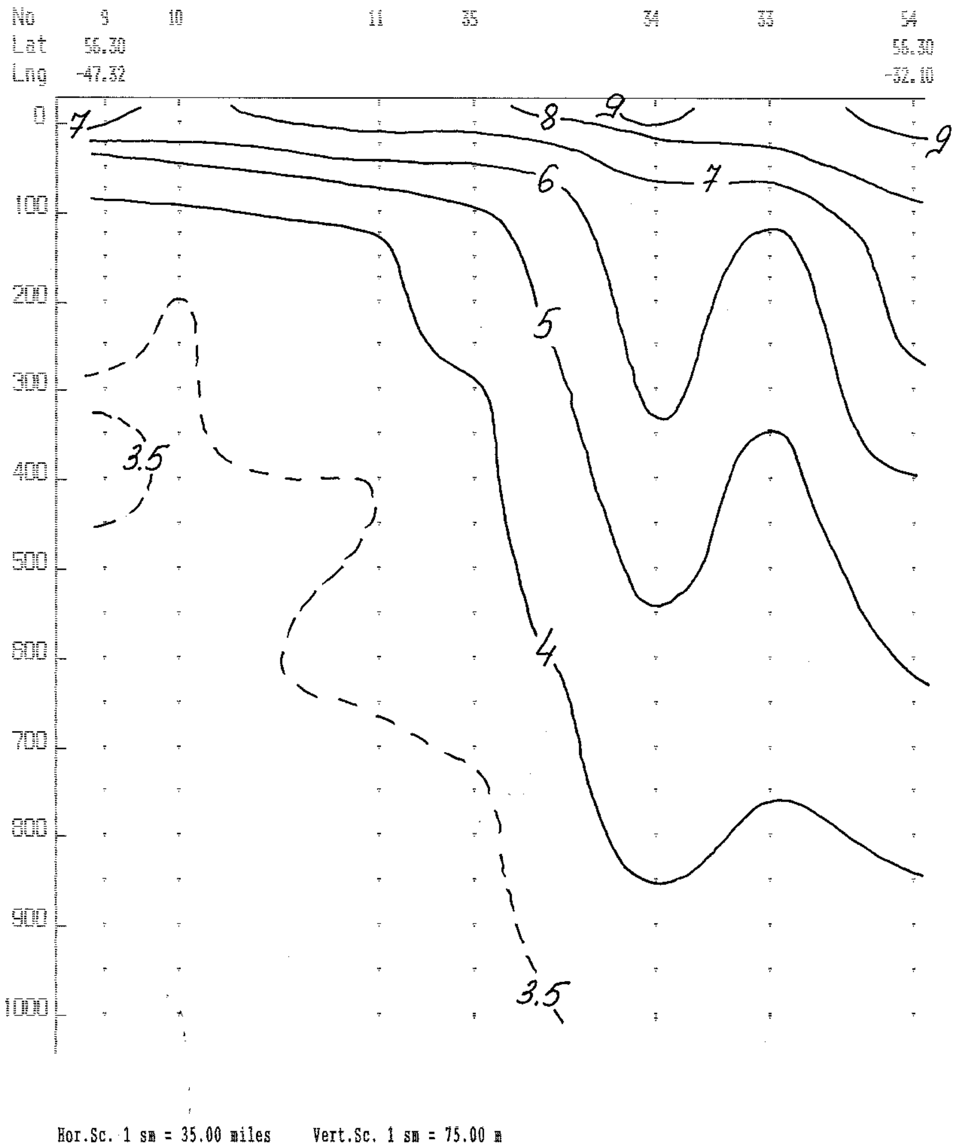

Figure 18 Vertical temperature distribution (tºC) on a section along the 56º30ºN latitude between 47º30V and 32º10V.

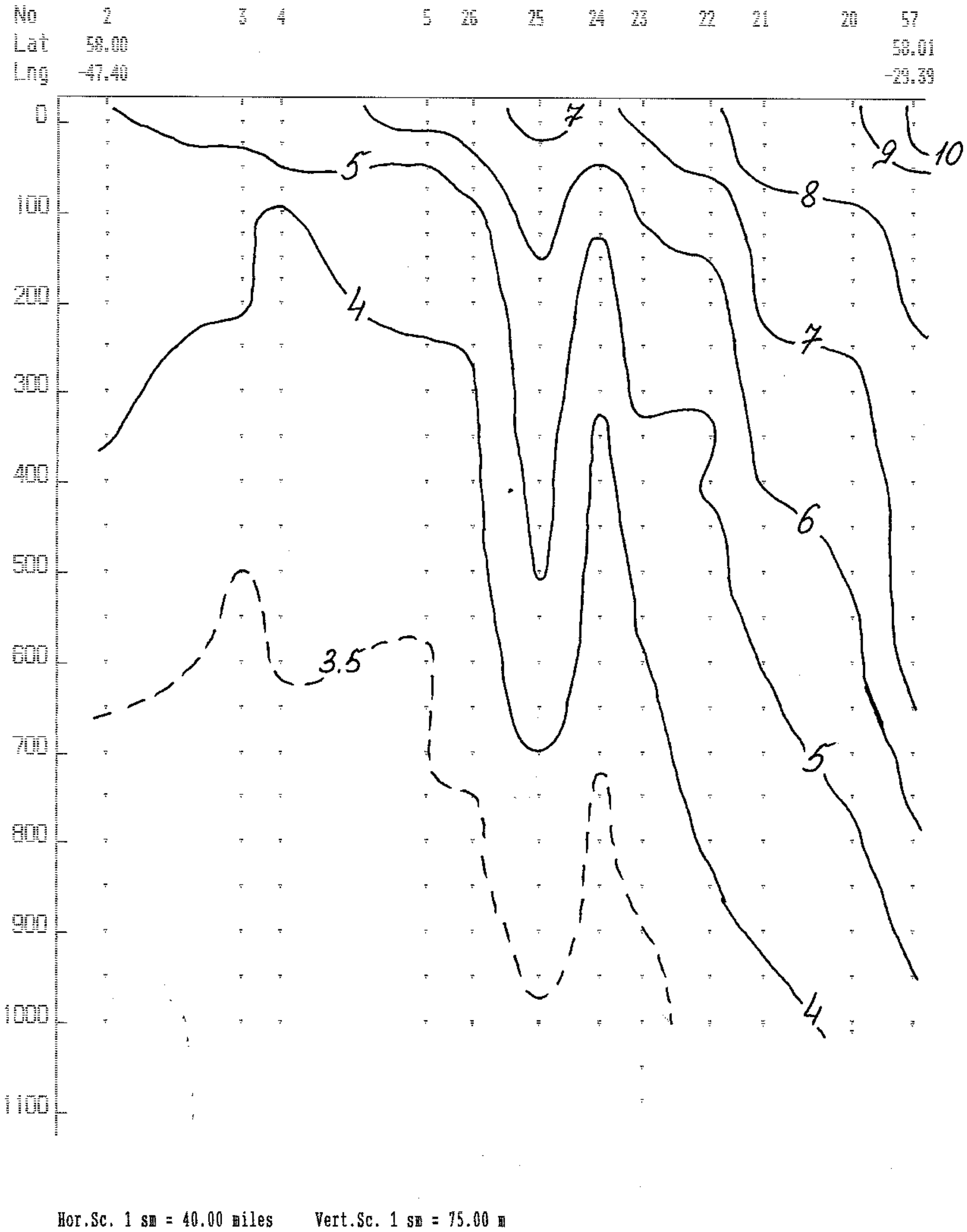

Figure 19. Vertical temperature distribution (t°C) on a section along the 58°N latitude between 47°40V and 29°40V.

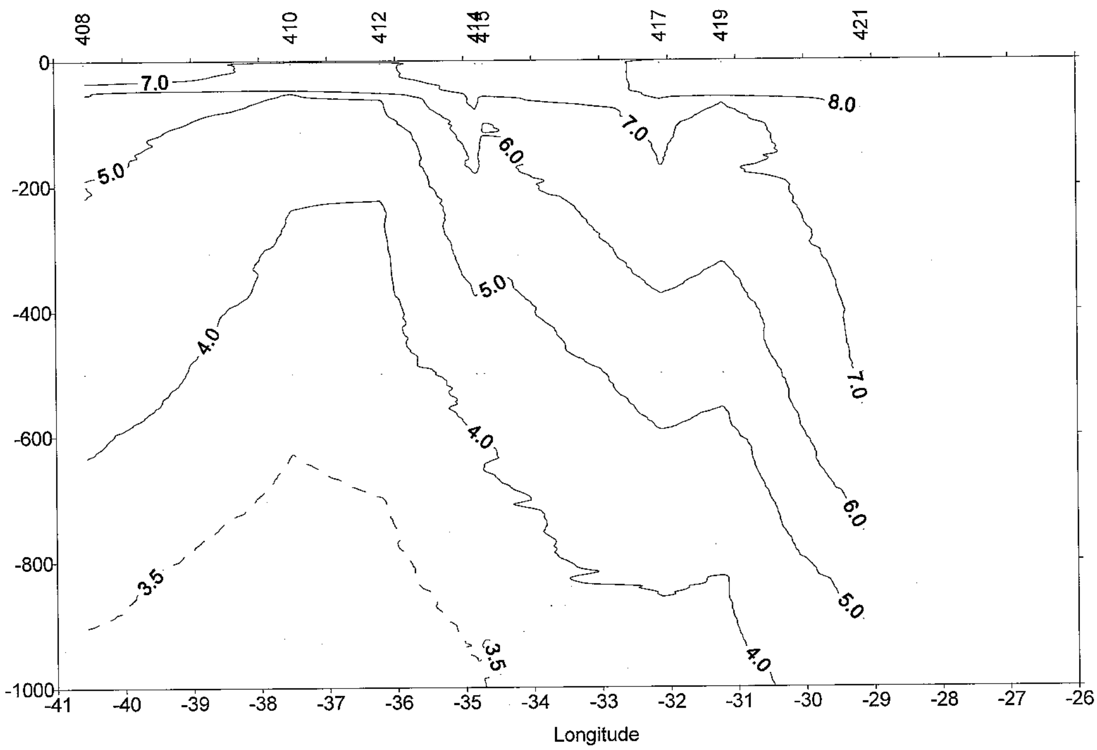

Figure 20. Vertical temperature distribution (tºC) on a section along the 60ºN latitude between 41ºV and 29ºV.

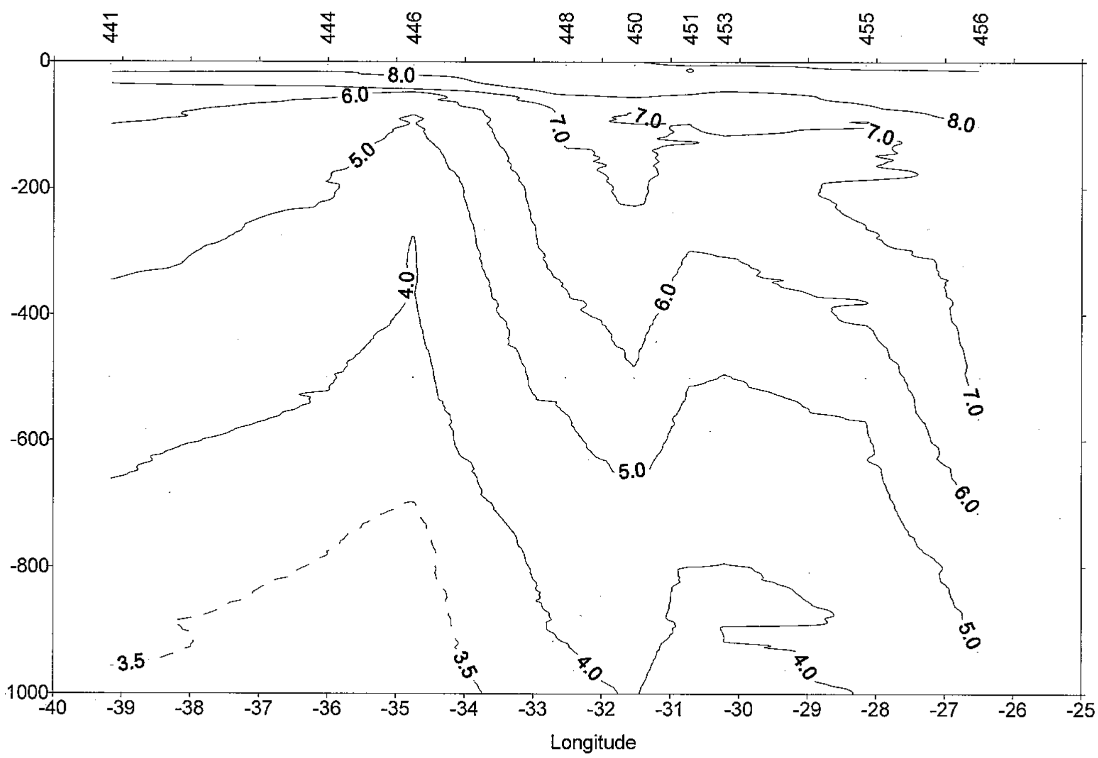

Figure 21. Vertical temperature distribution (tºC) on a section along the 62º30N latitude between 40ºV and 26ºV.

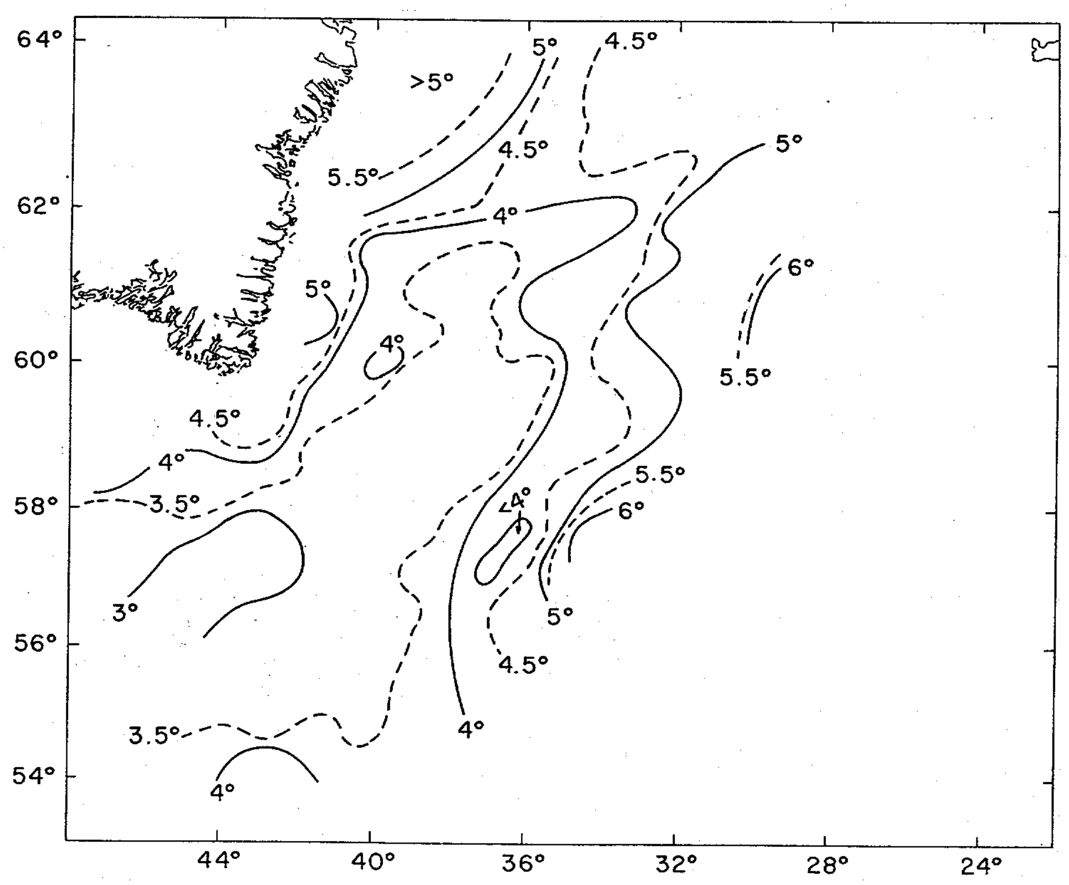

Figure 22. Temperature at 200 m depth in June/July 1994 (ICES C.M 1994/G:44).

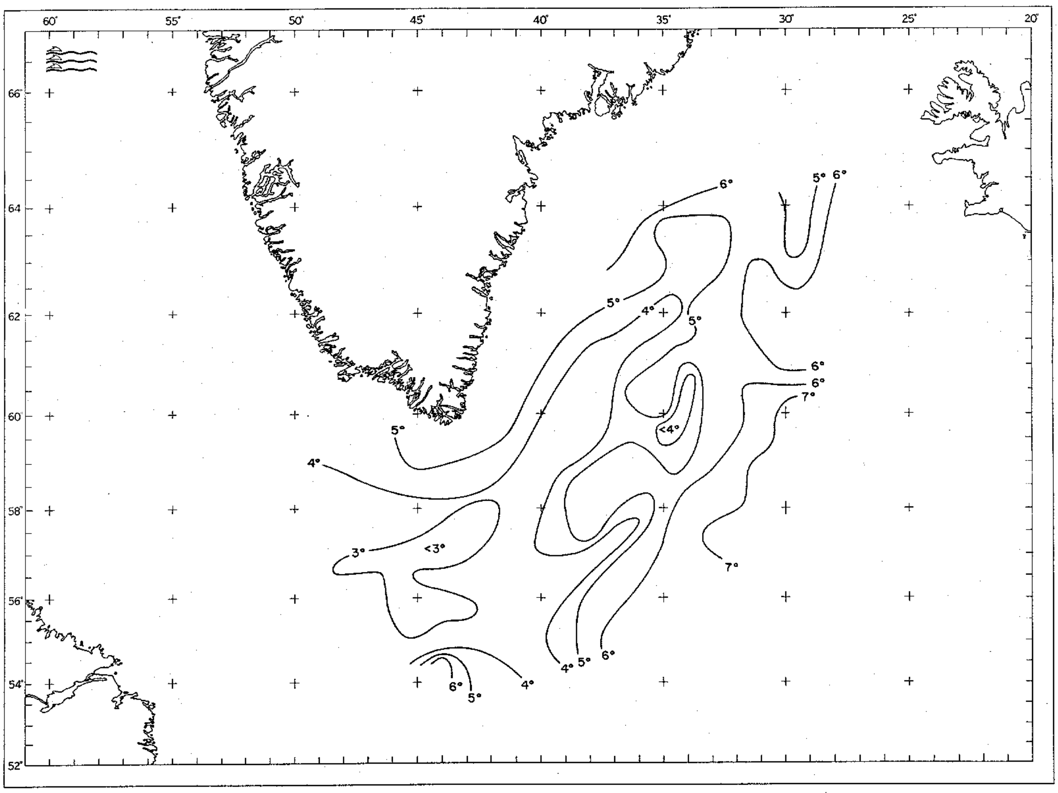

Figure 23. Temperature at 200 m depth in June/July 1996 (ICES C.M 1996/G:8).