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Report of the Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys (PGNAPES)

18–21 August 2009

Tórshavn, Faroe Islands

ICES

International Council for the Exploration of the Sea

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Contents

Executive Summary

This present report was prepared by the Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys (PGNAPES) which met in Tórshavn, Faroe Islands from 18–21 August 2009. 14 persons from six nations participated in the meeting chaired by Alexander Krysov (Russian Federation). The participants of the group analysed and discussed the results of the acoustic, hydrographic, plankton and fish sampling from two international ICES coordinated survey in 2008:

International Blue whiting spawning stock survey. Five vessels participated, the Dutch RV "Tridens", the Irish RV "Celtic Explorer", the Russian RV "Fridtjof Nansen", the Faroese RV "Magnus Heinason" and the Norwegian F/V "Brennholm".

International ecosystem survey in the Nordic Seas with main focus on Norwegian spring-spawning herring and blue whiting in the Norwegian Sea and Barents Sea in May-June 2009 with the participation of the Danish RV "Dana", the Norwegian RV "Johan Hjort", the Icelandic RV "Árni Fridriksson", the Faroese RV "Magnus Heinason" and the Russian RV "Fridtjof Nansen".

In addition to the surveys that are being dealt with by PGNAPES, information from ecosystem survey in the Norwegian Sea in July-August 2009 on F/V "Libas" and F/V "Eros" are also used here .

The report includes survey results about the distribution and the biomass estimate of spawning blue whiting in March-April west of the British Isles, and the distribution, migration and stock estimates of Norwegian spring-spawning herring and blue whiting, and the environment (oceanographic conditions and biomass of zooplankton) of the Norwegian Sea, Barents Sea and adjacent waters in spring and summer of 2009. The abundance estimates are used in the fish stock assessments of Norwegian spring-spawning herring and blue whiting in ICES Working Group on Widely distributed Stocks (WGWIDE). The collection of environmental data further improves the basis for ecosystem modelling of the Northeast Atlantic. Broad plans for the ICES coordinated surveys for 2010 are also outlined with descriptions of the relevant protocols, preliminary participants and suggested survey designs.

Results of the scrutiny of echogram workshop (WKECHOSCRU, 17–19 February, Bergen, Norway) were assessed.

1 Introduction

1.1 Terms of Reference 2009

The **Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys** [PGNAPES] (Chair: Alexander Krysov, Russian Federation) will meet in Torshavn, Faroe Islands, from 18–21 August 2009 to:

a) critically evaluate the surveys carried out in 2009 in respect of their utility as indicators of trends in the stocks, both in terms of stock migrations and accuracy of stock estimates in relation to the stock – environment interactions;

b) review the 2009 survey data and provide the following data for the Northern Pelagic and Blue Whiting Working Group:

   i. stock indices of blue whiting and Norwegian spring-spawning herring.

   ii. zooplankton biomass for making short-term projection of herring growth.

   iii. hydrographic and zooplankton conditions for ecological considerations.

   iv. aerial distribution of such pelagic species as mackerel.

c) describe the migration pattern of the Norwegian spring-spawning herring and blue whiting stocks in 2009 on the basis of biological and environmental data;

d) plan and coordinate the surveys on the pelagic resources and the environment in the North-East Atlantic in 2010 including the following:

   v. the international acoustic survey covering the main spawning grounds of blue whiting in March-April 2010.

   vi. the international coordinated survey on Norwegian spring-spawning herring, blue whiting and environmental data in May-June 2010.

   vii. national investigations on pelagic fish and the environment in June-August 2010.

e) Asses the results of the scrutiny of echogram workshop [WKECHOSCRU].

f) respond to the findings of the Planning Group on Redfish Surveys;

g) Provide time-series of the abundance-at-age, of North Sea herring in the Norwegian Ecosystem survey (with variance), also with the associated target strengths used to determine those estimates of abundance.

PGNAPES will report by 1 September 2009 for the attention of SCICOM and ACOM.

1.2 List of participants

Alexander Krysov (Chair),	Russia
Karl-Johan Staehr	Denmark
Jan Arge Jacobsen,	Faroe Islands
Leon Smith,	Faroe Islands
Høgni Debes	Faroe Islands
Guðmundur Oskarsson	Iceland
Ciaran O'Donnell,	Ireland

Bram Couperus	Netherlands
Matthias Kloppmann	Germany
Are Salthaug,	Norway
Erling Stenevik	Norway
Øyvind Tangen,	Norway
Webjørn Melle	Norway
Valantine Anthonypillai	Norway

A full address list for the participants is provided in Annex 1.

1.3 Background and general introduction

1.3.1 History of the expert group

Based on an ICES recommendation in 1948, pelagic surveys on herring and blue whiting in the Norwegian Sea were conducted under the flag of ICES from 1950 to the late 1970s. National surveys were continued after this time. After the recovery of Atlanto Scandic Herring stock in the early nineties, fishery was opened again in 1994. It was agreed amongst the Norwegian Sea countries that the stock should be surveyed under the flag of ICES and that all countries that fished the stock should take part. In 1995 the Planning Group on Surveys on Pelagic Fish (PGSPFN) in the Norwegian Sea saw the light. The first meeting was attended by Norway, Faroes, Iceland and Russia joined from 1997 onwards by representatives from the EU countries (but not in 2002 and 2003). In 2004 the group was renamed to PGNAPES (Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys). Because of the similarity in methods and the fact that Blue whiting was also covered in the Norwegian Sea the coordination of that survey was brought under PGNAPES, consisting of the same parties as its predecessor PGSPFN.

1.3.2 Surveys

Since 1995, the Faroes, Iceland, Norway, and Russia, and since 1997 also the EU, jointly coordinate hydro acoustic survey for spring-spawning herring in the Norwegian Sea (Norwegian spring spawners or Atlanto Scandian Herring).

In 2005 the joint survey on blue whiting in the spawning grounds west of the British Isles was included in the total survey effort in the Northeast Atlantic. Before 2005 the spawning areas of blue whiting west of the British Isles have most actively been surveyed by Norway and Russia. Some coordination of these survey activities took place over a number of years, until the Russian spawning stock survey was discontinued in 1996. Russia resumed the blue whiting spawning stock survey in 2001. In 2003 ACFM recommended the following: "Several surveys on blue whiting are currently going on. ICES recommends that a coordinated survey be organized covering the main spawning grounds of blue whiting"

In addition to the coordination of the two international surveys, the data provided by National surveys are taken into account and results are normally briefly presented. This has enhanced the possibility to assess abundance and describe the distribution of the pelagic resources, and their general biology and behaviour in relation to the physical and biological environment.

The International Blue whiting Spawning stock Survey (IBSS, Section 3.1) is aimed at assessing the spawning-stock biomass of blue whiting during the spawning season in March-April. The International Ecosystem Survey in the Nordic Seas (IESNS, Section 3.2) covers the Norwegian Sea and Barents Sea in late spring (late April-early June) aims at the observation of the pelagic ecosystem in the area, with particular focus on Norwegian Spring-spawning herring, blue whiting, zooplankton and hydrography.

The objectives of these surveys are to map the distribution and migrations of blue whiting and herring and other pelagic fish and to assess their biomass. In addition zooplankton biomass and distribution and hydrography are monitored.

The biomass estimates of herring and blue whiting are important indices for the assessments of the species by the Northern Pelagic and Blue Whiting Fisheries Working Group (WGNPBW)

1.3.3 Main fish species

Norwegian spring-spawning herring are a highly migratory and straddling stock carrying out extensive migrations in the NE Atlantic. After a major stock collapse in the late 1960s the stock has been rebuilt and varied from approximately 5 to 10 million tonnes of biomass during the 1990s. During this period the main spawning areas have been situated along the Norwegian coast from approximately 58–69°N, with the main spawning occurring off the Møre coast from approximately 62–64°N. After spawning in February – March the herring have migrated NWwards towards the Norwegian Sea feeding grounds. In general, the main feeding has taken place along the polar front from the island of Jan Mayen and NEwards towards Bear Island. During the latter half of the 1990s there has been a gradual shift of migration pattern with the herring migrations shifting north and eastwards. In 2002 and 2003 this development seems to have stopped and the herring had at more southerly distribution at the end of the feeding season than in 2001. This south-westward shift continued in 2004 through 2006, and especially in 2007 the fishery has continued in the southwestern areas throughout summer, leading to some speculations of a change in their late autumn migrations of parts of the adult stock. After feeding, the herring have concentrated in August in the northern parts of the Norwegian Sea prior to the southern migration towards the Vestfjord wintering area (68°N, 15°E). However, during the last four winter periods an increasing fraction of the stock has wintered in the Norwegian Sea off Lofoten. In January the herring start their southerly spawning migrations.

Two other large stocks in the Northeast Atlantic are blue whiting and mackerel which are using the Norwegian Sea during their feeding migration during summer.

The main spawning areas of the blue whiting are located along the shelf edge and banks west of the British Isles. The eggs and larvae can drift both towards the south and towards the north, depending on the spawning location and oceanographic conditions. The northward drift spreads the major part of the juvenile blue whiting to all warmer parts of the Norwegian Sea and adjacent areas from Iceland to the Barents Sea. Adult blue whiting carry out active feeding and spawning migrations in the same area as herring. Blue whiting has consequently an important role in the pelagic ecosystems of the area, both by consuming zooplankton and small fish, and by providing a food resource for larger fish and marine mammals. Mackerel are usually found in warmer waters and with a shorter northward migration during summer; they also feed on plankton in the southern and central Norwegian Sea.

2 Material and methods

The PGNAPES report is mainly based on results from the two international surveys listed below but results from relevant national surveys in the area are also reported.

Technical details of all participating vessels are given in the survey report as annexes to this report.

International Blue whiting spawning stock survey. Five vessels participated, the Dutch RV "Tridens", the Irish RV "Celtic Explorer", the Russian RV "Fridtjof Nansen", the Faroese RV "Magnus Heinason" and the Norwegian F/V "Brennholm" (Table 1 in Annex 2). The surveyed area (cruise tracks) in March-April 2008 is shown in Figure 1 in Annex 2. All details are given in the combined cruise report (Annex 2).

International ecosystem survey in the Nordic Seas. Five vessels participated, the Danish RV "Dana", the Norwegian RV "Johan Hjort", the Icelandic RV "Árni Fridriksson", the Faroese RV "Magnus Heinason" and the Russian RV "Fridtjof Nansen". The surveyed area (cruise tracks) in May-June 2009 is shown in Figures 1 and 2. Map showing area I to III used in the acoustic estimate of herring and blue whiting is shown in Figure 3. All further details are provided in the combined cruise report (Annex 3).

Other relevant surveys. In addition to the survey that are dealt with by PGNAPES, information from ecosystem survey in the Norwegian Sea in July-August 2009 on F/V "Libas" and F/V "Eros" are also used here. All details are provided in the cruise report (Annex 4).

2.1 Hydrography

The hydrographic observations were made using CTD-Probes. Details of the hydrographic sampling intensity during the *International ecosystem survey in the Nordic Seas* are given in Annex 3, Table 1, and during the *International Blue whiting spawning stock survey* are given in Annex 2, S2.

2.2 Plankton

Sampling intensity of plankton and spatial coverage made by the participating vessels are shown in Annex 3, Figure 10. During the International ecosystem survey in the North East Atlantic in 2009 in all 270 plankton stations were conducted. All vessels used WP2 nets (180 or 200 μm) to sample plankton according to the standard procedure for the surveys, except the Russian vessel that used Djedy net (74 stations). The net was hauled vertically from 200 m or the bottom to the surface and all data obtained are presented as g dry weight m^{-2}. Further details about the sampling procedure are given in Annex 3, S3.

2.3 Fish sampling

During the surveys trawling was carried out opportunistically for identification of the acoustic recordings and for representative biological sampling of the populations. In most cases fishing was carried out on fish traces identified on the echosounders. All vessels used a large or medium-sized pelagic trawl for biological sampling as detailed in Annex 3 (S2) and Annex 2 (Table 5).

With ordinary rigging, the trawls could be used to catch deep fish schools, in some cases down to depth of 500 meters or more but small trawls such as used onboard DANA in previous years prove to have a much lower catch efficiency at depth. The trawls could also be rigged to catch fish near or in the surface layer by removing the weights, extending the upper bridles and/or attaching buoys to each upper wing. The codends used varied amongst vessels, which may be of influence when collecting herring scales or when possibly analysing distribution of deep-sea species in future with the data.

Each trawl catch was sorted and weighed for species composition. Further details about the procedure and intensity regarding the samples are given in Annex 3 (S2).

2.4 Acoustics and biomass estimation

During the surveys, continuous acoustic recordings of fish and plankton were collected using calibrated echo integration systems using 38 kHz as the primary frequency.

The recordings of area backscattering 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.

The equipment of the research vessels was calibrated immediately prior or during the surveys against standard calibration spheres. A vessel intercalibration was performed during March-April blue whiting survey (Annex 2, S3).

Acoustic estimates of herring and blue whiting abundance were obtained during the surveys. This was done by visual scrutiny of the echo recordings using different post-processing systems (Annex 3, S2). The allocation of s_A-values to herring, blue whiting and other acoustic targets was based on the composition of the trawl catches and the appearance of the echo recordings. To estimate the abundance, the allocated s_A-values were averaged for ICES-rectangles (0.5° latitude by 1° longitude for the May survey and by 1° latitude by 2° longitude for the March/April survey), as detailed further in Annex 3 (S2) and Annex 2 (S2).

To estimate the total abundance of fish, the unit area abundance for each statistical square was multiplied by the number of square nautical miles in each statistical rectangle then summed for all the statistical rectangles within defined subareas and for the total area. Biomass estimation was calculated by multiplying abundance in numbers by the average weight of the fish in each statistical square then summing all squares within defined subareas and the total area. The Norwegian BEAM software (Totland and Godø 2001) was used to make estimates of total biomass and numbers of individuals by age and length in the whole survey area and within different subareas.

3 Survey results

3.1 Hydrography

The 2009 winter NAO index was slightly negative and lower than the long-term average (1950–2009; and see Figure 3.1.1). Hence, favorable winds supporting a strong Atlantic influence in the waters west of the British Isles were lower than during high NAO years.

Temperatures during the blue whiting spawning stock survey were relatively warm reaching values between < 9°C in the North and > 11°C in the southern part of the survey area. Due to the early season and to the deep convection occurring in the deeper parts of the area, there was not much stratification in the water column rather than a relatively uniform distribution of temperatures down the water column. A transect across Porcupine Bank also showed the typical doming of isothermals indicating at upwelling of deeper waters along its margins and a recirculation cell above the bank. A comparison with data collected during a cruise in 1994 at the same location and at almost the same time of the year revealed that apart from the similarity in the hydrographical structures above the bank, temperatures in 2009 were a full 1°C higher throughout the examined depths than in 1994.

In May, during the Acoustic Survey in the Nordic Seas, temperatures in the surface ranged between < 2°C northeast of Iceland and > 8°C in the southern part of the survey area. The polar front was encountered slightly below 65°N east of Iceland extending eastwards towards the 0° Meridian where it turned almost straight northwards up 70°N. North of 70°N was still apparent along the northwestern edge of the survey area.

Particularly north and west of the polar front temperatures decreased to values < 0°C while south and east of it the drop in temperature was not as pronounced. The warmer North Atlantic water formed a broad tongue that stretched far northwards along the Norwegian coast with temperatures > 7°C in the surface layers. With increasing depth this core of warm water became more confined to areas closer to the Norwegian coast in the South and forming only a narrowband of warmer water centred along the 15° meridian in the North. Relative to a 15 years long-term mean, from 1995 to 2009, temperatures in 2009 were warmer over most of the Norwegian Sea. Differences reached up to 1°C in some areas. In the western areas, however, a cooling is observed compared to the mean.

There were only weak indications of warmer North Atlantic water entering the Barents Sea while temperatures decreased gradually to values < 3°C eastwards, although temperatures were still higher than the long-term mean for the area.

Another striking feature encountered during the 2009 survey was the warming of the sea surface waters northwest of Iceland. Temperatures were up to 3°C warmer than normally.

Detailed information is given in the respective survey reports (Annexes 2, 3 and 4)

3.2 Plankton

In 2009 zooplankton biomass distribution showed a clear change compared to 2008 (Figure 3.2.1). Zooplankton biomass was lower in most areas and particularly so in the cold water of the East Icelandic current (Figure 3.2.1). The highest zooplankton biomasses were observed in the eastern and in the northern Norwegian Sea, while biomass was low especially in the southwestern and northeastern Norwegian Sea. High concentrations in the east were patchy. Biomass in the Barents Sea was low.

Total average biomass of zooplankton in May 2009 was lower than in 2008 and the lowest measured since 1997 (Table 3.2.1). This means that the trend of reduction in biomass that started in 2004 continued in 2009. Additionally, following the trend from the previous 5–6 years, the recorded zooplankton biomass in the two areas west and east of 2°W also continued to decrease. The decreasing trend was relatively stronger in the western area until this year when there was a further strong drop in zooplankton biomass in the east (see text table below showing average zooplankton biomass [g dry weight m^{-2}]).

3.3 Norwegian Spring-spawning herring

During the ecosystem survey in the Norwegian Sea and Barents Sea in May 2009, the coverage of Norwegian spring-spawning herring was considered adequate. Herring was recorded throughout the survey area with highest values observed in the central part of the Norwegian Sea at the edge of the cold waters of the East Iceland Current. The distribution was similar to what was observed in May 2008. This is reflected in the center of gravity of the distribution (Figure 3.3.1), which has been calculated since 1996. Since 2003 there has been a southwestward shift in the center of gravity of herring, but this did not continue in 2009 when a slight northeastward shift was observed. As in previous years, the smallest and youngest fish were found in the northeastern area and both size and age increased southwestward. The stock is now dominated by the 2002 and 2004 *year class*es while the 2003 *year class* also seems to be above average. No strong *year class*es were found in the Barents Sea, indicating weak recruitment since 2004. The time-series of abundance (both in numbers and biomass) of Norwegian spring-spawning herring in May is shown in Table 3.3.1. The total biomass of Norwegian spring-spawning herring was estimated to 10.7 million tons which is higher than the 2008 estimate of 10 million tons.

In July, the Norwegian spring-spawning herring had moved out of the central part of the Norwegian Sea and was observed feeding in a wide area around the fringes of the survey area. Highest values were found in the northern and western region, while there were very low concentrations in the central area. This is a typical distribution which has been observed this time of the year during the last few years. Similarly to May, the biggest and oldest fish were found in the southwestern part of the survey area.

3.4 Blue Whiting

International blue whiting spawning stock survey

Blue whiting were found distributed all areas covered during the spawning stock survey. Combined survey transects accounted for area coverage of 134 thousand square nautical miles (See Annex 2, Figures 4–6, Table 1). The highest concentrations of blue whiting were observed in the areas of the Hebrides, Rockall and Faroe Bank which is consistent with the results from previous surveys. However in 2009, the bulk of the stock was located further north around the Hebrides and Rosemary Banks and less on the slope areas around the northern Porcupine area. The large shift in distribution northwards can be accounted for by the earlier spawning of the stock in 2009. Southern core areas saw a reduction in biomass whereas northern areas were found to contain more biomass, relative to the size of the stock, as compared to 2008 (Table 3.4.1). Biomass in the peripheral southern Porcupine region remained unchanged from 2008.

In the western extremes, biomass within the Rockall subarea was significantly lower than observed in 2008 even with increased survey effort (area coverage was increased by 5% in the western periphery in 2009). Fishing effort within this subarea was higher than observed in previous years. Commercial vessels were observed tracking migrating schools from 20ºW north-eastwards along the western slopes of the Rockall Bank ahead of the survey vessels. The main body of blue whiting had already migrated out of the area some days earlier to the northeast when the area was surveyed leaving residual low density schools containing juveniles. However, the north-eastern migration pathway of this component of the stock was contained within the western Faroe/Shetland subarea and so this biomass was included in the estimate.

Individuals of ages 1 to 14 years were observed from the survey. The stock within the survey area is now dominated by 6, 5 and 7 year old fish, of the 2003, 2004 and 2002 year classes, which together contribute over 75% of spawning-stock biomass (Annex 2, Table 4, Figures 8 and 9). The spawning-stock biomass represented over 99% of the total-stock biomass. The contribution of juveniles to the total-stock biomass was the lowest observed in the current time-series. Overall, mean length (29.5 cm) and weight (130 g) are the highest on record in the international survey time-series (2004–2009).

Juvenile blue whiting were encountered in the Porcupine and Rockall subareas as low background acoustic registrations. Juveniles within these areas can be considered as resident and not part of the main body of the migrating stock. The low abundance of immature fish within the main body of the migrating stock is a further signal of poor recruitment within this stock.

The estimated total abundance of blue whiting for the 2009 international survey was 6.07 million tonnes, representing an abundance of 46.7x10^9 individuals. The spawning stock was estimated at 6.03 million tonnes and 45.8x10^9 individuals. In comparison to 2008, there is a significant decrease (24%) in stock biomass and a 31% decrease in stock numbers (Table 3.4.2). An age disaggregated estimate of abundance is presented in Table 3.4.3.

Area coverage in 2009 was increased by 5% as compared to 2008. In 2009, all subareas were surveyed by more than one vessel which provided a high degree of resolution and transect interlacing throughout. Good geographical containment of the stock was achieved and the entire survey area was surveyed within a 4 week window ensuring good temporal alignment (Figure 3, Annex 2). As a result the 2009 estimate of abundance can be considered robust.

International ecosystem survey in the Nordic Sea

The total biomass of blue whiting registered during the May 2009 survey was 0.9million tons (Annex 3), which is very low (the corresponding estimates from 2006, 2007 and 2008 were 6.2, 2.4 and 1.1 mill. tons, respectively). The stock estimate in number for 2009 is 5.7 billion, which is about 70 % of the 2008 estimate. The reduction in estimate is seen in all ages, but most severe for ages 2–5.

An estimate was also made from a subset of the data; A "standard survey area" between 8°W–20°E and north of 63°N (Annex 3) have been used as an indicator of the abundance of blue whiting in the Norwegian Sea because the spatial coverage in this are provides a coherent time-series with adequate spatial coverage – this estimate is used as an abundance index in the WGWIDE. The age-disaggregated total stock estimate in the "standard area" is presented in Annex 3, showing that the part of the stock in this index area is dominated by 4 year old blue whiting. Time series from the "standard survey area" is presented in Annex 3.

Blue whiting were observed mostly in connection with the continental slope in south and east and very little were found in the open sea (Annex 3). The mean length of blue whiting is shown in Annex 3. It should be noted that the spatial survey design was not intended to cover the whole blue whiting stock during this period.

Joint surveys in the Nordic Sea

The blue whiting population within the covered cruise tracks and areas was estimated to be 2.3 million tons consisting of 14.9 billion individuals (Annex 4). The average weight of blue whiting was 155.9 grammes and mean length was 30.1 cm. Altogether 10 different year classes were present in the catches, although only four year classes constituted more than 5% of the catches.

Blue whiting and herring had spatial overlap in frontal and Arctic waters, whereas blue whiting had overlap with mackerel in the western areas, whereas little spatial overlap with mackerel in the central part of the Norwegian Sea. It should also be noted for this survey that the spatial design was not intended to cover the whole blue whiting stock during this period.

3.5 Mackerel

Mackerel distribution from the IBSS survey

In the years 2004–2008 mackerel have been encountered along the shelf slope west of the Hebrides and further south as schools of medium to high density. In general, mackerel distribution, as encountered during the blue whiting spawning stock survey, can be considered sporadic. However in 2009, mackerel were found to be distributed widely across the combined survey area and in high densities. Mackerel were taken in trawl samples from 60ºN north to as far south as 51ºN and west to 15ºW on the Hatton Bank. Ordinarily confined to the shelf slope, mackerel were encountered in open waters in depths of between 60–300m forming distinct schools occurring over large areas. Stomach contents revealed mackerel to be actively feeding on mesopelagic fish and were most frequently encountered within this layer. During daylight hours mackerel were discernible as single schools (Annex 2, Figure 7c-d). At night mackerel schools dispersed through the mesopelagic layer.

Mackerel distribution from the International ecosystem survey in the Nordic Seas (IESNS) survey

In later years an increasing amount of mackerel has been observed in the Norwegian Sea during the combined survey in May targeting herring and blue whiting, and there seem to be an increase in the northern and western distribution limit during summer. In 2008 during the Faroese survey mackerel was found in the southeastern part of the investigated area, but in 2009 mackerel was found up to 64ºN in the Faroese area (Annex 3). During the survey with the Norwegian *Johan Hjort* in May, mackerel was observed off the Norwegian shelf between 62 and 68ºN. The catches were dominated by the 2005 *year class* (Annex 3, Figure 17 and 18). Most of the mackerel were in maturity stage 4, 5 and 6 which means that they were probably spawning in the area (Annex 3, Figure 19).

Mackerel distribution from the joint Norwegian-Faroese mackerel/salmon(Salsea) survey in July-August

Three chartered fishing vessels performed a joint ecosystem survey in the Norwegian Sea and adjacent areas, two Norwegian M/V "Libas" and M/V "Eros" from 15 July to 6 August 2009, and one Faroese M/V "Finnur Frídi" from 15 to 25 July 2009 (Annex 4). The abundances of Northeast Atlantic mackerel, Norwegian spring-spawning herring and blue whiting were measured acoustically. Estimated biomass of mackerel was calculated to 4.4 million tons in the Norwegian Sea. Mackerel was distributed over larger areas than previously documented in the Norwegian Sea in July. Furthermore, a northwestern distribution was more pronounced in July 2009 compared to previous years. Repeated offshore catches of one and two year's old individuals indicate that the Norwegian Sea is now also an important nursery and feeding ground for immature mackerel. The 2005- and 2006 year classes dominated representing ¼ each of total catches. Large mackerel caught in the area north of the Icelandic shelf had adult capelin in their stomach, this has never been reported before.

Surface waters in the northwestern part of the Norwegian Sea in the Jan Mayen zone and in the northern part of the Icelandic zone were considerably warmer compared to the last two decades, and coincided with increased presence and concentrations of large herring and mackerel in the area. The northernmost areas in the Norwegian Sea were in contrast colder than previous years, limiting the extent of northern migration by herring and mackerel compared to the last few years.

Mackerel distribution from the national Faroese salmon (Salsea) survey in July

During the Faroese survey targeting salmon (Salsea project, FP7) in the Norwegian Sea, mackerel was caught in every surface haul made by RV *Magnus Heinason* in the northern part of the Norwegian Sea (68–69N 0–2E) during the first two weeks in July 2009.

4 Discussion

4.1 Hydrography

For both surveys the apparent features were that temperatures in areas influenced by the North Atlantic Current (NAC) were considerably higher than the long-term average while a slight cooling was observed in the arctic waters carried by the East Icelandic Current (EIC).

West of the British Isles, the water characteristics are chiefly influenced by three major components: the Subpolar Gyre that may carry cool Subarctic water into the area, the North Atlantic Current (NAC) and by the advection Eastern North Atlantic Water (ENAW) that both may carry warmer and saline waters. Ultimately, the Subpolar Gyre dominates the influence of the two latter in the area. When the gyre is large, more cold Subarctic water is advected to the area in the Rockall Bank vicinity while the NAC and the ENAW is shifted eastwards towards the shelf edge. Under weak Subpolar Gyre situations the major northward branch of the NAC runs west of Rockall Bank while more warm and saline ENAW is advected to the area between the British Isles and Rockall Bank (Hatun *et al.*, 2009). This situation might have been responsible for the warm and saline waters encountered west of the British Isles during the 2009 blue whiting spawning stock survey. The long-term trends for the area also indicate that temperatures and salinity were steadily rising in the area after the exceptionally cold period the ended in the mid 90s (Hughes *et al*., 2008) indicating at a stronger influence of warm ENAW since then in the area. However, there are indications that this trend might possibly be reversing currently since salinity anomaly is declining, although temperatures are still anomalously high, but slightly declining only since 2007 (Hughes *et al*., 2008).

In the Norwegian Sea, where the herring stock is grazing the two main features of the circulation 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 southwestern 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 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. The NWAC is rather narrow in the southern Norwegian Sea, but when meeting the Vøring Plateau off Mid Norway it is deflected westward. The western branch of the NWAC reaches 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.

It has been shown that atmospheric forcing largely controls the distribution of the water masses in the Nordic Seas. Hence, the lateral extent of the NWAC, and consequently the position of the Arctic Front in the Norwegian Basin, is correlated with the large-scale distribution of the atmospheric sea level pressure. This is clearly indicated for example by the correlation with winter index of the North Atlantic Oscillation (NAO). Current measurements south in the Norwegian Sea have also shown that high NAO index gives larger Atlantic inflow, along the shelf edge, in the eastern part of the Norwegian Sea.

After two years with strong westerlies (high NAO index) during 2007–2008, with an increased influence of Arctic water in the southern Norwegian Sea, the strength of the westerlies was in winter 2009 about normal. However, the increased Arctic influence in the western areas of the Norwegian Sea is still observed in 2009. After several years with large westerly extension of Atlantic water and additional warm Atlantic water in the Norwegian Sea, especially in 2003 and 2004, a temperature reduction in the western Norwegian Sea had been observed over the last several years. This is due to a lower extension of Atlantic water and the occurrence of an increased transport of Arctic water to the area. Thus, the temperature in the western Norwegian Sea in 2009 is close to and in some areas less than the 1995–2009 average. In the central and eastern parts, however, the Atlantic water is still warmer than the 1995–2009 average, about 0–1^{o}C dependent on the area and depths. The main reason for this is that the inflowing Atlantic water is significantly warmer and more saline than normal, and in particular the Atlantic water that flows northward through the Faroe-Shetland Channel is observed to be considerable warmer and saltier than normal.

The anomalously high sea surface temperature in north-western Icelandic waters in summer 2009 were probably a consequence of strong atmospheric warming of the surface layers further south and subsequent advection to that area.

4.2 Plankton

Recent years decrease in zooplankton biomass is dramatic in the sense that biomass in the cold water has decreased by 70% since 2003, while in the warmer water biomass has decreased by 75% since 2002. The reason for this drop in biomass is not obvious to us. The unusually high biomass of pelagic fish feeding on zooplankton has been suggested to be one of the main causes for the reduction in zooplankton biomass (ICES, 2008). However, pelagic fish are probably not the main predators of zooplankton in the Norwegian Sea (Skjoldal *et al.*, 2004). A fairly strong relationship between NAO and zooplankton biomass was observed, particularly during the late 1990ies (ICES, 2006). However, this relationship seems to be less pronounced now. During 2008 and 2009 the western part of the Norwegian Sea has cooled during input of more Arctic water. The eastern Norwegian Sea has become warmer mainly due to input of warmer Atlantic water. The warming of the Atlantic water masses do not seem to be in favour of increased zooplankton production in the Norwegian Sea. Summing up, the reason for the reduction in zooplankton biomass is not clear to us and more research to reveal this relationship is strongly recommended.

4.3 Norwegian spring-spawning herring

The Norwegian spring-spawning herring is characterized by large dynamics with regard to migration pattern. This applies to the wintering, spawning and feeding area. The following discussion will only concentrate on the situation in the feeding areas in the period May-July.

Similarly to the previous five years, it was decided not to draw up a suggested herring migration pattern for 2009 due to lack of data. However, the general migration pattern is believed to resemble that of 2003 with the exception that the herring as in the previous years had a somewhat more southerly and westerly distribution than in 2003. There was, however, a slight northeastward shift of the center of gravity of the distribution in 2009 compared to 2008.

In May the herring was migrating westward into the Norwegian Sea to start feeding and main concentrations were found in the central part of this area, mostly consisting of the strong 2002 year class while the 2004 *year class* was observed in the northeastern region. During the last several years, a temperature reduction has been observed in the western part while a temperature increase has been observed in the eastern part of the Norwegian Sea. This could explain the slight north-eastward displacement of the centre of gravity of the herring distribution observed in May 2009, beside the fact that the feeding migration is still ongoing during the survey period. Additionally, the plankton situation in the Norwegian Sea was this year at a very low level, particularly in the western area.

In July the herring are spread out over a wide area feeding around the fringes of the Norwegian Sea, particularly in the northern and western region, while almost no herring were observed in the central region. The age distribution from July showed that the 2004 year class, which in May was distributed close to the Norwegian coast outside Lofoten Islands, had migrated northward and was feeding in the northeastern part of the survey area while older herring, which was observed in central Norwegian Sea in May, had spread out to feed. Anomalously high sea surface temperature was observed in north Icelandic waters in July 2009 and herring was observed feeding in eastern part of that area. The western boundary of the herring distribution was not found in July.

4.4 Blue whiting

The northern distribution of the spawning stock observed in 2009 can be attributed to the earlier peak spawning of the stock in western waters. The international survey is fixed temporally to coincide with peak spawning events and to reduce the level of variability between surveys. Annual variations in the timing of peak spawning are common but have not been as pronounced as in 2009. However, it was agreed that this change in distribution was contained within the survey area and so did not affect on the precision of the estimate. This considered the decrease in biomass from 2008 to 2009 is significant.

The estimate of abundance from the 2009 spawning stock survey is considered robust. The survey was carried out with a high degree of inter-vessel coverage, good temporal alignment and containment of the stock within the survey area. Good agreement was reached between countries regarding the age determination of the blue whiting from survey samples.

The precision of the estimate and level of uncertainty remain unchanged from previous years as described by the analysis carried out by Mikko Heino. Mean acoustic density also follows a similar range to previous surveys, with the exception of 2007. However, the decline in biomass observed in 2008–2009 can be regarded as statistically significant and is more than could be attributed by spatial-temporal variability alone. The 2009 estimate therefore is the lowest in the time-series.

Over 75% of the spawning-stock biomass is now composed of three year classes. Results from the Nordic Seas surveys carried out in May and July confirm the continued lack of juveniles in summer feeding grounds of this stock with no signs of improved recruitment levels in the short term. The contribution of juvenile blue whiting to the total stock estimate is now almost entirely composed of resident components of the stock present on the spawning grounds in western waters. The contribution of juveniles to the total-stock biomass during the spawning survey has always historically low but relatively stable. In 2009, the contribution of juveniles is 50% less than during the period from 2006 onwards.

4.5 Mackerel

In the years 2004–2008 mackerel have been encountered along the shelf slope west of the Hebrides and further south as schools of medium to high density during April. In general, mackerel distribution, as encountered during the blue whiting spawning stock survey west of the British Isles and north to the banks south of the Faroes, can be considered sporadic. However in 2009, mackerel were found to be distributed widely across the combined survey area and in high densities. In May mackerel had already migrated into the southern and eastern part of the Norwegian Sea, and later in July-August mackerel was distributed far to the north and west (north of Iceland) in the Norwegian Sea. Special attention should be paid to the observation of mature mackerel ready to spawn in the Norwegian Sea in May, indicating a northwards extension of the spawning area. This was also observed in 2008, but to a lesser extent. This should be considered by the WGMEGS before the next mackerel egg survey is run in 2010.

As for herring there seemed to be less mackerel in the central part of the area. A reason to the lesser abundance could be the low biomass of zooplankton in the central area as compared to last year, indicating possibly poorer feeding conditions. The fish was distributed in the warm surface layer. The age distribution from May indicated that the 2005 *year class* dominated in the Faroese area, but in July-August the proportions 2005 and 2006 were equally abundant. The anomalously high sea surface temperature observed in north Icelandic waters in July 2009 contained large concentrations of rather large mackerel feeding on plankton and capelin in that area. The western boundary the mackerel distribution was not found in July. Later reports from Icelandic research surveys in August had reported mackerel even further to the west of Iceland.

During the joint Norwegian-Faroese mackerel survey in July-August 2009 an attempt was made to estimate the biomass in the Nordic Seas with acoustic methods using multi frequency echosounder systems. An estimate of nearly 4.5 million tonnes was obtained in the area surveyed. The results should be read with some caution because this is the first time has been estimated acoustically.

5 Planning

5.1 Planned acoustic survey of the NE Atlantic blue whiting spawning grounds in 2010

It is planned that five parties;, Faroe Islands, the Netherlands (EU-coordinated), Ireland (EU-coordinated) Norway and Russia, will contribute to the survey of blue whiting stock survey in March-April 2010.

Survey timing and design were discussed in some detail. It was decided to that the survey should be reduced temporally from 4 to 3 weeks in a bid to reduce the effects of double counting of northward migrating schools. Careful consideration was given to the start and ends time of this 3 week window so as to not adversely affect the integrity of the time-series while still providing synoptic coverage. The group agreed that the stock was well contained within the existing geographical bounds and that the allocation of effort was well balanced. The group also agreed that survey design, in terms of transect structure, is effective and should be maintained in 2010. To ensure transect coverage was not replicated the start points of each participant will be randomized in 2010.

Area allocation for each survey participant is listed below and Figure 5.1.1. shows the position of target areas described in the text.

Ship	Nation	Vessel time (days)	Active survey time (days)	Preliminary survey dates	Primary target area [secondary]
Celtic Explorer	EU (Ireland)	21	18	17/3–7/4	1
G.O. Sars	Norway	14	12	17/3–7/4	1 [2a,b]
Magnus Heinason	The Faroes	14	11	25/3–7/4	2c [1]
Tridens	EU (Netherlands)	21	14	17/3–7/4	2a [1,3a]
Vinus or F. Nansen	Russia	30	21	17/3-7/4	2a [1,2c]

Preliminary cruise tracks for the 2010 survey are presented in Figure 5.1.2.

As survey coordinator in 2010 Ireland has been tasked with communicating cruise tracks and survey coverage to the group. Detailed cruise lines for each ship will be agreed and circulated to the group as soon as final vessel availability and dates has been decided. As the survey is planned with inter-vessel cooperation in mind it is hoped that participants will stick to the planned transect positioning to ensure that survey effort is evenly allocated within the survey area as observed during the planning stages.

The survey will be carried according to survey procedures described in the "Manual for Acoustic Surveys on Norwegian Spring-spawning herring in the Norwegian Sea and Acoustic Surveys on Blue whiting in the Eastern Atlantic" (PGNAPES report 2008).

5.2 Planned International ecosystem survey in the Nordic Seas, spring/summer 2010

It is planned that five parties; Denmark (EU-coordinated), Faroe Islands, Iceland, Russia and Norway, will contribute to the survey of pelagic fish and the environment in the Norwegian Sea and the Barents Sea in May 2010.

The area covered by the international survey in May is divided in two standard areas defining the Norwegian Sea and the Barents Sea. The two subareas are limited by the 20°E north of northern Norway, the following latitudes and longitudes confines the two Subareas:

Norwegian Sea: 62°00'N-75°N, 15°W-20°E

Barents Sea: Coast-75°N, 20°E-40°E

The areas to be covered during the survey in May 2010 are given in Figure 5.2.1.

All estimates should be run for each of these subareas separately and for the total area. By definition all dataseries collected by all boats within the two subareas are included in the dataseries of the international May survey, irrespective of which vessels were planned to be included.

Øyvind Tangen, Norway has been appointed as coordinator of the survey for 2010. Final dates and vessels shall be communicated to the coordinator no later than 15 January 2010. Each participating vessel shall also inform the coordinator on harbour for departure and embarkation together with date and harbour for eventual exchange of crew during the survey. Detailed cruise tracks for each ship will be provided by the coordinator by the end of January 2010.

It is proposed that the Danish vessel starts its survey at the beginning of May. Prior to surveying the proposed area all the acoustic equipment will be calibrated. The survey with then start in the area north of 62°N and east of 2°W on latitudinal transects. The Norwegian vessel(s) will also start their cruises at the beginning of May (the date(s) and name(s) of vessel(s) will be decided by mid November 2009) by conducting the Svinøy hydrographic section. After this the area north of 66°N will be surveyed by the Norwegian and EU vessel(s). The Faroes will start at the same time as the other vessels and survey the area north of 62°N chiefly the Faroese area. The Icelandic vessel has planned to conduct their survey at the same time covering mostly Icelandic waters.

The Russian vessel will start the survey in the middle of May in the Barents Sea and cover the area between 38° and 20° E and will continue in the Norwegian Sea in June-July. The Barents Sea part of the survey will cover young herring.

The proposed vessels and dates is shown in the text table below.

The following subjects should be targeted:

Herring

Blue whiting

Plankton

Temperature and salinity

If possible the participating vessels should be rigged for surface trawling. For age-reading of the Norwegian spring-spawning herring scales should be utilized, and if possible the codend of the trawls should be equipped with some device (soft inlet or other) for reduction of scale losses.

The surveys will be carried according to survey procedures described in the "Manual for Acoustic Surveying in the North East Atlantic", Version 2.1 (PGNAPES report 2008).

It is important that intercalibration of acoustic and trawl equipment between the vessels takes place. It has been agreed that during the May 2009 survey intercalibration will be attempted carried out between the Faroes, Danish and Norwegian vessels. No intercalibration has taken place since the 2005 survey. It is recommended, that serious effort should be put into intercalibrations at the 2010 survey, as it failed in 2009, . Furthermore the proposed intercalibration should be taken into consideration when detailed cruise tracks for participating vessels are planned by the survey coordinator. Fishing should also be carried out during this intercalibration exercise in order to compare the trawl efficiency.

It is recommended that communications between vessels operating in the same area shall be established on a daily basis during the Norwegian Sea Survey. The communication shall preferably be made by e-mails or, alternatively, by radio communication. Cruise tracks, acoustic findings and catches (position, fishing depth, species composition by weight and numbers, and if desired the length distribution of the target species) shall be communicated daily by each vessel. Email addresses for cruise leaders for all participating vessels shall be distributed by the survey coordinator together with the cruise tracks.

Ship	Nation	Vessel time (days)	Active survey time (days)	Preliminary dates
Johan Hjort	Norway	30	28	1/5 – 30/5
RV	Russia	21	21	15/5 – 05/6
Dana	Denmark (EU)	30	23	29/4 – 29/5
Magnus Heinason	Faroes	14	12	2/5 – 16/5
Arni Fridriksson	Iceland	26	23	28/4 – 24/5

Final dates will be decided by the end of the year 2009.

6 Survey protocol and standardization

The combined survey manual for which was made from the existing hydro acoustic manuals managed by PGHERS and PGNAPES which was adopted by the group in 2008 has been rejected by the PGIPS (the new name of the former PGHERS). PGIPS states that is more practical to have a separate manual for each survey. This leaves the group no other choice than to make a new manual for the surveys coordinated by PGNAPES, taking over the updates and improvements from the joined manual. There was no time to do this during the present meeting. The preparation of the new manual will have to be done before or during the meeting in 2010.

6.1 Biological sampling procedure

Presently participating countries collect either scales or otoliths for age reading. This raised the question whether the results are different and whether one should choose for one of the two methods in order to standardize the survey procedures.

A working paper on the exchange of scales and otoliths between Norway, Faroe Islands, Iceland and Denmark presented at WGWIDE in 2008 (Anonymous, 2008) examining the age readings of 159 spring-spawning herring (of which 30 specimens were 6 years or older) showed that the age readings of both otoliths and scales were very similar. There was no significant difference. Another working paper (Couperus, 2008) was presented at PGNAPES in 2008. Here otoliths and scales of 92 herring van the EU participation in the May survey of 2008 were read by an experienced scale reader in Denmark and an experienced otoliths reader in the Netherlands. There was no indication that there is any difference in performance between age reading from scales and otoliths, although it was noted that the sample was limited and the specimens were not older than 7 years.

Taking into account these results the EU survey on board FRV Dana will switch from scales to otoliths in 2010. An important consideration also being that scales easily come off and get lost during processing of the catch and sometimes it is difficult to find suitable specimens for age reading.

6.2 Trawling

Last year it was noted that for some participants in the surveys on Norwegian spring-spawning herring in the Norwegian Sea problems occurred in catching larger schools. The EU vessel FRV Dana has switched from the Foto trawl to the bigger Miljonair trawl, resulting in bigger catches.

6.3 PGNAPES exchange format

On the recommendation from last year the ITIS (Integrated Taxonomic Information System, www.itis.usda.gov) system has been implemented in the data exchange format and adopted by all members. The status of the international time-series data are currently being reviewed and participants will be contacted to update datasets where necessary.

7 PGNAPES database

Internet database

A PGNAPES Internet database (Oracle 10g Express platform) was established at Faroe Marine Research Institute before the post-cruise meeting in IJmuiden, April 2007.

Now more than 2 years have gone. Seven international surveys have been uploaded (36 national cruises), the first ones with difficulties, but as the group has conformed to new data formats and routines, the submission and upload of data now is completed within a week after the cruise completion.

To have data in place before the meetings is important for the group's achievements, as no time is used to collect and organize data during the meetings.

Data from the International Blue Whiting Spawning Stock Survey.

Data from all participating countries, very satisfactory, where received and uploaded to the database, before the post cruise meeting in Galway. This is the same experience as last year, where the submission of data from the April Blue Whiting survey was flawless.

Data from International Ecosystem Surveys in the Nordic Seas and the "15 June Experiment"

9 June 2009 data from all participating countries were received and uploaded to the database. The aim was to have the estimate ready before the 15 June. All data and the estimates were available 15 June and the PGNAPES meeting could in principle be held in the week after.

Beatriz Roel (CEFAS) initiated the "15 June Experiment" as ICES is trying to move some working groups meetings to earlier in summer.

Species code table

Countries are still encouraged to deliver names in their own language. The 3-letter ASFIS code is still a key value in the database, making it easier to allocate species to acoustic values during the scrutinizing operations.

The species list includes the TSN's (Taxonomical Serial Number) and NODC-codes and results can be obtained using either code from the database.

The species list will evolve over time, as the participating countries introduce "new" species.

PGNAPES PGHERS/Fish Frame cooperation

PGHERS is using the Fish Frame database to organize their data. In 2006 PGHERS invited PGNAPES to attend their meeting to consider the opportunity of cooperation. Already then it was obvious that data can easily be interchanged between the two databases.

The Fish Frame version 5.0 should be finished in spring 2008, making upload of PGNAPES data very easy.

The PGNAPES group had expected the development of an assessment application as well, built on top of the Fish Frame database.

This would mean that the PGNAPES group could perform calculations on the Internet application in future in a more transparent way, as several scientists could perform assessment calculations on the same dataset in their own way, before the working group sessions.

But development of Fish Frame has stopped due to lack of funding.

As is, the assessment calculation is made by the Norwegian part of the group, using the BEAM application, using data from the PGNAPES database. A raw assessment calculation is also made by the Faroese part of the group, allocating the mean length and weight from all trawl stations to the whole area. Comparing the results from BEAM and the raw assessment calculation, gives the group a good indication of the quality of calculations.

To have an assessment application available for the whole group is essential to ensure the quality of the work. IMR, Norway is developing a new BEAM application. If this application could get direct access to the PGNAPES database, the group would be able to produce several different assessment calculations before each meeting.

This would definitely lift the quality and speed of our work. Therefore the group urges our Norwegian colleagues, to incorporate an option for remote data access, such as an ODBC-connection, into their application, making it possible to extract data directly from the database.

Future Effort

Effort has to be made to streamline the national data systems to be able to produce data tables in the PGNAPES exchange format, immediately after the national cruises.

The members of the working group are urged to collect their PGNAPES data into a local (MS Access) copy of the PGNAPES database, to ensure that the integrity and consistency of the dataset is perfect, before the data are submitted to the coordinator. This will facilitate the upload of data into the database.

The working group still concentrates its effort getting the most recent data worked up to PGNAPES format, but are also committed to work up their old datasets into PGNAPES format, and submit them to the PGNAPES Internet database.

Data overview

Country	Year	Vessel	Cruise	Log	Catch	Bio	Hydr	Acoustic	Acoustic Val	Pl
DK	2008	OXBH	308	193	71	2379	48625	559	850	54
DK	2009	OXBH	200904	124	113	3416	3360	554	554	40
FO	2006	OW2252	624	36	58	1598	1359	260	4196	
FO	2007	OW2252	724	27	42	1948	729	337	5222	
FO	2007	OW2252	732	76	29	1109	2994	359	4925	31
FO	2008	OW2252	816	51	32	1199	1890	1249	16954	13
FO	2008	OW2252	824	77	43	2656	2619	1670	19172	27
FO	2009	OW2252	920	67	44	1521	2229	1359	21731	
FO	2009	OW2252	932	90	30	1234	3239	1404	7037	23
IE	2006	EIGB	403	45	15	2961	545	516	2637	
IE	2007	EIGB	BWAS07	45	72	2700	534	2445	12368	
IE	2008	EIGB	BWAS08	70	48	2250	2647	2002	11048	
IE	2009	EIGB	BWAS09	65	84	2850	1323	2800	12219	
IS	2007	TFEA	B08–2007	50						50
IS	2007	TFNA	A08–2007	130	39	9873	363	4005	26405	68
IS	2008	TFEA	B8–2008	20						20
IS	2008	TFNA	A6–2008	137	27	5386	43240	4271	43923	98
IS	2009	TFNA	A6–2009	190	29	6671	4624	3834	9266	97
NL	2006	PBVO	BWHTS2006	41	10	400	14778	1363	1363	
NL	2007	PBVO	BWHTS2007	27	8	420	7958	897	8760	
NL	2008	PBVO	BWHTS2008	35	19	982	9988	1419	14569	
NL	2009	PBVO	BWHTS2009	36	9	3749	1898	1853	1057	
NO	2006	LMEL	2006104	131	53	2576	57743	3515	7582	
NO	2007	LIVA	2007845	30	36	656	1580	1491	19460	
NO	2007	LMEL	2007106	274	409	8871	5749	4478	111484	
NO	2008	LJBD	2008834	107	117	2712	2319	2235	43796	29
NO	2008	LMEL	2008103	118	39	551	3735	686	24537	24
NO	2008	LMOG	2008809	65	29	842	10335	1399	1657	
NO	2009	LDGJ	2009206	217	119	2265	5278	664	2556	59
NO	2009	LIWG	2009833	59	29	1351	528	323	511	
RU	2006	UHOB	2006048	102	30	371	701	2512	2512	
RU	2007	UALU	2007046	21	10	377	190	919	919	
RU	2008	UANA	2008067	105	18	1393	909	2461	2461	
RU	2008	UANA	2008068	186	64	669	602	456	2844	64
RU	2009	UANA	2009072	99	21	1377	939	2081	2207	
RU	2009	UANA	2009073	142	70	960	648	354	378	61

The table shows number of records in logbook, catch, biology, hydrography, acoustic, acoustic values and plankton tables' per nation, year, vessel and cruise by 19 August 2009.

8 Agreement and Recommendations

Agreements:

- The ITIS, the Integrated Taxonomic Information System, as the standard taxonomic reference system has been adopted by the group as an additional identifier for species identification for survey data.
- The location of the next post-cruise meeting of the International Blue whiting spawning stock survey will be in Bergen, Norway and will take place from the 14–16 April, 2010.
- The next PGNAPES meeting will take place in Hamburg, Germany from the 17–20 August, 2010. The group discussed the possibility of moving the meeting to June but decided that this was not a recommended as this would mean not all survey data would be available to the PGNAPES group
- The group elected Ciaran O'Donnell (Ireland) as the new PGNAPES Chair in 2010.
- The WG agreed a request that members of the research project NorEx-Change (a project funded by the Nordic Minister Council aimed to assess the effects of future climate changes on distribution of pelagic fish stock in the Norwegian Sea) could have a copy of the data in the PGNAPES databases to store in the NorExChange database, giving that it will be accessible in future to all members of the WG that have provided the data initially.

Recommendations:

Listed below is a range of recommendations compiled by the group.

General recommendations

- Standardisation of gear types should be achieved in future with special emphasis on the use of a standardized codend.
- An efficient Internet connection should be set up on all vessels participating in internationally coordinated surveys to ensure timely and essential data exchange.
- For a comparison of softwares used for scrutinizing the acoustic data from the May survey, it is recommended that part of the data from RV DANA May survey 2009, and already scrutinized with BI500 onboard, will be sent to IMR to be scrutinized with LSSS and to Havstovan to be scrutinized with Echoview. The results from the three different software's should then be compared statistically and presented to the group prior to the surveys in May 2010, along with conceivable recommendation.
- The group welcomed the presence of plankton specialists during the 2009 meeting. The group still lacks the presence of a full time oceanographer

Survey recommendations:

- It is recommended that during IESNS surveys bongo samples for mackerel eggs should be taken where spawning mackerel are found in order to support WGMEGS with information on mackerel spawning in the survey area. Prior to the survey Matthias Kloppmann will contact cruise leaders to communicate sampling methods and sample handling procedures.

- During the coming IESNS surveys acoustic and fishing inter-calibrations between vessels should be carried out following the procedures described in the Manual for hydro acoustic surveying in the Northeast Atlantic. Although not achieved in 2009, the group recommends that special attention be focused on carrying out inter-calibrations in 2010.
- Acoustic log interval distance in the exported data should be set to 1 nautical mile and in 50m vertical depth channels by all participating vessels as agreed by the group and adopted in 2007.
- Continued daily communication between vessels (via e-mail or radio) at sea during cruises should be maintained in 2010. This should be undertaken and initiated by the appointed survey coordinator.
- In order to differentiate between Norwegian spring-spawning herring and North Sea herring otoliths should be collected from the herring in the potential area of mixing. This was implemented in 2009 and it is recommended that it continue in 2010.
- At the PGNAPES Scrutinize workshop in Bergen it was recommended that scrutinization of echograms in the surveys should be conducted in the presence of at least one experienced scientist familiar with the target species and the survey area.
- At the PGNAPES Scrutinize workshop in Bergen it was recommended that the layer approach should be used in the scrutinizing procedure until a thorough comparison has been made between a layer and a school approach.
- For the IBSS survey it was recommended that to increase the precision of the estimate, by reducing the effects of double counting, the time frame on which the survey is carried out is reduced still further from 4 weeks to 3 weeks.

Suggested tasks to new chair:

- Initiate survey coordination throughout the year and keeping track of responsibilities
- Appointing reporting tasks to individual members prior to the planning group meeting.
- Collecting ongoing issues and requests from members of the WG or other groups.

Achievements:

- All survey data from the ecosystem survey in May 2009 were within the database prior to June 15 as agreed in order to make the results available as soon as possible.
- A deep-sea species photo guide was initiated at the PGNAPES meeting in 2008 and was further developed in 2009. It is recommended that the development of this guide continue.
- Annual update of database status at the PGNAPES meeting realized.
- As agreed at the PGNAPES meeting in 2008, a scrutinization workshop was carried out in Bergen in February 2009. New methods were presented and standardization of current procedure was discussed and agreed (ICES 2009).

- From the IBSS survey spatial and temporal coverage of core and peripheral areas was further improved during the 2009 survey.
- Good agreement achieved in age determination between countries during the spawning stock survey.
- For the IBSS survey all data were delivered to the PGNAPES database 1 week prior to the post cruise meeting. This allowed for the timely delivery of the survey estimate and report.

9 References

Anonymous, 2008. Report of scale and otoliths exchange of Norwegian spring spawning herring, 2007–2008, between Norway, Faroe Islands, Iceland and Denmark. Working paper presented at WGWIDE,: 3pp.

Couperus, A.S. 2008. Comparison of age reading from scales and otoliths for Norwegian spring spawning herring. Working paper presented at PGNAPES, : 2pp.

Hátún, H., Payne, M.R., Beaugrand, G., Reid, P.C., Sandø, A.B., Drange, H., Hansen, B., Jacobsen J.A. and Bloch, D. 2009: Large bio-geographical shifts in the north-eastern Atlantic Ocean: From the Subpolar Gyre, via plankton, to blue whiting and pilot whales. Progress in Oceanography 80 (2009) 149–162.

Hughes, S. L., Holliday, N. P., and Beszczynska-Möller, A. (Eds). 2008. ICES Report on Ocean Climate 2007. ICES Cooperative Research Report No. 291. 64 pp.

Hurrel, J. 2009: NAO Index Data provided by the Climate Analysis Section, NCAR, Boulder, USA. http://www.cgd.ucar.edu/cas/jhurrell/indices.html

ICES. 2007. Report of the Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys (PGNAPES). ICES CM2007/RMC:07: 94 pp.

ICES. 2009. Report of the PGNAPES Scrutiny of Echogram Workshop (WKCHOSCRU) 17–19 February 2009, Bergen, Norway ICES CM 2009/RMC.

Totland, A., and Godø, O. R. 2001. BEAM – an interactive GIS application for acoustic abundance estimation. In T. Nishida, P.R. Kailola and C.E. Hollingworth (Eds): Proceedings of the First Symposium on Geographic Information System (GIS) in Fisheries Science. Fishery GIS Research Group. Saitama, Japan.

10 Tables and Figures

Table 1.3.1. Organisational frame of the coordinated herring investigations in the Norwegian Sea, 1995–2008.

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 (ICES CM 1997/H:3)	Reykjavík (Vilhjálmsson, 1997/Y:4)
1998	Faroe Islands, Iceland, Norway, Russia, EU	11	Reykjavík (ICES CM 1997/Assess:14)	Lysekil (Holst *et al.*, 1998/D:3)
1999	Faroe Islands, Iceland, Norway, Russia, EU	10	Lysekil (Holst *et al.*, 1998/D:3)	Hamburg (Holst *et al.*, 1999/D:3)
2000	Faroe Islands, Iceland, Norway, Russia, EU	8	Hamburg (no printed planning report)	Tórshavn (Holst *et al.*, 2000/D:03)
2001	Faroe Islands, Iceland, Norway, Russia, EU	11	Tórshavn (no printed planning report)	Reykjavik (Holst *et al.*, 2001/D:07)
2002	Faroe Islands, Iceland, Norway, Russia	8	Reykjavik (no printed planning report)	Bergen (ICES CM 2002/D:07)
2003	Faroe Islands, Iceland, Norway, Russia, EU	5	Bergen (ICES CM 2002/D:07) + correspondence	Tórshavn (ICES CM 2003/D:10)
2004	Faroe Islands, Iceland, Norway, Russia, EU	5	Tórshavn (ICES CM 2003/D:10) + correspondence	Murmansk (ICES CM 2004/D:07)
2005	Faroe Islands, Iceland, Norway, Russia, EU	13	Murmansk (ICES CM 2004/D:07) + correspondence	Galway (ICES CM 2005/D:09)
2006	Faroe Islands, Iceland, Norway, Russia, EU	14	Galway (ICES CM 2005/D:09) + correspondence	Reykjavik (ICES CM 2006/RMC:08)
2007	Faroe Islands, Iceland, Norway, Russia, EU	4	Reykjavik (ICES CM 2006/ RMC:08) + correspondence	IJmuiden (ICES CM 2007/ RMC:07)
2008	Faroe Islands, Iceland, Norway, Russia, EU	3	IJmuiden (ICES CM 2007/ RMC:07) + correspondence	Hirtshals (ICES CM 2008\RMC:05)
2009	Faroe Islands, Iceland, Norway, Russia, EU	3	Hirtshals (ICES CM 2008\RMC:05+ correspondence	Torshavn (this report)

Table 3.2.1. Average zooplankton biomass [g dry weight m-2] at the international ecosystem surveys in the Nordic Seas carried out in May for the period 1997–2009. Zooplankton biomass calculated from vertical plankton net (WP2) hauls from 200m to the surface.

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean
Total area	8,2	13,4	10,6	14,2	11,6	13,1	12,4	9,2	9,2	8,9	8	7,1	3,9	9,984615
Region W of 2°W	9,1	13,4	13,5	15,7	11,4	13,7	14,6	9,2	10,7	12,6	10,3	7,1	4,4	11,20769
Region E of 2°W	7,5	14,4	10,2	11,8	8,7	13,6	9	8	8,2	4,8	5,6	7,1	3,3	8,6

Table 3.3.1. Norwegian spring-spawning herring in the Norwegian Sea and Barents Sea estimated at the international ecosystem survey in the Nordic Sea in May given in numbers '000 and total biomass '000 tons for the period 1997–2009.

Survey year/Age	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008*	2008**	2009
0	0	0	0	0	0	0	0	0	0	0	0	0		0
1	0	24	0	0	0	0	32,073	0	0	3,688	2,058	0	43	202
2	0	1,404	215	157	1,540	677	8,115	13,735	1,293	35,020	4,122	1,193	381	906
3	1,169	367	2,191	1,353	8,312	6,343	6,561	1,543	19,679	5,604	15,437	587	199	2,980
4	3,599	1,099	322	2,783	1,430	9,619	9,985	5,227	1,353	15,894	7,783	8,332	279	2,754
5	18,867	4,410	965	92	1,463	1,418	9,961	12,571	1,765	1,035	20,292	8,270	5	14,292
6	13,546	16,378	3,067	384	179	779	1,499	10,710	6,205	1,810	1,261	16,345		9,487
7	2,473	10,160	11,763	1,302	204	375	732	1,075	5,371	6,336	1,992	1,381		11,629
8	1,771	2,059	6,077	7,194	3,215	847	146	580	651	7,372	6,781	1,920		1,472
9	178	804	853	5,344	5,433	1,941	228	76	388	558	5,581	3,958		1,253
10	77	183	258	1,689	1,220	2,500	1,865	313	139	651	647	2,500		2,587
11	288	0	5	271	94	1,423	2,359	367	262	171	486	416		1,357
12	415	0	14	0	178	61	1,769	1,294	526	344	371	242		267
13	60	112	0	114	0	78	0	1,120	1,003	807	403	159		183
14	2,472	0	158	0	0	28	287	10	364	792	1,047	217		60
15+	0	415	128	1,135	85	26	45	88	115	324	953	408		258
Number in '000	44,915	37,415	26,016	21,818	23,353	26,115	75,625	48,709	39,114	80,406	69,214	45,928	908	49,687
Biomass in '000 tons	9,141	8,053	6,392	5,798	4,714	5,027	8,562	8,869	7,045	10,342	12,373	9,996	49	10,700

***Norwegian Sea**

****Barents Sea (western limit 30°E)**

Table 3.4.1. Biomass by target subarea in 2008 and 2009 from the International blue whiting spawning stock survey.

		Biomass (million tonnes)				
		2008		2009		
Sub-area			% of total		% of total	Change (%)
I	S. Porcupine Bank	0.1	1	0.1	2	0
II	N. Porcupine Bank	1.2	15	0.3	5	-75
III	Hebrides	4.13	52	3.8	62	-8
IV	Faroe/Shetland	0.74	9	0.9	15	22
V	Rockall	1.8	23	1	16	-44

Table 3.4.2. Total stock biomass and spawning-stock biomass time-series from the International blue whiting spawning stock survey, 2004–2009.

		2004	2005	2006	2007	2008	2009	Change from 2008 (%)
Biomass (mill. t)	Total	11.4	8	10.4	11.2	8	6.07	-24.1
	Mature	10.9	7.6	10.3	11.1	7.9	6.03	-23.7
Numbers (109)	Total	137	90	108	104	68	46.7	-31.3
	Mature	128	83	105	102	67	45.8	-31.6
Survey area (nm2)		149,000	172,000	170,000	135,000	127,000	133,900	5.15

Table 3.4.3. Age disaggregated estimate of total stock numbers and biomass from the International blue whiting spawning stock survey, 2004–2009.

Total stock numbers (in millions)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	Total
2004	4886	17603	34350	44397	16775	5521	3111	1962	1131	127		129,863
2005	3631	4320	18774	25579	26660	8298	2016	728	323	2	4	90,335
2006	3162	5540	32201	38942	16608	7972	2459	791	293	7		107,975
2007	1723	2654	16343	32851	24794	13952	7282	2509	951	420	235	103,714
2008	956	1672	4443	17814	20144	11710	6418	3093	791	908		67,948
2009	2747	3384	3147	6617	16067	15764	8970	4685	2891	514		46,705

Total stock biomass (in 1000 tons)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	Total
2004	138	1092	2697	3762	1775	713	427	262	205	34		11,105
2005	99	217	1377	2194	2546	1046	320	128	76	0.5	0.7	8,004
2006	87	329	2598	3603	1896	1104	495	206	73	3		10,394
2007	68	181	1415	3285	2793	1732	1006	393	167	153		11,193
2008	40	98	409	1786	2273	1501	976	521	178	176		7,958
2009	29	95	103	518	1711	1856	1026	436	170	127		6,070

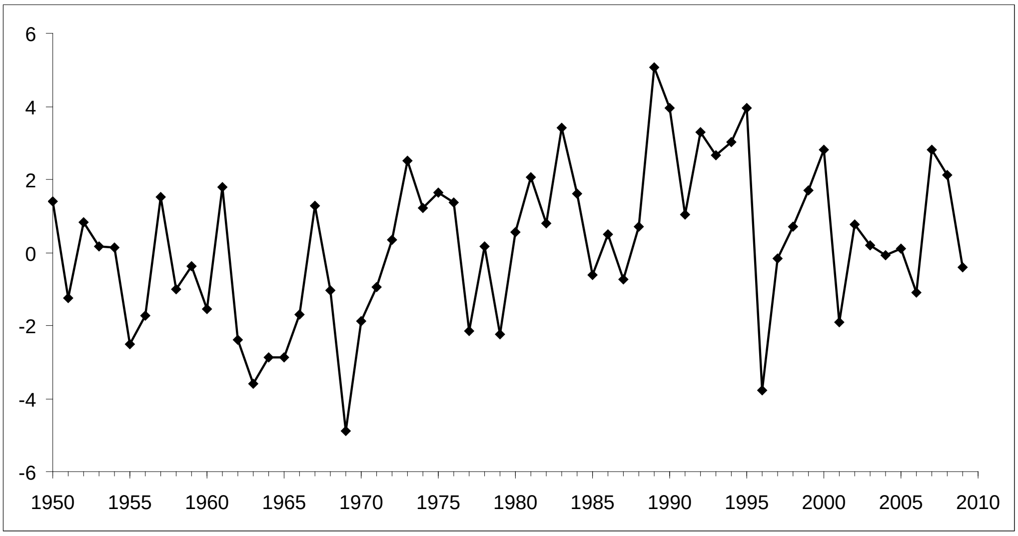
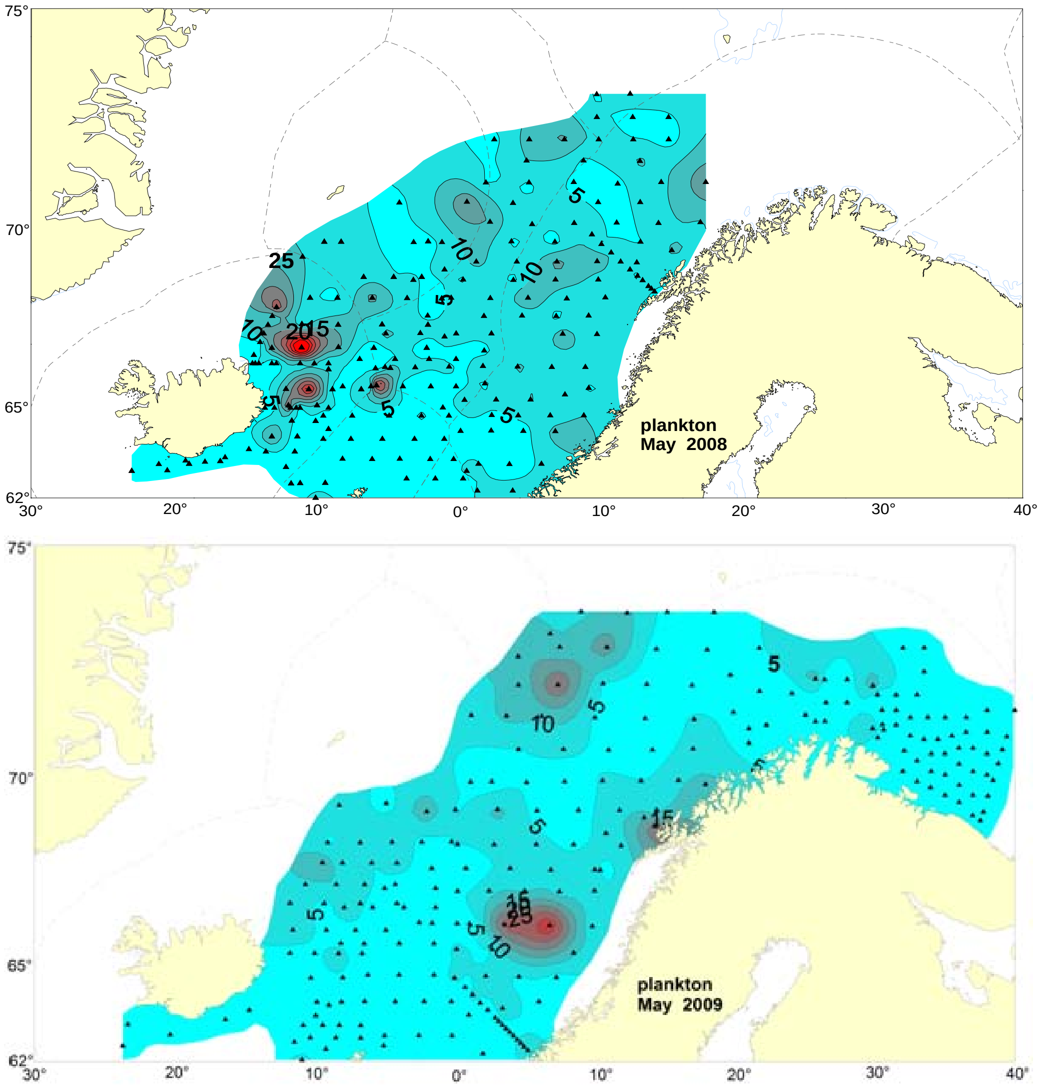


Figure 3.1.1. The winter NAO index between 1950 and 2009. Data from Hurrel 2009.



3.2.1. Zooplankton biomass (g dw m-2; 200–0 m) in May 2008 and 2009.

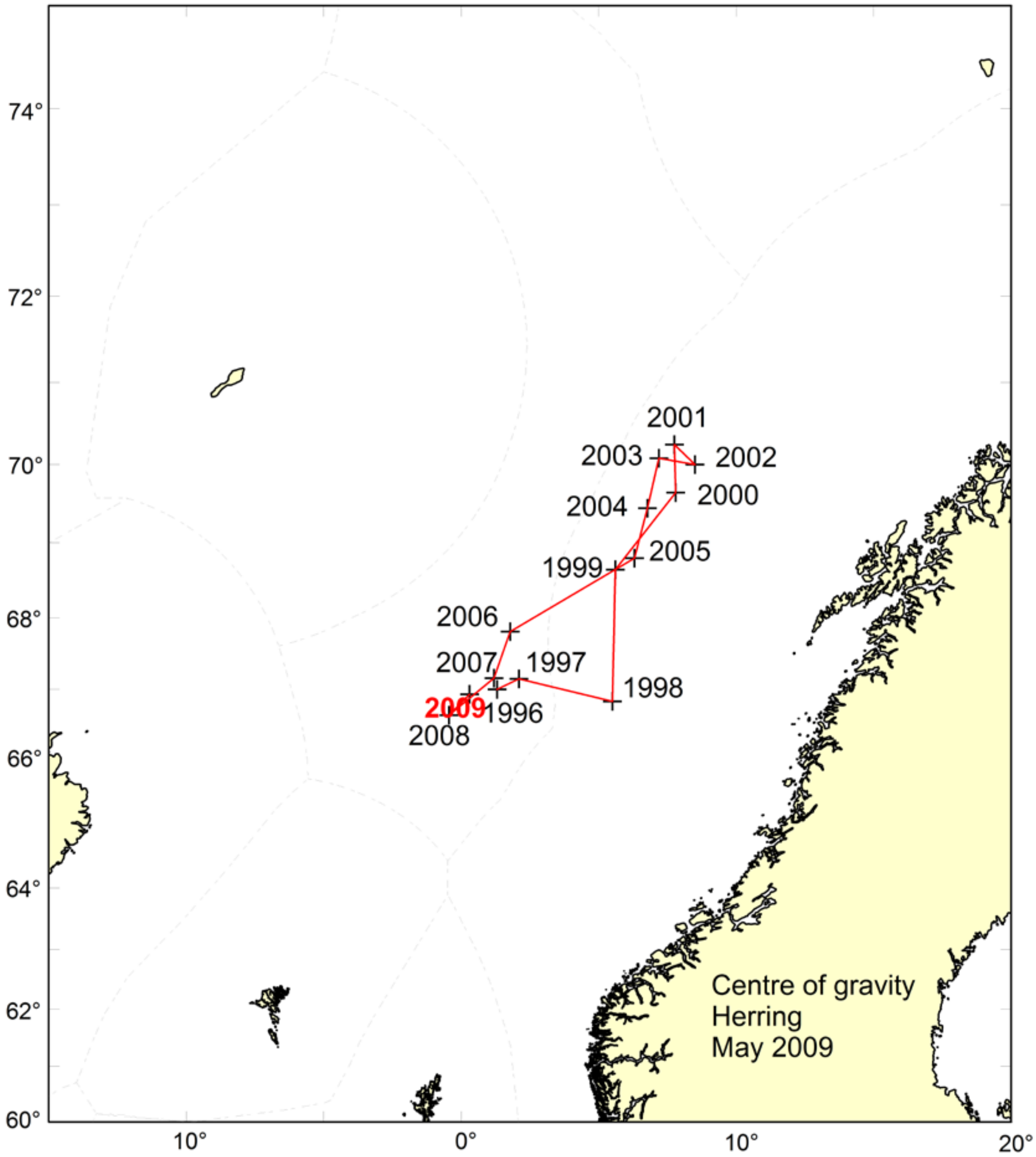


Figure 3.3.1. Centre of gravity of herring during the period 1996–2009 derived from acoustic. Acoustic data from area II and III only, i.e. west of 20°E.

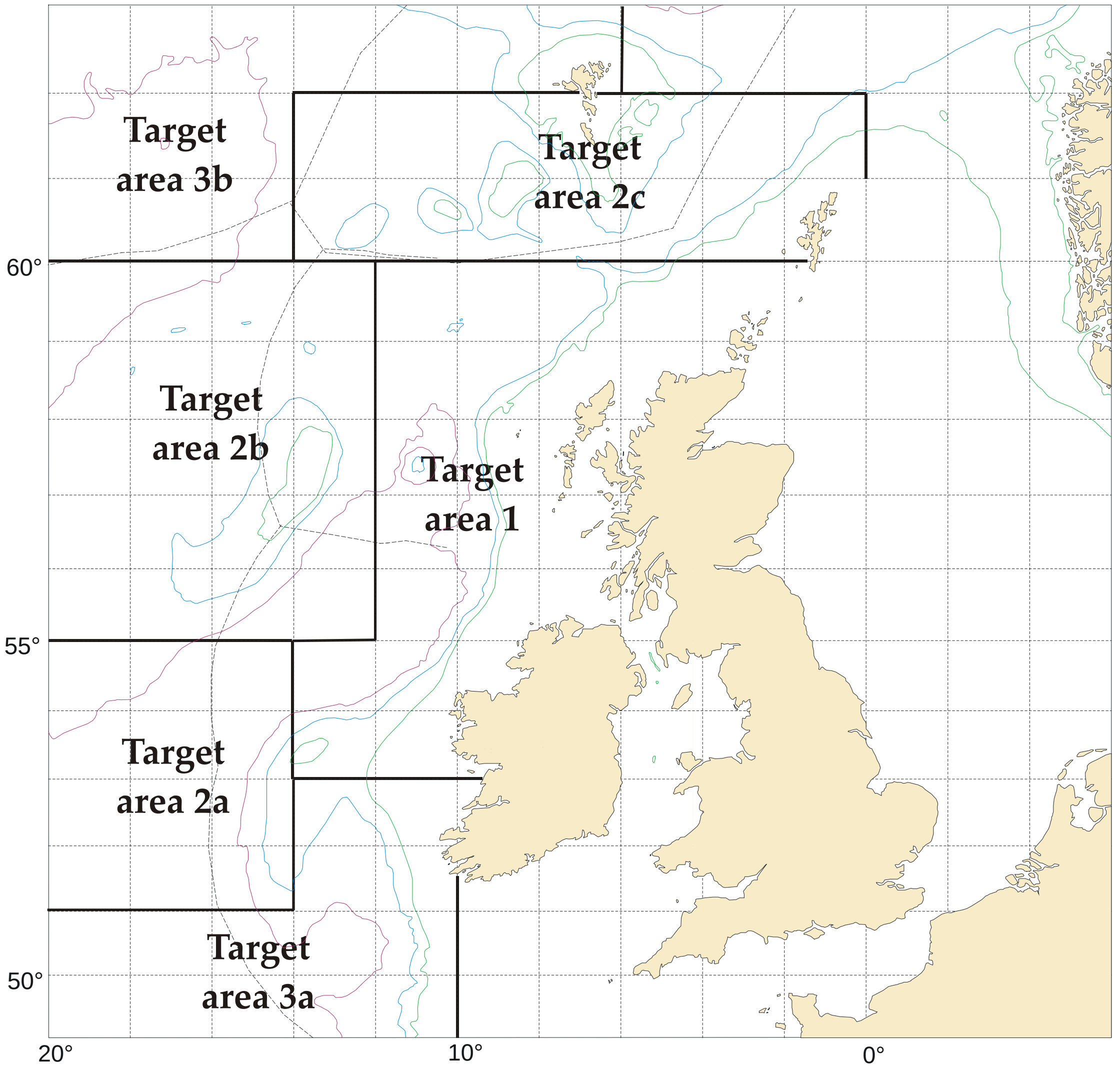


Figure 5.1.1. Target areas for the International blue whiting spawning stock surveys.

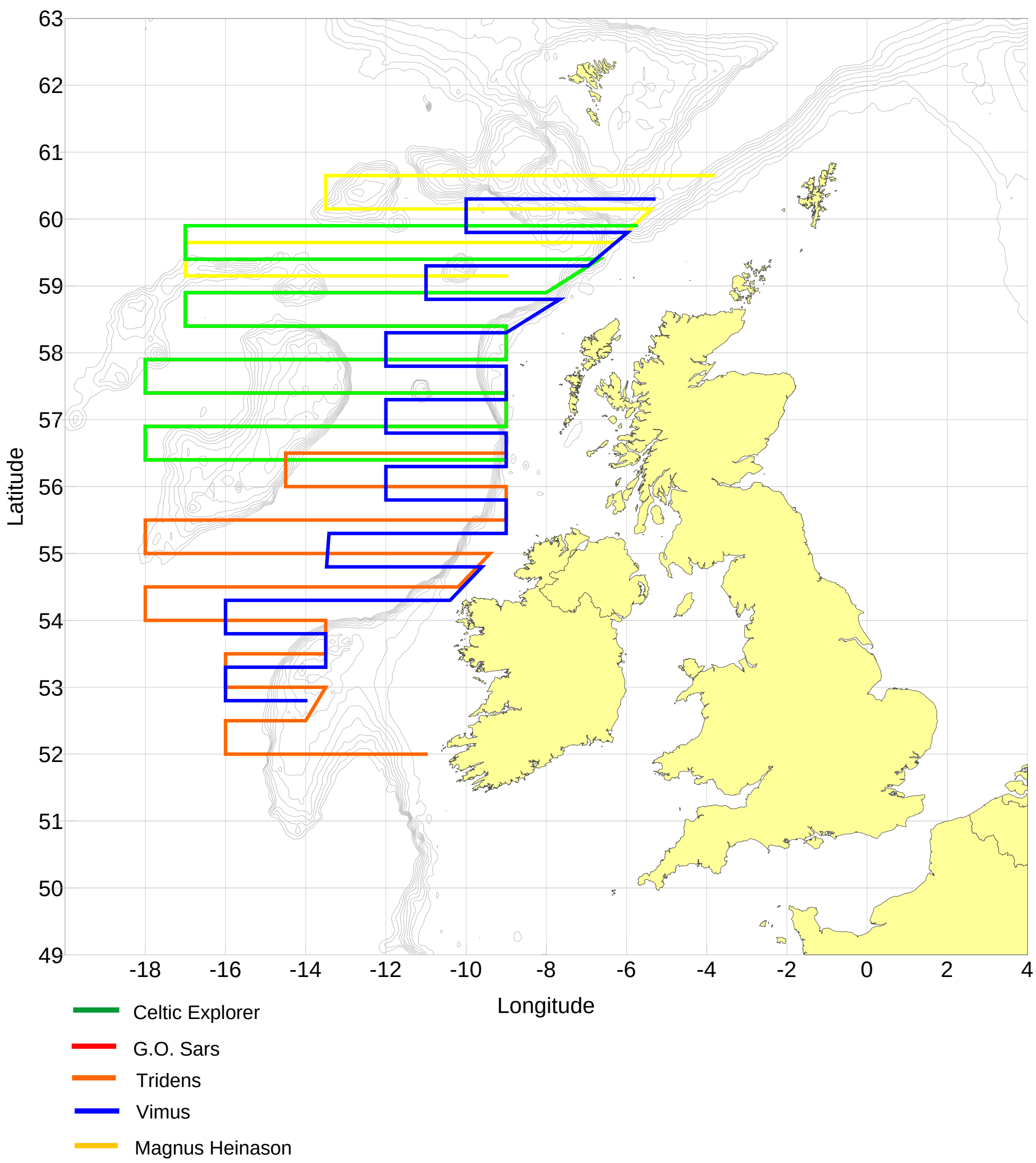


Figure 5.1.2. Preliminary survey tracks for the 2010 International blue whiting spawning stock.

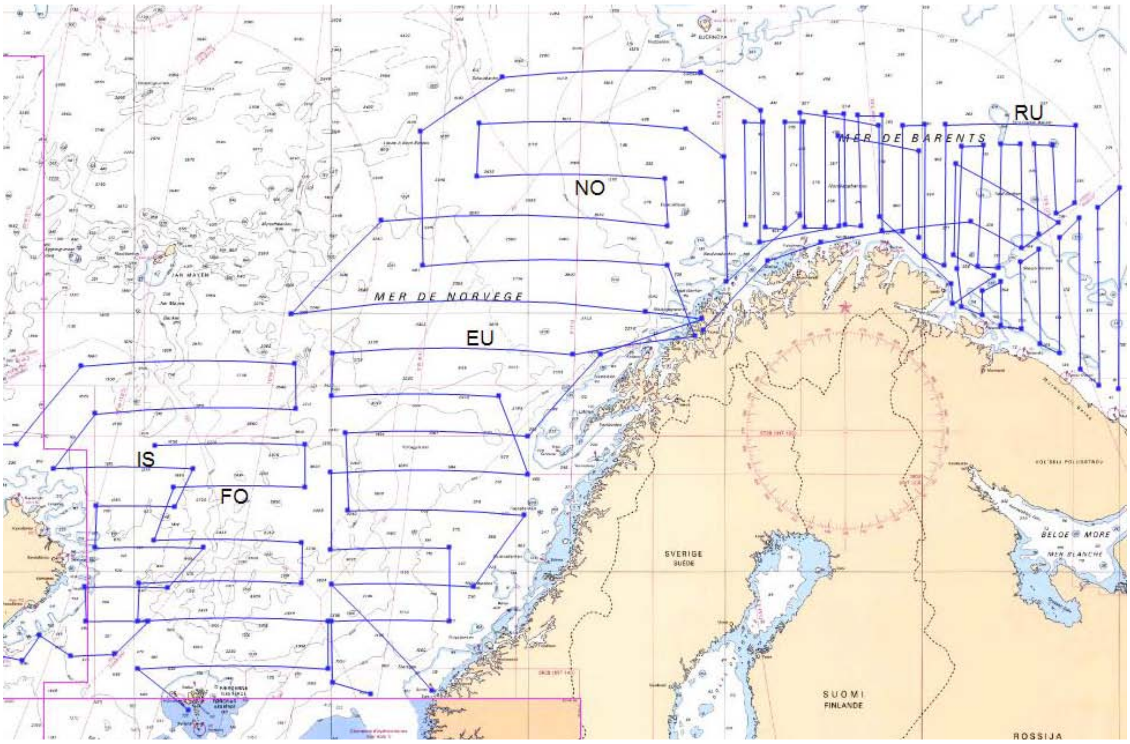


Figure 5.2.1. Preliminary survey tracks for the 2009 International ecosystem survey in the Nordic Seas.

Annex 1: List of participants

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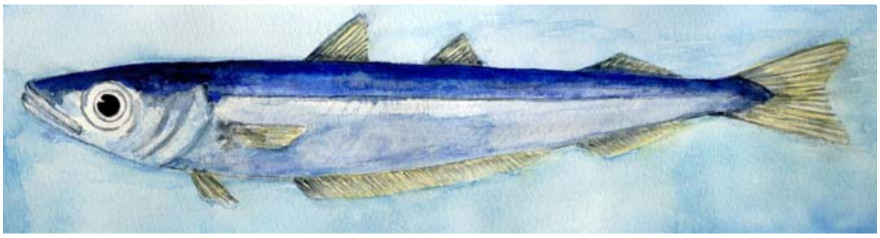
Working Document

Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys

Torshavn, Faroe Islands, 17-21 August 2009

Working Group on Widely distributed Stocks

ICES, Copenhagen, 2-8 September 2009



INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY SPRING 2009

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Introduction

In spring 2009, five research vessels representing the Faroe Islands, Ireland, the Netherlands, Norway and Russia surveyed the spawning grounds of blue whiting west of the British Isles. International co-operation allows for wider and more synoptic coverage of the stock and more rational utilisation of resources than uncoordinated national surveys. The survey was the sixth coordinated international blue whiting spawning stock survey since 2004. The primary purpose of the survey was to obtain estimates of blue whiting stock abundance in the main spawning grounds using acoustic methods as well as to collect hydrographic information. Results of all the surveys are also presented in national reports (F. Nansen: Oganin et al. 2009; Celtic Explorer: O'Donnell et al. 2009; M. Heinason: Jacobsen et al. 2009; Tridens: Ybema et al. 2009; Holst et al. 2009).

This report is based on a workshop held after the international survey in Galway, 22–24/4/2009 where the data were analysed and the report written.

Material and methods

Survey planning and Coordination

Coordination of the survey was initiated in the meeting of the Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys (PGNAPES, ICES 2008) and continued by correspondence until the start of the survey. The participating vessels together with their effective survey periods are listed below:

Vessel	Institute	Survey period
Fridtjof Nansen	PINRO, Murmansk, Russia	27/3–11/4
Celtic Explorer	Marine Institute, Galway, Ireland	27/3–16/4
Brennholm	Institute of Marine Research, Bergen, Norway	24/3–06/4
Magnus Heinason	Faroese Fisheries Laboratory, Faroe Islands	02/4–14/4
Tridens	Institute for Marine Resources & Ecosystem Studies, the Netherlands	17/3–30/3

Cruise tracks and trawl stations for each participant vessel are shown in Figure 1. Figure 2 shows combined CTD stations. Survey effort by each vessel is detailed in Table 1. All vessels worked in a northerly direction (Figure 3). Regular communication between vessels was maintained during the survey (via email, InmarSat C and VHF radio) exchanging distribution data, fleet activity and biological information.

Sampling equipment

All vessels employed a single vessel midwater trawl for biological sampling, the salient properties of which are given in Table 5. Acoustic equipment for data collection and processing are also presented in Table 5. The survey and abundance estimate are based on acoustic data collected through scientific echo sounders using 38 kHz frequency. Transducers were calibrated with a standard calibration sphere (Foote et al. 1987) prior to the survey for all vessels, with the exception of the Celtic Explorer which was calibrated post survey. Acoustic settings are summarized in Table 2.

Acoustic Intercalibration

Inter-vessel acoustic calibrations are carried out when participant vessels are working within the same general area and time and weather conditions allow for an exercise to be carried out. The procedure follows the methods described by Simmonds & MacLennan 2007.

Biological sampling
All components of trawl catches were sorted and weighed; fish were identified to species (when possible) and other taxa to higher taxonomic levels. The level of blue whiting sampling of by each vessel is shown in Table 5.

Hydrographic sampling
Hydrographic sampling by way of vertical CTD casts was carried out by each participant vessel (Figure 2 and Table 1) up to a maximum depth of 1,100m in open water. Hydrographic equipment specifications are summarized in Table 5.

Acoustic data processing
Acoustic scrutiny was mostly based on trawl information and subjective categorisation. Post-processing software and procedures differed among the vessels. On Fridtjof Nansen, the FAMAS post processing software was used as the primary post-processing tool for acoustic data. Data were partitioned into the following categories, blue whiting, plankton, mesopelagic species and other species. The acoustic recordings were scrutinized once per day.

On Celtic Explorer, acoustic data were backed up every 24 hrs and scrutinised using Sonar data's Echoview (V 4.2) post processing software for the previous days work. Data was partitioned into the following categories; plankton (<120 m depth layer), mesopelagic species, blue whiting and plankton & mesopelagic species.

On Blennholm, the acoustic recordings were scrutinized using the Large Scale Survey System (LSSS) once or twice per day. Blue whiting were separated from other recordings using catch information and characteristics of the recordings.

On Magnus Heinason, acoustic data were scrutinised every 24 hrs on board using Sonar data's Echoview (V 4.3) post processing software. Data were partitioned into the following categories: plankton (<200 m depth layer), mesopelagic species, blue whiting and krill. Partitioning of data into the above categories was based on trawl samples.

On Tridens, acoustic data were scrutinized every 24 hrs using Sonar data's Echoview (V 4.30) post processing software. Data were partitioned into only blue whiting using a new developed detection algorithm. Plankton will be partitioned in a later stage. To monitor transceiver output, a monitoring algorithm was created in Echoview. Both algorithms will contribute to a general Echoview template used in this survey.

Acoustic data analysis
The acoustic data as well as the data from trawl hauls were analysed with a SAS based routine called "BEAM" (Totland and Godø 2001) to make estimates of total biomass and numbers of individuals by age and length in the whole survey area and within different sub-areas (i.e., the main areas in the terminology of BEAM). Strata of 1º latitude by 2º longitude were used. The area of a stratum was adjusted, when necessary, to correspond with the area that was representatively covered by the survey track. This was particularly important in the shelf break zone where high densities of blue whiting dropped quickly to zero at depths less than 200m.

To obtain an estimate of length distribution within each stratum, all length samples within that stratum were used. If the focal stratum was not sampled representatively, additional samples from the adjacent strata were used. In such cases, only samples representing a similar kind of registration that dominated the focal stratum were included. Because this includes a degree of subjectivity, the sensitivity of the estimate with respect to the selected samples was crudely assessed by studying the influence of these samples on the length distribution in the stratum. No weighting of individual trawl samples was used because of differences in trawls and numbers of fish sampled and measurements. The number of fish in the stratum is then calculated from the total acoustic density and the length composition of fish.

The methodology is in general terms described by Toresen et al. (1998). More information on this survey is given by, e.g., Anon. (1982) and Monstad (1986). Traditionally the following target strength (TS) function has been used:

$$TS = 21.8 \log L - 72.8 \text{ dB},$$

where L is fish length in centimetres. For conversion from acoustic density (s_A, m^2/n.mile^2) to fish density (ρ) the following relationship was used:

$$\rho = s_A / \langle\sigma\rangle,$$

where $\langle\sigma\rangle = 6.72 \cdot 10^{-7} L^{2.18}$ is the average acoustic backscattering cross section (m^2). The total estimated abundance by stratum is redistributed into length classes using the length distribution estimated from trawl samples. Biomass estimates and age-specific estimates are calculated for main areas using age-length and length-weight keys that are obtained by using estimated numbers in each length class within strata as the weighting variable of individual data.

BEAM does not distinguish between mature and immature individuals, and calculations dealing with only mature fish were therefore carried out separately after the final BEAM run separately for each sub-area. Proportions of mature individuals at length and age were estimated with logistic regression by weighting individual observations with estimated numbers within length class and stratum (variable ’popw’ in the standard output dataset ’vgear’ of BEAM). The estimates of spawning stock biomass and numbers of mature individuals by age and length were obtained by multiplying the numbers of individuals in each age and length class by estimated proportions of mature individuals. Spawning stock biomass is then obtained by multiplication of numbers at length by mean weight at length; this is valid assuming that immature and mature individuals have the same length-weight relationship.

Results

Inter-calibration results

One inter-vessel acoustic calibration was performed between R/V Celtic Explorer and R/V Magnus Heinason during the 2009 survey. Results are detailed in Appendix 1.

Distribution of blue whiting

Blue whiting were recorded all areas surveyed relating to 9,800 nautical miles of survey transects and an area coverage of 134 thousand square nautical miles (Figures 4–6 and Table 1). The highest concentrations were recorded in the area between the Hebrides, Rockall and Faroe Banks and are consistent with the results from previous surveys. However, when surveyed, the bulk of the stock was located further north in 2009 around the Hebrides and Rosemary banks and less on the slope areas around northwest Ireland as observed in 2008. This can be attributed to the earlier spawning and subsequent northward migration of the stock, as reported by the national commercial fleets actively targeting blue whiting in the area. Schools with the greatest recorded density were observed by the Magnus Heinason in the north, in the Hebrides sub area (Figure 7a).

In the southern Porcupine area, biomass was of a similar level to that observed in 2008. The northern porcupine core area was found to contain significantly less biomass than during the same time period in 2008. Peak spawning had already taken place in this area and the bulk of the stock had migrated northwards along the shelf edge. This biomass was picked up in the Hebrides core area where an increase in biomass was observed compared to 2008. In 2009 over 62% of the total biomass was observed within the Hebrides area, as compared to over 50% in 2008. In the northern extreme, the Faroe/Shetland core area also saw an increase in biomass when compared to 2008 related to this earlier migration.

In the western extremes, biomass within the Rockall sub area was significantly lower than observed in 2008 even though survey effort was increased. Fishing effort within this sub area was higher than observed in previous years. Vessels were observed following actively migrating schools from 20ºW north eastwards along the western slopes of the Rockall Bank ahead of the survey vessels. The main body of blue whiting had already migrated out of the area some days earlier to the northeast when the area was surveyed leaving residual low density schools. The north-eastern migration pathway of this component of the stock was contained within the western Faroe/Shetland sub area during the survey.

Area coverage was good and showed an increase of 5% on 2008 mainly in the western periphery. For the first time all sub areas were surveyed by more than one vessel providing a high degree of resolution and transect interlacing (Figure 1). Cooperating vessels also worked within a 4 week window to cover the entire area with good temporal alignment (Figure 3). Good agreement was achieved in terms of recorded acoustic densities within core areas of high abundance but some discrepancies did occur (Figure 5). Differences can be attributed to spatial and temporal heterogeneity in abundance of target schools.

Stock size

The estimated total abundance of blue whiting for the 2009 international survey was 6.07 million tonnes, representing an abundance of 46.7x10^9 individuals (Table 3). The spawning stock was estimated at 6.03 million tonnes and 45.8x10^9 individuals. In comparison to 2008, there is a significant decrease (24%) in the observed stock biomass and a related decrease in stock numbers (31%) within an increased overall survey area (see table below).

		2004	2005	2006	2007	2008	2009	Change from 2008 (%)
Biomass	Total	11.4	8	10.4	11.2	8	6.07	-24.1
(mill. t)	Mature	10.9	7.6	10.3	11.1	7.9	6.03	-23.7
Numbers	Total	137	90	108	104	68	46.7	-31.3
(10^9)	Mature	128	83	105	102	67	45.8	-31.6
Survey area (nm^2)		149,000	172,000	170,000	135,000	127,000	133,900	5.15

The Hebrides core area was found to contain 62% of the total biomass observed during the survey and is relatively consistent with the results from previous surveys (50% in 2008). Rockall and Faroe/Shetland ranked second and third highest contributing 16% and 15% to the total respectively.

		Biomass (million tonnes)				
		2008		2009		
	Sub-area		% of total		% of total	Change (%)
I	S. Porcupine Bank	0.1	1	0.1	2	0
II	N. Porcupine Bank	1.2	15	0.3	5	-75
III	Hebrides	4.13	52	3.8	62	-8
IV	Faroe/Shetland	0.74	9	0.9	15	+22
V	Rockall	1.8	23	1	16	-44

Stock composition

Individuals of ages 1 to 14 years were observed during the survey. Good agreement was achieved across all participants in age estimates of blue whiting (Appendix 3). Stock in the survey area is dominated by age classes 6, 5 and 7 years, of the 2003, 2004 and 2002 year classes respectively, contributing over 75% of spawning stock biomass (Table 4, Figure 8).

The Hebrides area has consistently contributed over 50% to the total SSB over the survey time series. In general the age structure of stock in this area resembled that of the total survey area, with the exception of the Porcupine (N and S) and Rockall sub areas which contained the highest proportion of juvenile fish observed during the survey (Figures 7b & 9).

Juveniles within these areas can be considered as resident and not part of the main body of the migrating stock. Larval retention due to localised hydrographic conditions that encircle these offshore Banks supports a residual year round population. The contribution of these immature fish to the total biomass relates to 0.6% or 39,000t. The low abundance of immature fish within the core Hebrides area is a further signal of poor recruitment within this stock. The presence/absence of immature fish within the core areas is an indication of those that have actively migrated with the main body of the stock.

In 2009, 85% of 2 year old fish (2007 year class) were found to be mature. In addition 15% of 1 year old fish (2008 year class) were also mature. However, it is important to note that the majority of 1 and 2 year old fish encountered were from the Rockall and Porcupine Banks and thus should be considered resident. Due to the lack of immature fish in the main core areas it was not possible to determine if this level of early maturity was observed throughout the stock.

Mackerel distribution

In the years 2004-08 mackerel have been encountered along the shelf slope west of the Hebrides and further south as schools of medium to high density. In 2009, mackerel were found to be distributed widely across the combined survey area and in greater abundance than seen previously. Mackerel were taken in trawl samples from 60ºN north to as far south as 51ºN and west to 15ºW on the Hatton Bank. Ordinarily confined to the shelf slope mackerel were encountered in open waters in depths of between 60-300m forming distinct schools occurring over large areas. Stomach contents revealed mackerel to be actively feeding on mesopelagic fish and were most frequently encountered within this layer. During daylight hours mackerel were discernable as single schools (Figure 7c-d). At night mackerel schools were inclined to disperse through the mesopelagic layer.

The relatively high abundance and wide distribution of mackerel encountered during the survey could be attributed to the current robust state of the mackerel stock. Acoustic registrations of mackerel were encountered by all participants across the survey area and would allow for scrutinisation of this species in future surveys. However, limitations exist regarding the use of multi-frequency analysis in deeper waters due to the extinction of high frequency signals at depth.

Hydrography

A combined total of 155 CTD casts were undertaken over the course of the survey. However, at this time the group was only able to produce horizontal plots of temperature and salinity due to the absence of a physical oceanographer again at this year's post-cruise meeting. Horizontal plots of temperature and salinity at depths of 10m, 50m, 100 and 200m as derived from vertical CTD casts are displayed in Figures 10-13 respectively.

Porcupine hydrographic transect

The Tridens conducted measurements of temperature and salinity down to a maximum depth of 1000 m in open water and to close to the sea floor on the shelf. This kind of investigation was carried out in order to examine the physical environment of blue whiting within the research area. Unlike birds and mammals fish are unable to maintain a constant body temperature, and thus their bodily functions are ultimately linked to the ambient temperatures. This is particularly true for the development and ripening of the gonads and, hence, the timing of spawning. Temperature differences around 1 °C can already make a difference of several weeks. Furthermore, analysis of the relationship between temperature and salinity can provide information about characteristics and origin of surrounding water masses. This information can then be utilized to describe the climatological regime during the spawning season and may allow for predictions of recruitment in a fish species.

During the current cruise sea surface temperatures (SST) ranged between 10.3 and 11.5 °C within the investigated area. The low temperatures being encountered in areas closer the coast while surface temperatures above the greater depths were generally higher. Illustrated by the standard hydrographic transect conducted across Porcupine Bank at about 53° 18’ N (Figure 14).

In the surface layers to about 100 m depth temperatures decrease gradually from > 11.1 °C in the West to < 10.4 °C above the Porcupine Bank, further to the East SST increase again slightly to values > 10.4 °C. Over the deeper waters west of Porcupine Bank temperature was relatively stable change down to 300 – 400 m. Illustrated by the narrowing isothermals, temperatures decrease at a faster rate thereafter. Striking features above the western slope of Porcupine Bank are the steep and almost vertical isothermals that illustrate upwelling of cool waters from the depth. Here, upwelling is predominantly caused by the impingement of tidal currents onto the slopes of Porcupine Bank (Mohn 2000). The upwelled water carries nutrients from depth into the illuminated layers and promotes enhanced production above the bank (McMahon et al. 1995, White et al. 1996, Hillgruber and Kloppmann 1999).

The situation described in Figure 14 is almost identical to the situation found by a German expedition in 1994 at almost exactly the same time of the year and in the same area (Figure 15). As during this cruise the researchers found warmest temperatures in the surface layers west of Porcupine Bank with temperatures declining to the East. Also in 1994 upwelling was discernible above the slopes of Porcupine Banks (Kloppmann et al. 2001). The only striking difference is that almost throughout the complete water masses temperatures were roughly 1°C cooler in 1994 than today.

Based on the high number of blue whiting eggs found in their ichthyoplankton catches Kloppmann et al. (2001) concluded that spawning was at its peak at the respective time of the year. This year, many of the examined blue whiting had spent gonads, indicating that peak spawning in 2009 is already over. It is most likely that the higher water temperatures made blue whiting spawn earlier than observed in the mid 90s of the past century.

Concluding remarks

Main results

- The sixth international blue whiting spawning stock survey shows a significant decrease in stock biomass (24%) and a related decrease in stock numbers (31%) as compared to the previous year’s survey.

- The stock in the survey area is dominated by 6, 5 and 7 years, of the 2003, 2004 and 2002 year classes respectively. Together these year classes account for 75% of spawning stock biomass.
- Mean length (29.5 cm) and weight (130 g) are the highest on record in the international survey time series indicating the reliance of the stock on larger older individuals.
- The survey area was increased by 5% from 2008. Core areas were covered with the same intensity as in previous years and increased coverage was achieved in the western Rockall. All sub and core areas were surveyed by more than one vessel providing a high degree of resolution both temporally and spatially.
- The observed shift in distribution northwards can be attributed to an earlier northward migration of the stock in 2009. However, this does not account for the observed decrease in biomass from 2008 to 2009.
- The contribution of immature fish to the total biomass is the smallest observed to date in the main core areas.
- A higher increased proportion of 1 and 2 year old fish (2008 and 2007 year classes) were observed to be mature in the Rockall and Porcupine sub areas than observed previously.

Interpretation of the results

- The 2009 estimate of abundance can be considered robust due to the high degree of inter-vessel coverage and the short time window in which the survey area was covered.
- The precision of the survey index remains unchanged from previous years (Appendix 2).
- Survey timing is fixed annually to coincide with peak spawning of the stock. However, peak spawning is not determined by time but other factors including water temperature. In 2009 the bulk of the stock was located further north than in 2008 indicating an earlier migration northwards. This earlier migration of the stock northwards was contained within the survey area and so was considered not to have adversely affected the precision of the estimate.
- Resident 1 and 2 year olds from the Rockall and Porcupine sub areas were found to contain a higher percentage of mature individuals as compared these areas in previous years. Direct comparison with those within the main body of the migratory stock was not possible due to the absence of 1-year old and the lack of 1 and 2 year olds observed in the core spawning areas.

Recommendations

- As in previous years the possibility of double counting remains an issue during this survey. To increase precision of the abundance index the time frame on which the survey is undertaken needs to be reduced further still.
- It is recommended that the working group not consider the use of 1 and 2 year old fish from the Porcupine and Rockall areas as they may not represent maturity within the entire stock.
- It is recommended that the PGNAPES group review the spawning stock survey design at the meeting in August.
- Taking into account the current international interest in monitoring the mackerel stock it is recommended that the group discuss the potential for mackerel scrutinisation at the August meeting.

Achievements

- Spatial and temporal coverage of core and peripheral areas was the best to date in the international time series.
- Deep sea species identification: Further development of implementation of ecosystem approach in this survey by focusing on deep sea fish species composition and distribution.

- Marine mammal observations: Both a visual and passive acoustic survey were conducted on board Tridens as an ancillary project in 2009. Visual surveys were first established onboard the Celtic Explorer in 2004. Acoustic surveys coupled with visual observations provided a very robust data-set. It is recommended that marine mammal observers carry out visual cetacean surveys during future Blue whiting surveys, as the repetition of these surveys would lead to a better understanding of the diversity and abundance of cetaceans occurring in the blue whiting habitat.
- Good agreement was achieved in age determination of samples across participants.
- Delivery of survey data in the PGNAPES format to Leon Smith was achieved 1 week prior to the post meeting. This allowed for the timely delivery of the combined survey report.

Previous recommendations	Originating from	Status
We have had no dedicated hydrographer present at the post cruise meeting to review the oceanographic data.	April 2007	Still remains an issue. However, Porcupine hydrographic data analysed prior to the 2009 post cruise meeting.
Echoview Template. Leon Smith has updated Template (V9) with common species codes. Sytse Ybema has also been working on a template that includes a school detection algorithm and transmission detection window. For the 2009 survey it is recommended the templates are combined	April 2008	Templates were not been exchanged during the 2009 survey
Intercalibration methods to be reviewed and the manual updated to include R-scripts and compatible data formats	April 2008	2009 intercalibrations were executed according to the standard method and R-script was circulated amongst members.
Discussions are to take place in the PGNAPES meeting mismatch between planned and executed survey tracks	April 2007	Has been addressed and was adhered to in 2009.
Discussions are to take place in the PGNAPES meeting on how to use hydrographical data within this group.	April 2006	A sub meeting during the 2009 PGNAPES needs to clarify how to use hydrographic data more effectively.
A member from each participant country should be present at the post cruise meeting to present the survey data and ensure the timely production of the combined cruise report	April 2008	Russian members were not present at the 2009 meeting.

References

Anon. (Monstad et al.), 1982. Report of the International acoustic survey on blue whiting in the Norwegian Sea, July/August 1982. ICES CM 1982/H:5.

Foote, K. G., Knudsen, H. P., Vestnes, G., MacLennan, D. N., and Simmonds, E. J. 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. ICES Coop. Res. Rep. 144: 1–57.

Godø, O. R., Heino, M., Søiland, H., Alvarez, J., Dahl, M., de Lange, J., Gullaksen, O., Tangen, Ø. & Torkelsen, T. 2002. Blue whiting survey during spring 2002. Working Document to The Northern Pelagic and Blue Whiting Fisheries Working Group, Vigo, Spain, 29 April–8 May 2002. 27 pp.

Heino, M., Godø, O. R., Søiland, H., Nygaard, J. E., Alvarez, J., de Lange, J., Drivenes, L., Gullaksen, O., Tangen, Ø. and Torkelsen, T. 2003. Blue whiting survey during spring 2003. Working Document to The Northern Pelagic and Blue Whiting Fisheries Working Group, Copenhagen, 29 April–8 May 2003.

Heino, M. , Søiland, H., Dahl, M., Pedersen, G., Alvarez, J., Anthonypillai, V., Hovland, T., de Lange, J., Meland, E. S., Myklevol, S., Svendsen, B. V., Tangen, Ø., Torkelsen, T., Stowasser, G. and Varne, R. 2005. Blue whiting survey during spring 2005. Toktrapport/Havforskningsinstituttet/ISSN 1503-6294/Nr. 5 – 2005.

Heino, M. 2004: Norwegian acoustic surveys on blue whiting stock. Improvement of instrumental methods for stock assessment of marine organisims. Porceedings of the Russian- Norwegian Workshop on Hydroacoustics, 11-14. November 2003, Murmansk, Russia (ed. Chernook, V.) pp. 76-83. Pinro Press, Murnansk.

Hillgruber, N. and M. Kloppmann (1999). Distribution and feeding of blue whiting *Micromesistius poutassou* larvae in relation to different water masses in the Porcupine Bank area, west of Ireland." Marine ecology progress series **187**: 213-225.

Holst, J.C, Anthonypillai, V., Tangen, O., Kristiansen, J. and Meland, E. 2009. Blue whiting survey during spring 2009.

ICES 2007a. Report of the Northern Pelagic and Blue Whiting Fisheries Working Group. ICES CM 2007/ACFM:29.

ICES 2007b. Report of the Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys (PGNAPES). ICES CM 2007/RMC:07, Ref. LRC, ACFM, ACE.

Jacobsen, J. A., Joensen, M.M., Mortensen, E. and Skúvadal, F. 2009. Joint investigations on blue whiting south of the Faroes and in the area west of the British Isles. March-April 2009. R/V Magnus Heinason Faroese Fisheries Laboratory, Tórshavn, the Faroes.

Kloppmann M., Mohn C. and J. Bartsch (2001). The distribution of blue whiting eggs and larvae on Porcupine Bank in relation to hydrography and currents. Fisheries Research 50, 89-109.

McMahon, T., Raine, R., Titov, O. and S. Boychuk (1995). Some oceanographic features of northeastern Atlantic waters west of Ireland. ICES J. Mar. Sci. 52, 221-232.

Mohn, C. (2000). Über Wassermassen und Strömungen im Bereich des europäischen Kontinentalrandes westlich von Irland. Dissertation, Universität Hamburg, Germany, 138 pp.

Monstad, T., 1986. Report of the Norwegian survey on blue whiting during spring 1986. ICES CM 1986/H:53.

O'Donnell, C., Mullins, E., Johnston, G., Saunders, R., Beattie, S., McCann, K., Brikt, Z, and O'Leary, E. 2009. Irish Blue Whiting Acoustic Survey Cruise Report 2009. Marine Institute, Ireland.

Oganin., I., Ignashkin, V. and Firsor, Y.. 2009. Report of the Russian survey on blue whiting during spring 2009.

Pedersen, G., Pedersen, R. and Torkelsen, T. 2006. *In situ* target strength measurements of blue whiting. Appendix 7 in Heino et al. 2006.

Simmonds, J. and Mac Lennan D. 2007. Fisheries acoustics, theory and practice. Second edition. Blackwell publishing

.Toresen, R., Gjøsæter, H. and Barros de, P. 1998. The acoustic method as used in the abundance estimation of capelin (*Mallotus villosus* Müller) and herring (*Clupea harengus* Linné) in the Barents Sea. Fish. Res. 34: 27–37.

Totland, A. and Godø, O.R. 2001. BEAM – an interactive GIS application for acoustic abundance estimation. In T. Nishida, P.R. Kailola and C.E. Hollingworth (Eds): Proceedings of the First Symposium on Geographic Information System (GIS) in Fisheries Science. Fishery GIS Research Group. Saitama, Japan.

White, M., C. Mohn and M. Orren (1998). Nutrient distributions across the Porcupine - Bank, ICES J. Mar. Sci. 55 , 1082-1094.

Ybema S., Pasterkamp T.,, Bakker K., Balle J.D. , Gastauer S., Tribuhl S., Van Assendelft C., Armstrong E., Thaarup F., Kloppman M. and O'Brien J. 2009. Cruise report hydro acoustic survey for blue whiting (*Micromesistius poutassou*), 17- 2009. Institute for Marine Resource & Ecosystem Studies, IJmuiden, The Netherlands.

Table 1. Survey effort by vessel. March-April 2009.

Vessel	Effective survey period	Length of cruise track (nm)	Trawl stations	CTD stations	Aged fish	Length-measured fish
Fridtjof Nansen	28/3–11/4	2,110	21	69	1377	4,855
Celtic Explorer	27/3–16/4	2,475	23	27	950	2,850
Brennholm	24/3–06/4	2,007	12	11	280	999
Magnus Heinason	02/4–14/4	1,353	11	28	208	821
Tridens	17/3–30/3	1,853	11	25	450	1,935
Total		9,798	78	160	3,265	11,460

Table 2. Acoustic instruments and settings for the primary frequency. March-April 2009.

	Fridtjof Nansen	Celtic Explorer	Brennholm	Magnus Heinason	Tridens
Echo sounder	Simrad ES60	Simrad EK 60	Simrad EK 60	Simrad EK 500	Simrad EK 60
Frequency (kHz)	**38**, 120	**38**, 18, 120, 200	**38**	**38**	**38**
Primary transducer	ES38B	ES 38B	ES 38B	ES38B	ES 38B
Transducer installation	Hull	Drop keel	Hull	Hull	Towed body
Transducer depth (m)	4.5	8.7	6	3	7
Upper integration limit (m)	10	15	15	7	12
Absorption coeff. (dB/km)	10.1	9.9	9.8	10	9.7
Pulse length (ms)	1.024	1.024	1.024	Medium	1.024
Band width (kHz)	2.425	2.425	2.425	Wide	2.43
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	21.9	21.9
2-way beam angle (dB)	-20.73	-20.6	-20.6	-20.9	-20.6
Sv Transducer gain (dB)				27.22	25.11
Ts Transducer gain (dB)	25.57	25.55	26.5	27.35	
s_A correction (dB)	-0.61	-0.65	-0.65		-0.67
3 dB beam width (dg)					
alongship:	6.99	6.39	7.10	7.02	6.99
athw. ship:	6.99	6.67	7.10	6.86	6.96
Maximum range (m)	750	1000	900	750	750
Post processing software	FAMAS	Sonardata Echoview	LSSS	Sonardata Echoview	Sonardata Echoview

Table 3. Assessment factors of blue whiting. March-April 2009.

Sub-area		Numbers (10^9)			Biomass (10^6 tonnes)			Mean weight	Mean length	Density
	n.mile^2	Mature	Total	%mature	Mature	Total	%mature	g	cm	ton/n.mile^2
I S. Porcupine Bank	9428	0.75	1.1	72	0.1	0.1	90	105	26.8	10.6
II N. Porcupine Bank	23542	2.5	2.7	94	0.3	0.3	98	116	29.0	12.7
III Hebrides	33305	28.8	29.0	99	3.8	3.8	100	130	30.0	114.1
IV Faroe/Shetland	14891	6.0	6.1	98	0.9	0.9	100	142	30.0	60.4
V Rockall	52734	7.4	7.9	95	1.0	1.0	99	127	29.0	19.0
Tot.	133900	45.5	46.7	97.4	6.0	6.1	98.4	117	28.5	

Table 4. Stock estimate of blue whiting, March-April 2009.

Length	Age in years (year class)										Numbers	TSB	Mean	Prop.
	1	2	3	4	5	6	7	8	9	10+		Biomass	weight	mature*
(cm)	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	(*10-$^{6)}$	(10^6 kg)	(g)	(%)
16.0 – 17.0	2										2	0	22	0
17.0 – 18.0	47										47	1	26	0
18.0 – 19.0	124	2									126	4	31	0
19.0 – 20.0	247	5									252	9	38	0
20.0 – 21.0	195	60									255	11	43	0
21.0 – 22.0	92	88									180	9	50	50
22.0 – 23.0	11	288	7								306	18	60	75
23.0 – 24.0	20	345	66	13							444	29	64	100
24.0 – 25.0		308	150	8	35						501	36	73	100
25.0 – 26.0		177	232	193	82	48					732	60	82	100
26.0 – 27.0		57	359	483	474	73					1446	137	95	100
27.0 – 28.0		20	252	1225	2023	911	173	48			4652	481	103	100
28.0 – 29.0		25	41	1663	4210	2359	698	145	41		9182	1048	114	100
29.0 – 30.0			31	639	4372	3385	1623	373	31		10454	1325	127	100
30.0 – 31.0				252	1835	3634	1562	490	104	13	7890	1086	138	100
31.0 – 32.0				41	785	2017	1206	464	85	41	4639	710	153	100
32.0 – 33.0				51	179	748	772	415	95	17	2277	384	168	100
33.0 – 34.0				13	35	316	556	403	80	54	1457	275	189	100
34.0 – 35.0				27	28	154	156	96	151	46	658	137	208	100
35.0 – 36.0						78	120	109	199	55	561	130	232	100
36.0 – 37.0						15	64	68	37	111	295	73	248	100
37.0 – 38.0						17	18	13	23	78	149	41	272	100
38.0 – 39.0							13	39	21	13	86	25	293	100
39.0 – 40.0								11	15	22	48	15	324	100
40.0 – 41.0								2		35	37	13	347	100
41.0 – 42.0										18	18	9	494	100
42.0 – 43.0										7	7	3	356	100
43.0 – 44.0														
44.0 – 45.0										4	4	1	402	100
TSN (10^6)	2747	3384	3147	6617	16067	15764	8970	4685	2891	514	46705	6069.3		
TSB (10^6 kg)	29.1	94.5	102.6	517.9	1710.5	1855.9	1026.1	435.9	170.3	127.1	6069.9			
Mean length (cm)	19.9	23.8	26.2	28.2	29.1	30.1	30.9	31.8	33.5	36.1	29.5			
Mean weight (g)	39.4	68.7	90.3	112.4	121.7	134.9	147.4	162.9	193.1	246	130			
% mature*	15	85	100	100	100	100	100	100	100	100				
% of SSB	15	85	100	100	100	100	100	100	100	100				

* Percentage of mature individuals per age or length class

Table 5. Country and vessel specific details, March-April 2009.

	Fridtjof Nansen	Celtic Explorer	Brennholm	Magnus Heinason	Tridens
Trawl dimensions					
Circumference (m)	716	768	2400	640	1120
Vertical opening (m)	50	50	140	40	30-70
Mesh size in codend (mm)	16	20	40	40	±20
Typical towing speed (kn)	3.2-4.2	3.5-4.0	3.5-4.0	3.0-4.0	3.5-4.0
Biological sampling					
Length Only					200
Lenth/Weight	200	100	70	100	
Length/Weight/Sex/Maturity	100	50	30	100	50
Hydrographic sampling					
CTD Unit	SBE911	SBE911	SBE911	SBE911	SBE911
Standard sampling depth (m)	1000	1000	1000	1000	1000

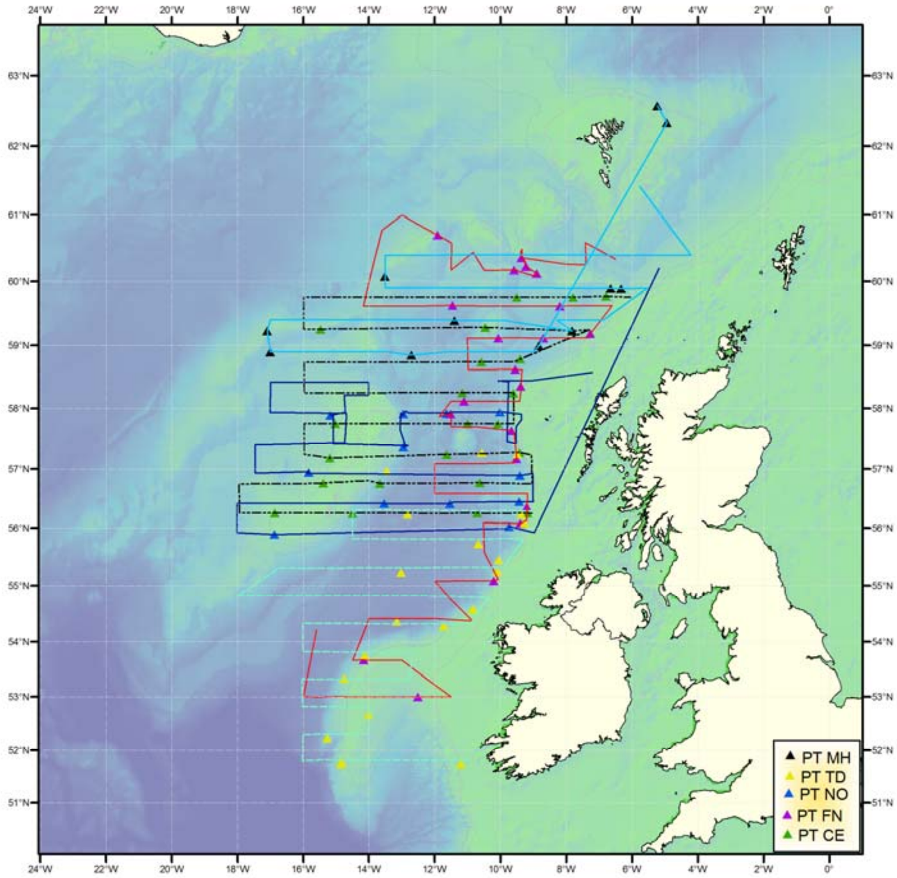


Figure 1. Combined vessel cruise tracks and trawl stations. PT: Indicates pelagic trawl station. CE: Celtic Explorer; MH: Magnus Heinason; TD: Tridens; FN: Fridtjof Nansen: NO: Brennholm. March-April 2009.

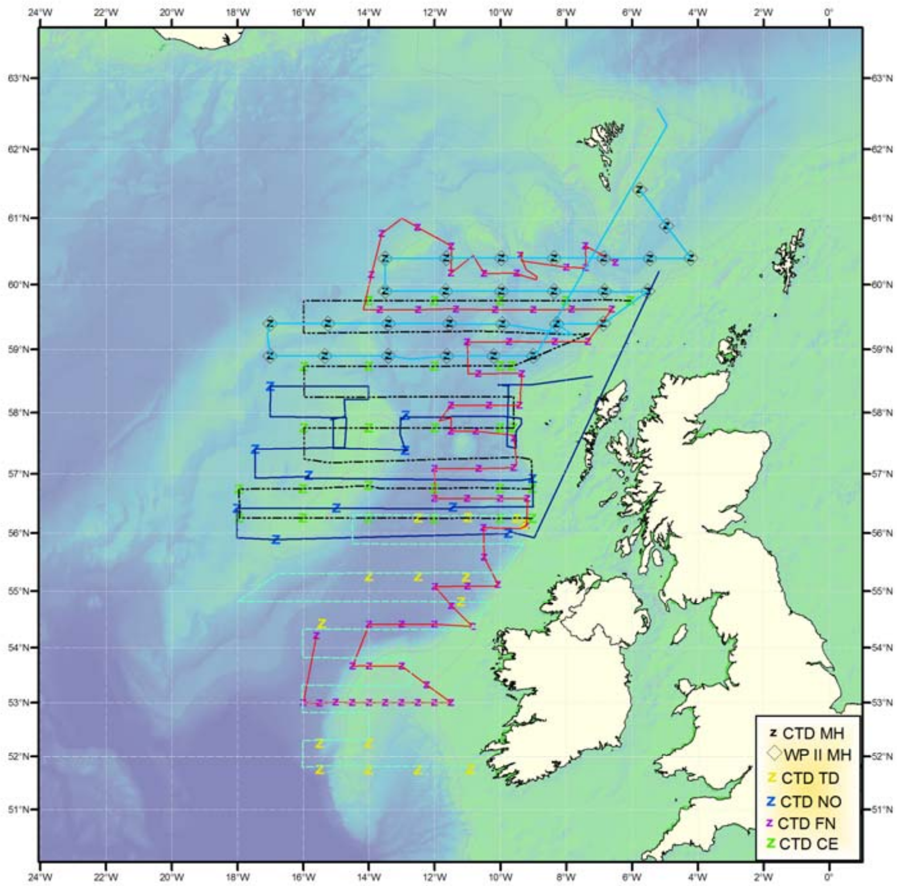


Figure 2. Combined CTD stations overlaid onto vessel cruise tracks. WP II: Indicates plankton trawl. CE: Celtic Explorer; MH: Magnus Heinason; TD: Tridens; FN: Fridtjof Nansen: NO: Brennholm. March-April 2009.

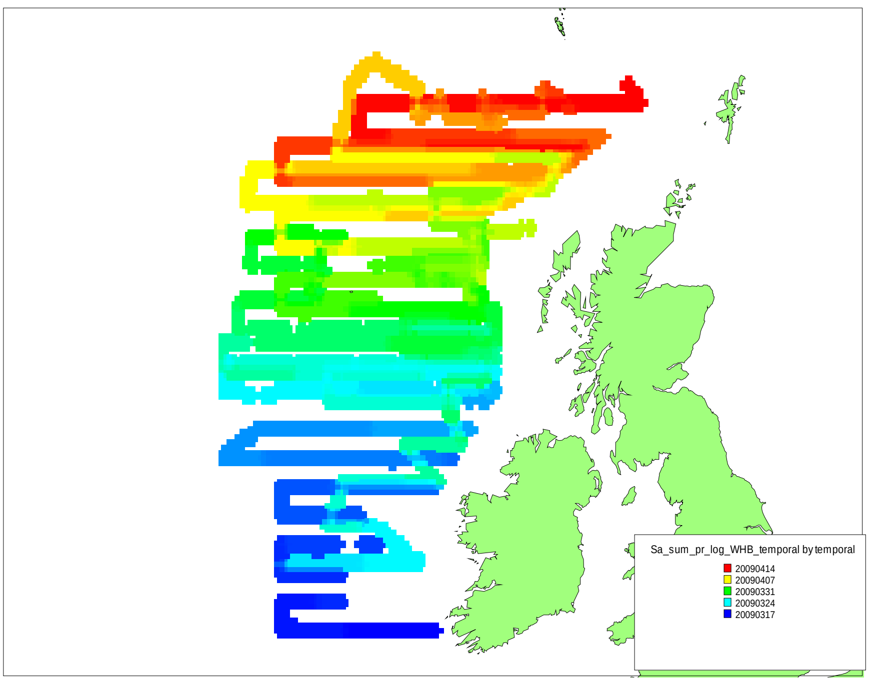
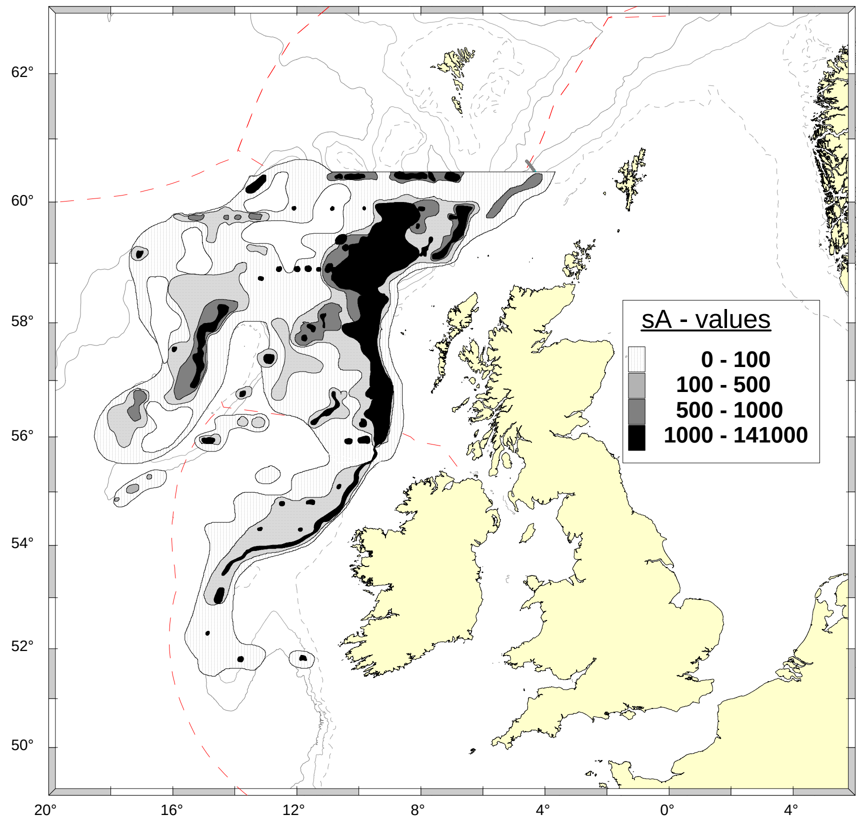


Figure 3. Temporal progression of the combined survey, 17 March–14 April 2009.



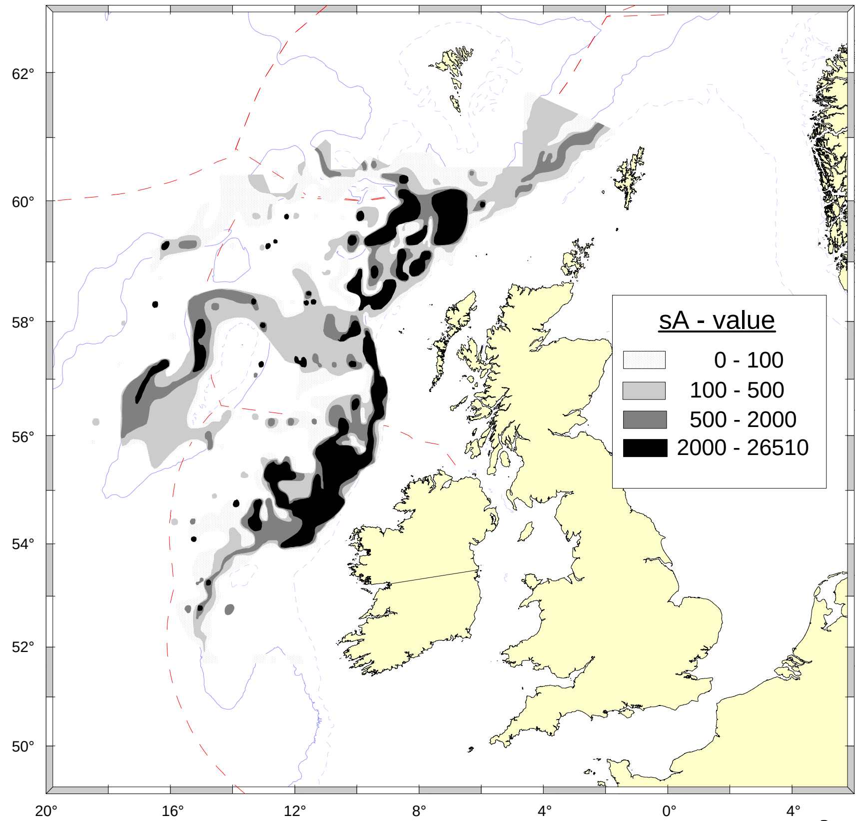


Figure 4. Schematics maps of combined blue whiting acoustic density (s_A, m^2/nm^2) in March-April 2008 (lower panel) and 2009 (upper panel).

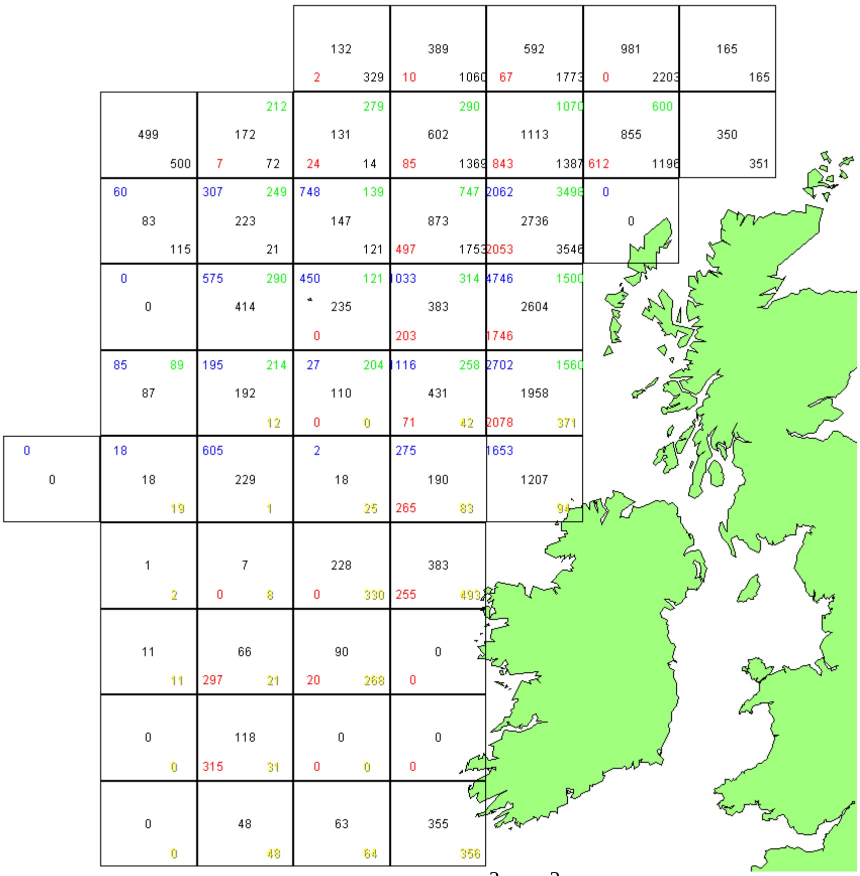


Figure 5. Mean blue whiting acoustic density (s_A, m^2/nm^2) for all vessels combined and for each individual vessel: Celtic Explorer: green, Magnus Heinason: grey, Netherlands: yellow, Fridtjof Nansen: red, Brennholm: blue. Combined totals are displayed in the middle of the square in bold black. March-April 2009.

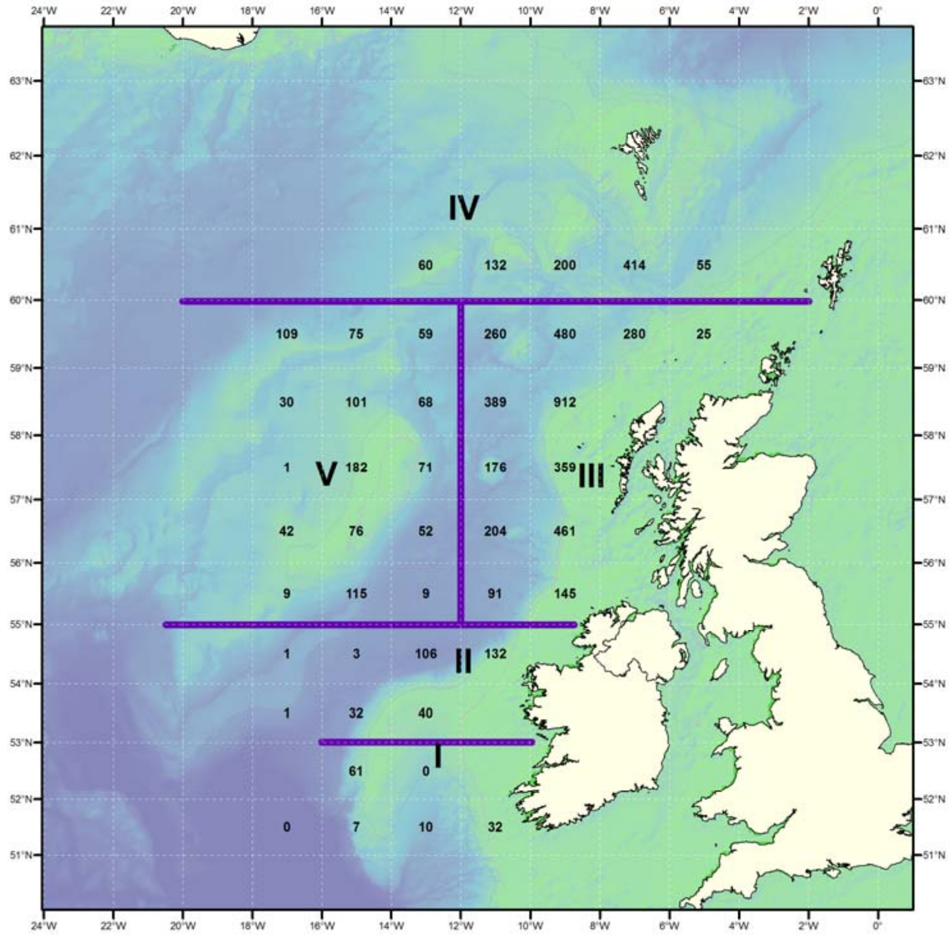
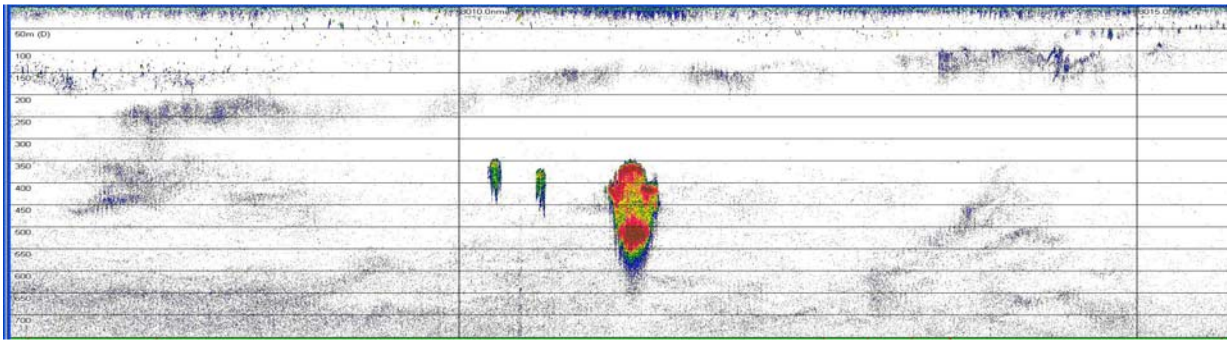
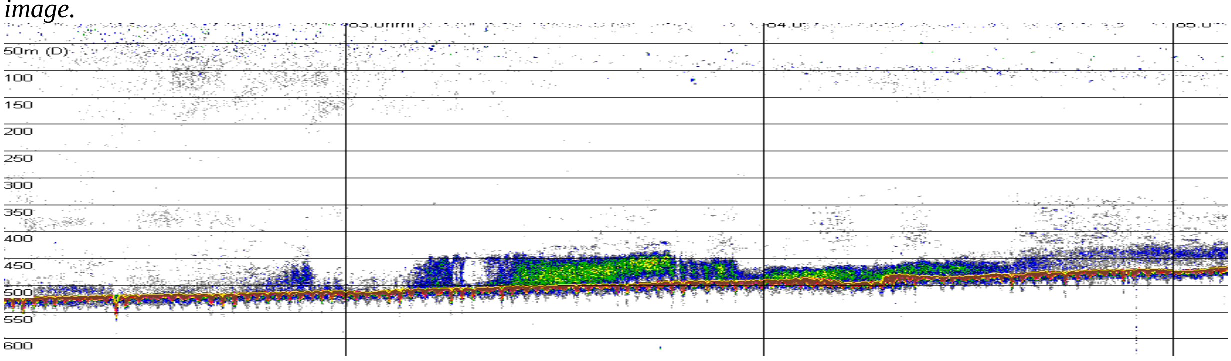


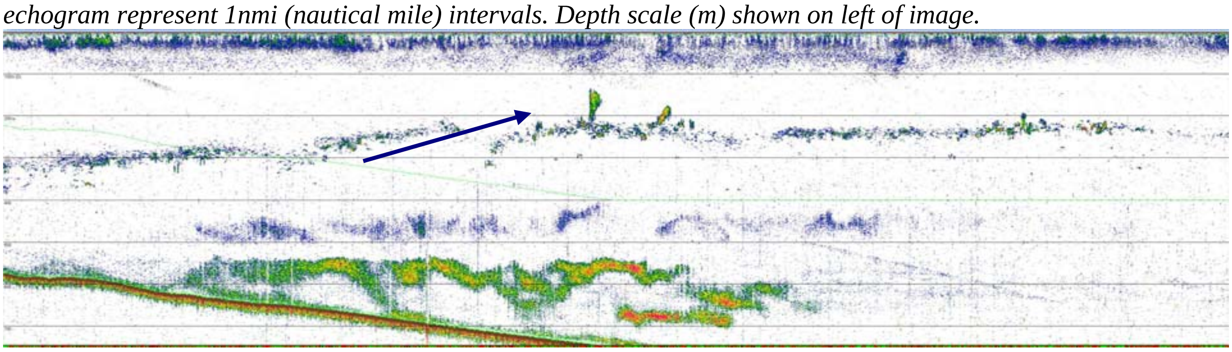
Figure 6. Blue whiting biomass in 1000 tonnes by sub-area as used in the assessment. March-April 2009.



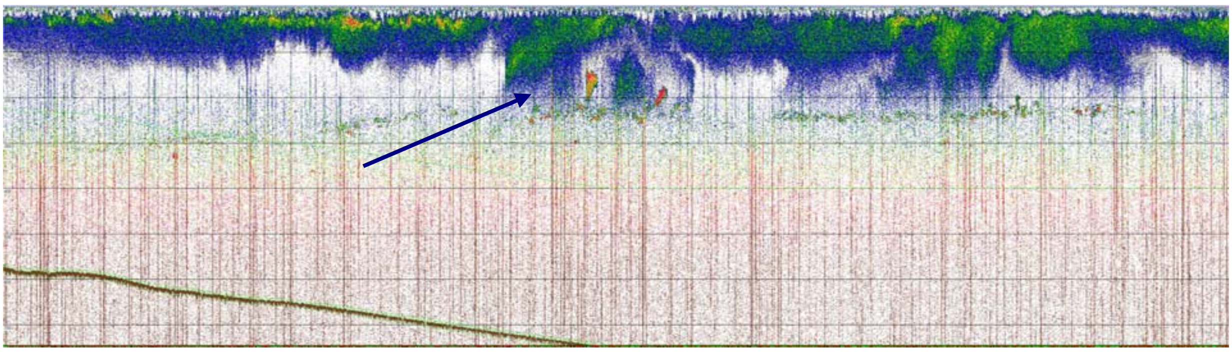
a). The *highest density schools of blue whiting recorded by the RV Magnus Heinason during the combined International survey. NASC value 140,578. Located on the northeast of the Rosemary Bank (55°54N & 10°40W). Vertical bands on echogram represent 1nmi (nautical mile) intervals. Depth scale (m) shown on left of image.*



b). *Low to medium density schools of blue whiting containing juveniles, typical of those encountered along the south-western slopes of the Rockall Bank (56°43N & 15°23W) by the RV Celtic explorer. Vertical bands on echogram represent 1nmi (nautical mile) intervals. Depth scale (m) shown on left of image.*



c). *Echograms recorded by the Tridens at 38 kHz clearly shows a number of distinct fish layers, with plankton from 0 to 100m,a layer containing mackerel and mesopelagics from 150 to 300m and blue whiting from 500 to 700m.*



d) The same echogram at 120 kHz, organisms can only be resolved to a depth of around 250m before noise becomes the dominant part of the return signal, completely obscuring any organisms present.

Figure 7. Blue whiting echograms encountered by the Magnus Heinason during the survey (a), Celtic Explorer (b) and mackerel echograms recorded by Tridens (c-d). March-April 2009.

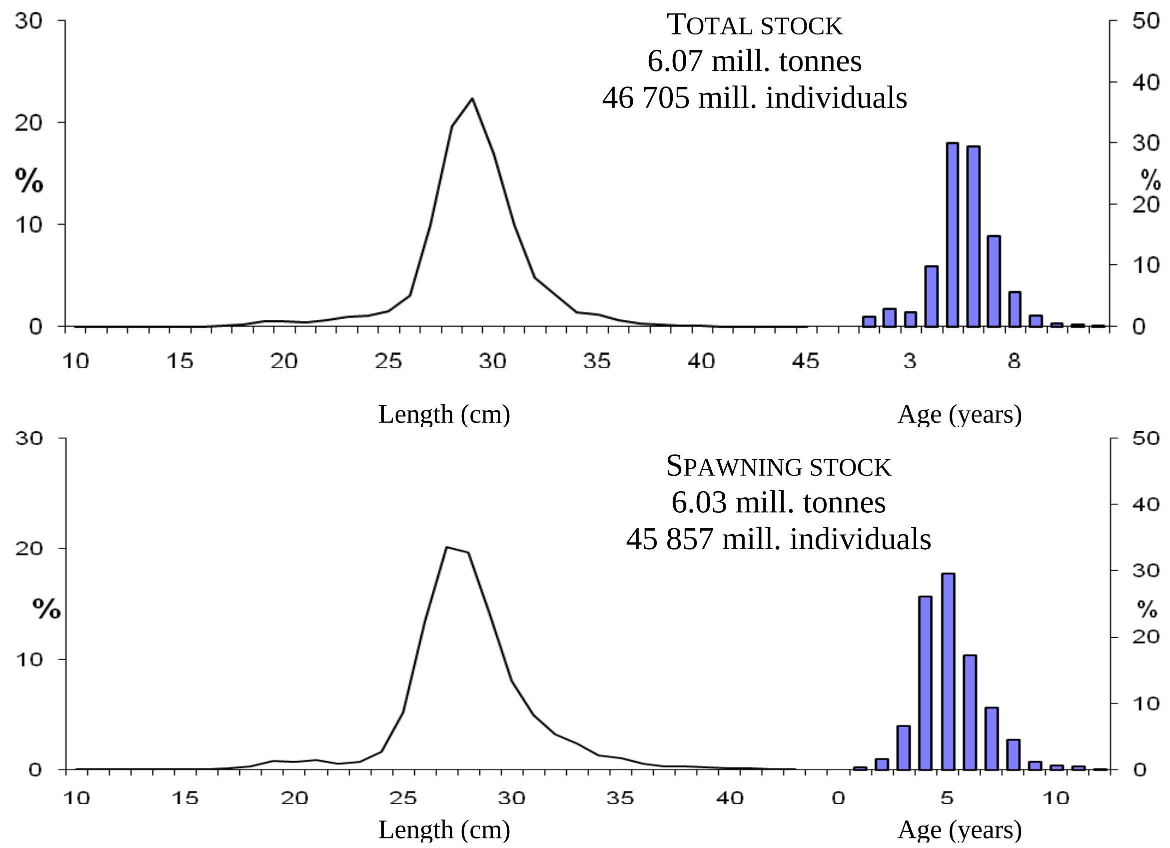


Figure 8. Length and age distribution in the total and spawning stock of blue whiting in western waters. March-April 2009.

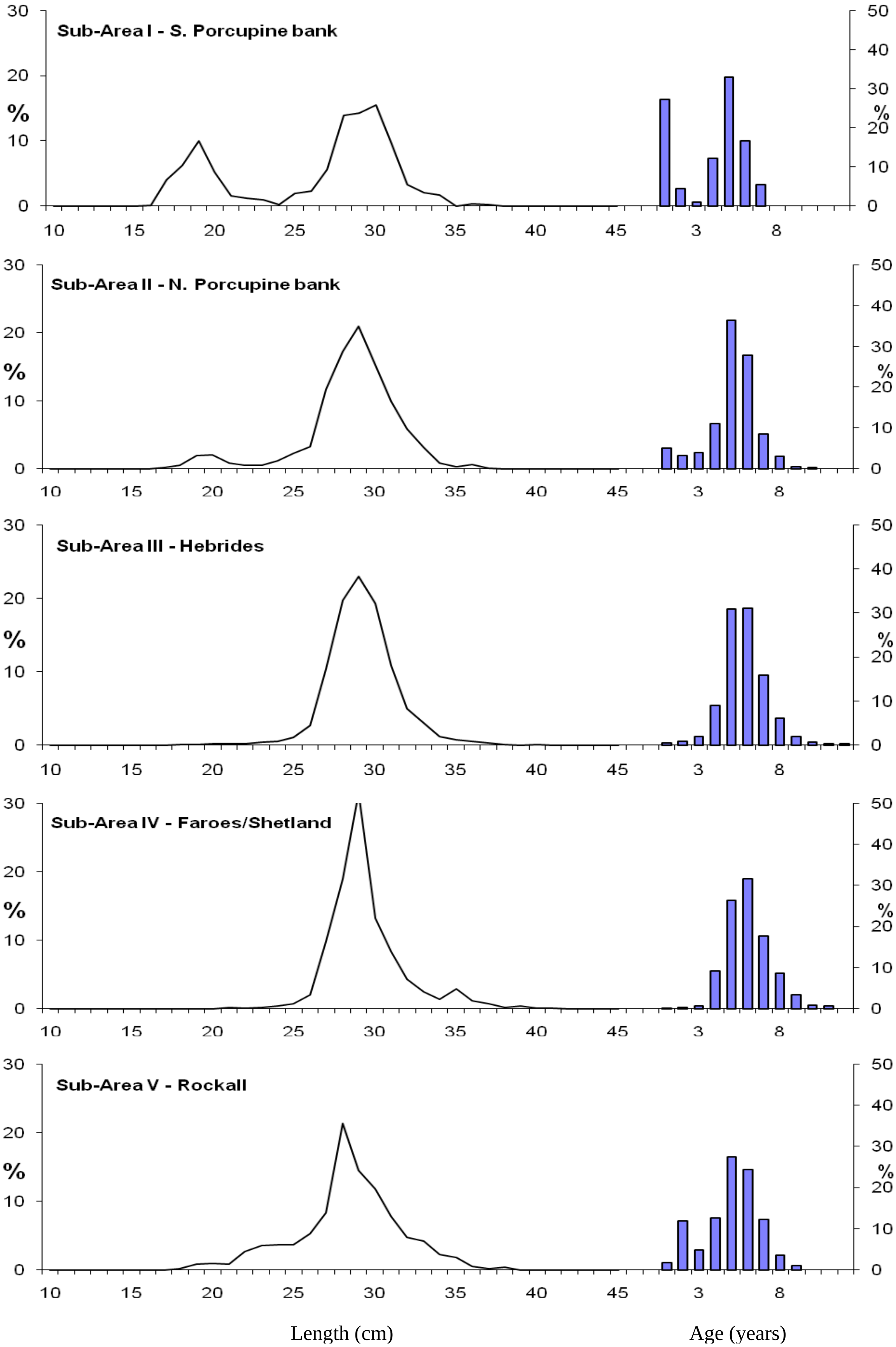


Figure 9. Length and age distribution (numbers) of blue whiting by sub-areas (I–V). March-April 2009.

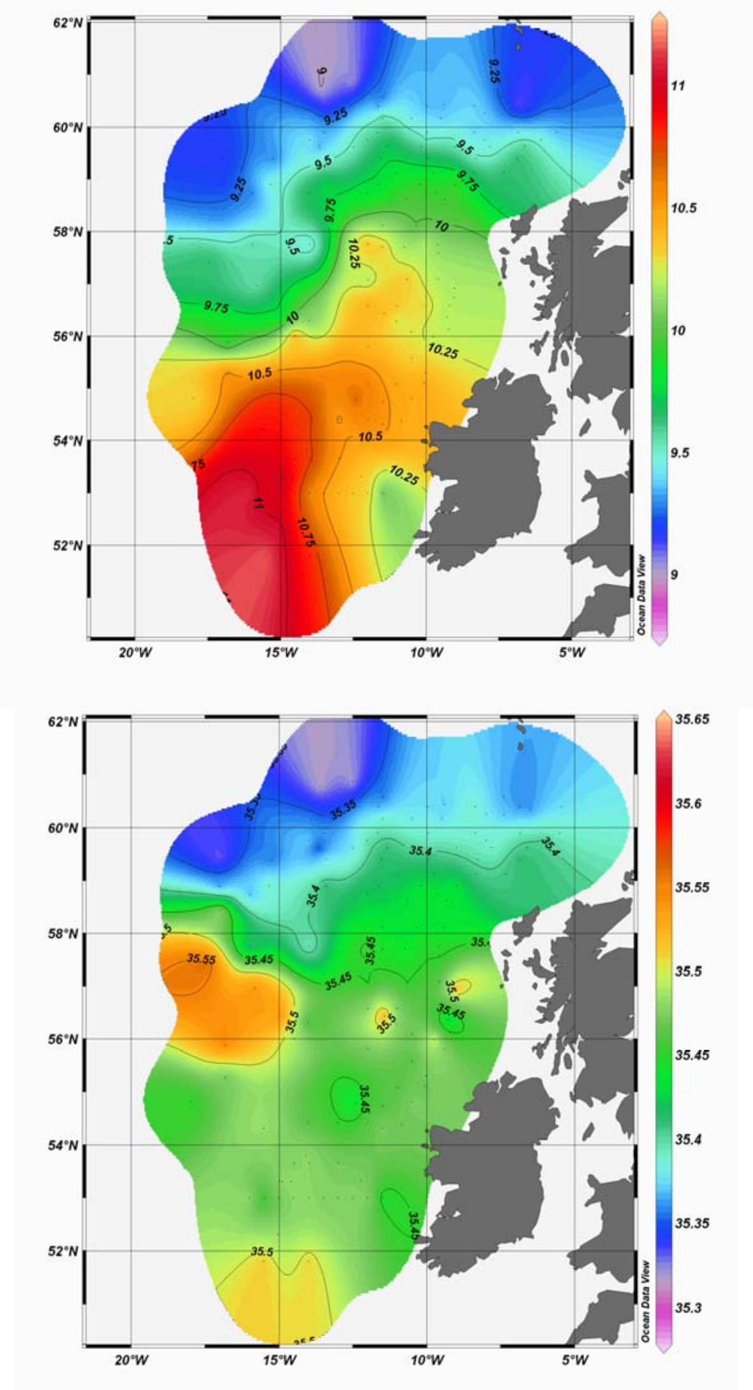


Figure 10. Horizontal temperature (top panel) and salinity (bottom panel) at 10m subsurface as derived from vertical CTD casts. March-April 2009.

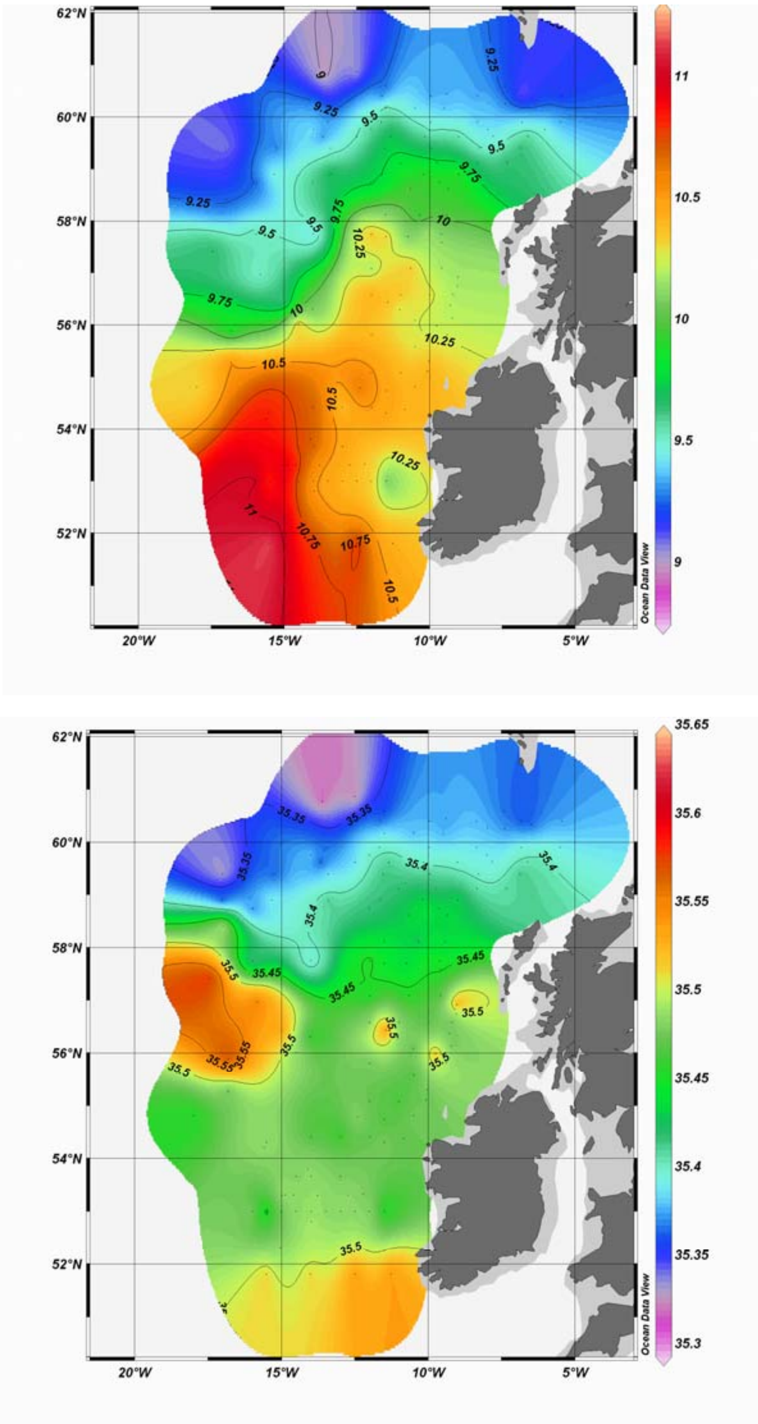


Figure 11. Horizontal temperature (top panel) and salinity (bottom panel) at 50m as derived from vertical CTD casts. March-April 2009.

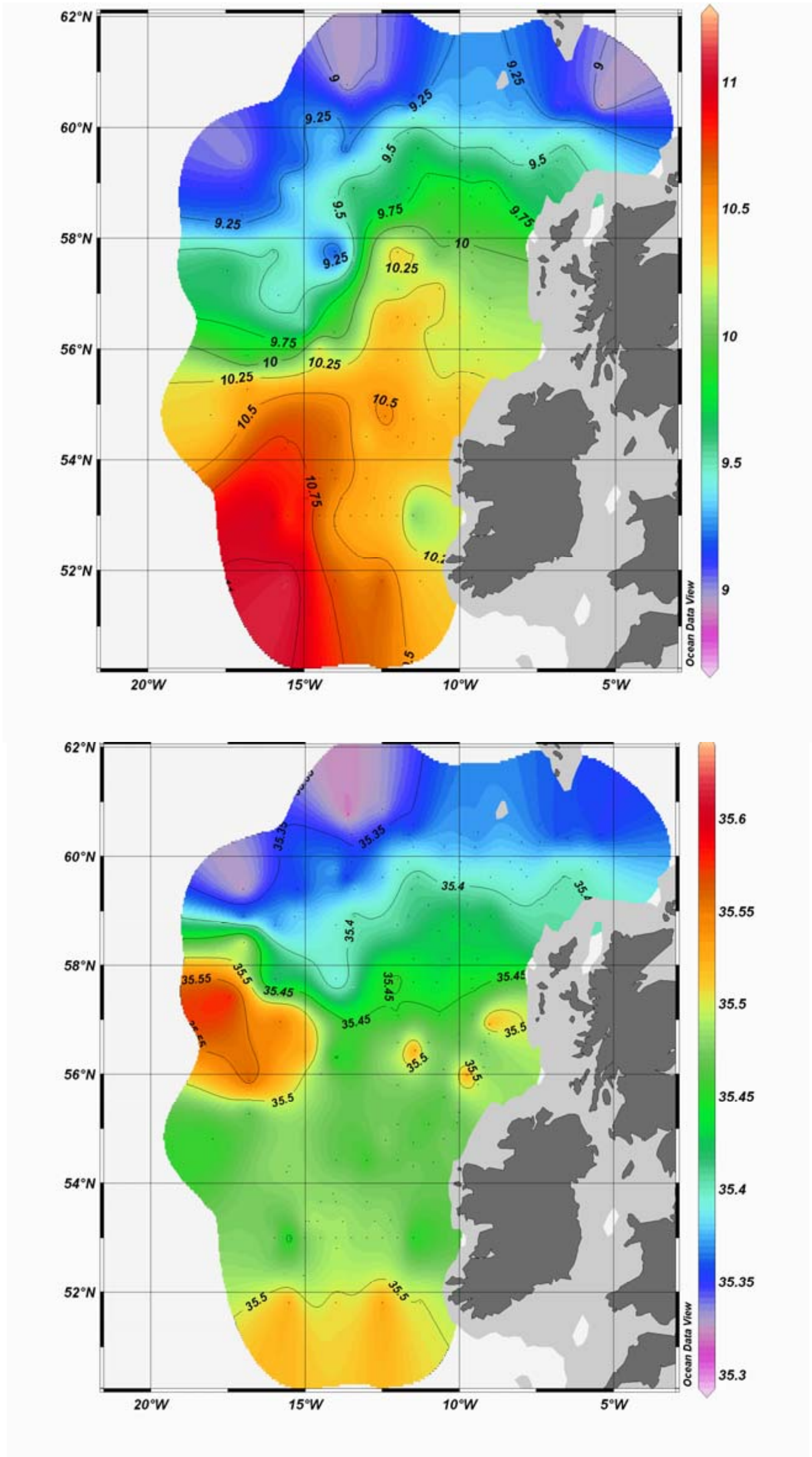


Figure 12. Horizontal temperature (top panel) and salinity (bottom panel) at 100m as derived from vertical CTD casts. March-April 2009.

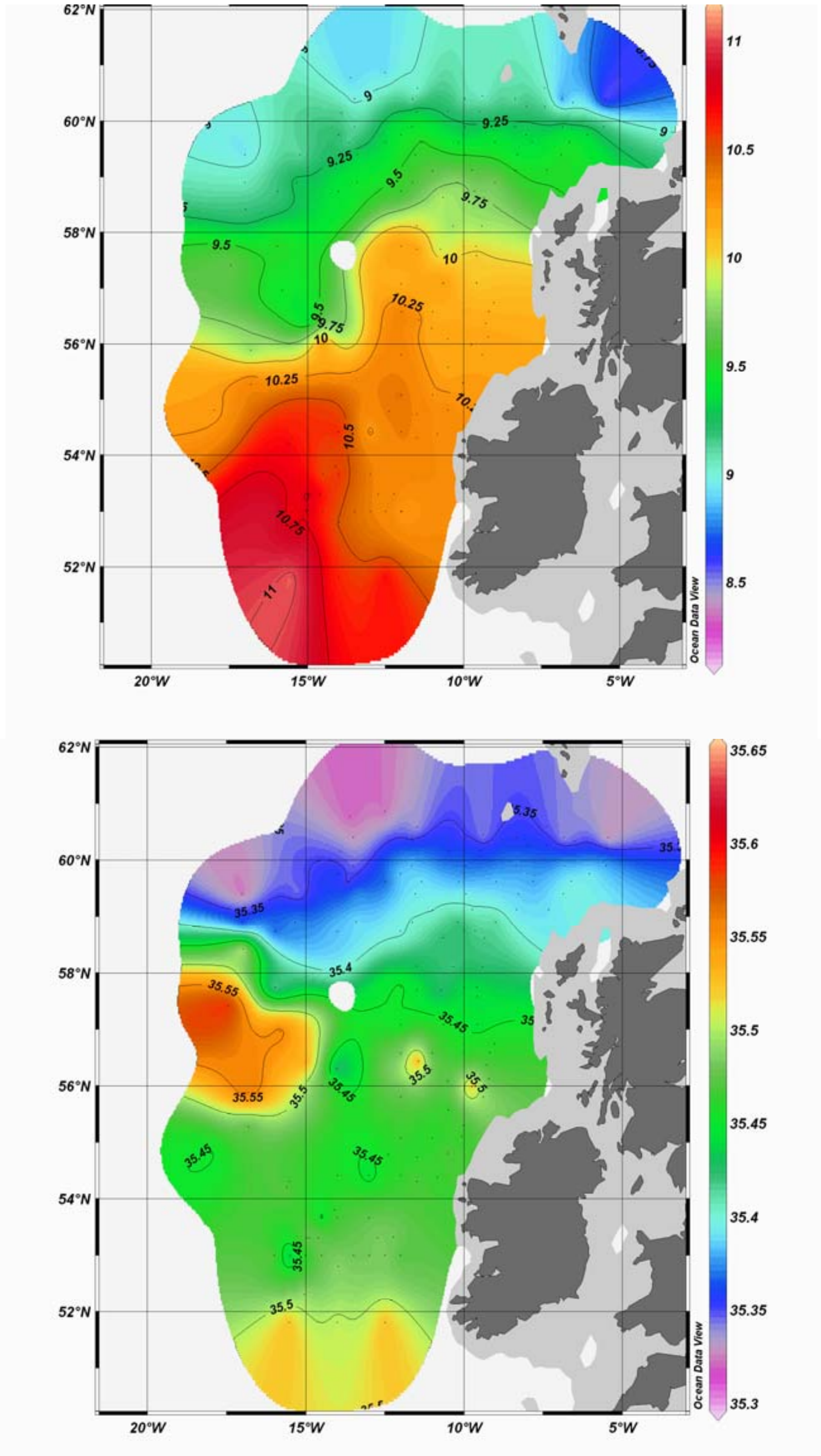


Figure 13. Horizontal temperature (top panel) and salinity (bottom panel) at 200m as derived from vertical CTD casts. Yellow circles indicate CTD positions. March-April 2009.

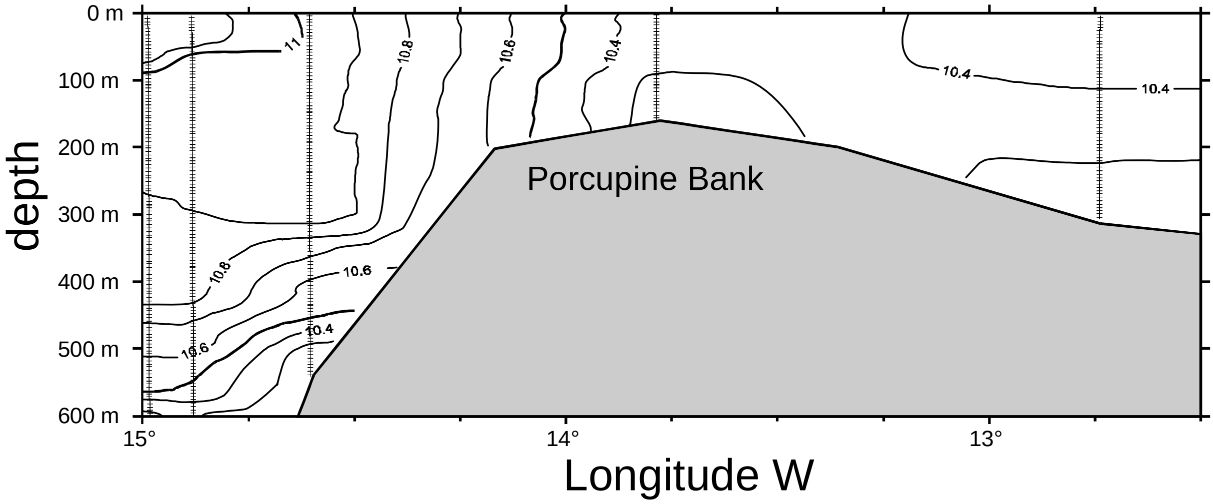


Figure 14. Temperature distribution along a transect across Porcupine Bank in the upper 600 m during the 2009 Hydroacoustic Survey on Blue Whiting with Dutch RV Tridens

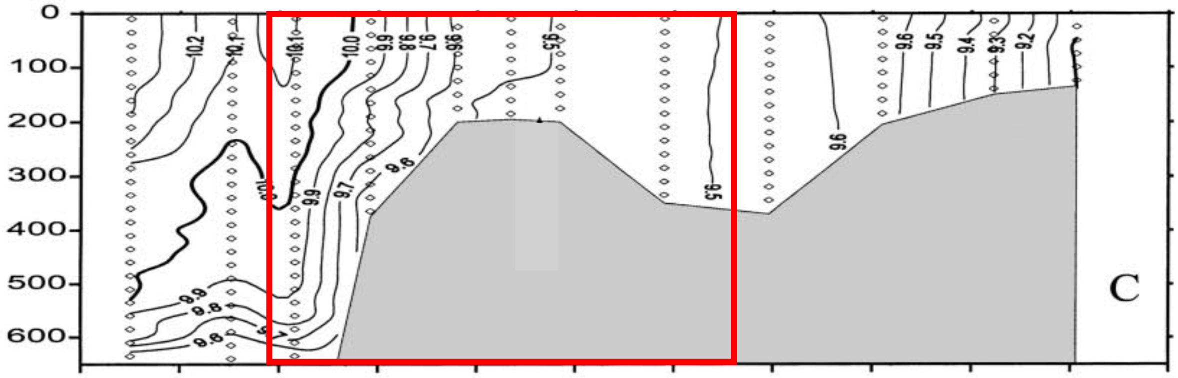


Figure 15. Temperature distribution along a transect across Porcupine Bank in the upper 650 m during the 1994 survey on blue whiting eggs and larvae with German RV Heincke. The red box indicates the area that has been sampled with CTD probes during the 2009 Tridens cruise.

Appendix 1. Inter-calibration between R/V Celtic Explorer and R/V Magnus Heinason

Acoustic inter-calibration between R/V Celtic Explorer and R/V Magnus Heinason was conducted on 9 April at 06:00 to the northeast of the Rosemary Bank at position 59º 14N & 008º 21W. The first 10nmi transect was conducted with the M. Heinason acting as the lead vessel cruising at 8 knots in a south easterly direction. A second 10nmi transect was carried out with the Explorer as the lead vessel. Weather conditions were moderate with winds of 20-25 knots from the SE and a northerly swell of 2-2.5 m.

The main acoustic features in the area were (1) patchy schools of blue whiting in depths between 360 and 420 metres recorded intermittently throughout out the exercise, (2) a layer of presumed macro-zooplankton from depth 300 metres downward, partly mixed with the blue whiting layer, and (3) plankton and mesopelagic fish, in the uppermost 200 metres. The exercise was carried out based on the acoustic registrations of blue whiting only.

The inter-calibration was the run over 20nmi over 2 transects between 06:00-09:25 GMT. Vessels were cruising SSE at parallel courses, with the distance between the tracks being about 0.5 nm to take best advantage of the weather conditions.

Data analysis focused on acoustic densities (c, m^2/nm^2) allocated to blue whiting. On both vessels the routine procedures were followed for scrutinizing the data. Figure 1 shows acoustic densities recorded by the two vessels allocated to blue whiting. The recordings show variable agreement. Overall mean s_A values observed by both vessels were relatively low. The Magnus Heinason tended to record much higher acoustic densities during the first 1-9nmi than the Explorer on what appears to be similar registrations. At the end of the first transect the Celtic Explorer recorded its highest registration during the exercise whereas the Magnus Henson reported a zero value for the same log interval. During the first section of the second transect the Magnus Heinason recorded a single registration over 6 miles whereas the Celtic Explorer low but consistent values. Agreement was more closely aligned from 17-20nmi. Vessel cruise tracks are closely aligned for both vessels each of the 10nmi transects (Figure 2). The degree of variability between vessels over a closely aligned cruise track may be accounted for to a degree by spatial heterogeneity of the patchy schools encountered during the exercise.

At the end of the acoustic inter-calibration a comparative trawl exercise was undertaken. Both vessels turned and towed in parallel over the reciprocal course at a distance of about 0.5 nm apart. Celtic Explorer actively towed for 20 minutes at depths of 410–460 m and caught 400 kg of blue whiting. Magnus Heinason towed in the same depth for the same time and caught 7 kg of blue whiting.

The blue whiting in the catch of Celtic Explorer were larger overall as (mean length: 30.30.cm, range 22.5-37 cm) compared to the blue whiting in the catch of Magnus Heinason (mean length: 28.25cm, range 20-35cm) as shown in Figure 3. It is difficult to draw any conclusions from the trawl data due to the large difference in the weight of the catch. As described earlier the distribution of schools within the area was patchy. In this case it appears that the Explorer encountered one of these schools and the Magnus Heinason did not.

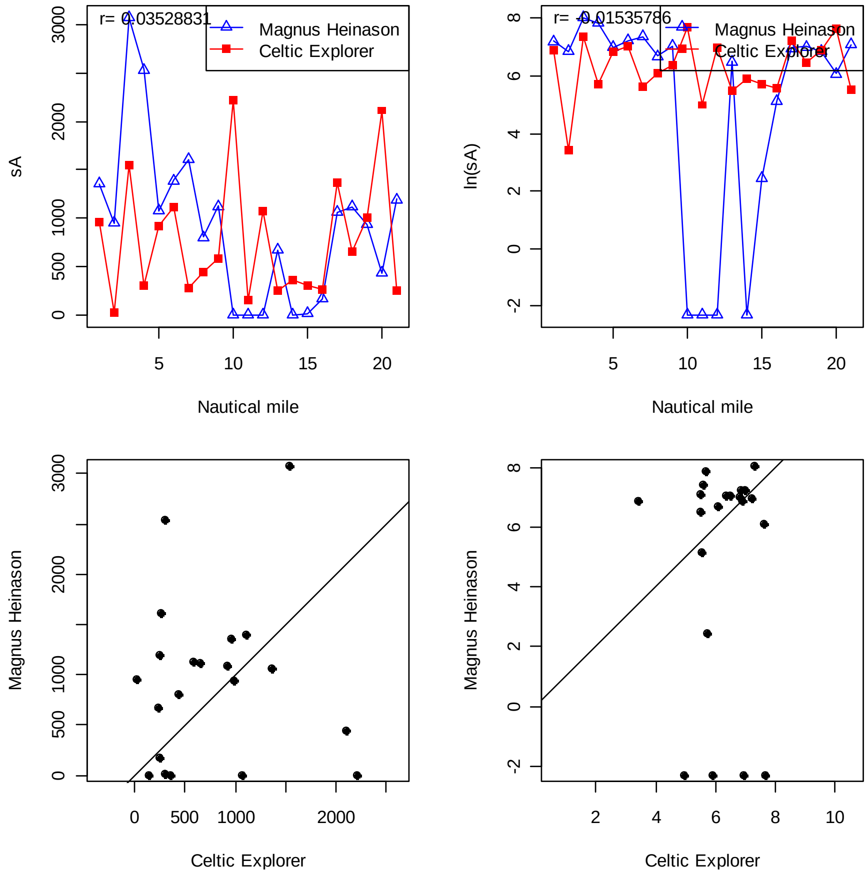


Figure 1. Comparison of blue whiting acoustic densities recorded by Magnus Heinason (open triangles) and Celtic Explorer (squares). The lower panels give same data as scatterplots. The diagonals are drawn as continuous lines.

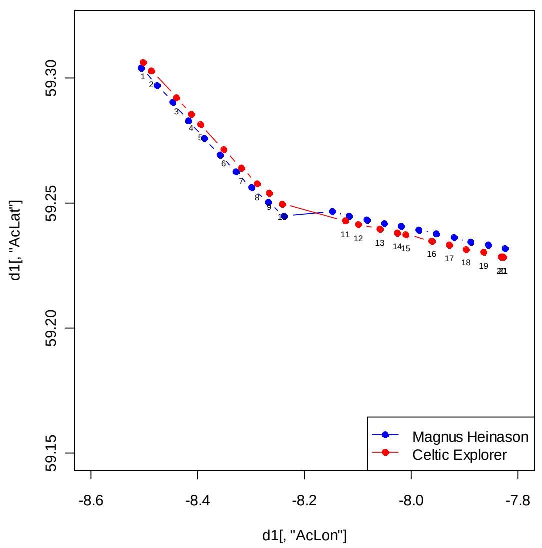


Figure 2. Intercalibration track followed by the Magnus Heinason (blue diamonds) and Celtic Explorer (red diamonds).

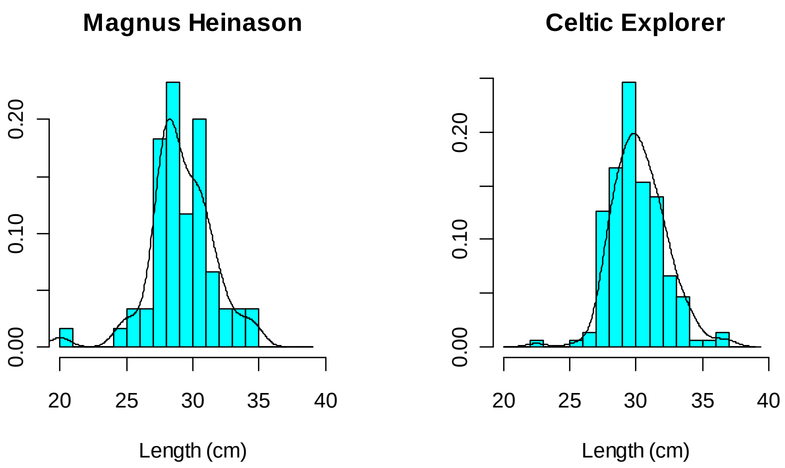


Figure 3. Length distributions from the trawls hauls by Magnus Heinason (mean length 28.25cm) and Celtic Explorer (mean length 30.30cm). Smoothing is obtained by normal kernel density estimates.

Appendix 2. Uncertainty in the acoustic observations and its implications on the stock estimate

Mikko Heino, Institute of Marine research & University of Bergen, Norway

The exercise to estimate uncertainty in acoustic blue whiting observations and the consequences of this uncertainty to stock estimates is repeated using the same procedure as in previous years (Appendix 3 in Heino et al. 2007 and Appendix 4 in O'Donnell et al. 2008).

For the purpose of calculating stocks estimates, acoustic data (acoustics density (s_A) representing blue whiting, in m^2/nm^2) from each vessel are expressed as average values over 5 nm stretches of survey track. Acoustic density for each survey stratum is calculated as an average across all observations within a stratum, weighted by the length of survey track behind each observation (some observations represent more or less than 5 nm). Normally, these values are then converted to stratum-specific biomass estimates based on information on mean length of fish in the stratum and the assumed acoustic target strength; the total biomass estimate is the sum of stratum-specific estimates. Here it is not attempted to repeat the whole estimation procedure, but instead uncertainty in global mean acoustic density estimate is characterized. Since mean size of blue whiting does not vary very much in the survey area, uncertainty in mean acoustic density should give a good, albeit conservative, estimate of uncertainty in total stock biomass.

Bootstrapping is used here to characterize uncertainty in the mean acoustic density. Bootstrapping is done by stratum, treating observations from all vessels equally and using lengths of survey track behind each observation as weights when calculating mean density. With 1000 such bootstrap replicates for each stratum, 1000 bootstrap estimates of mean acoustic density, weighted by the stratum areas, are calculated. Bootstrapped mean acoustic density is the mean of these 1000 bootstrap estimates, and confidence limits can be obtained as quantiles of that distribution.

Figure 1 shows the results of this exercise with the data from the 2009 survey as well five earlier international surveys. Mean acoustic density over the survey area is 378 m^2/nm^2, with 95% confidence interval being 334…424 m^2/nm^2. Relative to the mean, the approximate 95% confidence limits are –11%...+12%, and 50% confidence limits are –4.3%...+4.1%. This is similar level of acoustic uncertainty as observed in 2004–2006 and 2008, but much less as observed in 2007. This is caused by a few very high density observations in 2007, with three highest values accounting for more than 20% of total cumulative acoustic density. In other years there are no observations that are as influential.

Figure 2 summarizes the results and puts them in the biomass context. The results clearly show that the observed decline in biomass from 2008 to 2009 is more than could be expected from uncertainty arising from spatial heterogeneity. In other words, within the considered domain of uncertainty, the decline is statistically significant. Similarly, one can conclude with reasonable certainty that the estimate for 2009 is the lowest one in the time series.

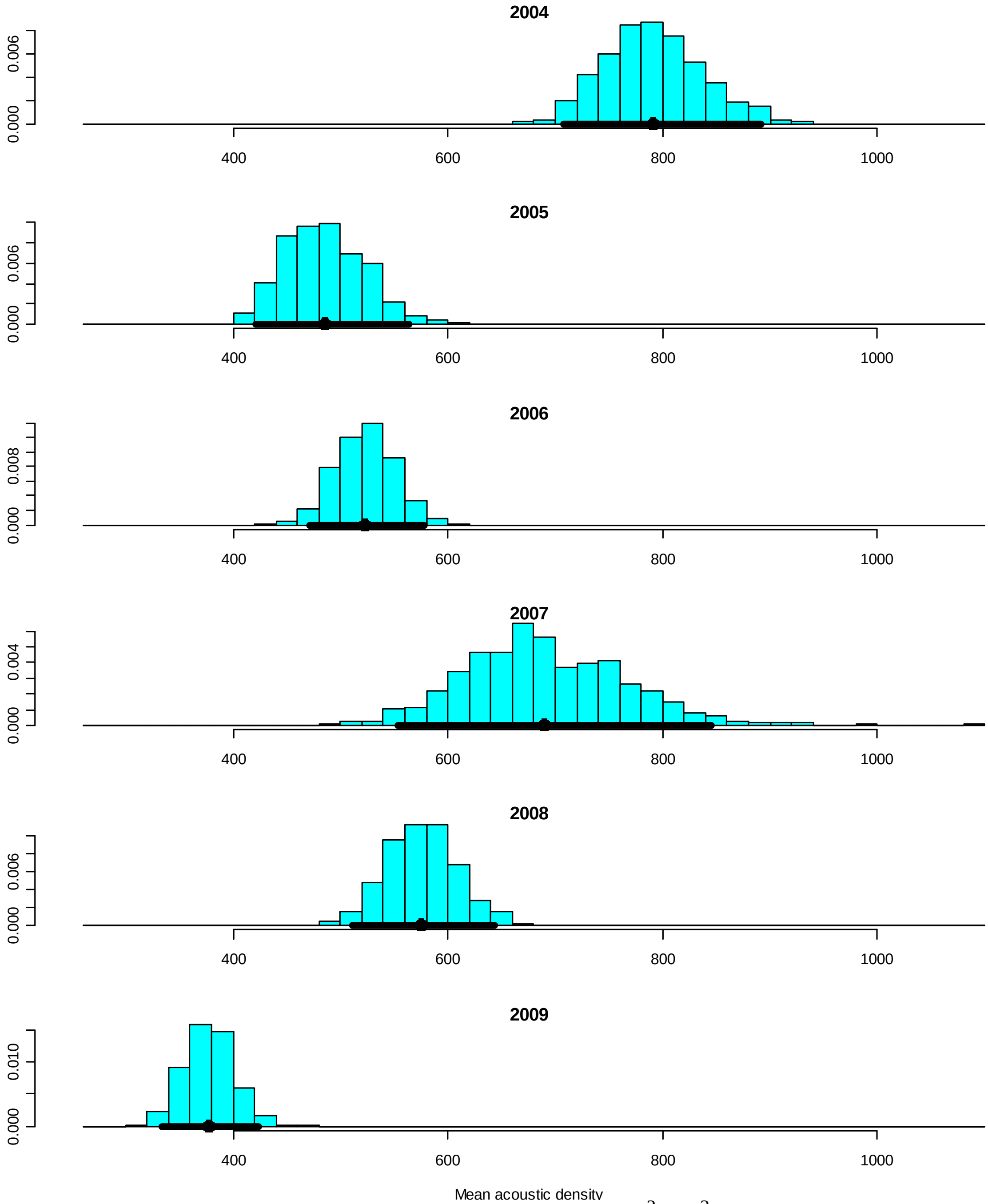


Figure 1. Distribution of mean acoustic density (in m^2/nm^2) based on 1000 bootstrap replicates of acoustic data from blue whiting surveys. Mean acoustic density is indicated with a black dot on the x-axis, while the horizontal bar shows 95% confidence limits.

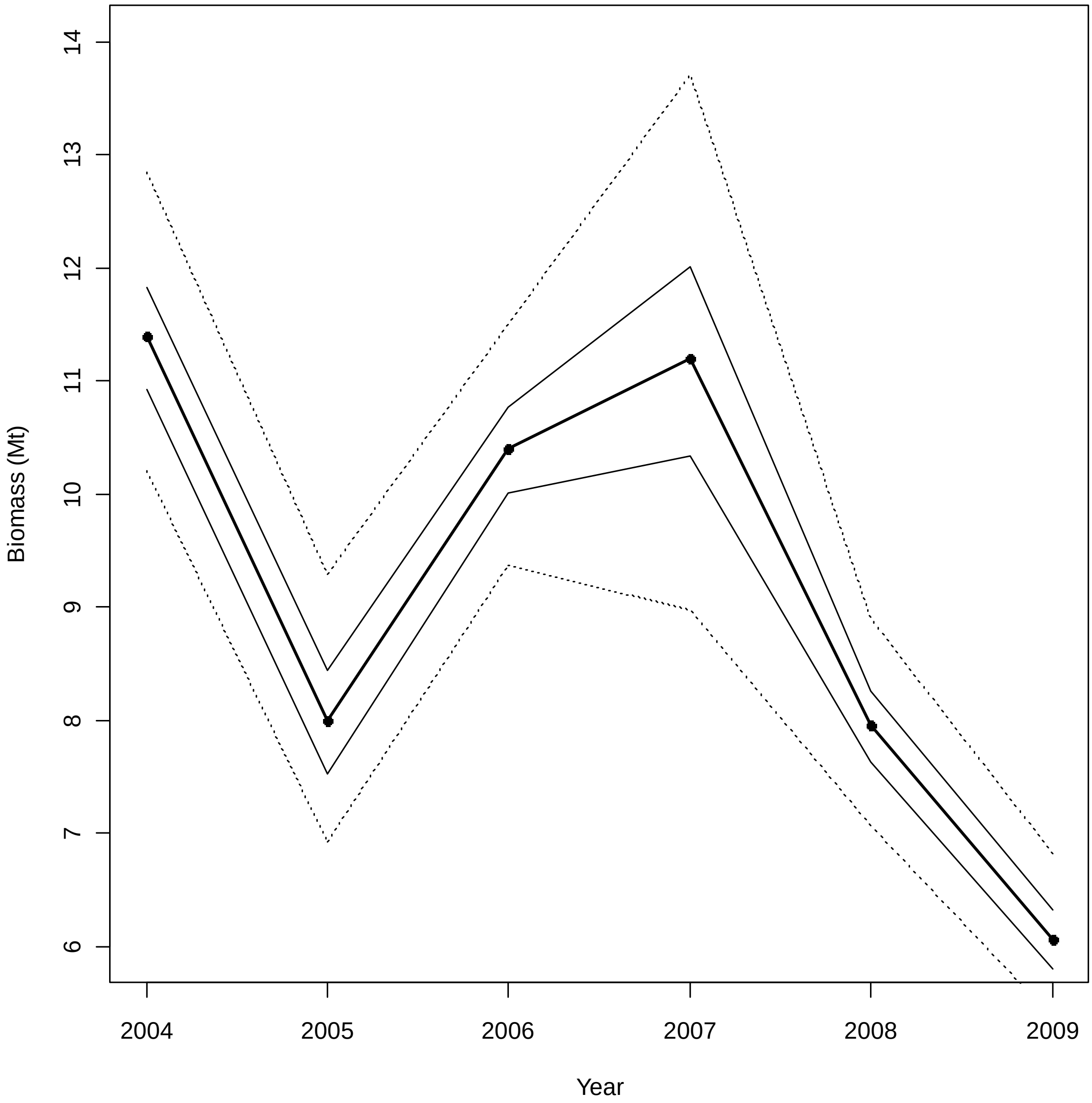


Figure 2. Approximate 50% and 95% confidence limits for blue whiting biomass estimates. The confidence limits are based on the assumption that confidence limits for annual estimates of mean acoustic density can be translated to confidence limits of biomass estimates by expressing them as relative deviations from the mean values. These confidence limits only account for spatio-temporal variability in acoustic observations.

Appendix 3. Review of age determination of blue whiting by national participants.

A review in the consistency of age readings was carried out by Øyvind Tangen using the data collected during the 2009 survey. Results show close agreement between all participants through ages 1-6 year. For older age classes 7-11 years some anomalies were observed with readings from the Netherlands and the Faroes.

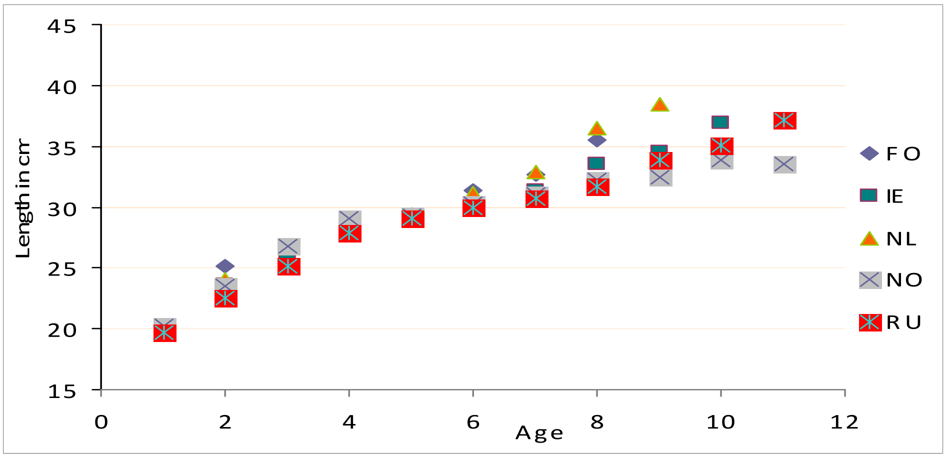


Figure 1. Profile of national age estimates as determined from otolith reading of trawl samples carried out during the blue whiting survey 2009.

Annex 3: International ecosystem survey in the Nordic Seas

Working Document

Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys

Torshavn, Faroe Islands, 17–21 August 2009

Working Group on Widely distributed Stocks

ICES, Copenhagen, 2–8 September 2009

INTERNATIONAL ECOSYSTEM SURVEY IN NORDIC SEA IN APRIL – MAY 2009

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RV Johan Hjort

Bram Couperus[6], Mathias Kloppmann[8], Karl-Johan Stæhr[3], Ryan Saunders[1]
RV Dana

Guðmundur J. Óskarsson[7], Sveinn Sveinbjörnsson[7]
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Introduction

In May-June 2009, five research vessels; RV Dana, Denmark (joined survey by Denmark, Germany, Ireland, The Netherlands, Sweden and UK), RV Magnus Heinason, Faroe Islands, RV Arni Friðriksson, Island, and RV Johan Hjort, Norway and RV Fridjof Nansen, Russia participated in the International ecosystem survey in the Nordic Seas. The survey area was split into three Subareas: Area I, Barents Sea area, Area II, Northern and central Norwegian Sea Area, and Area III, the South-Western Area (Figure 1). The aim of the survey was to cover the whole distribution area of the Norwegian Spring-spawning herring with the objective of estimating the total biomass of the herring stock, in addition to collect data on plankton and hydrographical conditions in the area. The survey was initiated by the Faroes, Iceland, Norway and Russia in 1995. Since 1997 also the EU participated (except 2002 and 2003) and from 2004 onwards it was more integrated into an ecosystem survey. This report is based on national survey reports from each survey (Dana: Anonymous 2009a, Magnus Heinason: FAMRI 2009, Arni Friðriksson: MRI 2009 Fridtjof Nansen: PINRO 2009 and Johan Hjort: not (yet) available).

Material and methods

Coordination of the survey was initiated at the meeting of the Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys (PGNAPES, formerly Planning Group on Surveys on Pelagic Fish in the Norwegian Sea) in August 2008 (ICES 2008/RMC:05), and continued by correspondence until the start of the survey. The participating vessels together with their effective survey periods are listed in the table below:

Vessel	Institute	Survey period
Dana	Danish Institute for Fisheries Research, Denmark	1/5–28/5
Johan Hjort	Institute of Marine Research, Bergen, Norway	30/4–2/6
Fridtjof Nansen	PINRO, Russia	16/5–7/6
Magnus Heinason	Faroese Fisheries Laboratory, Faroe Islands	29/4–13/5
Arni Friðriksson	Marine Research Institute, Island	27/4–19/5

Figure 2 shows the cruise tracks and the CTD stations and Figure 3 the cruise tracks and the trawl stations. Survey effort by each vessel is detailed in Table 1. Frequent contacts were maintained between the vessels during the course of the survey, primarily through electronic mail.

Periods of bad weather in the western part of the combine survey area hampered survey effort for some periods of time and more frequently than at least in the most recent years, causing either a reduction in vessel speed, or periods where surveying had to be suspended. In the eastern area the weather conditions were excellent during the survey with the exception of some short periods of bad weather in the eastern area.

The survey was based on scientific echosounders using 38 kHz frequency. Transducers were calibrated with the standard sphere calibration (Foote *et al.*, 1987) prior to the survey. Salient acoustic settings are summarized in the text table below.

Acoustic instruments and settings for the primary frequency (boldface).

	Dana	Johan Hjort	Arni Friðriksson	Magnus Heinason	Fridtjof Nansen
Echo sounder	Simrad EK 60	Simrad EK 60	Simrad EK 60	Simrad EK 500	ER 60
Frequency (kHz)	**38**, 18, 120	**38**, 18, 120, 200	**38**, 18, 120	**38**	**38**, 120
Primary transducer	ES38BP	ES 38B - Serial	ES38B	ES38B	ES38B
Transducer installation	Towed body, hull	Drop keel	Drop keel	Hull	Hull
Transducer depth (m)	3 (when hull 6)	8.7	8	3	7
Upper integration limit (m)	5	15	15	7	10
Absorption coeff. (dB/km)		9.6	10	10	10
Pulse length (ms)	Medium	1.024	1.024	Medium	1.024
Band width (kHz)	Wide	2.425	2.425	Wide	2.425
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	21.9	21.9
2-way beam angle (dB)	-20.5	-20.6	-20.9	-20.9	-20.9
Sv Transducer gain (dB)				27.22	27.3
Ts Transducer gain (dB)		27.64	24.64	27.4	27.64
s_A correction (dB)		-0.73	-0.84	None	-0.61
3 dB beam width (dg)					
alongship:	6.8	6.9	7.31	7.05	6.9
athw. ship:	6.86	6.8	6.95	6.83	6.8
Maximum range (m)	750	750	750	750	750
Post processing software	Simrad BI500	LSSS	Simrad BI500	Sonardata Echoview 4.3	FAMAS

Post-processing software differed among the vessels but all participants used the same post-processing procedure, which is according to an agreement at a PGNAPES scrutinizing workshop in Bergen in February 2009 (ICES WKCHOSCRU 2009).

As a general, acoustic recordings were scrutinized with the different softwares (see table above) on daily basis and species identified and partitioned using catch information, characteristic of the recordings, and frequency between integration on 38 kHz and on other frequencies by a scientist experienced in viewing echograms.

All vessels used a large or medium-sized pelagic trawl as the main tool for biological sampling. The salient properties of the trawls are as follows:

	Dana	Johan Hjort	Arni Friðriksson	Magnus Heinason	Fridtjof Nansen
Circumference (m)		586	640	640	560
Vertical opening (m)		25–35	45–50	45–55	40–50
Mesh size in codend (mm)		22	40	40	16
Typical towing speed (kn)		3.0–4.0	3.0–4.0	3.0–4.0	3.5–4.0

Catches from trawl hauls was sorted and weighed; fish were identified to species level, when possible, and other taxa to higher taxonomic levels. Normally a subsample of 50–100 herring and blue whiting were sexed, aged, and measured for length and weight, and their maturity status were estimated using established methods. An additional sample of 50–250 fish was measured for length.

Acoustic estimates of herring and blue whiting abundance were obtained during the surveys. This was carried out by visual scrutiny of the echo recordings using post-processing systems. The allocation of sA-values to herring, blue whiting and other acoustic targets were based on the composition of the trawl catches and the appearance of echo recordings. To estimate the abundance, the allocated sA-values were averaged for ICES-squares (0.5° latitude by 1° longitude). For each statistical square, the unit area density of fish (□A) in number per square nautical mile (N*nm-2) was calculated using standard equations (Foote *et al*., 1987; Toresen *et al*., 1998). Traditionally the following target strength (TS) function has been used:

Blue whiting: TS = 21.8 log(L) – 72.8 dB

Herring: TS = 20.0 log(L) – 71.9 dB.

To estimate the total abundance of fish, the unit area abundance for each statistical square was multiplied by the number of square nautical miles in each statistical square then summed for all the statistical squares within defined subareas and over the total area. Biomass estimation was calculated by multiplying abundance in numbers by the average weight of the fish in each statistical square then summing all squares within defined subareas and over the total area. The Norwegian BEAM software (Totland and Godø 2001) was used to make estimates of total biomass and numbers of individuals by age and length in the whole survey area and within different subareas.

The hydrographical stations by survey are shown in Figure 2. All vessels collected hydrographical data using a SBE 911 CTD.

Results

Hydrography

The temperature distributions in the ocean at selected depths between the surface and 400 m are shown in Figures 4–9.

Temperatures in the surface ranged between < 2°C northeast of Iceland and > 8°C in the southern part of the survey area. The polar front, that separates the warm North Atlantic waters from the cold Arctic waters, was encountered slightly below 65°N east of Iceland extending eastwards towards the 0° Meridian where it turned almost straight northwards up 70°N. North of 70°N was still apparent along the northwestern edge of the survey area. The front was discernible throughout the observed water column but was most pronounced only in the South (Figures 4 – 6), while further north it became apparent only below 100 m depth (Figures 7 – 9).

With depth, temperatures decreased to values < 0°C particularly north and west of the polar front while south and east of it the drop in temperature was not as pronounced. The warmer North Atlantic water formed a broad tongue that stretched far northwards along the Norwegian coast with temperatures > 7 °C in the surface layers (Figures 4 – 5). With increasing depth this core of warm water quickly eroded being more confined to areas closer to the Norwegian coast in the South and forming a narrowband of warmer water centred along the 15° meridian in the North (Figures 6 – 9). Relative to a 15 years long-term mean, from 1995 to 2009, temperatures in 2009 were warmer over most of the Norwegian Sea compared to the long-term-mean. At 100 m depth the difference is about 0 - 0.75°C, dependent on the area, but at the upper 20 m this difference can be 1°C. In the western areas, however, a cooling is observed compared to the mean.

In the Barents Sea the water temperature exceeded the long-term mean values by 0.5 – 1.0 °C practically in all depth layers. Thus, 2009 again falls into the category of warm years for the Barents Sea. However, there were only weak indications of warmer North Atlantic water entering the Barents Sea while temperatures decreased gradually to values < 3°C eastwards (Figures 4 – 9).

Zooplankton

Sampling intensity of plankton and spatial coverage made by the participating vessels are shown in Figure 10. During the International ecosystem survey in the North East Atlantic in 2009 in all 280 plankton stations were conducted. All vessels used WP2 nets (180 or 200 µm) to sample plankton according to the standard procedure for the surveys. The net was hauled vertically from 200 m or the bottom to the surface. All samples were divided in two and one half was preserved in formalin while the other half was dried and weighed. On the Danish and the Norwegian vessels the samples for dry weight were size fractionated before drying. All data obtained by WP2 are presented as g dry weight m^2.

The highest zooplankton biomasses were observed in the eastern and northern Norwegian Sea, while the biomass was low especially in the southwestern and northeastern Norwegian Sea. Sampling stations were relatively evenly spread over the area, and increased ship time compared to previous years facilitated better coverage of most oceanographic regions. Recorded zooplankton biomass in the two areas west and east of 2°W equaled 4.4 and 3.3 g dry weight m^{-2}, while total mean was 3.9 g dry weight m^{-2}.

In the Barents Sea highest zooplankton biomass was observed in the area west of 24°E.

Norwegian Spring-spawning herring

Survey coverage in the Norwegian Sea was considered adequate in 2009. Herring were recorded throughout most of the surveyed area in the Norwegian Sea as shown in Figure 11. The distribution was similar to that observed in 2008 with some minor differences. The highest values were like in 2008 recorded at the eastern edge of the cold waters of the East Icelandic Current. Similarly to last year the recorded concentrations of herring in the central Norwegian Sea were therefore higher compared to the recordings in the southwestern part of the surveyed area. However, there was a slight northeastward displacement reflected in a more northeastern centre of gravity of the acoustic recordings in 2009 as compared to 2008. It was mainly older herring that appeared in the southwestern Icelandic areas (1998, 1999 and 2002 year classes now at-ages 11, 10 and 7).

As in previous years the smallest fish are found in the northeastern area, size and age were found to increase to the west and south (Figure 12).

The herring stock is now dominated by 5 and 7 year old herring (2002 and 2004 year classes) representing 28.5 and 24.9 % in weight, respectively.

The large numbers (biomass) of the 2002 year class recorded this year confirm that this year class is very strong and has now completed its annual migration west and south to join the adult herring in their annual migration. In addition, the numbers for the 2004 year class is high, indicating that this year class is strong and comparable to the 1998 and 1999 year classes.

In the Barents Sea immature herring (Area I see Figure 1) were generally distributed between longitudes 31° E and 23° E and extending about 60 nm offshore. The herring were mostly recorded as single schools mainly in the upper 50 m layer of the water masses. Very often the herring schools were distributed near at a surface of the sea and were inaccessible to registration, but were marked in pelagic trawls. In this connection underestimation immature a herring in the Barents Sea is possible. In eastern part of surveyed area more smaller and young herring dominated as compared to the western part of the Barents Sea.

The herring in the Barents Sea were composed of the many year classes, but 2004, 2005, 2006 and 2007 year classes dominated in this area. There were no strong year classes detected. Herring in the Barents Sea were estimated at 2.6 billion individuals corresponding to a biomass of 0,296 million tonnes (Table 2).

The total number of herring recorded in the Norwegian Sea was 34.5 billion in the northeastern area and 12.6 billion in the southwestern area. This corresponds to a total acoustic herring estimate for the Norwegians Sea and the Barents Sea of 10.7 million tons. This biomass is higher than the estimated biomass in 2008 of 10 million tons.

Blue whiting

The total biomass of blue whiting registered during the May 2009 survey was 0.9million tons (Table 3), which is very low (the corresponding estimates from 2006, 2007 and 2008 were 6.2, 2.4 and 1.1 mill. tons, respectively). The stock estimate in number for 2008 is 5.7 billion, which is about 70 % of the 2008 estimate. The reduction in estimate is seen in all ages, but most severe for ages 2–5.

An estimate was also made from a subset of the data; A "standard survey area" between 8°W–20°E and north of 63°N have been used as an indicator of the abundance of blue whiting in the Norwegian Sea because the spatial coverage in this are provides a coherent time-series with adequate spatial coverage – this estimate is used as an abundance index in the WGWIDE. The age-disaggregated total stock estimate in the "standard area" is presented in Table 4, showing that the part of the stock in this index area is dominated by 4 year old blue whiting.

Blue whiting were observed mostly in connection with the continental slope in south and east and very little were found in the open sea (Figure 13). The mean length of blue whiting is shown in Figure 14. It should be noted that the spatial survey design was not intended to cover the whole blue whiting stock during this period.

Mackerel

In later years an increasing amount of mackerel has been observed in the Norwegian Sea during the combined survey in May targeting herring and blue whiting, and there seem to be an increase in the northern and western distribution limit during summer. In 2008 during the Faroese survey mackerel was found in the southeastern part of the investigated area, but in 2009 mackerel was found up to 64ºN in the Faroese area (Figure 15). The 2005 year class dominated in the Faroese area (Figure 16). During the survey with the Norwegian Johan Hjort in May, mackerel was observed off the Norwegian shelf between 62 and 68ºN. The catches were dominated by the 2005 *year class* (Figure 17 anf 18 NO). Most of the mackerel were in maturity stage 4, 5 and 6 which means that they were probably spawning in the area (Figure 19).

Discussion

Periods of bad weather in the western part of the combine survey area hampered survey effort for some periods of time and more frequently than at least in the most recent years, causing either a reduction in vessel speed, or periods where surveying had to be suspended. In the eastern area the weather conditions were excellent during the survey with the exception of some short periods of bad weather in the eastern area.

Survey coverage was considered adequate and it was a huge benefit that the Barents Sea was again included in the coverage, as this allows complete spatial coverage of the whole distribution area of the Norwegian spring-spawning herring.

Concluding remarks

- NSSH was dominated by the two strong year classes of 2002 and 2004
- The 2004 year class dominated in the northeastern area of the Norwegian Sea while the 2002 year class dominated in the southwestern area.
- No strong year classes of NSSH were observed in the Barents Sea indicating poor recruitment since 2004.
- The blue whiting stock show still no signs of recruiting *year class*es

- The decline in the stock continues and the reduction is seen in all ages, but most severe for ages 2–5.
- The increasing trend in the abundance of mackerel and the widening of its northern and western distribution limit during summer seem to continue in 2009.

References

Anon 2009. The international acoustic survey in the Norwegian Sea in May 2009. R/V DANA Cruise No. 4/2009. Calibration of Echo-sounders 28/4 – 30/4 2009. International Acoustic Monitoring of Herring and Blue whiting 1/5 – 28/5 2009. 18 pp.

Foote, K. G., Knudsen, H. P., Vestnes, G., MacLennan, D. N., and Simmonds, E. J. 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. ICES Coop. Res. Rep. 144: 1–57.

ICES 2008. Report of the Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys (PGNAPES). ICES CM 2008/RMC:05.

ICES 2009. Report of the PGNAPES Scrutiny of Echogram Workshop (WKCHOSCRU) 17–19 February 2009, Bergen, Norway ICES CM 2009/RMC

FAMRI 2009. Smith, L., Joensen, M. M., Debes, H. and Skuvadal, F. 2009. Joint investigations on Norwegian spring-spawning herring and blue whiting north of the Faroes, 29 April – 13 May 2009. Cruise no. 0932. Faroe Marine Research Institute, Tórshavn, the Faroes.14 pp.

MRI 2009. Survey report of "Pelagic fish off W- S- and SE-Iceland and the western Norwegian Sea 27 April - 19 May". Working document to "Planning Group for the Northeast Atlantic Ecosystem Survey (PGNAPES) 2009 The Marine Research Institute, Reykjavík, Iceland. 13 pp.

Toresen, R., Gjøsæter, H., and Barros de, P. 1998. The acoustic method as used in the abundance estimation of capelin (*Mallotus villosus Müller*) and herring (*Cluea harengus* Linné) in the Barents Sea. Fish. Res. 34:27–37.

Totland, A., and Godø, O.R. 2001. BEAM – an interactive GIS application for acoustic abundance estimation. In T. Nishida, P.R. Kailola and C.E. Hollingworth (Eds): Proceedings of the First Symposium on Geographic Information System (GIS) in Fisheries Science. Fishery GIS Research Group. Saitama, Japan

Table 1. Survey effort by vessel.

Vessel	Effective survey period	Length of cruise track (nm)	Trawl stations	CTD stations	Plankton station
Dana	1/5–28/5	3.502	38	43	43
Johan Hjort	30/4–2/6	4.073	128	68	62
Fridjof Nansen	16/5–7/6	3.300	18	84	74
Magnus Heinason	4/29–13/5	1.310	13	38	38
Arni Friðriksson	27/4–19/5	3.894	28	60	53
Total	27/4–2/6	16.079	195	293	270

Table 2. Age and length-stratified abundance estimates of Norwegian spring-spawning herring in May-June 2009 for total area and abstracts of estimates for subareas I, II and III.

Length	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Number	Biomass	Weight
10																0		
11	1															1	0	7
12	1															1	0	24
13	156															156	2.5	16
14	2															2	0	21
15	31	125														156	3.2	20
16		164														164	4.1	25
17		34		15												49	1.8	36
18		44	6	26												76	3.4	45
19		149	60	29												238	10.9	46
20		81	30	66												177	11.2	63
21		0	316	89												405	27.2	67
22		153	486	83												722	59.5	83
23		0	366	244	122											732	66.5	91
24		0	443	88	63											594	62.1	105
25		40	185	117	133											475	57.6	121
26			181	533	54											768	104.8	137
27			467	352	686	4										1509	228	151
28			306	314	2211	82										2913	478	164
29			43	146	2877	172										3238	583.1	180
30				361	3600	786	153									4900	965	197
31				183	3097	2235	887	49	162	81						6694	1431.6	214
32				162	1252	3778	3151	420	64	0			8			8835	2051.1	232
33				78	441	1729	3942	485	142	194	67					7078	1766.3	250
34				32	96	575	2305	380	329	701	328	95		10		4851	1311.6	270
35					62	96	385	182	405	1118	571	58	25	0	8	2910	861	296
36							74	56	157	414	348	67	67	22	37	1242	398.2	321
37							1	6	25	95	70	33	38	32	127	427	145.5	340
38												15	15	0	55	85	32.4	375
39															16	16	6.1	389
40															0	0	0	.
41															2	2	1.1	470
42																0		
N mill.	191	790	2889	2918	14694	9457	10898	1578	1284	2603	1384	268	153	64	245	49416	10674	

Table 2 (Cont'd)

Total area																	
Biomass 10^3 t	3.2	39.5	321	445.8	2846	2171.4	2690.2	406.8	353.3	750.8	409.4	81	49.1	20.7	85.9		10674.1
Length cm	13.8	19.1	24.7	27.5	30.2	32.3	33.3	33.8	34.5	35.2	35.5	35.8	36.6	36.7	37.7	Mean length	31.3
Weight g	17	50	111	153	194	230	247	258	275	289	296	302	321	322	348	Mean weight	216
Area I																	
Biomass 10^3 t	3.2	14.7	48.4	46.2	68.5	35.3	53.1	8.8	8.9								287.1
Length cm	13.8	17.4	22.2	26	29.1	32.4	33.6	33.6	33.7							Mean length	24.2
Weight g	16.8	31.2	72.9	119.8	165.7	230.1	254.5	255.3	254.8							Mean weight	112.2
Area II																	
Biomass 10^3 t		24.7	269	376	2383	1352.3	820.4	213.3	74.5	80.6	9.9	29.7	0	0	6.2		5640
Length cm		21.6	25.4	27.5	30.2	32.2	32.9	33.1	32.4	34.1	33.5	35.3			38.5	Mean length	30.4
Weight g		78	122	156	193	229	243	245	233	267	252	289			414	Mean weight	200
Area III																	
Biomass 10^3 t			3.1	23.7	394.9	783.9	1816.7	186.7	269.9	670.2	399.5	51.3	47.3	20.7	79.7		4747
Length cm			28.5	31	31	32.6	33.5	34.7	35.3	35.3	35.6	36.2	36.8	36.7	37.7	Mean length	33.6
Weight g			167	202.7	202.3	230.5	248.6	275.2	290.1	291.3	297.3	311	326	322	346	Mean weight	255

Table 3. Age and length-stratified abundance estimates of blue whiting in May-June 2009, west of 20°E for total area and abstracts of estimates for subareas I, II and III.

Length	1	2	3	4	5	6	7	8	9	10	11	12+	Number	Biomass	Weight
20													0		
21													0		
22	20												20	1.2	62
23													0	0	.
24		8	15										23	1.9	81
25		11	56										67	6.1	91
26			40	40	18								98	10.1	102
27			0	185	166	39							390	43.1	110
28			8	190	608	90	44						940	124.2	132
29			17	246	649	228	74	26	9				1249	178.9	143
30			16	182	545	398	129	28	8				1306	211.7	161
31				76	216	452	71	8	0				823	144.7	176
32				13	56	158	237	30	16				510	95.8	187
33					38	46	47	38	18				187	38.2	204
34						5	13	50	13				81	17.3	212
35						3	0	5	12				20	4.9	251
36								0					0	0	.
37								11					11	2.8	253
38															
39															
40															
41															
42															
43															
N mill.	20	19	152	932	2296	1419	615	196	76	0	0	0	5725	881	

Total area												
Biomass 10^3 t	2.6		1.7	17.1	139.7	330.2	230.1	106.4	38.5	14.5		881
Length cm	24.8		25.1	26.8	29.2	29.6	30.8	31.4	32.8	33	Mean length	30.1
Weight g	95		93	112	150	144	162	173	196	190	Mean weight	153.6
Area II												
Biomass 10^3 t			1.1	9.2	114.3	154	120.8	59.9	19.7	2.8		482
Length cm			25.5	28.6	29.6	30	30.8	31.3	31.9	30	Mean length	30.2
Weight g			102	145	163	169	182	190	200	169	Mean weight	173.4
Area III												
Biomass 10^3 t	1.2		0.6	8	25.4	177.6	109.3	46.5	18.8	11.7		399
Length cm	22.5		24.5	25.5	27.9	29.4	30.8	31.6	33.8	33.8	Mean length	29.9
Weight g	62		81	89	110	127	144	155	192	196	Mean weight	135

Table 4. Blue whiting "Standard Area" 8°W - 20°E and north of 63°N.

Length	1	2	3	4	5	6	7	8	9	10	11	12+	Number	Biomass	Weight
20													0		
21													0		
22													0		
23													0		
24		3											3	0.3	76
25		11											11	1.1	102
26			22	22	7								51	5.4	107
27			0	57	68	11							136	15.7	115
28			6	119	225	50	25						425	59.8	141
29			15	192	251	126	44	22	7				657	101.9	155
30			13	148	218	155	71	13	6				624	110.6	177
31				66	139	175	29	7	0				416	80.2	193
32				13	38	89	102	13	0				255	53.2	209
33					17	8	25	17	0				67	15.3	225
34						5		9	0				14	3.5	247
35						2		3	0				5	1.2	263
36													0		
37													0		
38													0		
39													0		
40													0		
41													0		
42													0		
43													0		
N mill.	0	14	56	617	963	621	296	84	13	0	0	0	2664	448.2	
Biomass 10^3 t		1.3	7.8	96.9	156	111	55.6	16.7	2.3						448
Length cm		25.3	28.4	29.5	29.8	30.7	31.2	31.8	30						30.1
Weight g		96	140	157	162	179	187	198	165						168.2

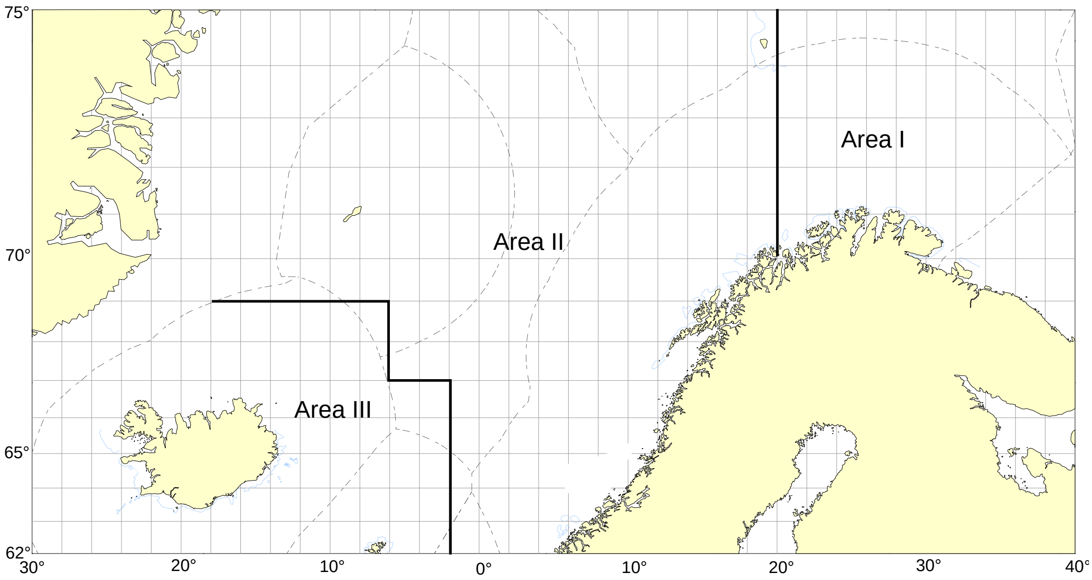


Figure 1. Areas defined for acoustic estimation of blue whiting and Norwegian spring-spawning herring in the Nordic Seas.

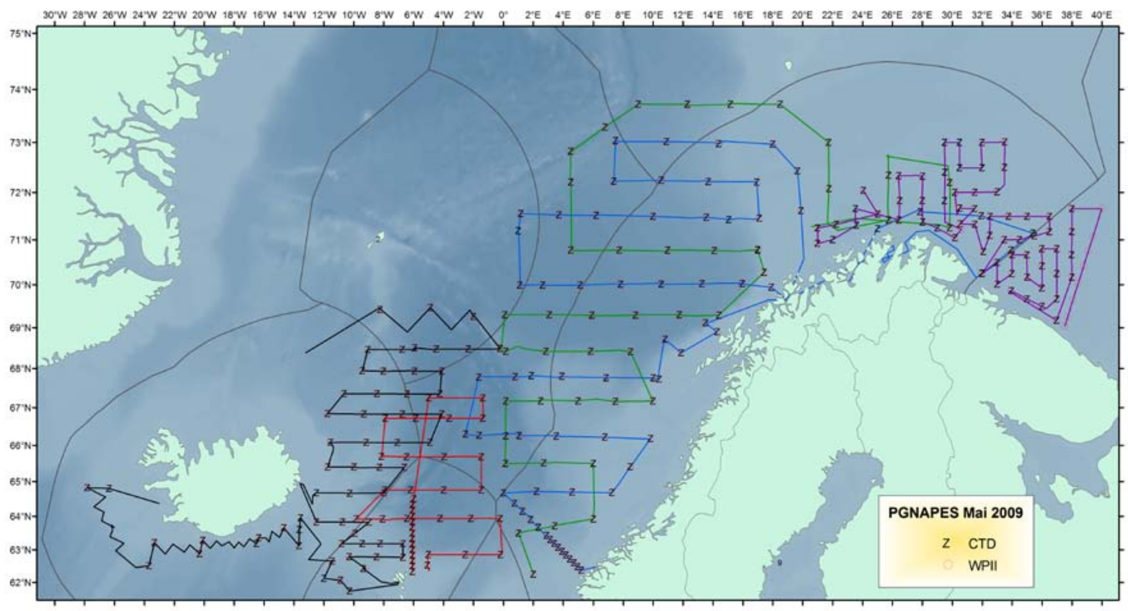


Figure 2. Cruise track and CTD stations by country for the International ecosystem survey in the Nordic Seas in May-June 2009.

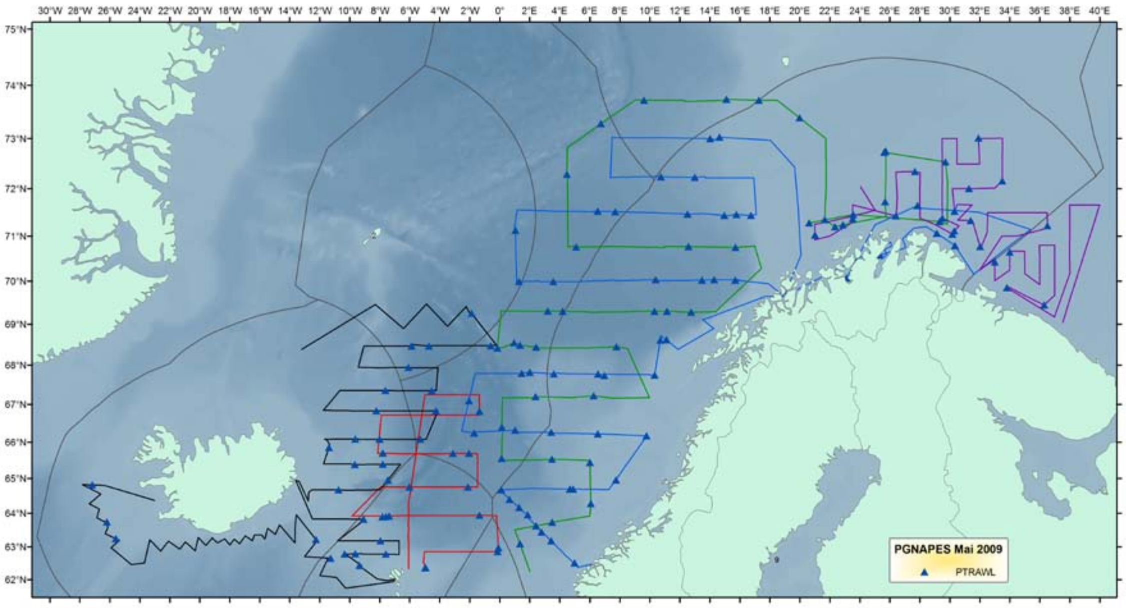


Figure 3. Cruise tracks during the International North East Atlantic Ecosystem Survey in April-May 2009 and location of trawl stations.

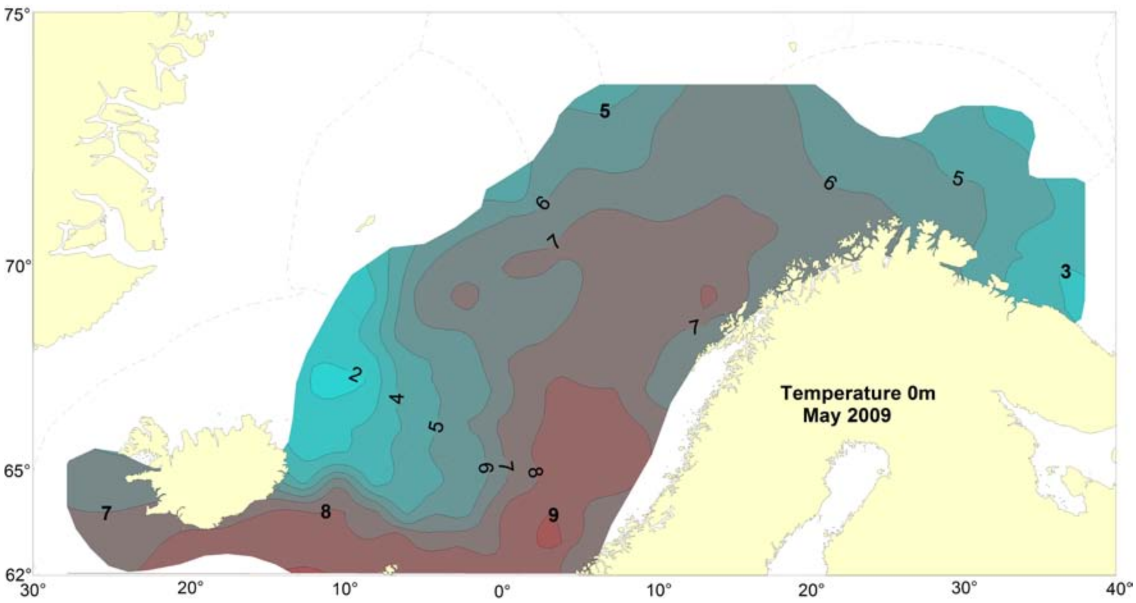


Figure 4. The horizontal sea surface temperature distribution in May 2009.

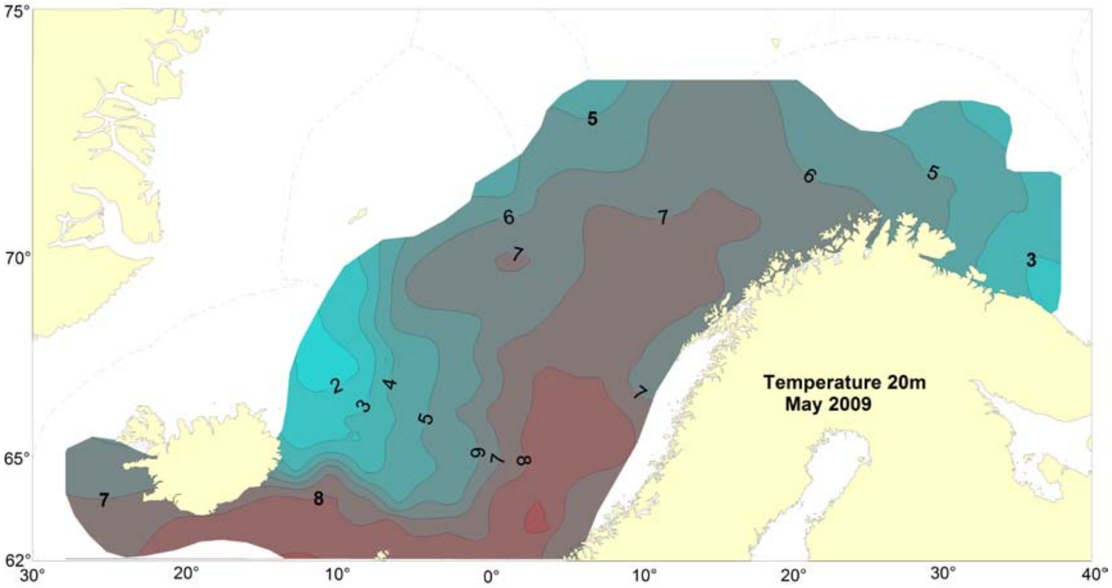


Figure 5. The horizontal distribution of temperatures at 20 m depth in May 2009.

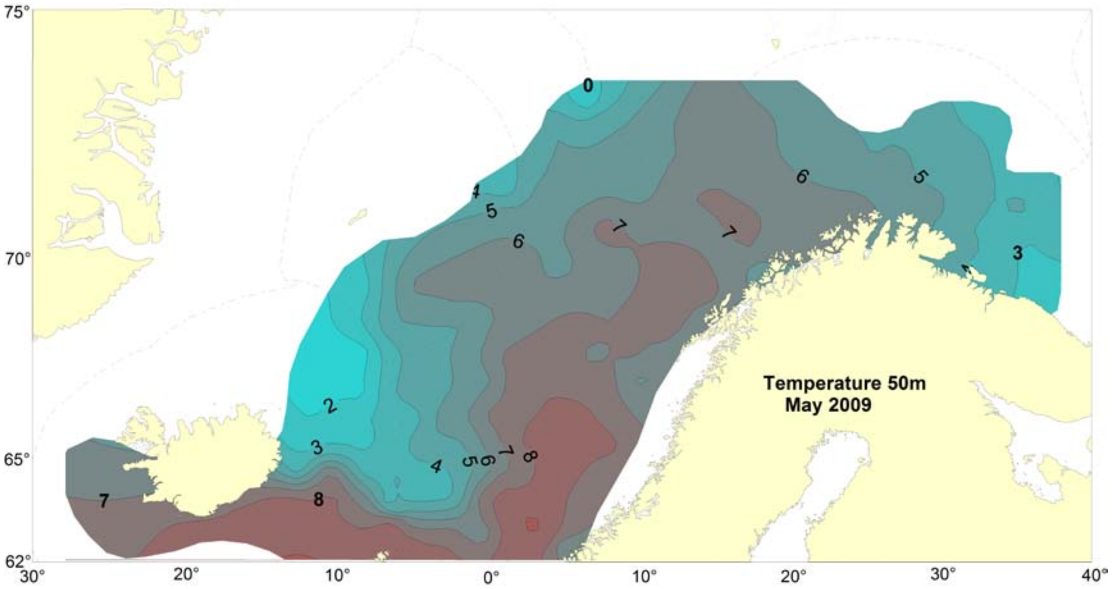


Figure 6. The horizontal distribution of temperatures at 50 m depth in May 2009.

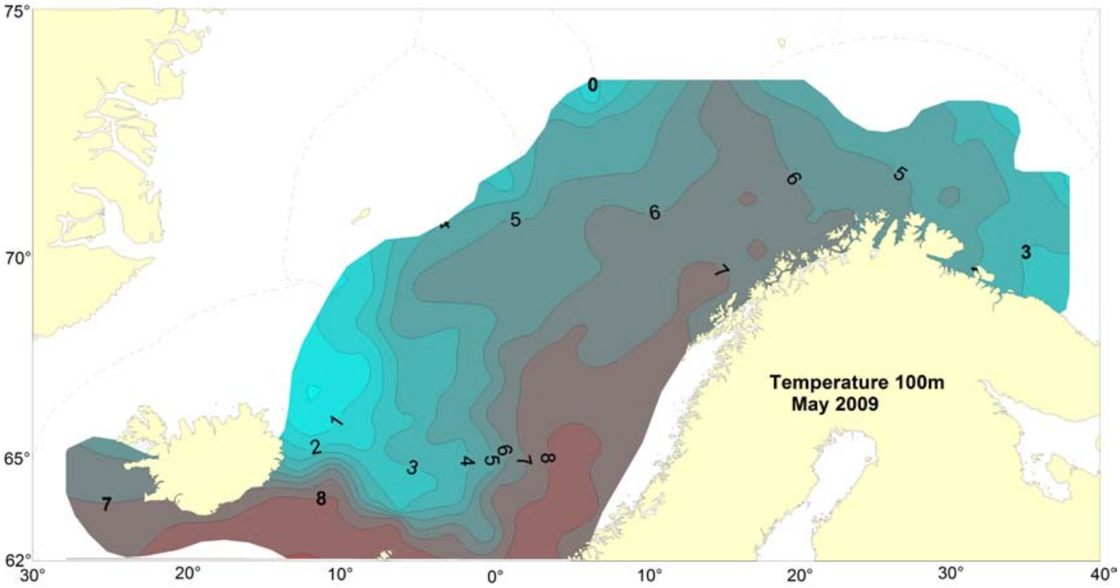


Figure 7. The horizontal distribution of temperatures at 100 m depth in May 2009.

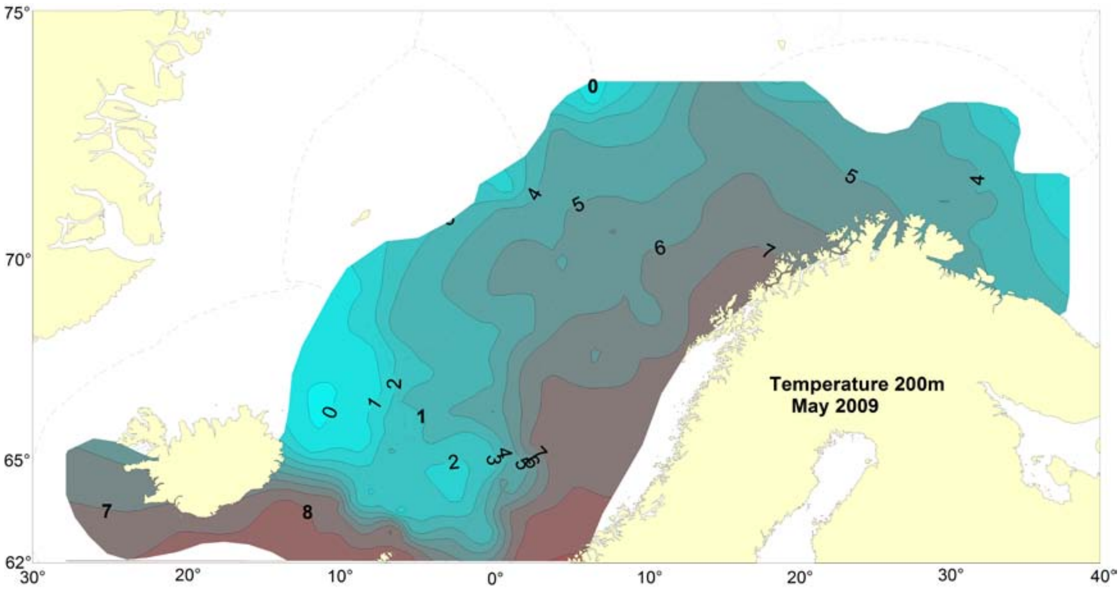


Figure 8. The horizontal distribution of temperatures at 200 m depth in May 2009.

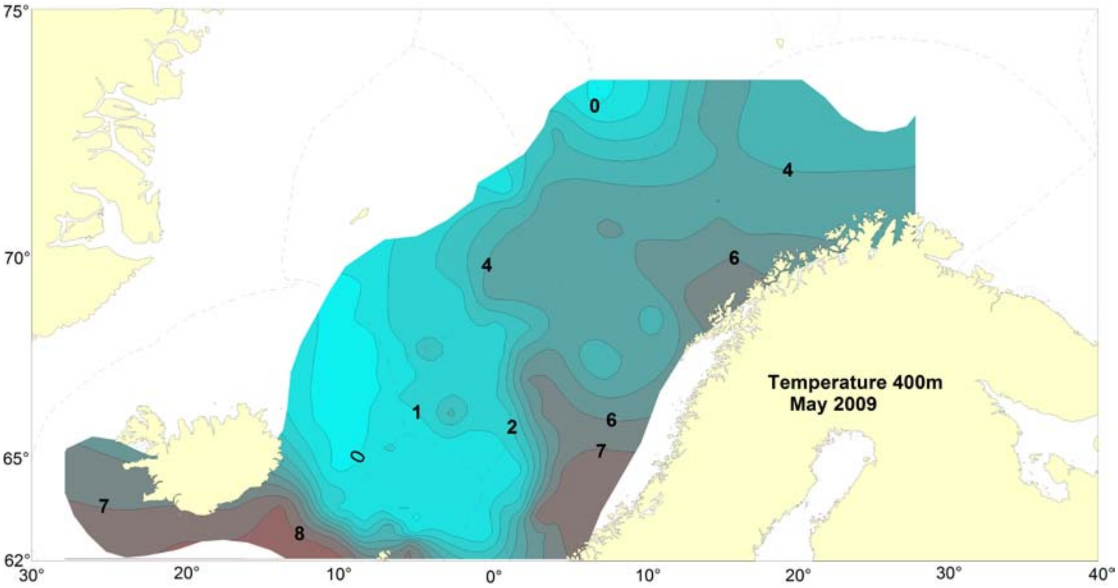


Figure 9. The horizontal distribution of temperatures at 400 m depth in May 2009.

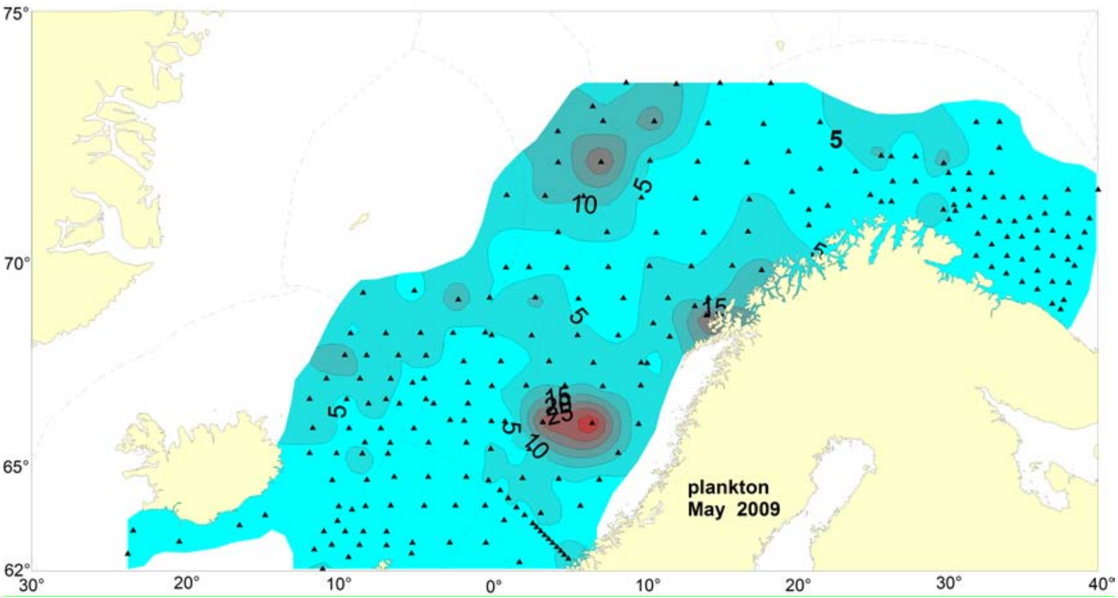


Figure 10. Zooplankton biomass (g dw m^{-2}; 200–0 m; 50–0 m in Icelandic standard sections) in May 2009.

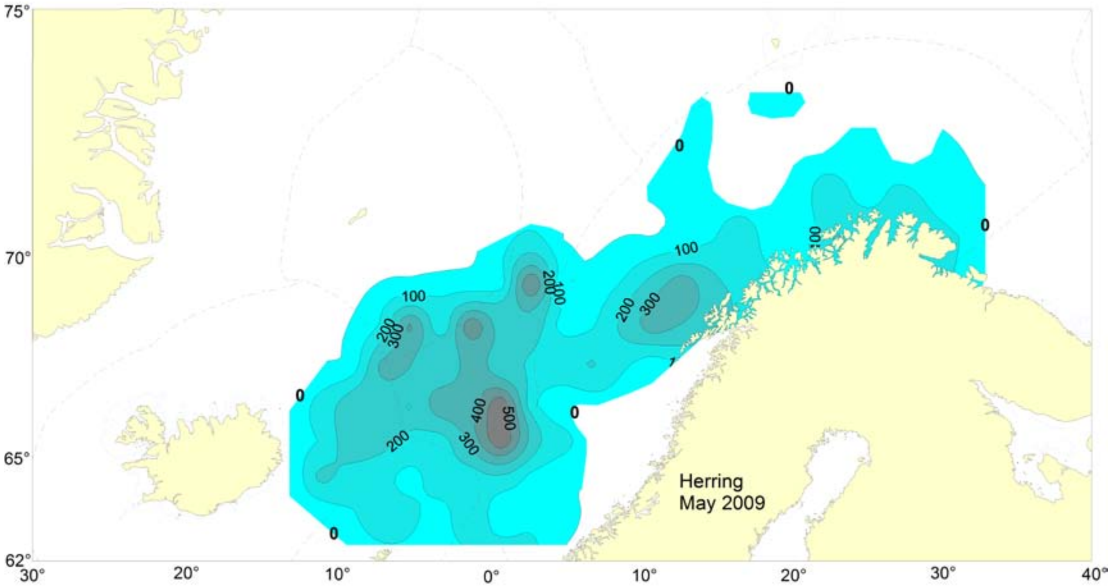


Figure 11. Distribution of Norwegian spring-spawning herring as measured during the International survey in April-June 2009 in terms of sA-values (m^2/nm^2) based on combined 5 nm values.

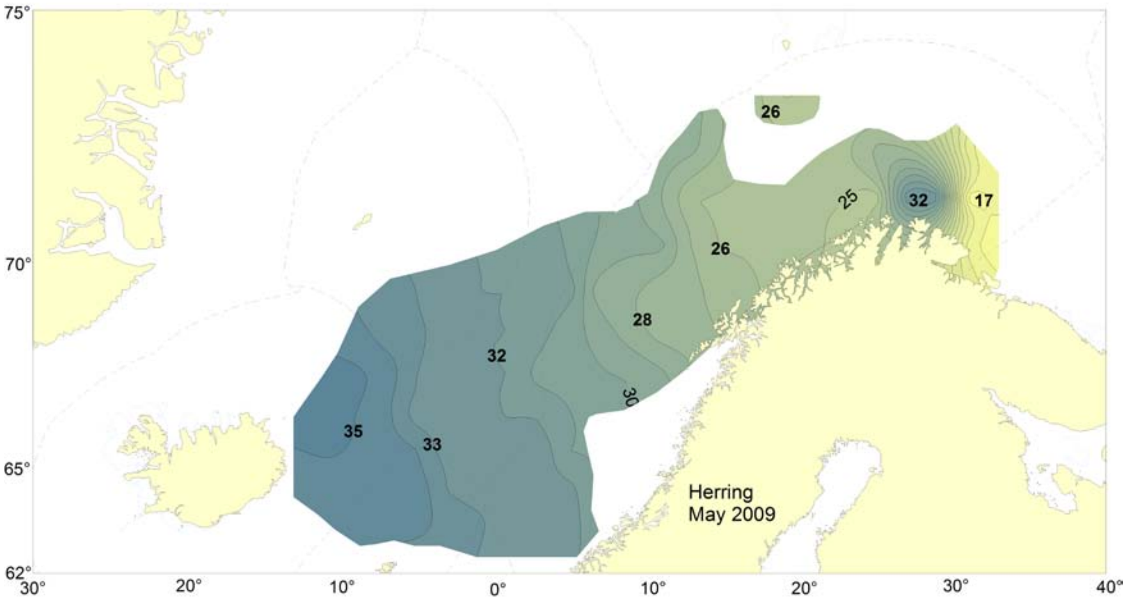


Figure 12. Mean length (cm) of Norwegian spring-spawning herring recorded in the North-east Atlantic Ecosystem Survey in May–June 2009.

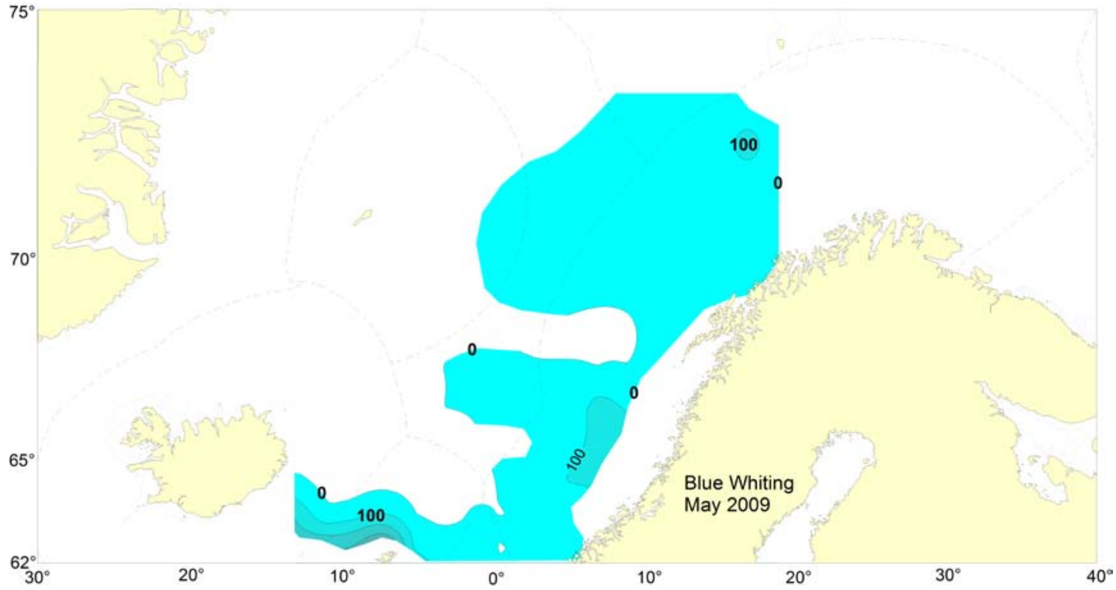


Figure 13. Distribution of blue whiting as measured during the International survey in April-June 2009 in terms of s_A-values (m^2/nm^2) based on combined 5 nm values. The standard area used in assessment (NPBWWG) is shown on the map.

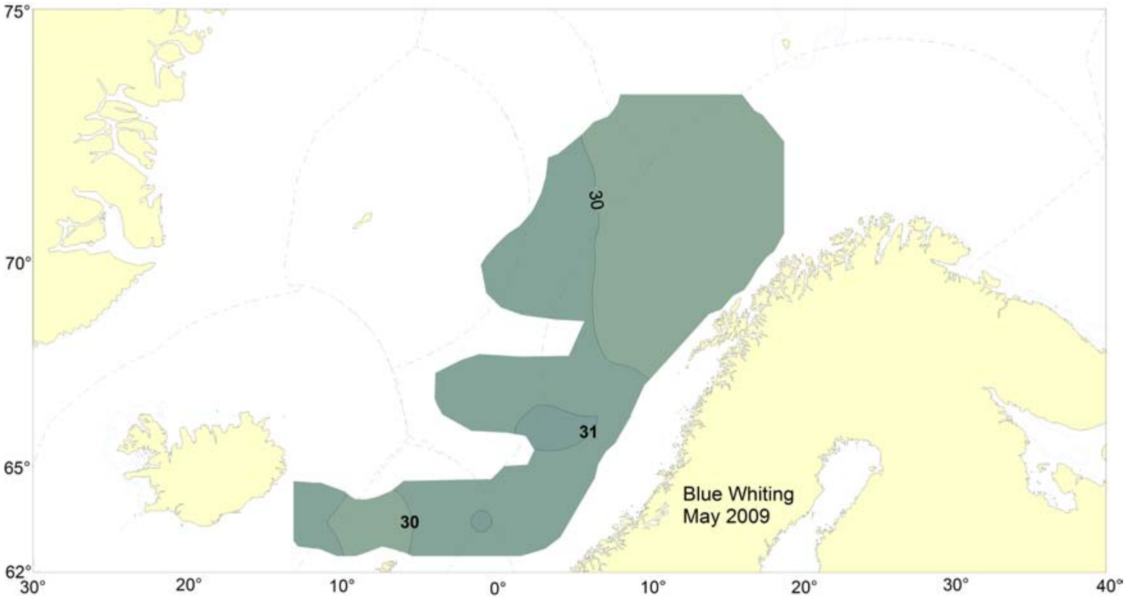
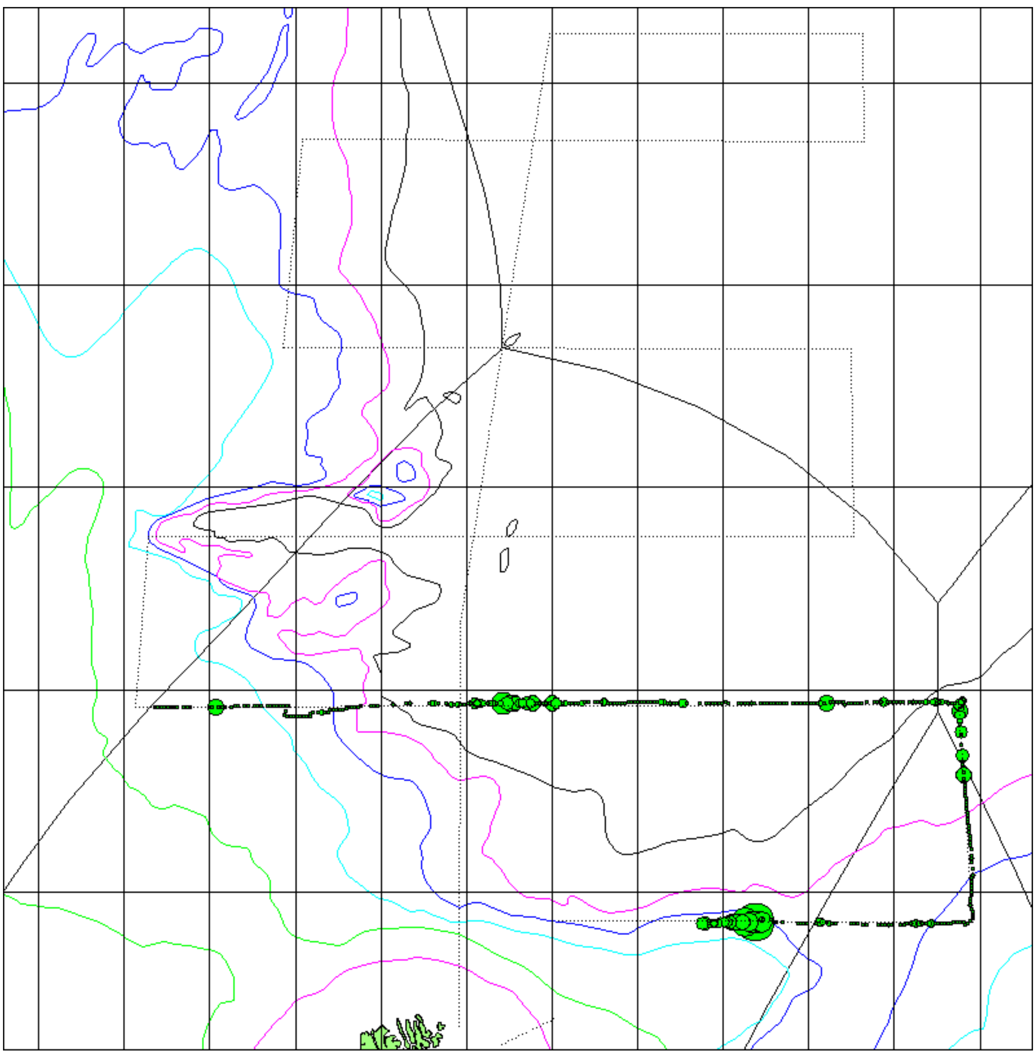


Figure 14. Mean length (cm) of blue whiting recorded in the North-east Atlantic Ecosystem Survey in May–June 2009.



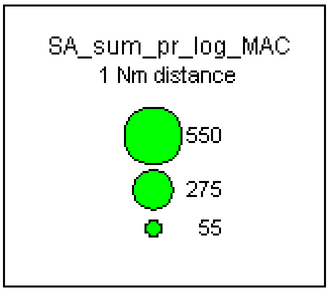


Figure 15. Acoustic values (sA, m2/nm2) of mackerel per 1 nm along the cruise tracks by the Faroese RV "Magnus Heinason", recorded in the North-east Atlantic Ecosystem Survey in May–June 2009.

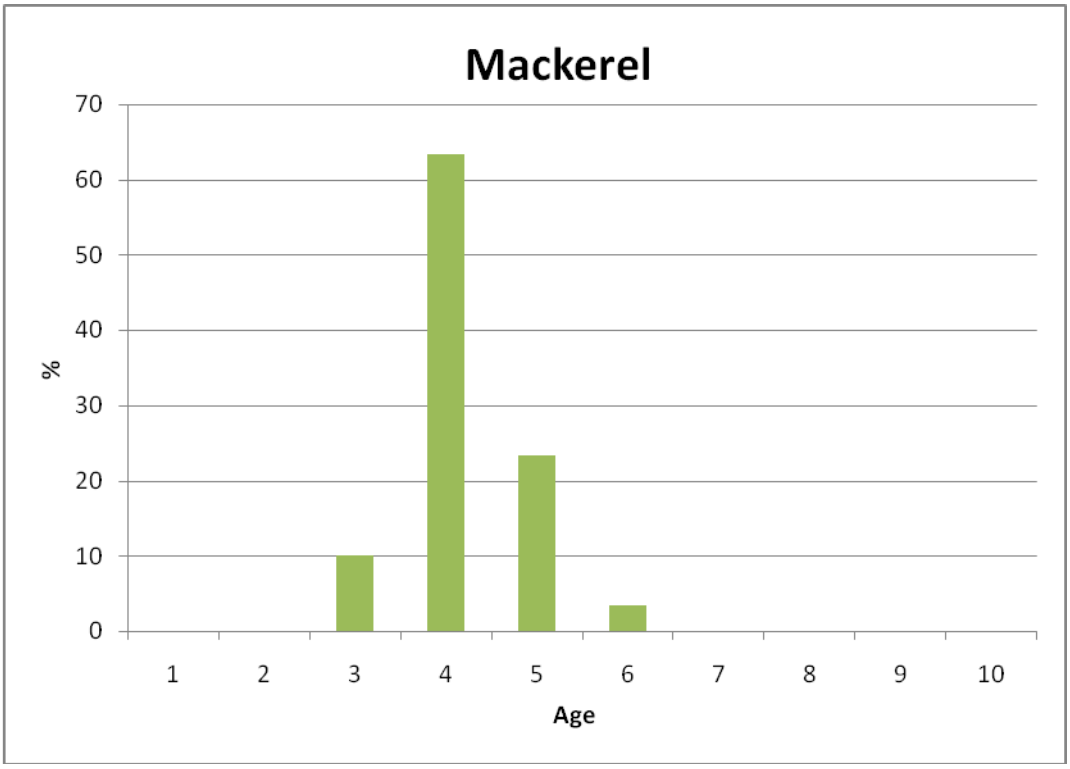


Figure 16. Age distribution of mackerel in the southern part of the investigated area the North-east Atlantic Ecosystem Survey in May–June 2009.

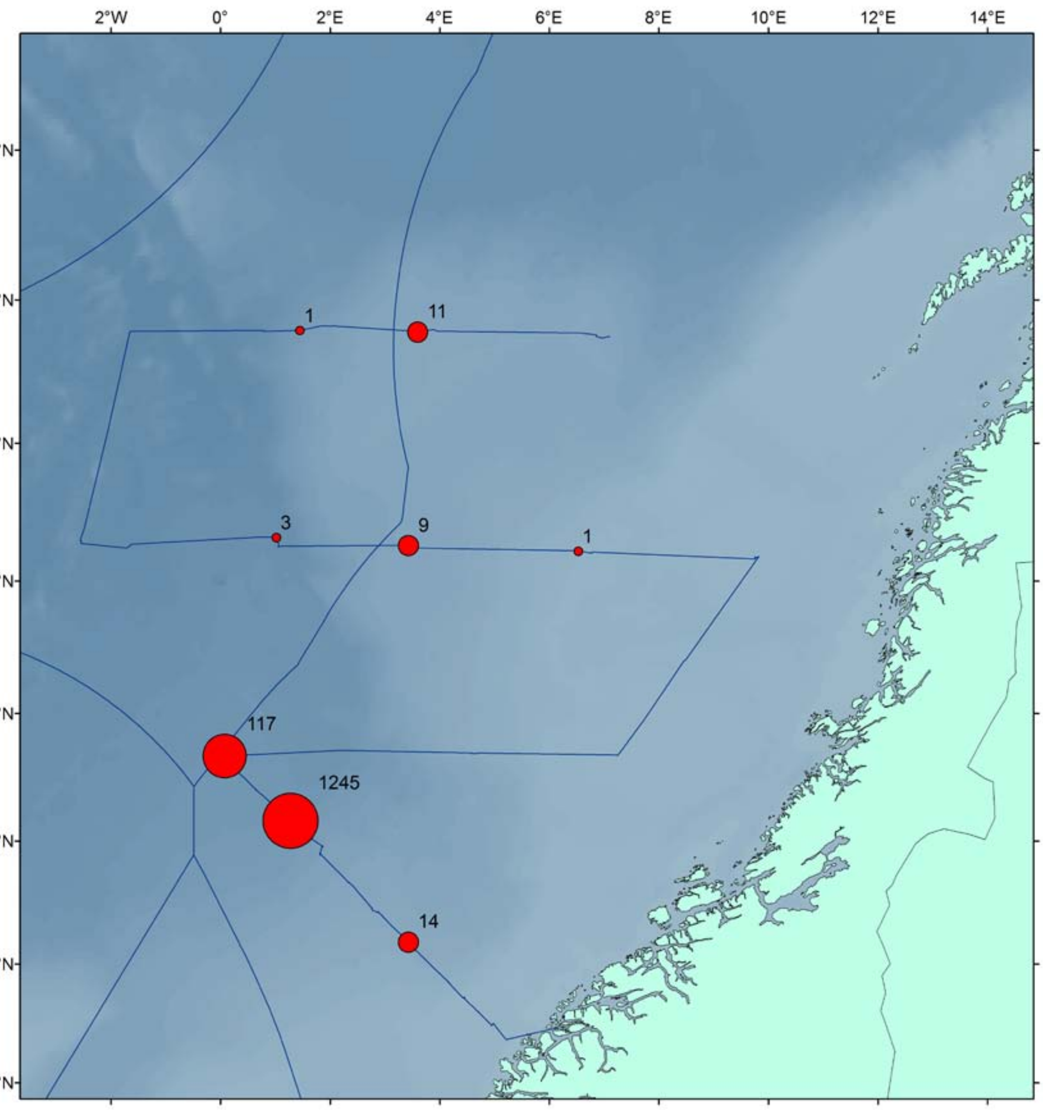


Figure 17. Norwegian catches of mackerel (pr. hour) in the Norwegian Sea in May 2009.

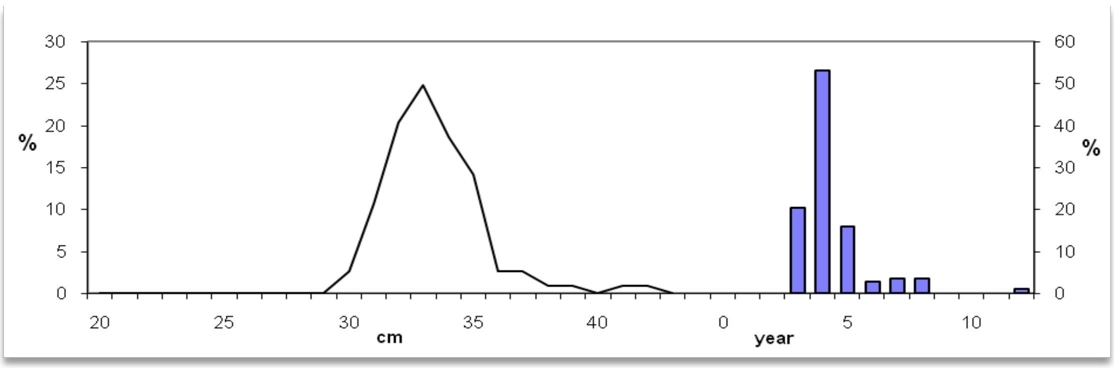


Figure 18. Length and age frequency of mackerel in the eastern part of the Norwegian Sea in May 2009.

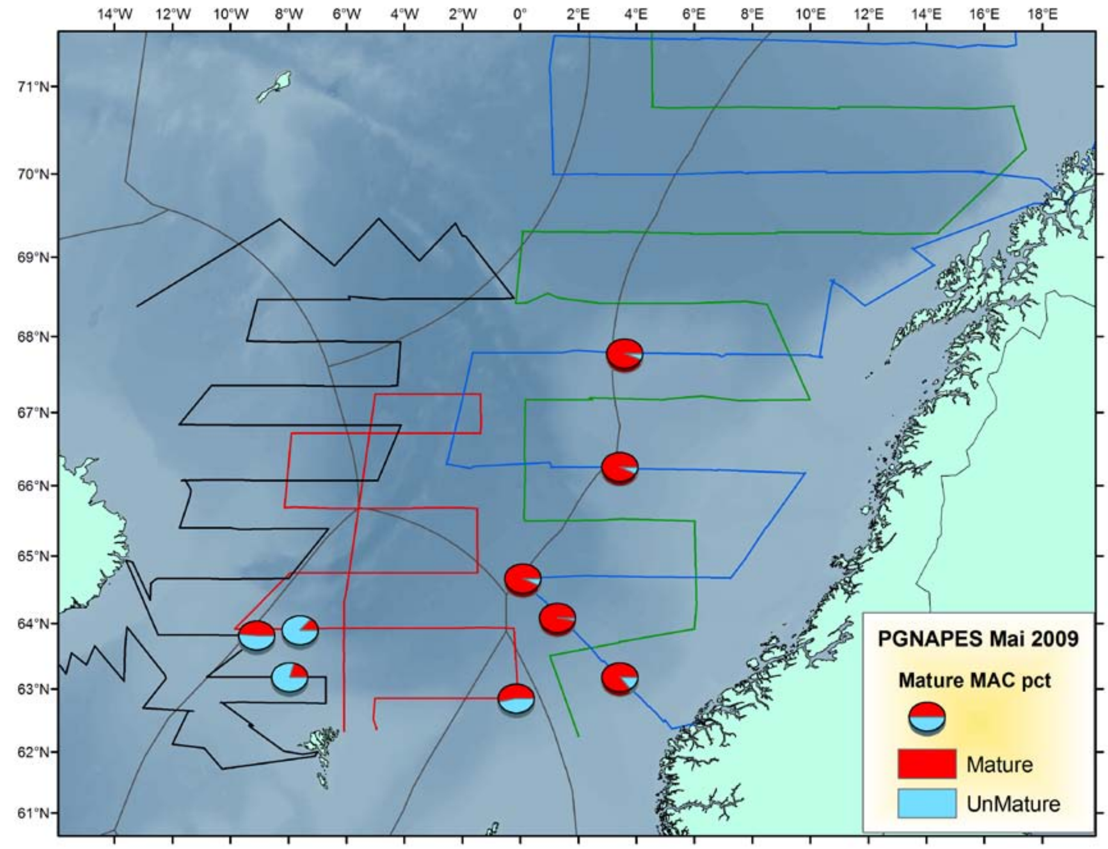


Figure 19. The maturity of mackerel in the Norwegian Sea in May 2009.

Annex 4: Coordinated Norwegian-Faroese ecosystem survey with M/V ”Libas”, M/V ”Eros”, and M/V “Finnur Fríði” in the Norwegian Sea, 15 July – 6 August 2009

Period:	15 July – 6 August 2009
Vessels:	M/V ”Libas” (LMQI), M/V ”Eros” (LIVA), ”Finnur Fríði” (XPXP)
Area:	Norwegian Sea and adjacent areas (62º30-80º00N, 24º00E-18º00W)
Main purpose:	Study abundance, spatio-temporal distribution, aggregation and feeding ecology of Northeast Atlantic mackerel, Norwegian spring-spawning herring, blue whiting and Atlantic salmon in relation to oceanographic conditions, prey communities and marine mammals.

Contents

1) Summary

Two chartered fishing vessels, two Norwegian M/V "Libas" and M/V "Eros" and one Faroese M/V "Finnur Fríði" performed an ecosystem survey from 15 July to 6 August 2009 in the Norwegian Sea and adjacent areas. The abundances of Northeast Atlantic mackerel (*Scomber scombrus* L.), Norwegian spring-spawning herring (*Clupea harengus* L.) and blue whiting (*Micromesistius poutassou* L.) were measured acoustically. Estimated biomass of mackerel was calculated to 4.4 million tons in the Norwegian Sea. Mackerel was distributed over larger areas than previously documented in the Norwegian Sea in July. Furthermore, a northwestern distribution was more pronounced in July 2009 compared to previous years. Repeated offshore catches of one and two year's old individuals indicate that the Norwegian Sea is now also an important nursery and feeding ground for immature mackerel. The 2005- and 2006 year classes dominated with 26% and 25% of total catches, respectively. Large mackerel ate adult capelin north of Iceland, which has never been reported before. Estimated biomass of herring was 13.6 million tons. Herring were distributed feeding in the colder and frontal waters in the western, northwestern and northeastern parts of the Norwegian Sea. The 2002- and 2004 year classes were most abundant representing 27% and 22% of total trawl catches, respectively. Estimated biomass of blue whiting was 2.3 million tons in the Norwegian Sea in July. The 2004 year class dominated with 29% of the catches, followed by the 2003 and 2002 year classes with 23% and 20% of total catches. No young year classes less than 4 years of age were found during the survey. Large blue whiting also ate adult capelin north of Iceland, representing new scientific information.

Surface waters in the northwestern part of the Norwegian Sea in the Jan Mayen zone and in Icelandic waters were considerably warmer compared to the last two decades, and coincided with increased presence and concentrations of large herring and mackerel in the area. The northernmost areas were in contrast colder than previous years, limiting the extent of northern migration by herring and mackerel compared to the last few years. Coastal waters off Norway were also colder than recorded in previous years.

Zooplankton concentrations including *Calanus finmarchicus*, krill and amphipods were generally low, except a few locations with elevated biomasses (20 g/m^2) of *C. finmarchicus* in the northern areas. The average concentration of zooplankton was only 4.8 g/m^2 in the Norwegian Sea in July, suggesting a reduction in biomass compared to previous years.

Very few marine mammals, except sperm whales, were present in the Norwegian Sea in July 2009, based on dedicated whale observations on Libas and opportunistic sightings on Eros and Finnur Fríði. Both herring and mackerel swam predominantly in small and loose aggregations as recorded from sonars and echosounder, making it difficult for marine mammals to prey cost efficiently on schooling fish. Low concentrations of krill and amphipods also suggest why baleen whales such as humpback whale and minke whale were scarcely present in the Norwegian Sea in July.

Keywords: Norwegian Sea, planktivorous fish, mackerel, herring, blue whiting, abundance, distribution, feeding ecology, schooling behavior, predator-prey interactions.

2) Introduction

Ecosystem survey

We aim to use these coordinated cruises with chartered vessels as part of an integrated platform to perform quantitative and qualitative ecological studies on the interplay between ecologically and economically very important pelagic fish species in the Norwegian Sea during summer. It is of great importance and interest for our understanding of the functioning of the Norwegian Sea ecosystem, how the distribution, aggregation and diet of mackerel, herring, blue whiting and horse mackerel are and to what extent they overlap in space and time. We therefore collected a wide range of data including hydrographical measurements (CTD casts), current measurements from ADCP, plankton samples (WP 2 nets, ringnet, bongo-bongo, krill trawl) and full biological analyses of pelagic fish species for each station applying epi-pelagic trawling at surface and deeper in the water column. Acoustic measurements and registrations were performed using multifrequency acoustics from Simrad ER60 echosounder, as well as high-frequency medium range Simrad SH 80 (Libas and Eros) and low-frequency long-range Simrad SP 90 (Libas) and Simrad SX (Eros) multibeam sonars.

The three weeks cruise is part of a long-term project to collect updated and relevant data on abundance, distribution, aggregation, migration and ecology of major pelagic species. The Institute of Marine Research, Bergen, Norway chartered two commercial vessels, M/V "Libas" and M/V "Eros", both fulfilling the required scientific specifications set for this ecosystem study. Both vessels have a drop keel installed and in operation when performing acoustic survey, in order to avoid bubble and surface generated noise during acoustic operation in Open Ocean under different sea state conditions. The Faroes Marine Research Institute, Faroes, chartered one commercial fishing vessel M/V "Finnur Fríði" fulfilling the requirements on acoustic equipment (ER 60 with 38 and 200 kHz systems).

3) Material and Methods

Calibration of echosounder transducers

Libas and Eros were calibrated after standard hydroacoustic calibration-procedure for each frequency prior to the cruise (Foote, 1987). The transducers are placed in the drop keel on-board Libas and Eros, and under the ordinary keel in Finnur Fríði. The frequencies calibrated involved 18, 38, 70, 120 and 200 kHz (38 and 200 kHz on Finnur Fríði).

Cruise tracks

All three vessels followed predominantly predetermined survey lines with preselected pelagic trawl stations and occasionally performed pelagic trawl stations on registration from acoustics (Figure 1). An adaptive survey design was also adopted, as a result of uncertain geographical distribution of our main pelagic planktivorous schooling fish species. Some modifications in the central western part in between Icelandic and Jan Mayen and were performed as a result of higher concentrations of herring and mackerel in these areas. The cruising speed was 11-12 knots if the weather permitted it, otherwise 10 knots. CTD stations (0-500 m) in combination with WP2 net samples (0-200 m) were taken systematically on every pelagic trawl station (Figure 1). A ringnet of 1.5 m diameter sampled plankton organisms in the upper 50 m of the water column. A bongo-bongo net was towed with 2.5–3.0 knots in 20 min at the surface after trawling on the Norwegian vessels.

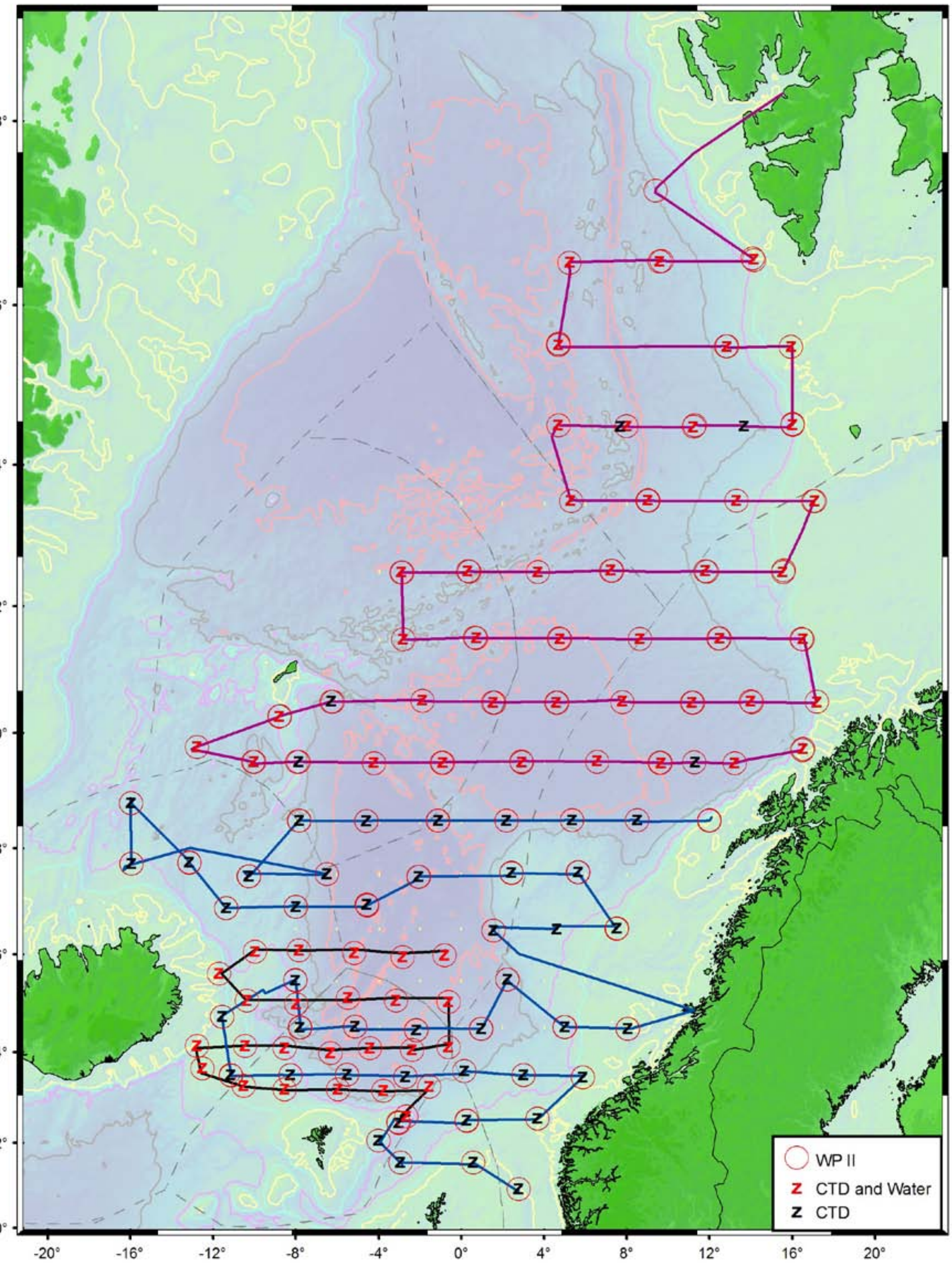


Figure 1. Survey lines along the cruise tracks with predefined CTD stations (0-500 m) and WP2 samples (0-200 m) for M/V"Libas", "Eros", and "Finnur Fríði", 15 July – 6 August 2009. This large ocean area included the following Economical Exclusive Zones (EEZ): Norwegian EEZ, UK EEZ, Faroe Island EEZ, Iceland EEZ, Jan Mayen fishery protection zone, Spitsbergen protected area and International waters.

Biological sampling

Pelagic planktivorous fish species

Trawling was done with a small specially designed pelagic trawl from Åkra trawl with a trawl opening between 10-13 m, spread of 60 m using 300-350 m wire length. Most of the trawling was done in the surface area with floats attached to the wings and the headline. Towing speed at the surface was 4.2–5.3 knots and towing time was normally 1 hour. Targeted herring and blue whiting trawl hauls on registrations were performed with a capelin/herring trawl from 10–250 m depth (Norwegian vessels). This trawl had an opening of 45 m and spread of 70 m using 200-600 m wire length. The tow duration was maximum 30 min. The Faroese vessel had a mesopelagic trawl with 30 m opening and 50 m spread to sample herring in deeper layers. Towing speed at depths varied between 3.5-4.8 knots depending of the vessel performance, current, wind and wave conditions. The catch was sorted at each station and full biological sampling including otoliths of up to 25 mackerel, herring and blue whiting was taken in addition to length and weight measurements of 100 specimen and stomach samples of 10 individual per species (Alvsvåg *et al.*, 2003, Mjanger *et al.*, 2007). We aimed to study possible interactions between species, and therefore decided when several pelagic species was caught in the same trawl haul that the sampling procedure should be adapted to allow studying ecological questions in more detail. Length and weight were measured for all other non-target species caught in the pelagic trawl hauls, as well as total weight for each species. Estimated biomasses for mackerel, herring and blue whiting were done in situations where not all the fish could be sampled and weighted from a pelagic trawl haul.

Hydrography

Libas and Eros were both equipped with SAIV SD200 CTD sensor recording temperature, salinity, pressure (depth) from the surface down to 500 m, or when applicable as linked to maximum bottom depth. Finnur Fríði was equipped with a Seabird portable CTD operated in a similar manner. CTD data from the downcast were used for further analyses. Sea surface temperature (6 m depth) was also recorded manually from a bottom-mounted temperature sensor with a display on the bridge systematically every hour during cruising between stations for both vessels. A thermosalinograph recorded surface temperature and salinity every 1 min throughout the cruise onboard Eros. Temperature at 6 m depth was noted each hour during the entire cruise on-board Libas.

Plankton sampling

Zooplankton sampling was performed at 44 stations on Libas and 47 stations on Eros. With few exceptions as a consequence of bad weather conditions the following sampling procedure was followed:

- A WP-2 net, 56 cm in diameter, 180 μ m mesh size, from 200 m depth to the surface (all vessels)
- A 160 cm diameter net (T-160), 375 μ m mesh size, from 50 m depth to surface (NO vessels)
- A 2 x 60 cm diameter Bongo, mesh size 375 μ m, trawled horizontally in the very surface layer for 20 min. at a speed of 2.5 knots (NO vessels)

A Macrozooplankton trawl (krill trawl) was used on-board Eros with tow duration of 30 min at the surface, 5 m spread and about 7-8 m vertical opening. The trawl was operated without trawl doors and buoys attached to the wings to keep the trawl as high as possible in the water column.

Sample treatment

Macroplankton trawl

Samples were sorted, species identified and length measured according to working standards. All subsamples were frozen to -30°C and the whole sample was frozen after length measurements in those cases were the total samples were small.

WP2 net

One plankton haul was sampled on each predefined station from 200 m – 0 m depth. The choice of depth range was taken to link plankton concentrations directly within the depth ranges were the pelagic schooling species (mackerel and herring) are actively feeding during summer. The hauling speed should not exceed 0.5 m/s in order to avoid bucking effect. The plankton sample is divided into equal fractions; 1) stored in formaldehyde preservation for taxonomic analyses (taxonomic species, size, and stadium composition, and 2) dry weighing for biomass estimates. This part was separated into three size categories by filtering at 2000, 1000 and 180 mesh size sieves.

T-160 ringnet

Samples were conserved in borax neutralized 4 % formaldehyde. Special findings were noted in the zooplankton cruise journal.

Bongo

All Bongo and large ringnet samples were preserved in borax neutralized 4 % formaldehyde after a brief visual examination. Special findings were noted in the zooplankton cruise journal.

Acoustics

Sonar

Two sonars were used simultaneously and continuously as a high priority activity during the survey, in order to identify and sample mackerel and herring schools along the entire cruise track. The high frequency sonar, Simrad SH80 (from 110 to 122 kHz), was used as primary sonar on-board Libas, which software includes the option to save the sonar raw data using a "Scientific Output" through an Ethernet connection. The processing of these data are time-consuming task that will be done in a later stage and is not included in the present cruise report. Raw data from areas with school detections were stored for both Simrad SH80 and SP90. Extraction and visualization of number, position, size, density and shape of schools as well as swimming direction and speed on automatically detected individual schools were performed.

Echosounder

Continuous data-logging and raw data recording from 18, 38, 70, 120 and 200 kHz Simrad ER60 echosounder were performed down to maximum 500 m depth on both Libas and Eros (38 and 200 kHz on Finnur Fríði). The data collection was done using standard settings for later echo-integration calculations distance based reference using GPS data for position and vessel speed. The quantitative acoustic analyses and NASC species allocation were done with the software program Large Scale Survey

System (LSSS; http://www.marec.no/). The analyses were based on the following species and groups of species:

Main target species: mackerel, herring, blue whiting

Usable species: capelin, mesopelagic fish, plankton

Other species: redfish, krill, amphipods.

Marine mammal observations

The vessels Libas, Eros and Finnur Fríði conducted observations of marine mammals and basking sharks as well. There were opportunistic observations on-board Eros and Finnur Fríði without specialized personnel. Two dedicated marine mammal observers were present on-board Libas. Observing was held from the roof or from the bridge when the weather conditions were bad (Beaufort scale > 7). Two observers were watching permanently. Among the equipment were: angle boards, binoculars 7x50 with reticles, portable two-way radio for communication with bridge, GPS device, microphones connected to personal computers with special software for the sound recording and simultaneous registration of the vessel's position. Each observer monitored a 90 degree sector, starboard and port side respectively, in the line of the course. They shifted the sides every hour and took short breaks every two hours. The main sector of observation was 45 degrees port and starboard of the course line. The priority periods of observing were during the transport stretches from one trawl station to another. When the weather conditions were nearly excellent, observing was also conducted during the trawl stations with the purpose of tracking marine mammals, which could possibly appear. Weather conditions were noted every hour of observation. Sightings were spoken into a microphone. Later, the recordings were transcribed to a special Sighting form. Fields in the sighting form included date, time, position, species, number, group size, behaviour, angle from the vessel course and swimming direction. A diary summarizing each day's activities was kept by the observers. Data were summarized and presented in tables and a distribution map. Scientific personnel and crew members on-board Libas, Eros and Finnur Fríði also recorded incidental sightings of marine mammals more or less continuously on the bridge. Digital filming and photos were taken whenever possible for each registration from scientists on board.

4) Results

Hydrography

There were considerable changes in the temperature regime in the Norwegian Sea and adjacent waters in July 2009 compared to previous periods (Figure 2).

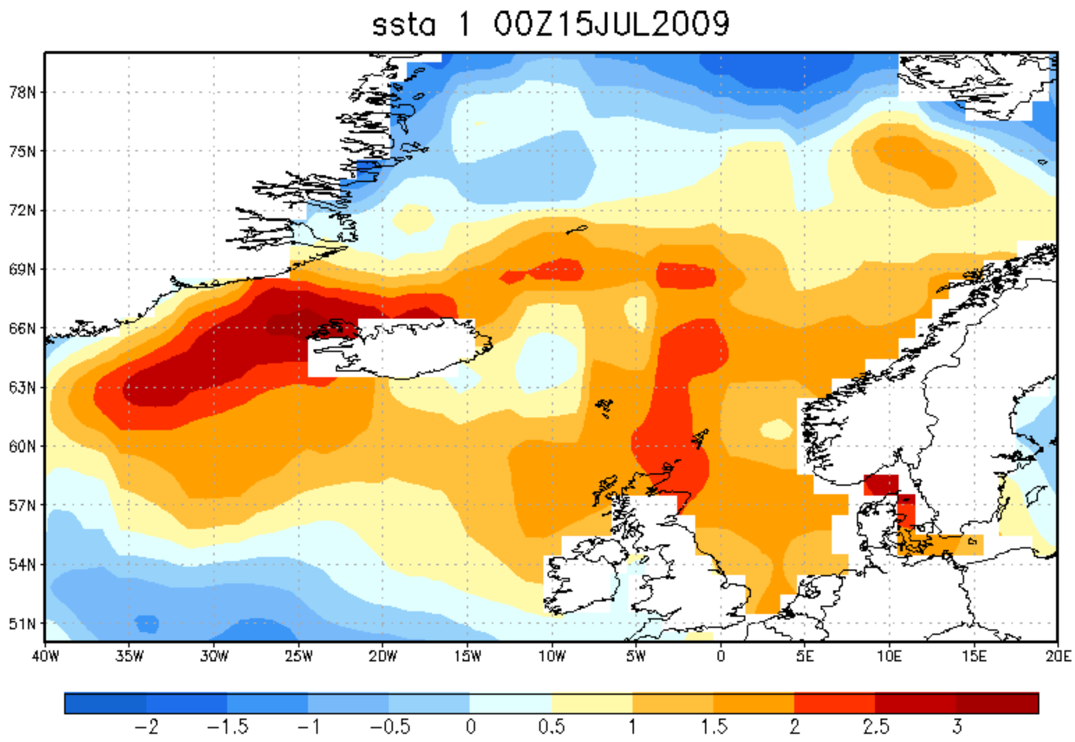


Figure 2. Sea surface anomalies (centered in week 15 July) showing warm conditions in all the area compared with a 20 year average.

Temperature maps were produced in Surfer 9.0 and ArcGis 10.0 based on 90 CTD casts from Libas (43) and Eros (47). Surface waters in the northwestern part of the Norwegian Sea in the Jan Mayen zone and in Icelandic waters were considerably warmer compared to the last two decades, and coincided with increased presence and concentrations of large herring and mackerel in the area. The northernmost areas were in contrast colder than previous years (Figure 3), limiting the extent of northern migration by herring and mackerel compared to last few years. Coastal waters off Norway were also colder than recorded previous years (Figures 3 and 4).

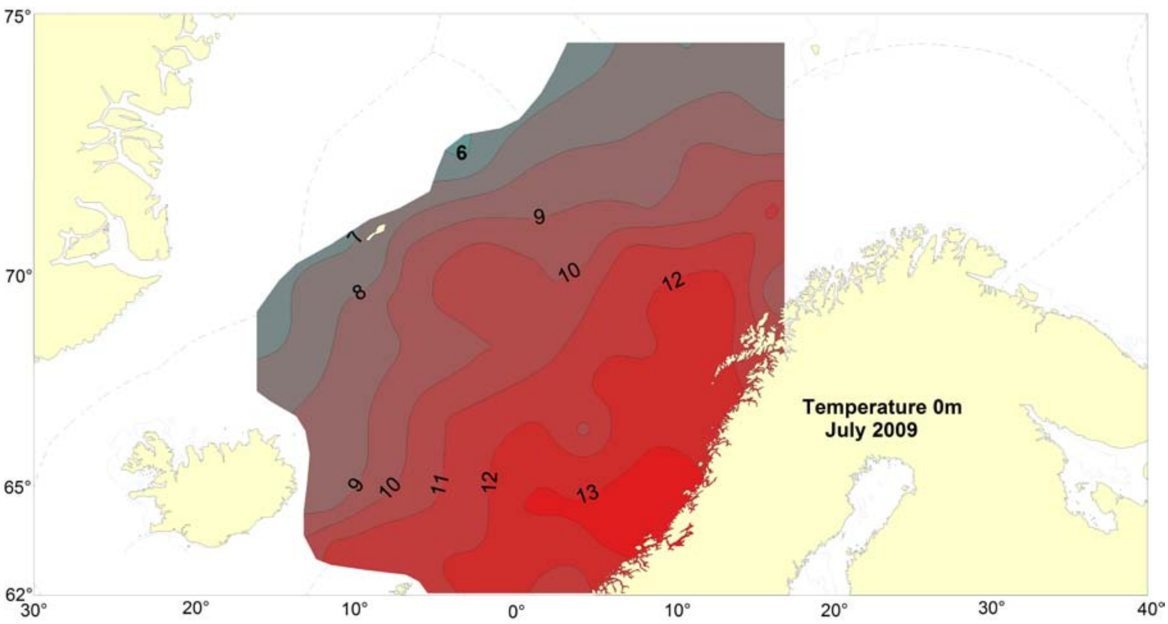


Figure 3. Sea surface temperature (SST) in the Norwegian Sea, 15 July – 5 August 2009.

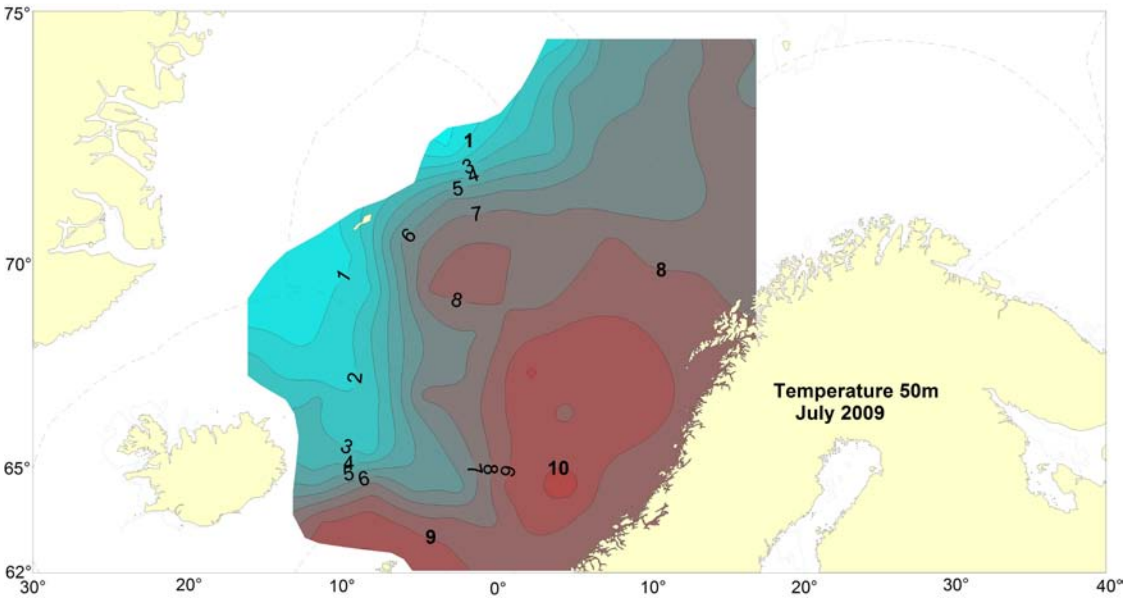


Figure 4. Temperature at 50 m depth in the Norwegian Sea, 15 July – 5 August 2009.

Weather conditions

The weather conditions were mostly favourable for acoustic recordings and visual sightings with low windspeed (Baufort scale: 0-3): However, windspeed reached Baufort scale 4–6 some days within the survey tracks for both Libas and Eros in the Norwegian Sea in July. Low precipitation and limited rainfall provided good visibility throughout the cruise. Fog and fogbanks were mostly experienced in the westernmost area south of Jan Mayen and near Bear Island.

Biological samples

Libas performed 54 pelagic trawl stations, Eros performed 56 pelagic stations, whereas Finnur Fríði performed 25 pelagic stations (Figure 5).

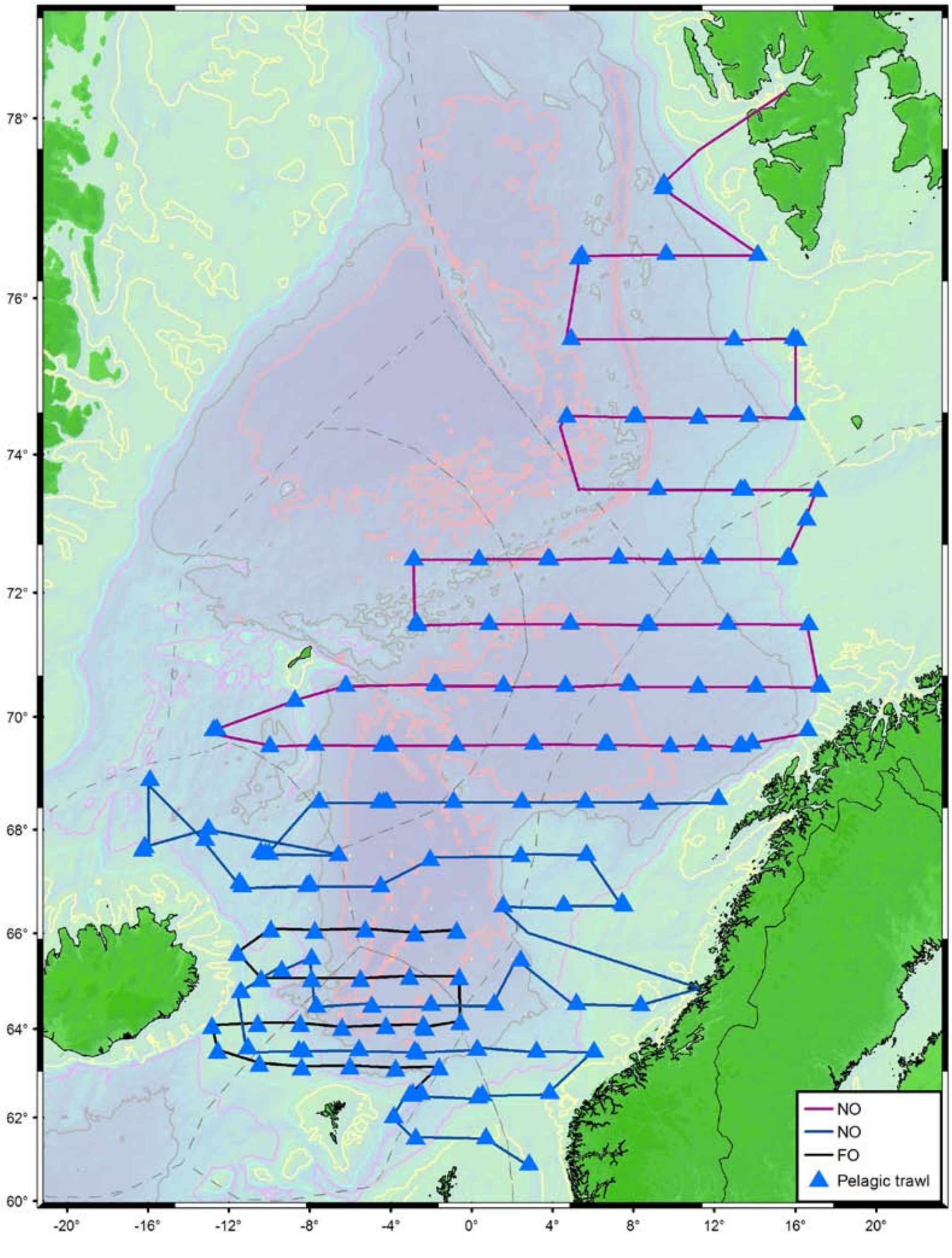


Figure 5. Map showing pelagic trawl hauls taken on Eros, Libas, and Finnur Fríði during the ecosystem survey.

Mackerel caught in the pelagic trawl hauls on Libas and Eros varied from 22 cm to 45 cm in length distribution with the concentration of individuals between 32–34 cm. Mackerel weight (g) distribution varied between 100 to 820 g (Figure 6). The 2005-

year class of mackerel together with the 2006-year class dominates the mackerel population in the Norwegian Sea with more than 50% (Figure 7).

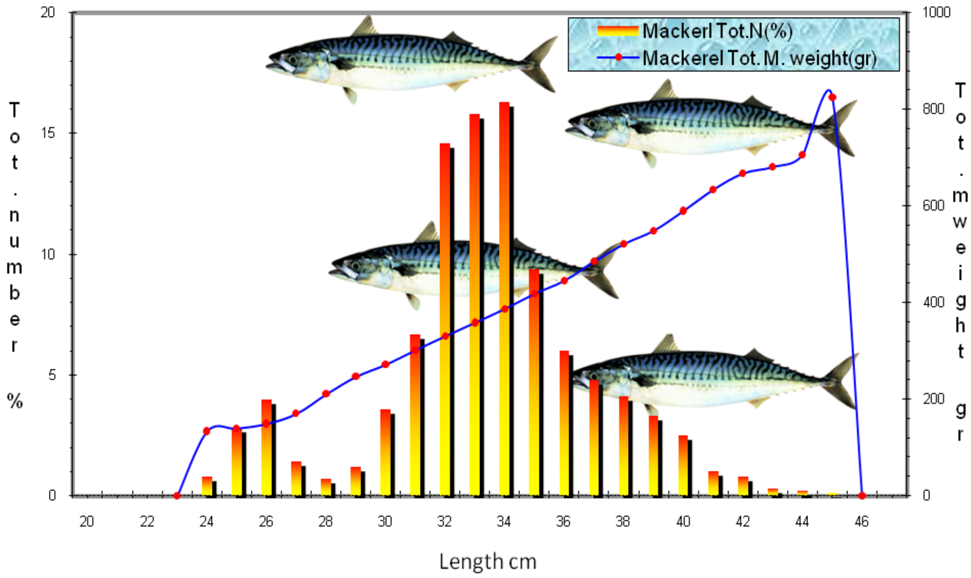


Figure 6. Total length (cm) and weight (g) distribution in per cent (%) for mackerel in all catches.

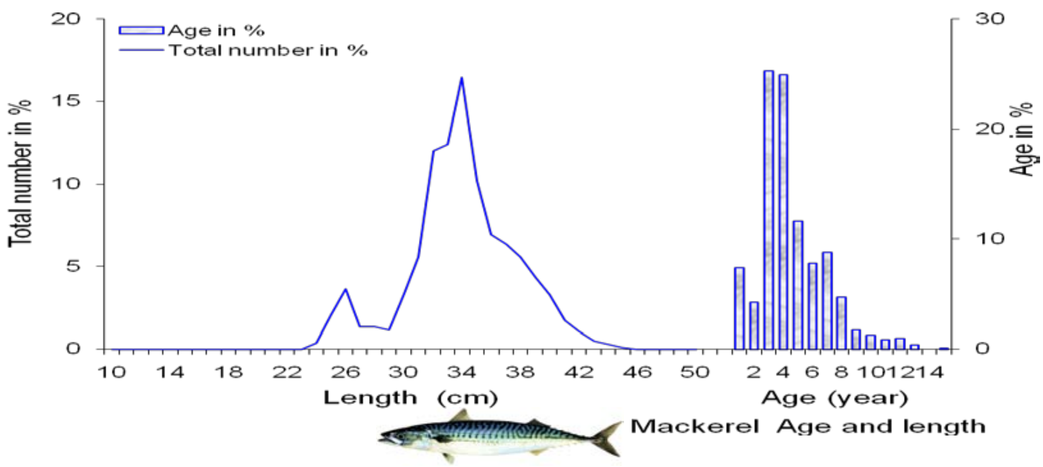


Figure 7. Age and length distribution in per cent (%) of Atlantic mackerel in the Norwegian Sea.

Norwegian spring-spawning herring had a length distribution from 19–38 cm with a peak at 31–34 cm in length, and a weight distribution from 50–410 gramme (Figure 8).

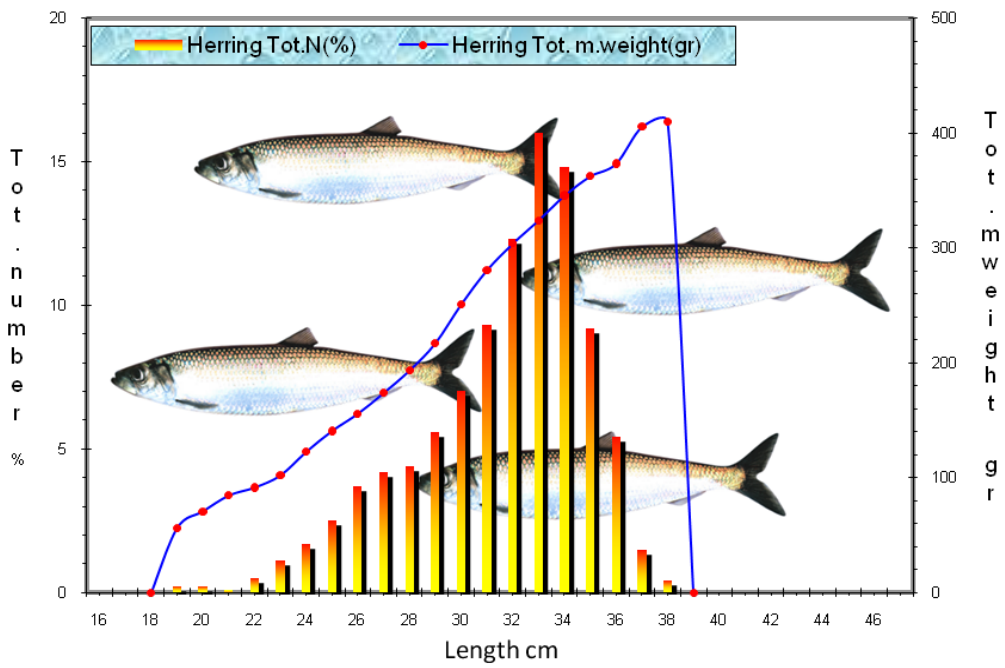


Figure 8. Length and weight distribution of herring in the pelagic trawl catches.

The age distribution in herring shows dominance of the 2002 year class. They constitute 27% of the total population. The 2004- (22%) and 2003 (15%) year classes are the second and third most dominant herring year classes, respectively. Younger herring than 3 years was practically absent in the trawl catches (Figure 9).

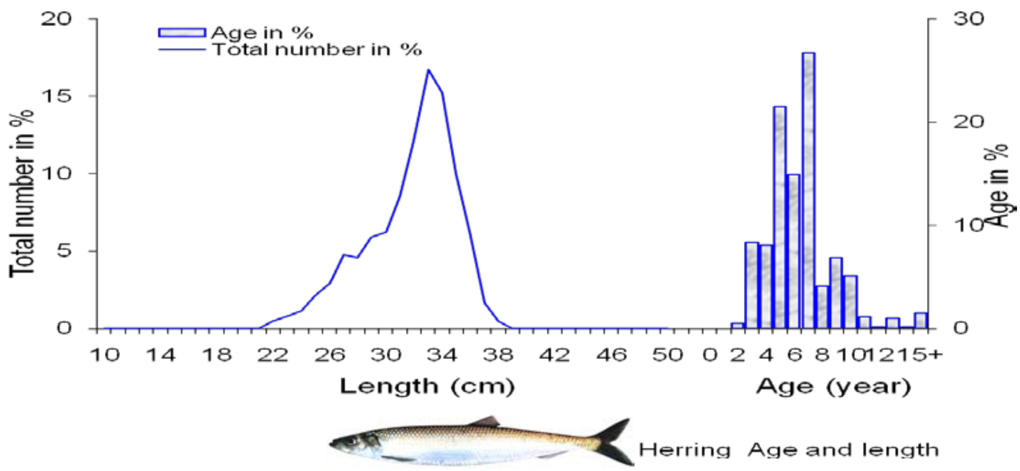


Figure 9. Herring age and length distribution in the pelagic trawl catches.

Blue whiting length distribution was from 27–36 cm and individual weight distribution was 100–240 gramme. Blue whiting between 30–32 cm dominated the catches (Figure 10).

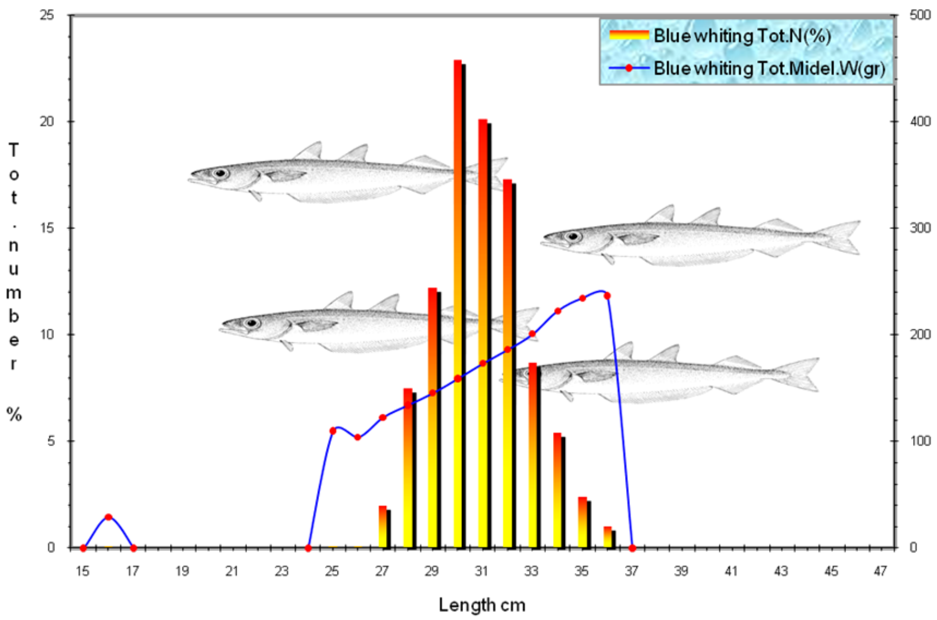


Figure 10. Length and weight distribution of blue whiting in the pelagic trawl catches.

The age distribution of blue whiting showed a dominance of 2003 year class (37%) followed by the 2004 year class (25%) and 2002 year class (22%). Blue whiting younger than 4 years of age was practically absent in the trawl catches (Figure 11).

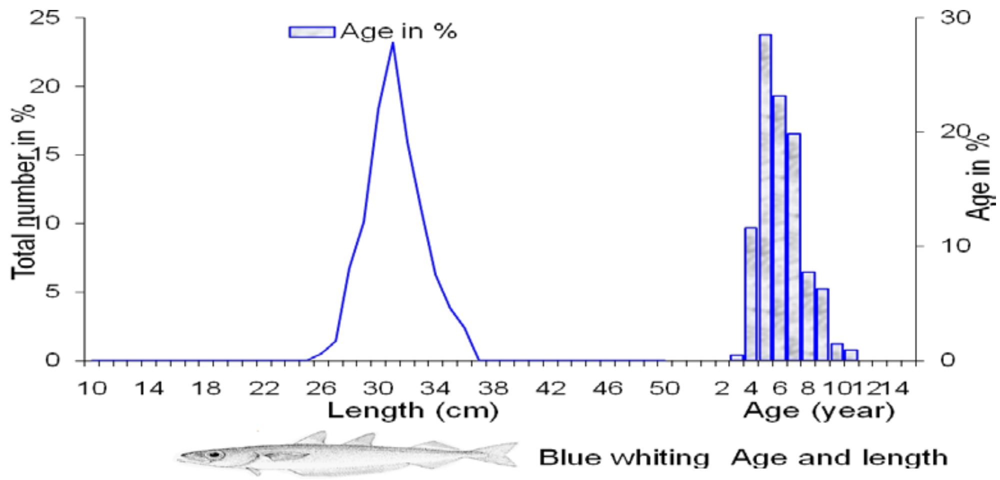


Figure 11. Blue whiting age and length distribution in the pelagic trawl catches.

Highest mackerel catches (kg/nmi) dominated in the southern and western Norwegian Sea and adjacent areas from 61ºN to 68ºN in the northwestern and northern areas with Arctic water masses (Figure 12). We have to note that only the small salmon trawl was used in the northern areas, whereas a larger pelagic trawl was used on Libas at the southernmost cruise tracks.

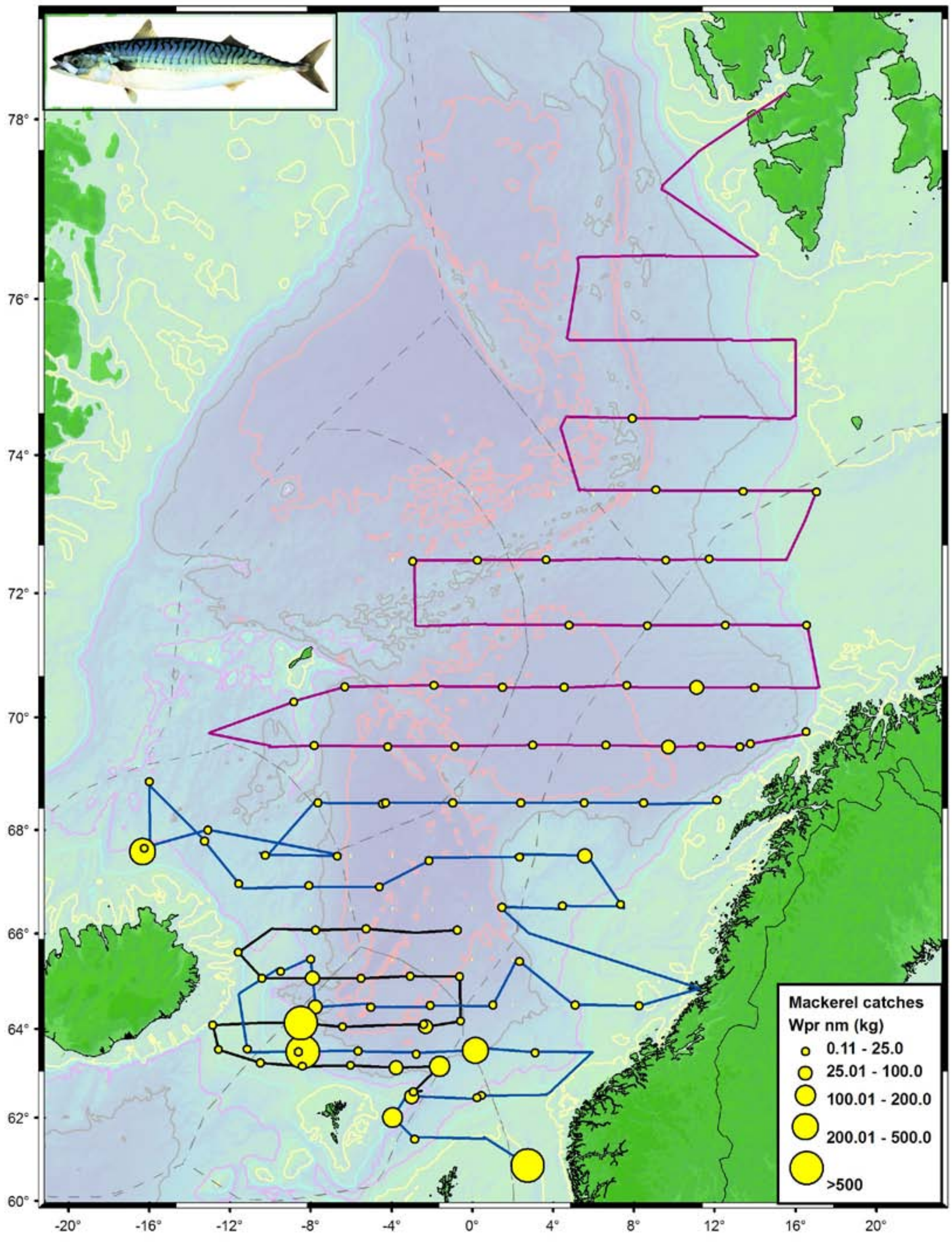


Figure 12. Mackerel catches (kg/nmi) from Libas, Eros and Finnur Fríði combined in the Norwegian Sea, 15 July – 6 August 2009.

Mean mackerel weight (g) within a category is shown for each biological station (Figure 13). A general trend is that the largest mackerel is found in the western and northwestern part of the Norwegian Sea.

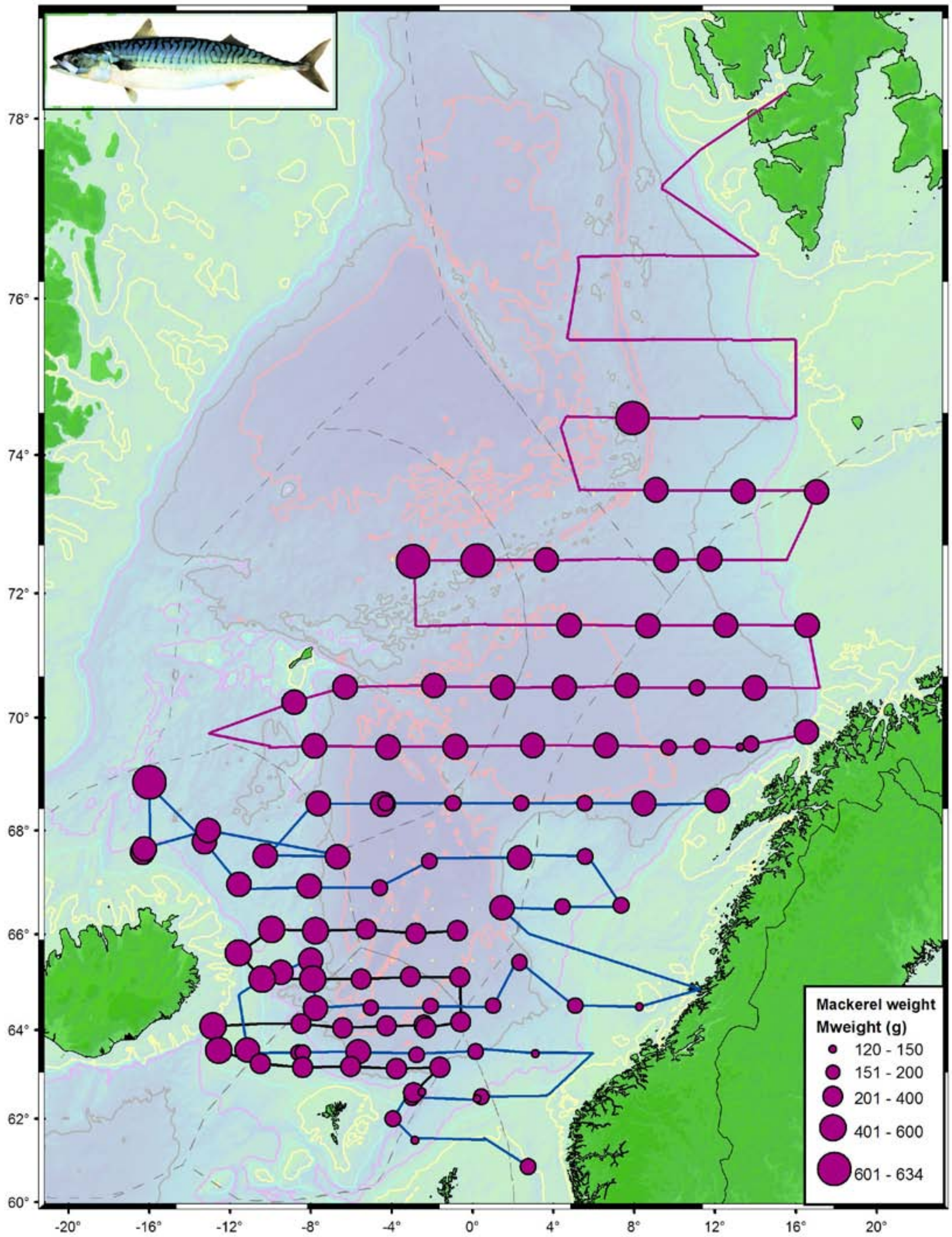


Figure 13. Mean mackerel weight (g) represented for each station within the categories shown. No catch of mackerel is indicated as a blank along the cruise track.

Mean mackerel length (cm) within each category is shown for each biological station (Figure 14). A general trend is that the longest mackerel is found in the western and northwestern part of the Norwegian Sea.

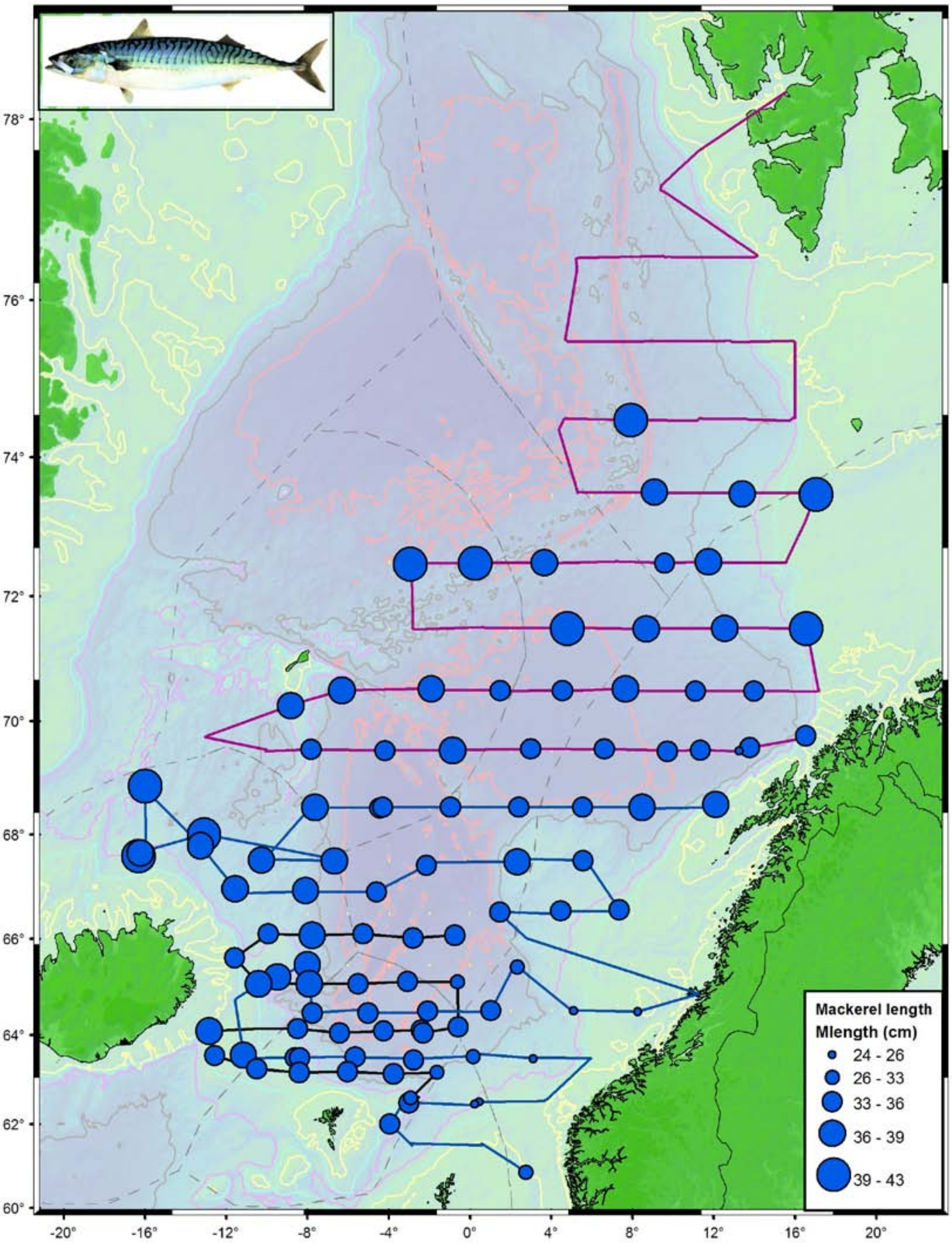


Figure 14. Mean mackerel length (cm) represented for each station within the categories shown. No catch of mackerel is indicated as a blank along the cruise track.

Mean herring wight (g) is shown in figure 15. We can see from the figure that herring is distributed over a substantial feeding area within the study area. The largest herring are found in the northern and western areas; with a relatively clear weight dependent migration pattern was found.

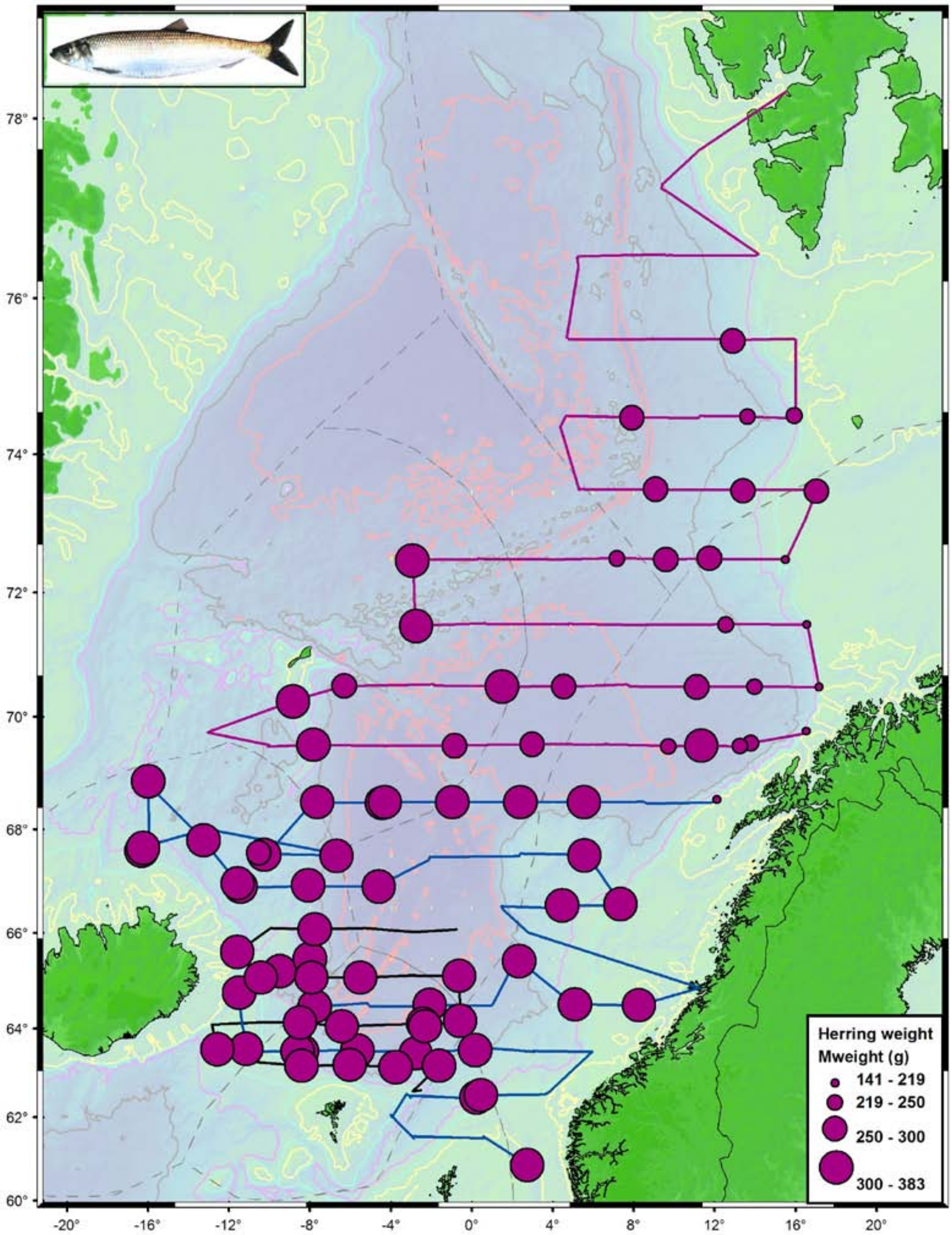


Figure 15. Mean herring weight (g) for herring represented for each station within the categories shown. No catch of mackerel is indicated as a blank along the cruise track.

Mean herring weight (g) is shown in figure 16. We can see from the figure that herring is distributed over a large feeding area within the study area. The longest herring were found in several areas with predominance in the southwestern and western part. A length-dependent herring migration was found.

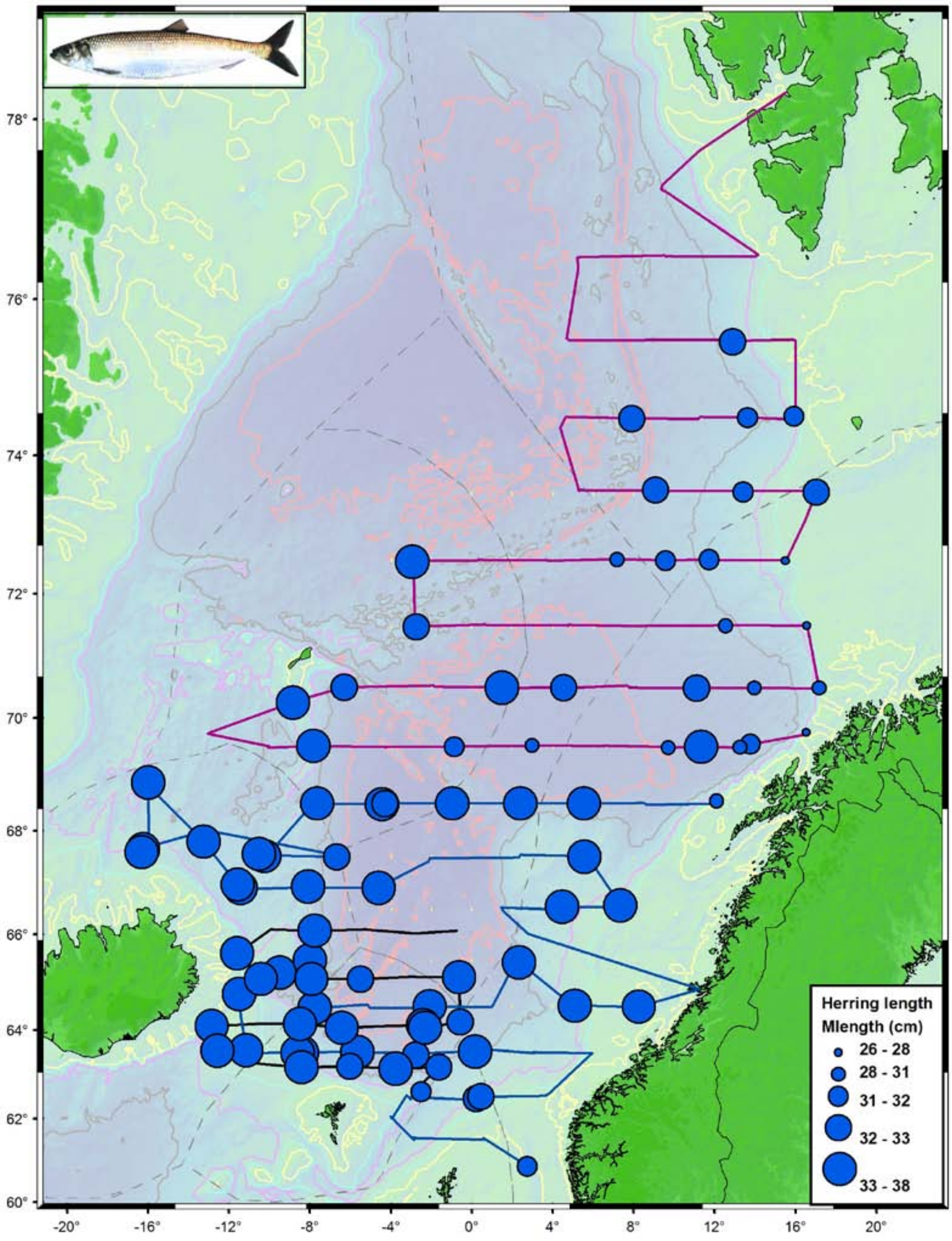


Figure 16. Mean herring length (cm) for each station within the different categories shown.

In order to illustrate and visualize the spatial and temporal overlap between mackerel, herring, blue whiting and salmon catches, we presented the catches for all species at each station to see where the abundant pelagic planktivorous species were present and compare their normalized catch rates (kg/nmi) from epi-pelagic trawling (Figure 16).

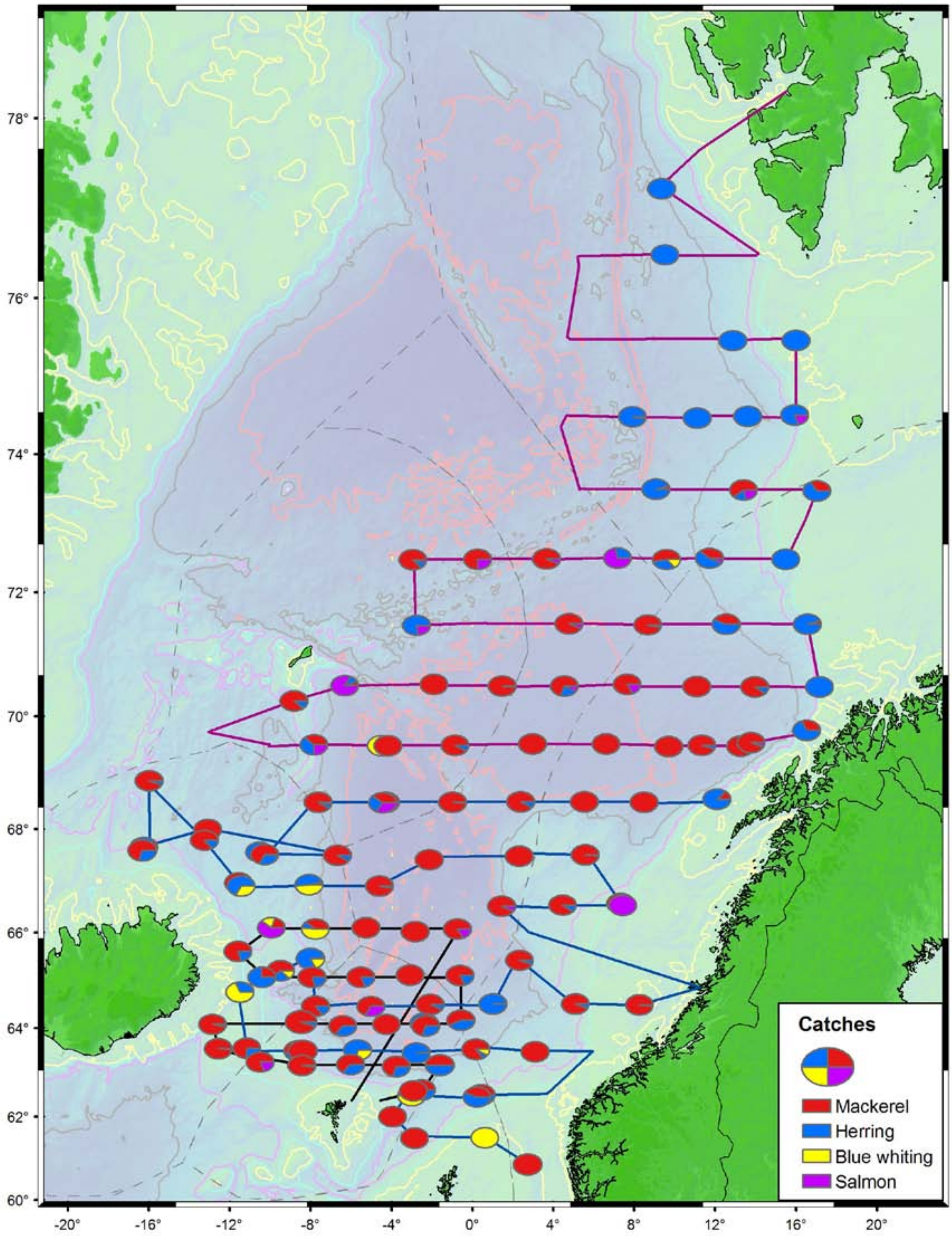


Figure 17. Distribution and spatial overlap between mackerel (red), herring (blue), blue whiting (yellow) and salmon (violet) in the Norwegian Sea between 15 July and 6 August 2009.

The spatial overlap between mackerel and herring were mostly found in the south-western part of the Norwegian Sea. Altogether 41 stations contained both mackerel and herring in the trawl samples. Herring were caught alone in the northeastern and northern part, whereas mackerel were caught alone in trawl catches in the coastal areas off Norway and central part of the Norwegian Sea. Blue whiting was predominantly caught in western part of the Norwegian Sea in Arctic and frontal water masses. Blue whiting and herring had spatial overlap in frontal and Arctic waters, whereas blue whiting had overlap with mackerel in the western areas, whereas little spatial overlap with mackerel in the central part of the Norwegian Sea.

Acoustics

Sonars

Mackerel schools detected on the sonars during the survey were located predominantly in the central Norwegian Sea. Nevertheless, sonar registrations were also detected in the southwestern and northwestern part of the ocean in Faroe Island, Icelandic and Jan Mayen area. This is a new situation compared to previous years and clearly shows a wider distribution pattern of mackerel as well as more westerly migration pattern than observed previously. The pelagic schools from mackerel were generally small and found in loose aggregations with low densities when tracked with Simrad SP90 and SH80 sonars. A similar tendency was found for herring with smaller schools and looser aggregations than previously found in July in the Norwegian Sea. School depths were from the surface down to approximately 50 m. Inter-school distances between neighbouring schools were quite consistent varying between 20-80 m in more densely aggregated areas.

Echosounders

Quantitative analyses of abundance, aggregation and distribution of mackerel, herring and blue whiting concentrations were also performed continuously based on Simrad ER60 raw data using 38 kHz as the primary frequency for fish species and nautical area scattering coefficient (NASC) allocation. Mackerel allocation was based on the formula:

$TS_{mackerel} = 20 \log L - 84.9$

where TS is the target strength of mackerel and L is the length of mackerel in cm. The S_v thresholds applied in LSSS to allocate mackerel from other species were in the range from

-69 to -75dB.

Herring allocation was based on the formula:

$TS_{herring} = 20 \log L - 71.9$

where TS is the target strength of herring and L is the length of herring in cm.

The S_v thresholds applied in LSSS to discriminate and allocate herring from other species were in the range from -50 to -55dB.

Blue whiting allocation was based on the formula:

$TS_{blue\ whiting} = 20 \log L - 64.2$

The S_v threshold applied in LSSS to discriminate and allocate blue whiting from other species was -68 dB.

Judging of the acoustic data were performed daily by two experienced scientists applying the post-processing system Large Scale Survey System (LSSS) http://www.marec.no/ .

Aundance estimation of pelagic fish

Acoustic abundance estimation using Large Scale Survey System (LSSS) was done for Norwegian spring-spawning herring, mackerel and blue whiting.

The herring population within the covered cruise tracks and areas was estimated to be 13.6 million tons consisting of 47 billion individuals (Figure 18). The average weight of herring was 286.9 gramme and mean length was 31.8 cm. Altogether 14 different year classes were present in the catches, whereas only five year classes constituted more than 5% of the catches.

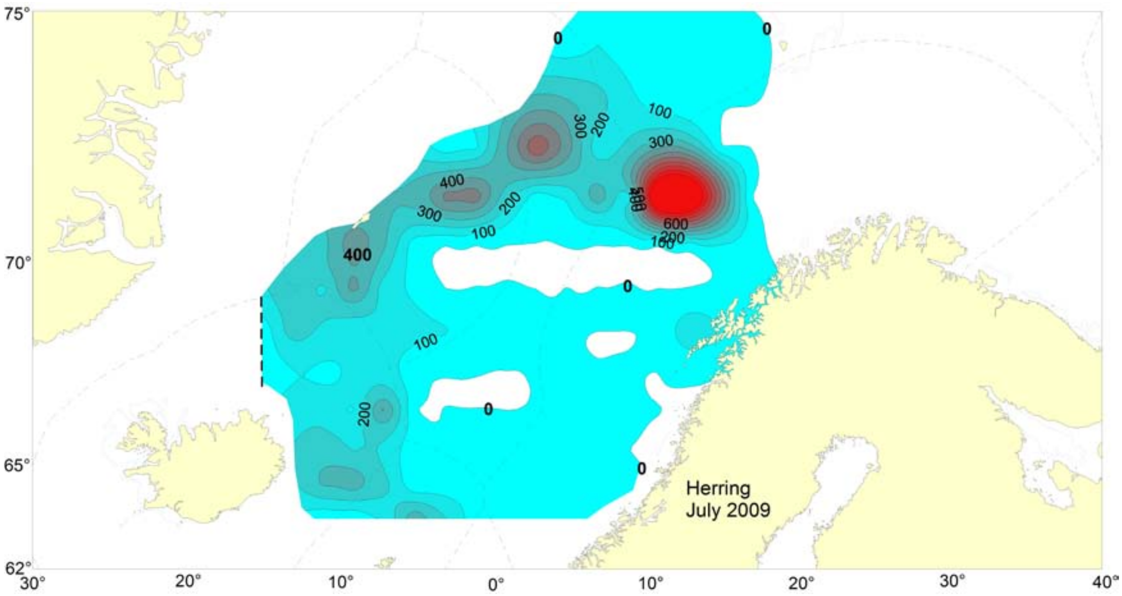


Figure 18. Sa or Nautical Area Scattering Coefficient (NASC) values of herring along the cruise track.

Acoustic detection of and NASC allocation to Atlantic mackerel were done based on the multifrequency response of the acoustic echoes and especially the characteristic frequency response on 200 kHz. Biological samples taken at each station were used in tight combination with sonar and echosounder data to allocate NASC values to mackerel.

The mackerel population within the covered cruise tracks and areas was estimated to be 4.4 million tons consisting of 11.9 billion individuals (Figure 19). The average weight of mackerel was 371.4 gramme and mean length was 33.9 cm. Altogether 13 different year classes were present in the catches, whereas seven year classes constituted more than 5% of the catches.

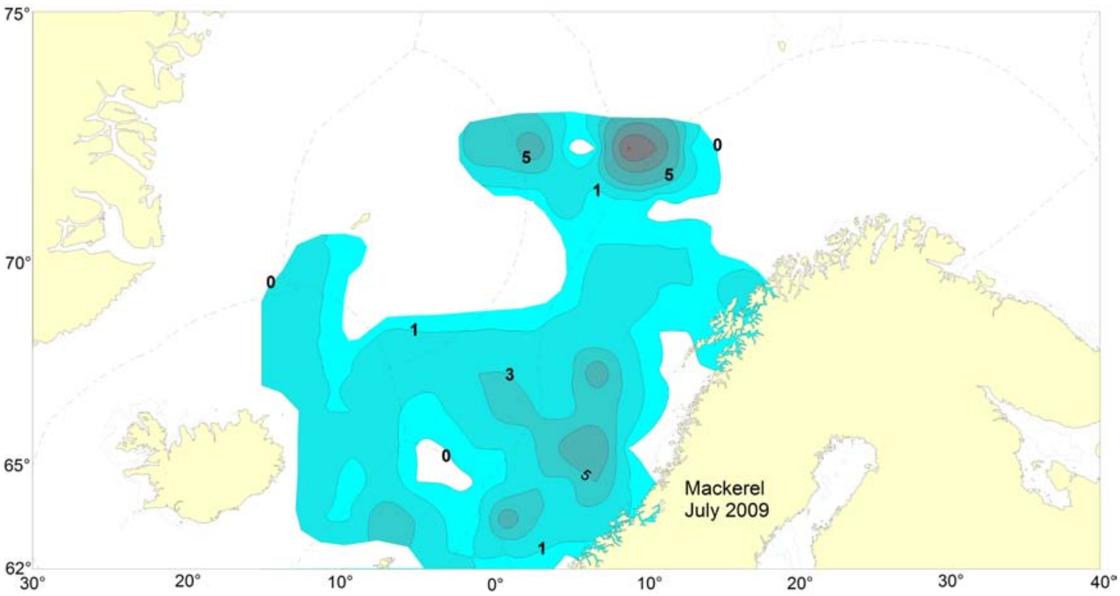


Figure 19. Sa or Nautical Area Scattering Coefficient (NASC) values of mackerel along the cruise track.

The blue whiting population within the covered cruise tracks and areas was estimated to be 2.3 million tons consisting of 14.9 billion individuals (Figure 20). The average weight of blue whiting was 155.9 gramme and mean length was 30.1 cm. Altogether 10 different year classes were present in the catches, although only four year classes constituted more than 5% of the catches.

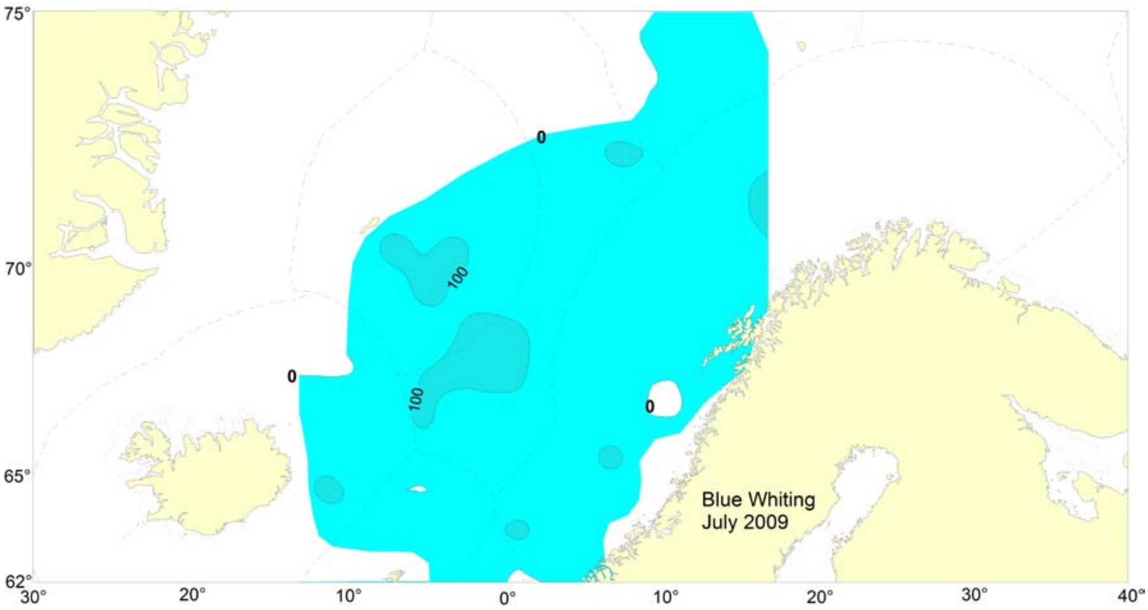


Figure 20. Map of blue whiting distribution and aggregation showing the Sa or Nautical Area Scattering Coefficient (NASC) values estimated acoustically in the Norwegian Sea ecosystem.

Plankton

Libas

The overall impression during the cruise was that zooplankton biomasses were low in most part of the investigated area. The average zooplankton biomass for the total area investigated south of 68 °30′N was 3.6 g m^{-2}. As expected the main part of the biomass consisted of the copepod *Calanus finmarchicus* regardless of sampling method, mainly copepodite stages IV-V and adults. At a few stations copepod nauplii were observed, indicating an ongoing production of a new generation. This was the case both east of Iceland to the west and over the Vøringen plateau to the east.

The Bongo samples also contained large amounts of the blue surface dwelling copepod *Anomalocera patersoni*. In the eastern and central part of the area to about 2° W the cirriped *Lepas* sp. was occasionally found clinging to drifting seaweed, indication a southerly origin of the water masses.

A large number of the Bongo samples also contained the 2–3 cm long silvered juveniles of rockling, probably *Rhinonemus cimbrius*, from the Norwegian coast westwards to about 8 °W, i.e. north of the Faroes. A few capelin larvae (*Mallotus villosus*) were observed in Bongo net samples in the western part of the ocean.

Euphausiids were observed only sporadically as most krill will not be caught in the nets used. However, at a few stations krill were observed stuck within the finer meshes of the fishing trawl. In one occasion, north of Iceland, the medium sized *Thysanoessa inermis* were identified, in some occasions closer to the Norwegian coast the larger *Meganyctiphanes norvegica* were observed. A few WP-2 and Bongo samples also revealed the presence of *M. norvegica* to the east.

Small 5-10 mm large individuals of the amphipod *Themisto abyssorum* were observed in Bongo samples, scattered throughout the area.

The larger copepod *Calanus hyperboreus* was not observed at all during the survey. This cold water species was expected to be found in rather large numbers in the area north of Iceland.

The zooplankton biomass varied throughout the area. The highest biomass, 15 g dry weight per m^2 was observed off Lofoten. Stations with biomasses above 5 g m^{-2} were found scattered both east and northeast of Iceland and in central parts of the ocean (Figure). In the East Icelandic Current the biomasses varied between 1.4 and 6.0 g m^{-2}. The average zooplankton biomass for the total area investigated south of 68 °30′N was 3.6 g m^{-2}. As a comparison the average biomasses at the Svinøy section in early to mid July 2008 was 4.6 g m^{-2}, supposed to decline toward the end of the month. Thereby the data from summer 2009 indicate only a minor decline in zooplankton biomass in relation to the same period previous year.

Eros

WP2 net

The average amount of zooplankton concentration sampled with the WP2 net was 5.9 g/m^2 dry weight in the northern part of the survey area covered with Eros. The highest concentrations were between 18-22 g/m^2 dry weight dominated by *Calanus finmarchicus* in three stations between 72.30- 75.30 °N. Average registrations of *C. finmarchicus* during the period 1994-2002 were 7 g/m^2. Amphipods were found at 23 out of 43 locations, and largest numbers were found in the northernmost areas dominated by *Themisto libellula* and *Themisto abyssorum*. Chaetognatha (*Sagitta elegans, Sag-*

itta maxima, Eukronia hamata) were found at 41 out of 43 stations, with the largest specimen and highest concentrations in the northernmost stations up to Spitsbergen. Only 15 specimens of krill (*Thyssanoessa longicaudata, Thyssanoessa inermis, Euphausiacea)* were caught in the WP2 net. Calanus hyperboreus was only found at five stations. Paraeuchaeta was found at 26 out of 43 locations. Catches from T-160 ringnet has not been properly analysed yet, although Themisto *libellula*, Copepods, *Limacina helicina* and gelatinous plankton were sampled.

Bongo

Amphipods (*Themisto libellula)* dominated the catches at the surface in the northern locations together with some copepods, whereas *Calanus finmarchicus* were most abundant further south. Other species caught included blååte, *Limacina helicina* and *Limacina retroversa*.

Krill trawl

A total number of 16 trawl hauls with the macroplankton trawl was done and six of the hauls had no catch. Krill were only caught in three hauls, exclusively in the northernmost survey area. The largest catch was 6.6 kg of krill caught south of Longyearbyen. Drifting fish larvae from various pelagic and demersal species were found in several hauls.

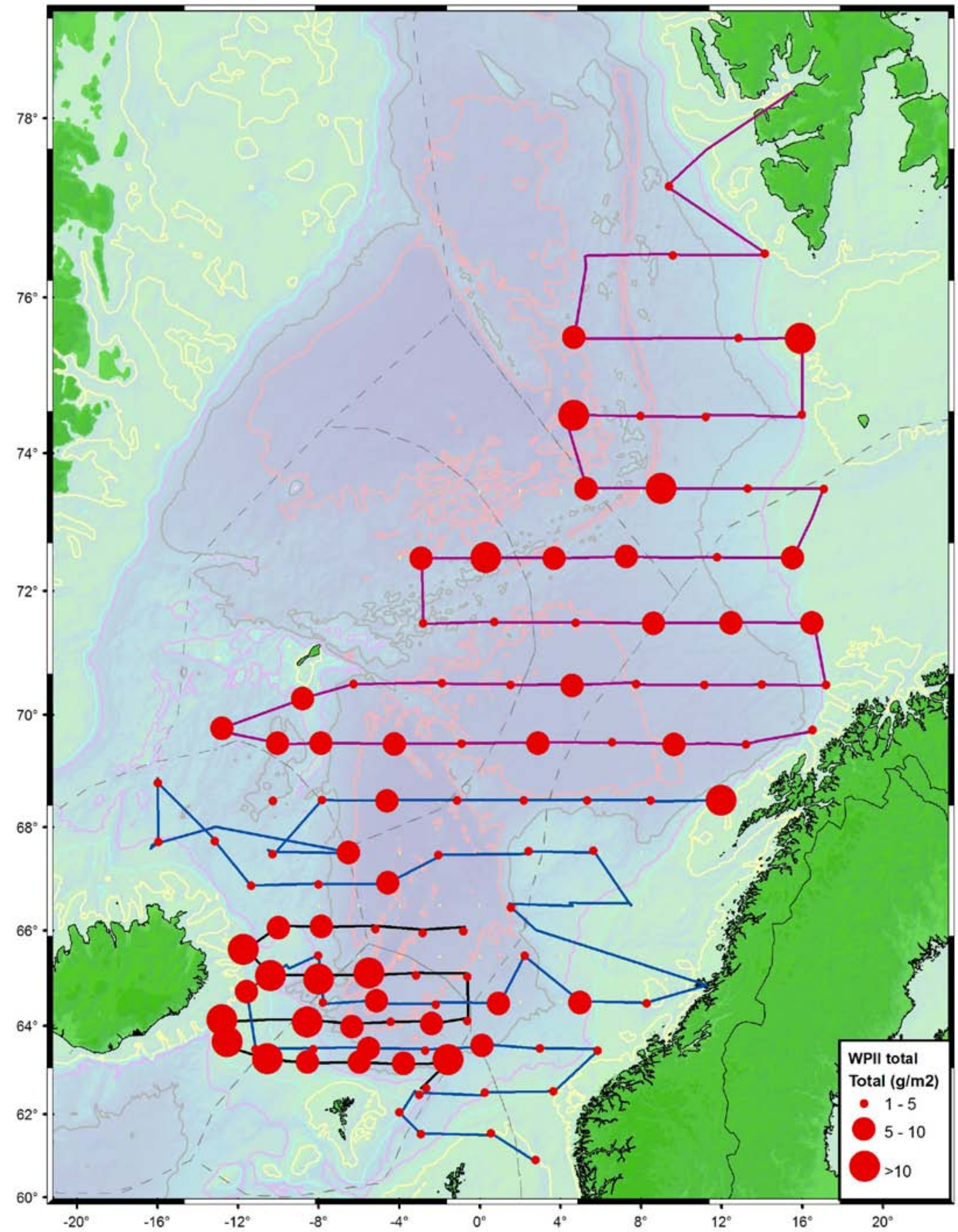


Figure 21. Map of total zooplankton concentrations (g/m^2) from WP2 net samples (0-200 m) at preselected stations.

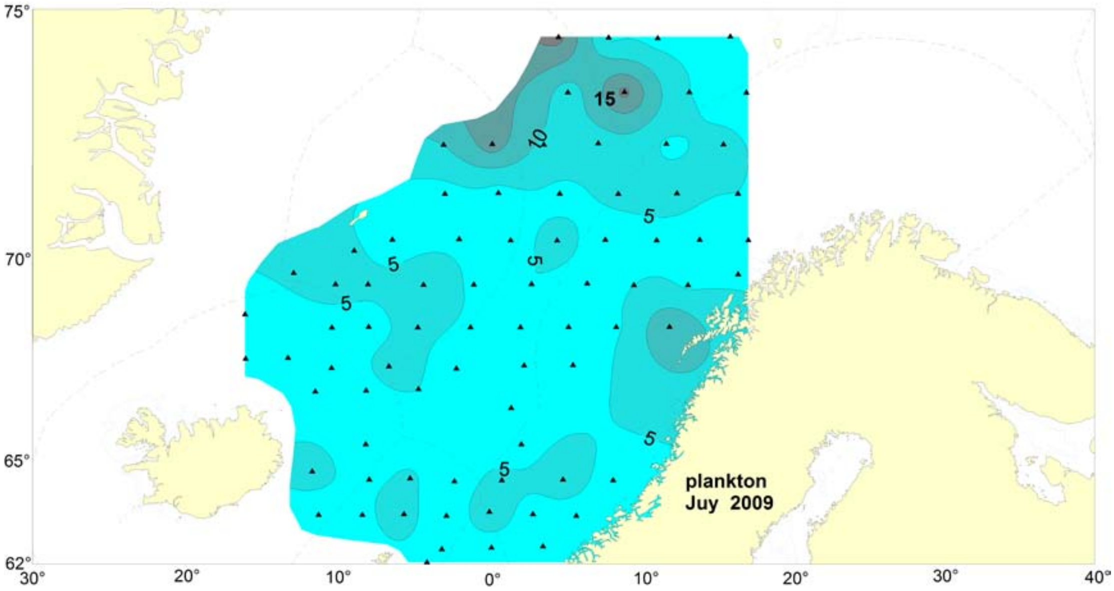


Figure 22. Total biomass of zooplankton (g/m^2) from WP2 net samples (0–200 m).

Marine mammals

The weather conditions were good and calm enough during the majority of the scientific cruise for carrying out dedicated observations from the roof according to marine mammal sighting procedure. In total, 132 hours were spent for dedicated observations on-board Libas. The distribution of marine mammals and basking sharks is presented in figure Z. Incidental sightings made by other scientists and crew members on-board Libas, Eros and Finnur Fríði were also used in creating the overall distribution map.

Although the observations were implemented precisely, there were generally very few observations of marine mammals, compared with previous years in the Norwegian Sea in July–August. There were especially few whales and almost no dolphins south of 69°N. The observations showed sperm whales along the deep continental slopes off Norway and in the northern part of the Norwegian Sea. Minke whales were detected in several areas, but mostly there were single animals or one small group. Fin whales were met only four times; two sightings in the western part and two in the northern part of the investigated area. Humpback whales were only sighted twice in the western part not far from Iceland. There were some observations of killer whales with a school size ranging from 1 to 15. A small group of pilot whales was sighted to the east of the Faroe Islands. The majority of dolphins were found north of the polar circle at 66.33°N. The basking shark appeared three times in the western and eastern parts of the survey area. Total number of sightings and registered animals is shown in the table 1. Total number of marine mammals sighted was significantly less than expected, with the highest sighting rates found along the continental shelf break north of Tromsø (Figure 23).

Table 1. Number of sightings and registered marine mammals and basking shark.

SPECIES	SIGHTINGS (NTOTAL)	ANIMALS (NTOTAL)
Sperm whale	35	36
Minke whale	22	30
Fin whale	4	5
Humpback whale	2	4
Killer whale	9	36
Pilot whale	1	6
Unidentified whale	24	32
Unidentified dolphin	9	74
Basking shark	3	3

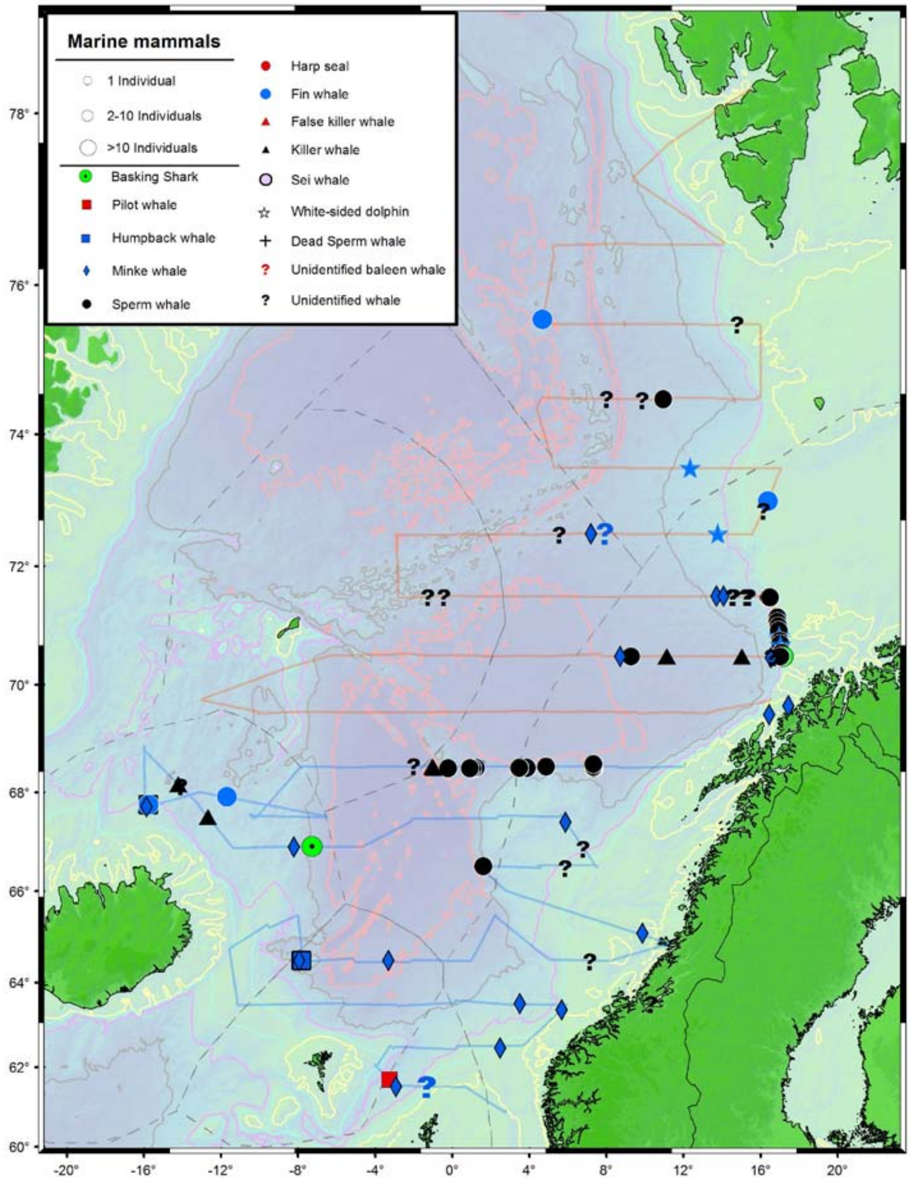


Figure 23. Marine mammals and basking sharks observed in the Norwegian Sea on-board "Libas" and "Eros" between stations in daylight hours, 15 July – 6 August 2009.

Stomach samples from pelagic fish

Stomach samples were taken at 54 mackerel, 36 herring, 10 blue whiting and 28 salmon trawl catches.

Genetic samples from pelagic fish species

Genetic samples were taken at 6 mackerel, 4 herring, 3 blue whiting and 27 salmon trawl stations.

5) Discussion

The ecosystem survey managed to cover the most central areas for the distribution and aggregation of mackerel, herring and blue whiting in the Norwegian Sea in summer. July–August is the feeding period where all the three major planktivorous species have their maximum geographical distribution. A major aim of this study was to map almost the entire populations of mackerel, herring and blue whiting in the Norwegian Sea. Based on the continuous acoustic recordings from hydroacoustics and extensive pelagic trawling near the surface and midwater, we managed to cover the vast majority of these species and consequently their maximum spatial distribution.

Chartered commercial fishing vessels are suitable and well-equipped platforms for large-scale mapping of pelagic fish species such as mackerel, herring and blue whiting. Modern combined stern trawlers/purse-seiners are also practical for more dedicated ecological studies. Because both Libas and Eros has drop keel the vessels can be used for abundance estimation using hydroacoustic recordings with scientific echosounders and multibeam sonars. This combined methodology will ensure more reliable abundance estimation and distribution patterns of pelagic fish during the feeding period from May to August in the Norwegian Sea.

The shallow distribution and absence of dense schooling behaviour in both mackerel and herring within most of the study area in July–August, challenges the quantitative value and credibility of acoustic recordings from echosounder measurements. Substantial concentrations of pelagic species (mackerel, herring, horse mackerel) were present above and close to the transducer depth. The upper acoustic blind zone is in the order of 10-15 m due to the drop keel on Eros and Libas. Furthermore, pronounced vessel avoidance during summer feeding may complicate these studies even more when applying standard echosounder technology.

Nevertheless, a complementary approach with continues use of multibeam sonars and multifrequency ensures a complete coverage of the water column along the cruise track.

Systematic stomach content analyses of our most important pelagic species mackerel, herring and blue whiting, combined with concurrent zooplankton analyses, mapping of marine mammals and measurements of the oceanographic conditions are paramount for a deeper understanding of the feeding ecology, potential interspecific feeding competition, spatio-temporal overlap and migration patterns of mackerel, herring and blue whiting in the Norwegian Sea.

Acknowledgements

We thank skippers and crew members on-board Libas, Eros, and Finnur Fríði for outstanding collaboration and practical assistance on the ecosystem cruise in the Norwegian Sea.

References

Foote, K. G. 1987. Fish target strengths for use in echo integrator surveys. J. Acoust. Soc. Am. 82: 981-987.

Slotte, A., and H. Pena. 2005. Estimating the summer distribution and abundance of herring and blue whiting in the northern Norwegian Sea. Cruise report (I) 13–27 June 2005, 20 p.

Røttingen, J., and E. Haugland 2005. Utbredelse og mengde av norsk vårgytende sild og kolmule i nordlige Norskehavet. (Distribution and biomass of Norwegian spring spawning herring and blue whiting in the northern part of the Norwegian Sea). Cruise report (II) 27 June–11 July 2005, 17 p.

Misund, O.A. og K. Misund Bringslid 2005. Utbredelse og mengde av norsk vårgytende sild og kolmule i nordlige Norskehavet. Akustisk tokt med "Hardhaus", Survey 3: 11 – 26 juli 2005, 29 p.

Mjanger, H., Hestenes, K., Olsen, E., Svendsen, B.V., Wenneck, T.dL., and Aanes, S. 2007. Håndbok for prøvetaking av fisk og krepsdyr. Institute of Marine Research, Bergen. 3.16:45-51.

Nøttestad L. *et al*. 2005. Cruise report for M/V "Libas, M/V "Møgsterbas" and Russian airplane "Arktika" 15-29 July 2005 in the Norwegian Sea. Insitute of Marine Research, Norway. 37 p.

Nøttestad L. *et al*. 2006. Økosystemtokt i Norskehavet med M/V "Libas" og M/V "Endre Dyrøy" i perioden 15 juli til 6 august 2006. Ukens Orientering. Havforskningsinstituttet. 13 september 2006.

Nøttestad L. *et al*. 2007. Cruise report for M/V "Libas" og M/V "Eros" 15 July til 6 August 2007. Insitute of Marine Research, Norway. 39 p.

Alsvåg, J., Hestenes, K., Mjanger, H.., Svendsen, B.V., and Wenneck, de Lange T. 2003 .Manual for Sampling of Fish and Crustaceans. Versjon 1.0. Institute of Marine Reseaarch, Quality system. Department of Marine Resources.

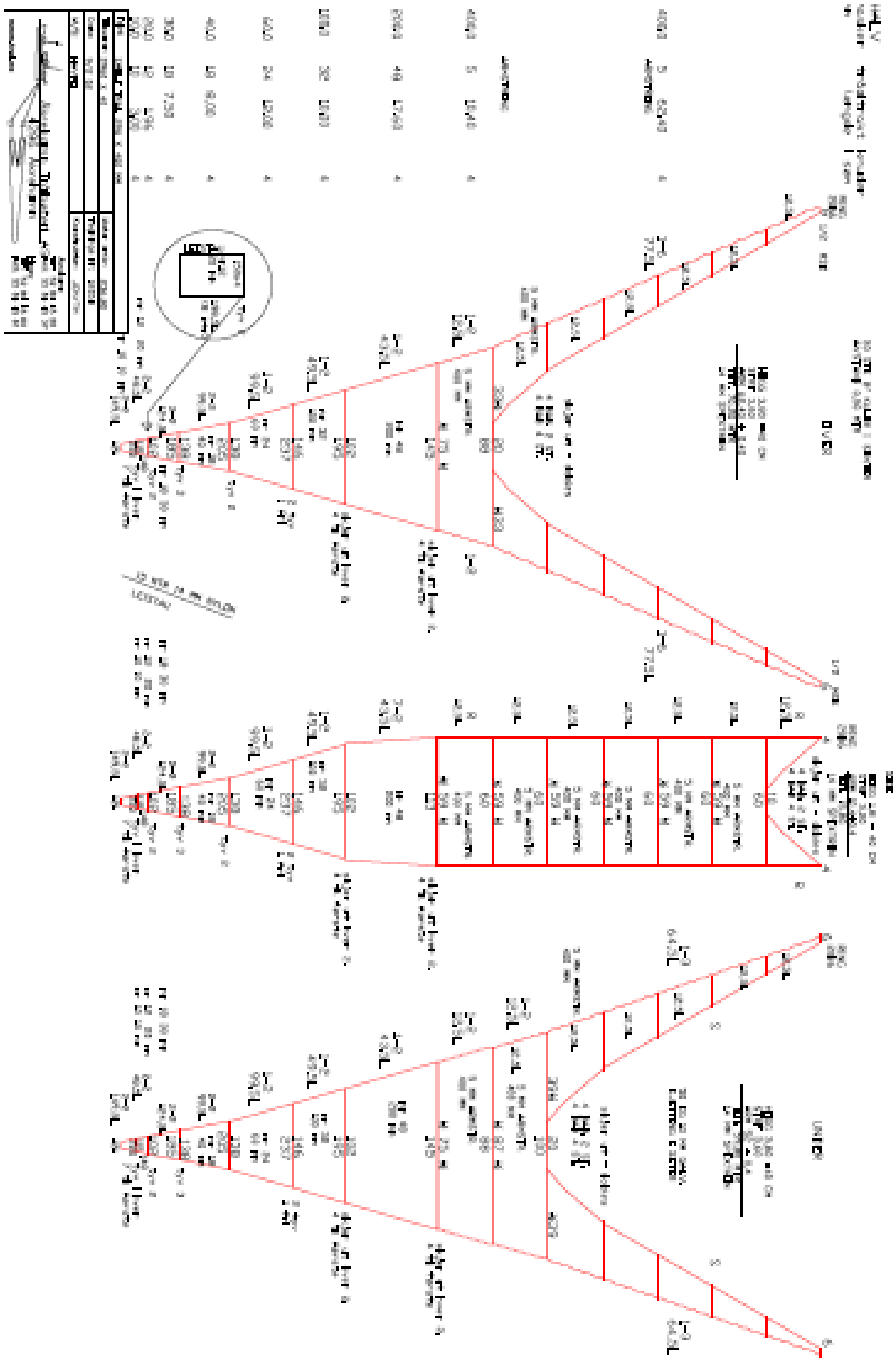
Mjanger, H., Hestenes, K., Olsen, E., Svendsen, B.V., Wenneck, T.dL., and Aanes, S. 2007. Håndbok for prøvetaking av fisk og krepsdyr. Institute of Marine Research, Bergen. 3.16:45-51.

Bjørke, H, Endresen, B., Ellertsen, B. Hansen, K., Hassel, A.Knutsen, T. Og Rey, L. 2002. Håndbok for innsamling, bearbeiding og punching av dyreplankton, og innsamling og bearbeiding av fiskeegg, og fiskelarver. Versjon 1.0. Havforskningsinsituttets kvalitetssystem. Senter for Marint Miljø.

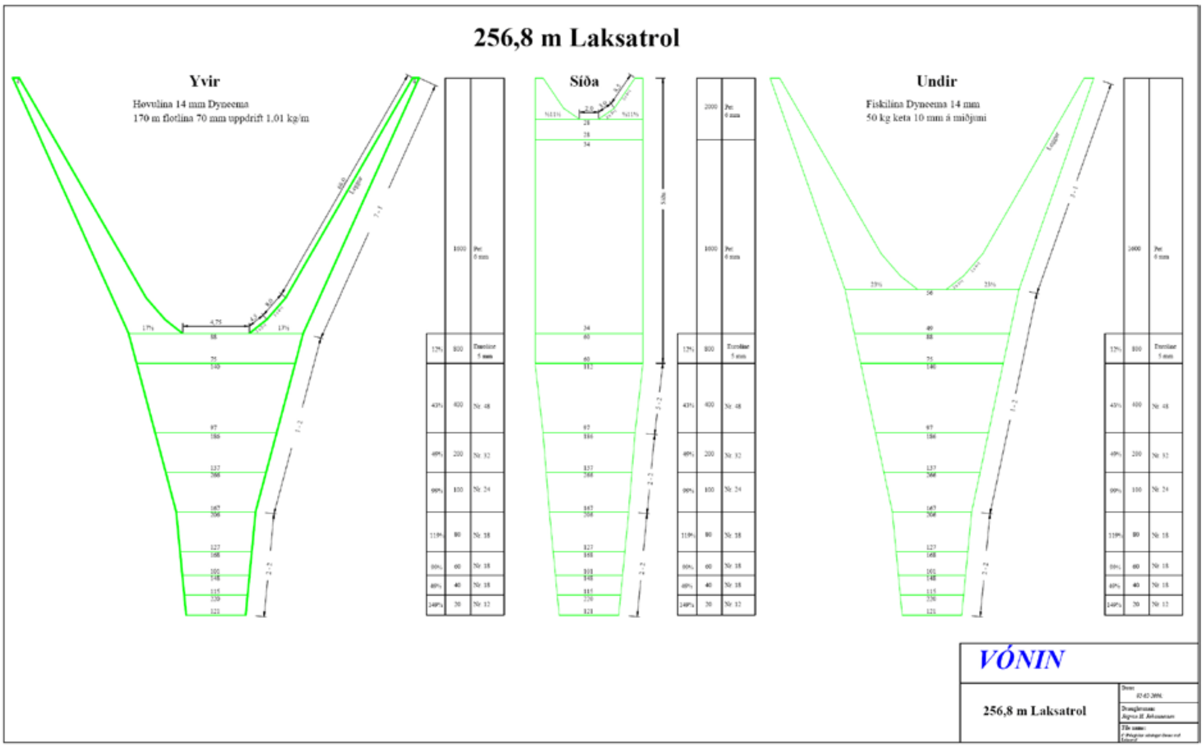
Hassel, A. 2004. Dyreplankton rutiner på tokt. Kort illustrert manual for toktdeltagere. Havforskningsinstituttet.

Appendix 1

Pelagic trawls used.



Appendix F1. Drawing of design and dimension for the pelagic salmon trawl used on Eros and Libas during the cruise.



Appendix F2. Drawing of design and dimension for the pelagic salmon trawl used on Finnur Fríði during the cruise.

Annex 5: Terms of Reference 2010

2010/2/RMC0 The **Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys** [PGNAPES] (Chair: Ciaran O'Donnell*, Ireland) will meet in Hamburg, Germany from 17–20 August 2010 to:

a) critically evaluate the surveys carried out in 2010 in respect of their utility as indicators of trends in the stocks, both in terms of stock migrations and accuracy of stock estimates in relation to the stock – environment interactions;

b) review the 2010 survey data and provide the following data for the Working Group for Widely Distributed Stocks (WGWIDE):

- i) stock indices of blue whiting and Norwegian spring-spawning herring.
- ii) zooplankton biomass for making short-term projection of herring growth.
- iii) hydrographic and zooplankton conditions for ecological considerations.
- iv) aerial distribution of such pelagic species such as mackerel.

c) describe the migration pattern of the Norwegian spring-spawning herring, blue whiting and mackerel stocks in 2010 on the basis of biological and environmental data;

d) Respond to the findings of the Planning Group on Redfish Surveys

i) plan and coordinate the surveys on the pelagic resources and the environment in the North-East Atlantic in 2011 including the following:

ii) the international acoustic survey covering the main spawning grounds of blue whiting in March-April 2011.

iii) the international coordinated survey on Norwegian spring-spawning herring, blue whiting and environmental data in May-June 2011.

iv) national investigations on pelagic fish and the environment in June-August 2011.

PGNAPES will report by 1 September 2010 for the attention of SCICOM and ACOM.

Supporting Information

Priority:	The coordination of the surveys has strongly enhanced the possibility to assess abundance and provide essential input to the assessment process of two of the main pelagic species in the Northeast Atlantic and describes their general biology and behaviour in relation to the physical and biological environment.

Scientific Justification and Relation to Action Plan:	The Planning Group is a potential meeting place for interdisciplinary discussion and considerations on ecosystem approach to management of fisheries. **ToR a)** Two international and some national surveys with coordinated by PGNAPES. The Planning Group describes the procedures for acoustic, hydrographic, plankton, and fish sampling to be used during the surveys. **ToR b)** The abundance indices estimates of Norwegian Spring-spawning Herring and Blue Whiting produced from surveys are used in ICES Northern Pelagic and Blue Whiting Fishery Working Group (NPBWWG) in assessment. The collection of environmental data improves the basis for ecosystem modelling of the Northeast Atlantic. **ToR c)** The Planning Group describes the migrations of the stocks and considers possible stock – environment interactions. **ToR d)** There is a need to monitor the pelagic redfish in the Northern Norwegian Sea, where a fishery is rapidly expanding. The task at present for the Planning Group will be to coordinate and quality control surveys in the area where redfish is recorded. In the coming years, the Planning Group should also evaluate the surveys and analyse and report the results. For a survey in 2009, there may be a need for coordination during spring 2010 through consultations between interested parties. **ToR e)** The Planning Group contributes significantly to improving abundance surveys essential to fish stock assessment of herring and blue whiting and improving the collection of data for ecosystem modelling of the Northeast Atlantic. The Planning Group will identify existing procedures to ensure that the sampling gear and any instrumentation used to monitor its performance are constructed, maintained and used in a consistent and standardized manner. Where necessary, procedures and protocols should be established for intercalibration to evaluate platform and sampling tools-survey gear differences. In general, the remit of this group addresses Action Numbers 1.2.2, 1.3 and 1.11.
Resource Requirements :	None
Participants :	15
Secretariat Facilities:	Standard report production.
Financial:	None
Linkages to Advisory Committees:	ACOM
Linkages to other Committees or Groups:	WGWIDE, WGNAS
Linkages to other Organisations:	None

Annex 6: Recommendations

Listed below is a range of recommendations compiled by the PGNAPES:

Recommendation	For follow up by:
1.Standartitisation of gear types should be achieved in future with special emphasis on the use of a standardized codend.	Participants countries
2.An efficient Internet connection should be set up on all vessels participating in internionally coordinated surveys to ensure timely and essential data exchange.	Participants countries
3.For a comparison of softwares used for scrutinizing the acoustic data from the May survey, it is recommended that part of the data from the RV DANA May survey 2009, and already scrutinized with BI500 on-board, will be sent to IMR to be scrutinized with LSSS and to Havstovan to be scrutinized with Echoview. The results from the three different sofwares should then be compared statistically and presented to the group prior to the surveys in May 2010, along with conceivable recommendation.	PGNAPES
4.The group welcomed the presence of plankton specialists during the 2009 meeting. The group still lacks the presence of a full time oceanographer	Participants institutes
5. It is recommended that during IESNS surveys bongo samples for mackerel eggs should be taken where spawning mackerel are found in order to support WGMEGS with information on mackerel spawning in the survey area. Prior to the survey Matthias Kloppmann will contact cruise leaders to communicate sampling methods and sample handling procedures.	PGNAPES, WGMEGS
6. During the coming IESNS surveys acoustic and fishing inter-calibrations between vessels should be carried out following the procedures described in the Manual for hydro acoustic surveying in the Northeast Atlantic. Although not achieved in 2009, the group recommends that special attention be focused on carrying out inter-calibrations in 2010.	PGNAPES
7. In oder to differentiate between Norwegian spring-spawning herring and North Sea herring otoliths should be collected from the herring in the potential area of mixing. This was implemented in 2009 and it is recommended that it continue in 2010.	PGNAPES, WGWIDE
8. At the PGNAPES Scrutinize workshop in Bergen it was recommended that scrutinization of echograms in the surveys should be conducted in the presence of at least one experienced scientist familiar with the target species and the survey area.	Participants institutes
9. At the PGNAPES Scrutinize workshop in Bergen it was recommended that the layer approach should be used in the scrutinizing procedure until a thorough comparison has been made between a layer and a school approach.	PGNAPES
10. For the IBSS survey it was recommended that to increase the precision of the estimate, by reducing the effects of double counting, the time frame on which the survey is carried out is reduced still further from 4 weeks to 3 weeks.	PGNAPES
11. The next PGNAPES meeting will take place in Hamburg, Germany from the 23–26 August, 2010. The group discussed the possibility of moving the meeting to June but decided that this	SCICOM

was not a recommended as this would mean not all survey data would be available to the PGNAPES group	
12. The group elected Ciaran O'Donnell (Ireland) as the new PGNAPES Chair in 2010.	PGNAPES