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Report of the Working Group on Northeast Atlantic Pelagic Ecosystem Surveys (WGNAPES)

16-19 August 2011

Kaliningrad, Russian Federation

ICES International Council for the Exploration of the Sea
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International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Contents

Executive Summary

This report was prepared by the Working Group on Northeast Atlantic Pelagic Ecosystem Surveys (WGNAPES) which met in Kaliningrad, Russian Federation from 16–19 August 2011. Eleven participants from 7 nations attended the meeting chaired by Ciaran O'Donnell (Ireland). Participants analyzed and discussed the results of the acoustic, hydrographic, plankton and fish sampling components of two international ICES coordinated surveys in 2011:

International Blue whiting spawning stock survey (IBWSS). 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 RV "G.O. Sars" (Table 1 in Annex 2). The surveyed area (cruise tracks) in March-April 2011 is shown in Figure 1 in Annex 2. All survey methods and results are provided in the combined cruise report (Annex 2).

International ecosystem survey in the Nordic Seas (IESNS). Five vessels participated, the Danish RV "Dana", the Norwegian RV "G.O. Sars", the Icelandic RV "Árni Fridriksson", the Faroese RV "Magnus Heinason" and the Russian RV "Fridtjof Nansen". The surveyed area (cruise tracks) in May-June 2011 is shown in Annex 3, Figures 1 and 2. Map showing area I to III used in the acoustic estimate of herring and blue whiting is shown in Annex 3, Figure 3. All further details are provided in the combined cruise report (Annex 3).

Other relevant surveys. The data from the International summer ecosystem survey in the Nordic Seas (IESSNS) in 2010 were not available during the 2010 meeting due to a conflict in timing and so are presented in Annex 4. The same situation occurred in 2011 and it was decided that the 2011 cruise report will be discussed during the 2012 WGIPS meeting. Two chartered Norwegian fishing vessels M/V "Libas" and M/V "Brennholm", one chartered Faroese vessel M/V "Finnur Fridi" and the research vessel "Arni Fridriksson" participated in the survey during 9 July until 20 August 2010. The abundances of mackerel, herring and blue whiting were measured acoustically but swept area estimates were also made for mackerel from predefined trawl stations in the surface waters. Details about the procedure are provided in the survey report. The survey tracks and area covered are shown in Figure 23 in Annex 4.

An acoustic survey for boarfish (*Capros aper)* undertaken by the Irish fishing industry in collaboration with the Marine Institute was presented at the meeting. The survey was carried out onboard a commercial vessel (MFV *Felucca*) using an acoustic tow body system for 21 days in July 2011. The survey covered the shelf and slope areas from 53°-47°N. The survey report is presented in Annex 5

The WGNAPES report includes survey results about the distribution and the biomass estimate of spawning blue whiting in March-April west of Ireland and Scotland, 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 2011. 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 modeling of the Northeast Atlantic. Broad plans for the ICES coordinated surveys for 2012 are also outlined with descriptions of the relevant protocols, preliminary participants and suggested survey designs.

Survey derived abundance estimates from other relevant surveys such as the IESSNS and boarfish surveys are not considered as quantitative metrics at present during the assessment process due to problems with precision or methods. However these surveys provide important qualitative information on the dynamics of pelagics within the NE Atlantic.

1 Introduction

1.1 Terms of Reference 2011

The **Working Group on Northeast Atlantic Pelagic Ecosystem Surveys** (WGNAPES), chaired by Ciaran O'Donnell, Ireland, and will meet in Kaliningrad, Russian Federation, 16–19 August 2011 to:

a) Critically evaluate the surveys carried out in 2011 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 2011 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 Working Group on Redfish Surveys

- i) plan and coordinate the surveys on the pelagic resources and the environment in the North-East Atlantic in 2012 including the following:
- ii) the international acoustic survey covering the main spawning grounds of blue whiting in March-April 2012.
- iii) the international coordinated survey on Norwegian spring-spawning herring, blue whiting and environmental data in May-June 2012.
- iv) national investigations on pelagic fish and the environment in June-August 2012;

e) Prepare methods for delivery of the following information to assessment working groups in 2012:

- v) Proportion of fish larger than the mean size of first sexual maturation
- vi) Mean maximum length of fish found in research vessel surveys
- vii) 95th % percentile of the fish length distribution observed

The information should be provided for all major fish stocks covered by the survey.

f) "Initiate and complete planning with WGIPS so that the two Working Groups can be merged at the start of 2012. Proposed 2012 ToRs for the new WG should be drafted and the new WG should be co-chaired by the current WGNAPES and WGIPS chairs.

WGNAPES will report by 1 September 2011 (via SSGESST) for the attention of SCICOM and ACOM.

1.2 List of participants

Ciaran O'Donnell (Chair)	Ireland
Alexander Krysov	Russia
Nikolay Timosenko	Russia
Matthias Kloppman	Germany
Guðmundur Oskarsson	Iceland
Sascha Fässler	Netherlands
Leon Smith	Faroe Islands
Åge Høines	Norway
Valantine Anthonypillai	Norway
Øyvind Tangen	Norway
Erling Stenevik	Norway
Karl-Johan Staehr	Denmark (by correspondance)

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).

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 (IBWSS, 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 International Ecosystem Summer Survey in Nordic Seas in July-August (IESSNS, Annex 4) was initiated by Norway in 2005. In 2009 this survey became international due to participation of Iceland and Faroese. The main objectives there are to study abundance, spatiotemporal distribution, aggregation and feeding ecology of Northeast Atlantic mackerel, Norwegian spring-spawning herring, blue whiting and other pelagic species in relation to oceanographic conditions, prey communities and marine mammals.

WGNAPES provides a platform for the presentation and discussion of new research survey data through an expert forum. During the 2011 meeting a new survey was introduced to the group the Irish boarfish acoustic survey (Annex 5).

The abundance estimates of Norwegian spring spawning and blue whiting combined stock (generated by WGNAPES coordinated surveys) are important inputs for the assessments of these stocks which is carried out by WGWIDE (Working Group of Widely Distributed Stocks). Survey derived abundance estimates from other surveys such as the IESSNS and boarfish surveys are not considered as quantitative metrics for these stocks due to problems with precision or methods, however these surveys provide important qualitative information on the dynamics of pelagics within the NE Atlantic.

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 northwest 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 northeast 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 winter periods most 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

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 RV "G.O. Sars" (Table 1 in Annex 2). The surveyed area (cruise tracks) in March-April 2011 is shown in Figure 1 in Annex 2. All survey methods and results are provided in the combined cruise report (Annex 2).

International ecosystem survey in the Nordic Seas. Five vessels participated, the Danish RV "Dana", the Norwegian RV "G.O. Sars", the Icelandic RV "Árni Fridriksson", the Faroese RV "Magnus Heinason" and the Russian RV "Fridtjof Nansen". The surveyed area (cruise tracks) in May-June 2011 is shown in Annex 3, Figures 1 and 2. Map showing area I to III used in the acoustic estimate of herring and blue whiting is shown in Annex 3, Figure 3. All further details are provided in the combined cruise report (Annex 3).

Other relevant surveys. The data from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) in 2010 were not available during the compilation of the 2010 report and are therefore introduced here in Annex 4. In the same way, the results of the 2011 survey that was still ongoing when this 2011 report was compiled will be introduced in the 2012 WGNAPES report. Two chartered Norwegian fishing vessels M/V "Libas" and M/V "Brennholm", one chartered Faroese vessel M/V "Finnur Fridi" and the research vessel "Arni Fridriksson" participated in the survey during 9 July until 20 August 2010. The abundances of mackerel, herring and blue whiting were measured acoustically but swept area estimates were also made for mackerel from predefined trawl stations in the surface waters. Details about the procedure are provided in the survey report. The survey tracks and area covered are shown in Figure 23 in Annex 4.

An acoustic survey for boarfish (*Capros aper)* was undertaken by the Irish fishing industry in collaboration with the Marine Institute. The survey was carried out onboard a commercial vessel using an acoustic tow body system for 21 days in July 2011. The survey covered the shelf and slope areas from 53°-47°N. The survey report is presented in Annex 5.

2.1 Hydrography

The hydrographic observations were made using vertical CTD casts. Details of which are presented by survey:

International ecosystem survey in the Nordic Seas (IESNS) in 2011 are given in Annex 3, Table 1 and Figures 4-9.

International Blue whiting spawning stock survey (IBWSS) in 2011 are given in Annex 2, Table 1 and Figures 10-13.

International Ecosystem Summer Survey in the Nordic Seas (IESSNS) in 2010 in Annex 4, Figures 11-13.

2.2 Plankton

Sampling stations of plankton and cruise tracks of the participating vessels are shown in Annex 3, Figure 10. In total, 289 plankton stations were conducted during the IESNS survey in 2011. All vessels used WP2 nets (180 or 200 m) to sample plank according to the standard procedure for the surveys, except the Russian vessel that used Djedy net. The nets were 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 directed trawling was carried out opportunistically to ground truth 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 as a text table 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. 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 analyzing 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 within the relevant cruise reports (Annex's 2-4).

2.4 Acoustics and biomass estimation

During the surveys, acoustic recordings of fish and plankton were collected continuously and integrated using calibrated echosounder systems with a primary operating frequency of 38 kHz.

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 echo recordings to trawl catches.

The acoustic equipment on the research vessels was calibrated immediately prior or during the surveys against standard calibration spheres. No vessel inter-calibration was performed during either the IBWSS or IESNS surveys (Annex 2, S3).

Acoustic estimates of herring and blue whiting abundance were obtained by visual scrutiny of the echo recordings using different post-processing systems (Annex2, Table 2; Annex 3, S2). To estimate the abundance, the allocated s_A-values were averaged for each of the covered 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). Details about the swept area biomass estimates of mackerel are given in Annex 4.

To estimate the total abundance of fish in the survey area, the fish density (nm^{-1}) per ICES-rectangle was multiplied by the number of square nautical miles contained in each ICES- rectangle. Fish abundances for each ICES-rectangle were then summed for defined survey subareas and for the total survey area. Biomass estimates were calculated by multiplying abundances by the average weight of the fish in each ICES-rectangle and then summing all rectangles within defined survey 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 2011 winter NAO index was again negative though not as low than 2010 but lower than the long-term average (1950–2010; and see Figure 3.1.1). Hence, favorable winds supporting a strong Atlantic influence in the waters west of the British Isles continued to be lower than during high NAO years.

Temperatures during the blue whiting spawning stock survey were relatively warm reaching values between < 9°C southwest of the Faroese Islands and > 11°C west of Porcupine Bank. Temperature values were slightly higher than in 2010 as were the salinity values throughout the 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.

In May, during the IESNS, temperatures in the surface ranged between < 1°C northeast of Iceland and > 8°C in the southern part of the survey area. The polar front was encountered slightly south of 65°N east of Iceland extending eastwards towards the 0° Meridian where it turned almost straight northwards up 70°N. North of 70°N it turned north-eastwards and intersected the boundary of the survey area at about 5°E.

Particularly north and west of the polar front temperatures decreased with depth to values < 0°C while south and east of it the drop in temperature down the water column was not as pronounced. The warmer North Atlantic water formed a broad tongue that stretched northwards along the Norwegian coast with temperatures up to > 6°C in the surface layers. However, particularly in the surface layers the band of warmer water > 7°C was wider than in 2010 and didn’t reach as far North as in the preceding year. With increasing depth this core of warm Atlantic water became slightly more confined to areas closer to the coast stretching northwards, again finally centred along the 15° E meridian.

Surface temperatures of the East Icelandic Current were comparable to those observed in 2010. However, in the South and at depth, the cold arctic water that characterizes the area off the east coast of Iceland was distributed further east than in the previous year leading to a cooling of the deeper layers in those areas eastwards towards the 0 meridian.

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

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

3.2 Plankton

In May 2011 zooplankton biomass distribution was shifted westward compared to 2011 (Figure 3.2.1). Zooplankton biomass was highest in the western and northern Norwegian Sea (Figure 3.2.1). This means that zooplankton biomass distribution resembled more the distribution from some years back. Biomass in the Barents Sea was low.

In May 2010 we saw a weak increase in zooplankton biomass of the eastern Norwegian Sea, while the biomass of the western areas was still going down. In 2011 average zooplankton biomass of the whole sea was slightly higher than in 2010, but still one of the lowest biomass numbers measured since 1997 (Table 3.2.1). The reason for the increase in biomass was a markedly increase in the western Norwegian Sea, while biomass in the eastern areas remained similar to 2010. The increase in biomass of the eastern Norwegian Sea in 2010 and in the western parts in 2011 may be the first signs of a change in the decreasing trend of zooplankton biomass in the Nordic Seas. At least we in 2011 see the first increase in the biomass of the whole sea since 2002.

In the Barents Sea there was a reduction in total average Biomass from 2010 to 2011, from 1.7 to 1.1 g dry weight m^{-2}.

3.3 Norwegian Spring-spawning herring

Survey coverage in the Norwegian Sea was considered adequate in 2011 and in line with previous years. There were some differences in the herring distribution this year compared to 2010. In 2010, the herring was distributed throughout most of the surveyed area while in 2011 the herring was more concentrated in the central part of the Norwegian Sea. The highest values in 2010 were also recorded in the central Norwegian Sea although somewhat more to south, at the eastern edge of the cold waters of the East Icelandic Current. Moreover, in last year herring were also found in the northern part of the surveyed area, while in this year almost no herring were observed north of 70°N. Because of this, the center of gravity of the acoustic recordings shifted in a southwesterly direction compared to 2010 (Figure 3.3.1).

As in previous years the smallest fish were found in the northeastern area where size and age were found to increase to the west and south (Figure 12). Correspondingly, it was mainly older herring that appeared in the southwestern areas (area III), especially the 2002 year class. An exception of this general pattern was that in 2011 some bigger herring were observed in the southeastern area close to the Norwegian coast. According to the survey, the herring stock is now dominated by 7 year old herring (2004 year class) in numbers but 9 and 8 year old herring (2002 and 2003 year classes) are also numerous. The three year classes 2002, 2003 and 2004 contribute to 18%, 10% and 29%, respectively, of the total biomass.

No strong year classes 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 7.4 million tons which is an increase compared to the 2010 survey(5.8 million tons).

<u>International Ecosystem Summer Survey in the Nordic Seas (IESSNS) in July-August 2010</u>

Estimated biomass of herring was 10.7 million tons in the July/August survey 2010. Herring had rather periphery distribution in the Norwegian Sea and surrounding waters, and the majority of individuals were distributed feeding in the colder and frontal waters in the western, northwestern and northeastern parts of the Norwegian Sea (Figure 33 Annex 4).

This survey was carried out for the 2nd time in 2010 and does therefore not provide a time series yet. The survey area in 2010 was extended in order to cover all areas where herring may occur and might have been missed by the May survey the same year. The observed abundance in 2010 can be compared to 13.6 million tonnes observed in July/August 2009 from a smaller area.

3.4 Blue Whiting

<u>International blue whiting spawning stock survey (IBWSS)</u>

The 2011 survey adopted a revised methodology by aiming to cover the whole survey area twice. Nonetheless, not all participants managed to achieve double coverage of their assigned area and the survey design was adapted during the survey. Due to adverse weather conditions, the Russian RV Fridjof Nansen was delayed and only managed a single coverage of the southern area – still, their temporal coverage matched that of the other vessels. As a result, the RV Tridens re-allocated their effort in the second survey run in the northern area west of the Hebrides. Based on the commercial fleet distribution and observed acoustic recordings from the Norwegian RV G.O. Sars during her first run, most of the stock was concentrated in that area and additional coverage there was justified. Due to consistent bad weather in the second half of the survey period RV Celtic Explorer failed to cover the Rockall area. As a result the Rockall subarea was not covered in 2011. (Annex 2).

The specific survey design provided a series of 3 possible survey track combinations based on a combination of temporal and spatial area coverages (Table 1). Survey run 3 was selected to provide the final abundance estimate. Selection criteria were based on: (1) best temporal progression of survey tracks; and (2) largest geographical coverage of core spawning grounds. Consequently, unless otherwise stated, all further reported data refer to survey run 3.

Combined survey

The estimated total abundance of blue whiting for the 2011 international survey was 4.85 million tons, representing an abundance of 37.1x109 individuals. Spawning stock was estimated at 4.38 million tons and 28.6x109 individuals. In comparison to the 2010 survey estimate, there is a significant increase (+61%) in the observed stock biomass and a related increase in stock numbers (+93%).

Stock distribution

Blue whiting were recorded in all areas surveyed. 4,177 nmi (nautical miles) of survey transects were completed. The total area of all the sub-survey areas covered was 68,851 nmi^2. Compared to the combined survey in 2010, the survey coverage was down by 37.0% overall. The majority of this reduction can be attributed to the dropped Rockall area. The weather also affected the coverage of the Faroes/Shetland area (-70.7%).

The absence of the Rockall area from the stock abundance estimation may have resulted in an underestimate of the total stock biomass as the stock was not considered fully contained. The area did contain blue whiting as indicated by the presence of Russian and Norwegian fishing vessels around the southwest corner of the Rockall plateau during the early stages of the survey. One of these fishing vessels (FV *Eros*) was part of the IMR reference fleet and was operating in southwest Rockall at the time of the survey, using a calibrated echosounder. A quantification of a viable abundance estimate from these acoustic data in line with the research vessel survey data was not possible due to the sporadic nature in which it was collected. However, qualitative inspection of the data during the WGNAPES meeting revealed that blue whiting signatures on Rockall Bank at the time of the survey were scarce. They were not comparable to the quantities recorded on the shelf slopes in the Hebrides area.

The Hebrides core area was found to contain 76% of the total biomass observed during the survey and is consistent with but higher than the results from previous surveys (50% in 2008, 62% in 2009, 58% in 2010 relative to total stock biomass for that year). The Faroes/Shetland and north Porcupine areas ranked second and third highest contributing 18% and 5% to the total respectively. Overall the bulk of the stock was centered further north than during the same time in 2010. Medium and high density registrations were found along the shelf slope and did not extend further into the Rockall Trough as observed in 2010. To the north and south of this region blue whiting registrations of medium to high density were also distributed almost entirely within a narrow band running close the shelf edge.

Stock composition

Individuals of ages 1 to 16 years were observed during the survey. A comparison of age reading between nations was carried out and the results are presented in the combined survey report (Appendix 2 in Annex 2). Results show good agreement for most participants for all age classes with a broad range of lengths at age observed across readers but less so than in 2010. However, Russian age readings appear out of phase with other nations by between 1-4 years in 2011. The oldest fish observed according to Russian estimates was 16 years when compared to 12 years for Irish and Faroe readers. Older ages were noted for smaller fish in the order of one year.

The stock within the survey area is dominated by age classes 6, 7 and 5-years, of the 2005, 2004 and 2006 year classes respectively, contributing over 59% of spawning stock biomass. The age profiles of the other sub-areas were additionally represented by younger age classes (2, 3 and 4-year old). The Faroe/Shetland sub area was strongly dominated by 2-year fish.

Juvenile blue whiting were represented to various extents in all sub areas in 2011. Maturity analysis of combined survey samples indicate that 8% of 1-year old and 22% of 2-year old fish were mature as compared to 2010 estimates, where 10% 1-year old fish and 96% of 2-year old fish were considered mature.

From combined survey data the Faroese/Shetland sub area was found to contain significant proportions of immature blue whiting. The largest proportion of 1-yr old fish representing 0.4% (18,500t) of the total biomass and 1% (367 million individuals) of the total abundance was observed in the Faroese/Shetland area. The Hebrides also contained immature representing 0.1% (6,300t) of total biomass and 0.5% (174 million) of total abundance.

Faroe/Shetland area had a significant contribution of 2-year old fish (2009 year class) representing 85% (400,600t) of the total biomass and 87% (7212 million) of total abundance for this area. The positive signal of this pre-recruiting year class was not observed in any other sub area in the same proportion (Figure 10).

Overall immature blue whiting from the combined estimate represented 8% (397,300t) of the total biomass and 20% (749 million) of the total abundance recorded during the survey.

<u>International ecosystem survey in the Nordic Seas (IESNS)</u>

The total biomass of blue whiting registered during the May 2011 survey was 0.84 million tons (Annex 3), which is very low (the corresponding estimates from 2006, 2007, 2008 and 2009 were 6.2, 2.4, 1.1, 0.9 and 0.26 mill. tons, respectively). The stock estimate in numbers for 2011 is 9.2 billion, which is more than 5 times the 2010 estimate. The main reason for an increased estimate is better recruitment of blue whiting and 1- and 2-group constitute ca 50% of the total estimate in terms of biomass and 74% in terms of numbers. Such values have not been seen since 2005/2006. But still the values of young fish are well below the rich year classes recruiting in the first half of the decade.

An estimate was also made from a subset of the data or a "standard survey area" between 8°W–20°E and north of 63°N, which has been used as an indicator of the abundance of blue whiting in the Norwegian Sea because the spatial coverage in this area provides a coherent time-series with adequate spatial coverage. This standard survey area estimate is used as an abundance index in WGWIDE. The age-disaggregated total stock estimate in the "standard area" is presented in Annex 3 (Table 4), showing that the blue whiting in this index area was dominated by young fish, age groups 1 and 2 years old.

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.

International Ecosystem Summer Survey in the Nordic Seas (IESSNS) July-August 2010

The blue whiting population within the covered area was estimated to be 3.45 million tons, consisting of 21.1 billion individuals (Annex 4). Trawl hauls for verification of acoustic detections were sometimes scarce in part of the distribution area, particularly in the western and northern areas. Average weight and mean length of blue whiting was 164 gram 29.6 cm. Length distribution was from 28-41 cm and weight distribution from 100-240 gram. Lengths of 33-36 cm dominated the frequency distribution in the catches. A total of 10 different year classes were present in the catches, with 5 year classes accounting for more than 95%.

3.5 Mackerel

Mackerel distribution from the IBWSS survey

There were no significant observations of mackerel in the IBWSS survey in 2011 worth mentioning. In general, mackerel distributions during the blue whiting spawning stock survey are sporadic.

International ecosystem survey in the Nordic Seas (IESNS)

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. The edge of the distribution has also been found progressively further north and west. In 2011 the mackerel was found up to 64°N west of around 13°W but all the way to 69°N further east (Figure 15 in Annex 3). The mean length was 34-36 cm in most catches and no clear geographical pattern was in mean length of the fish.

International Ecosystem Summer Survey in the Nordic Seas (IESSNS) in July-August 2010

Highest mackerel catches (kg/nmi) dominated in the western and central Norwegian Sea and adjacent areas from 62ºN to 68ºN in the northwestern and northern areas with Arctic water masses in July-August 2010 (Figure 23 in Annex 4). The total swept area estimate of biomass of mackerel from trawl catches was 4.9 million tons (Figure A5 in Annex 4), while the total acoustical estimate was 12 million tons. Mackerel can not be identified and allocated as easily as e.g. herring and blue whiting during a normal scrutinizing approach due to its lack of swimbladder. Consequently the acoustic abundance estimate for mackerel is uncertain. The general trend was that the biggest mackerel was found in the western and northwestern part of the Norwegian Sea. Overall, the 2005- and 2006 year classes dominated with 24% and 31% of total catches, respectively. The spatial overlap between mackerel and herring were mostly found in the southern, southwestern and northern parts of the Norwegian Sea (Figure 28 in Annex 4).

4 Discussion

4.1 Hydrography

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 again have been responsible for the relatively warm and saline waters encountered west of the British Isles during the recent blue whiting spawning stock surveys, so also this year. 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. 2010) indicating at a stronger influence of warm ENAW since then in the area.

The hydrographic situation in the Norwegian Sea was broadly much the same as observed in previous years, 2009 and 2010.

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 carries relatively warm and saline water from the North Atlantic into the Nordic Seas. The EIC, on the other hand, carries cold 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 Faroese 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 the 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 winter NAO index) during 2007 and 2008, with an increased influence of Arctic water in the southern Norwegian Sea, the strength of the westerlies in winters of 2010 and 2011 were low. However, the increased Arctic influence in the western areas of the Norwegian Sea is still observed as well in 2011. 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 2011 is again close to and in some areas less than the 1995–2010 average. In the central and eastern parts, however, the Atlantic water is still warmer than the 1995–2010 average, about 0–1°C dependent on the area and depths. The main reason for this is that the inflowing Atlantic water is still warmer and more saline than normal, and in particular the Atlantic water that flows northward through the Faroe-Shetland Channel is observed to be considerably warmer and saltier than normal.

4.2 Plankton

Recent years decrease in zooplankton biomass until 2010 have been dramatic in the sense that biomass in the cold water has decreased by 80% since 2003, while in the warmer water biomass has decreased by 55% 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, carnivorous zooplankton and not pelagic fish are the main predators of zooplankton in the Norwegian Sea (Skjoldal et al., 2004), and we do not have good data on the development of the carnivorous zooplankton stocks. A fairly strong relationship between NAO and zooplankton biomass was observed, particularly during the late 1990s (ICES, 2006). However, this relationship seems to be less pronounced now. During 2008 and 2009 the western part of the Norwegian Sea cooled due to input of more Arctic water. The eastern Norwegian Sea has become warmer mainly due to input of warmer Atlantic water. In 2010 the south-eastern Norwegian Sea cooled a bit (probably surface cooling during the cold winter this year). The Arctic watermasses in the west spread further eastward compared to 2009. The warming of the Atlantic water masses did not seem to be in favour of increased zooplankton production in the Norwegian Sea. The cooling of the eastern Norwegian Sea was followed by increased biomass in 2010. This increase flattened in 2011, but then we saw a markedly increase in the zooplankton biomass of the western Norwegian Sea. The increase in the western part happened in spite of the water-masses still being cool in this region. This increase was large enough to bring about an increase for the whole area. Summing up, the reason for the observed changes in zooplankton biomass is not clear to us and more research to reveal this is 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 mainly concentrate on the situation in the feeding areas in May.

Similarly to the previous six years, it was decided not to draw up a suggested herring migration pattern for 2011 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 southwestward shift of the center of gravity of the distribution in 2011 compared to 2010 and the herring was more concentrated in the central part of the Norwegian Sea.

In May the herring were 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 2004 year class while the 2002 year class was observed in the southwestern area. The amount of herring measured in the survey was higher compared to the unexpected low estimate in 2010 and the year-class composition was more in line with what has been observed in 2009.

During the last several years, a temperature reduction has been observed in the western part, which continued this year, while a temperature increase has been observed in the eastern part of the Norwegian Sea. This could explain the slight eastward displacement of the main concentrations of herring observed in May 2011, beside the fact that the feeding migration is still ongoing during the survey period. Additionally, the plankton situation in the Norwegian Sea was again this year at a very low level. The southwestward shift in center of gravity is mainly caused by very low registrations of herring in the northern part of the surveyed area.

Concerns have been raised about the ageing of the herring, particularly the numerous 2002 year class, because the age distribution from the different participants shows some difference. This is likely due to variable growth conditions for the stock and consequently growth rate as seen on the fish scales and otoliths. The effects of this are that there are shifts between years in the relative proportions of the different year classes. Consequently, WGNAPES recommends that a workshop should be held as soon as possible, preferable in the winter 2011/2012, for all age readers of herring that participate in the WGNAPES surveys to verify this issue and standardize their methodology.

4.4 Blue whiting

The eighth international blue whiting spawning stock survey 2011 showed an increase of 61% when compared to the 2010 estimate. The updated survey time series show a decline in the observed stock but that rate of decline is not as abrupt if the 2010 estimate is excluded.

The stock in the survey area is dominated by 6, 7 and 5-years, of the 2005, 2004 and 2006 year classes respectively. Together these year classes account for 59% of spawning stock biomass. Mean length (28.7 cm) and weight (131.5 g) are lower than in previous years. The previously observed progressive increases in mean length and weight over the years were attributed to the 3 dominant year classes as they progressed through the stock. However, there is now a halt in this trend due to the observed relative increase in 2-year old fish.

The contribution of immature fish to the total biomass remains small. However, a small but positive signal of 2-year old fish was observed in the Faroe/Shetland area and is a somewhat encouraging sign in a period of prolonged poor recruitment. This positive signal was also observed during the IESNS survey in May. Maturity analysis indicated that peak spawning in 2011 was later than in previous years as could be seen in the proportion of spent fish observed.

The selected survey run was carried out over 14 days with good temporal progression. Compared to previous years, it was the shortest period required to complete the survey. The plan was to complete the survey within a 21 day window. Due to the revised survey design, there were several possible survey combination options that could be used to make an abundance estimate. This flexibility allowed for a choice of the most 'optimal' design in terms of timing and spatial coverage. Over 82% of the total biomass was observed in sub areas surveyed by more than one vessel. The 2011 survey commenced 2 days later than in 2010, so timing was considered comparable. The success of the International survey rests on cooperation from all survey vessels to survey as planned within agreed time and allocated areas.

Non-coverage of the Rockall area resulted in the stock not being fully contained within the survey area and may therefore have caused an underestimate of the stock size. Nonetheless, acoustic data was collected on southwest Rockall during the survey period by a vessel that is part of the IMR reference fleet (i.e. FV *Eros*). Analysis of these data revealed negligible recordings of blue whiting there. Moreover, portions of the stock present on Rockall early in the survey period may have been covered later after migrating into the Faroes/Shetland sub area. Nonetheless, potential spawning aggregations present on Rockall usually early in the survey period were and will be considered during survey planning.

Survey timing is fixed annually to coincide with peak spawning of the stock. In 2011, as in the two previous years, the time of peak spawning varied. However, in all these years the stock was contained within the surveyed area due to the extensive size of the survey area, making estimates of abundance reliable. For these and aforementioned reasons, the 2011 estimate of abundance for the combined survey can be considered robust.

4.5 Mackerel

The distribution of mackerel in May 2011 was comparable to the year before both in the eastern part of the Norwegian Sea and in the western part.

In July-August 2010, mackerel was distributed over larger areas than previously documented for the Nordic Seas. Furthermore, a central and western distribution was pronounced in July 2010. Based on the continuous acoustic recordings from hydroacoustics and extensive pelagic trawling near the surface and midwater, it was believed that the survey managed to cover the vast majority of these species and consequently their maximum spatial distribution. Repeated offshore catches of two year's old individuals indicate that the Norwegian Sea is increasingly showing to be an important nursery and feeding ground for immature mackerel.

5 Planning

5.1 Planned acoustic survey of the NE Atlantic blue whiting spawning grounds (IBWSS) in 2012

Five vessels are scheduled to participate in the 2012 spawning stock survey including the Faroe Islands, the Netherlands (EU-coordinated), Ireland (EU-coordinated) Norway and Russia.

Survey timing and design were discussed in detail during the meeting. The group decided that in 2012 the survey should be designed in a way to allocate maximum effort in the area traditionally containing the highest blue whiting concentrations during the survey period (i.e. sub-area III, Hebrides). Although the design adopted in 2011 delivered a high quality survey output, with a range of valid options to choose from, it was deemed impracticable due to coordination difficulties. The 2012 design is based on variable transect spacing, ranging from 30 nmi in areas containing less dense aggregation (e.g. sub-area I, south Porcupine), to 7.5 nmi in the core survey area (sub-area III, Hebrides). From past surveys it was evident that huge areas in the west of the Rockall Trough contained, if at all, only sporadic and small blue whiting concentrations. The western borders of the transects in sub-area III where therefore reduced to 11ºW in order to put more effort on the continental slope. To ensure transect coverage was not replicated transects were allocated systematically with a random start location.

The aim is to have all but the Faroese vessel start surveying in the north of sub-area II (North Porcupine) at the time when the Norwegian vessel G.O. Sars begins the survey there (around 28.03.2012). That way, the core survey sub-area III can be covered synoptically by 4 vessels with a similar temporal progression.

It was decided that the Dutch vessel Tridens and Russian Fridtjof Nansen would start the survey in the southern sub-areas I and II (Porcupine). The Irish Celtic Explorer would first cover sub-area IV (on south-west Rockall Bank). 2-4 days after beginning their individual surveys, these vessels will join G.O. Sars surveying the north of sub-area II and afterwards area III from the south progressing northwards. Once G.O. Sars has finished surveying sub-area III, she will continue northwards into the Faroese-Shetland channel if time allows. The Faroese vessel Magnus Heinason will primarily survey sub-area V (Faroese/Shetland) and join the other vessels in the north of area III once they are present there towards the end of the survey period. Survey extension in terms of coverage (52-61ºN) will be in line with the time series to ensure containment of the stock and survey timing will also remain fixed as in previous years.

Key will be to achieve coverage of area III in a consistent temporal progression between vessels. It is therefore very important that all 4 vessels covering the core Hebrides area are present on station in the north of sub-area II (just north of Porcupine Bank) on 28th March. Nonetheless, if some vessels are found to lack behind others, the tight 7.5 nmi transect spacing will allow for adaptation of the survey design without great loss of coverage. For instance, this may mean skipping some of the horizontal transects to catch up with the other vessels. Biological sampling should be carried out following methods normally applied to sampling acoustic registrations, again to provide detailed information on the progress of spawning between replicates.

Individual vessel dates are listed below:

Ship	Nation	primary coverage	preliminary survey dates
Celtic Explorer	EU (Ireland)	Rockall & Hebrides	24/3 – 11/4
G.O. Sars (TBC)	Norway	Hebrides & Faroes/Shetland	28/3 – 13/4
Magnus Heinason	Faroe Islands	Faroes/Shetland & Hebrides	28/3 – 13/4
Fridtjof Nansen	Russia	Porcupine & Hebrides	24/3 – 11/4
Tridens	EU (Netherlands)	Porcupine & Hebrides	26/3 – 11/4

Preliminary cruise tracks for the 2012 survey are presented in Figure 5.1.1.

As survey coordinator in 2012, Sascha Fässler (Netherlands) has been tasked with coordinating contact between participants prior to and during the survey. Detailed cruise lines for each ship will be circulated by the coordinator to the group as soon as final vessel availability and dates have been communicated (end of January 2012).

As the survey is planned with inter-vessel cooperation in mind it is vitally important that participants stick to the planned transect positioning to ensure that survey effort is evenly allocated and the situation observed in 2010 is not repeated.

Participants are also required to use the log book system for recording course changes, CTD stations and fishing operations. An example format was circulated to participants shortly after the WGNAPES 2011 meeting.

The survey will be carried out 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 (IESNS), spring/summer 2011

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 2012.

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 2012 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 data series collected by all boats within the two subareas are included in the data series 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 2012. Final dates and vessels shall be communicated to the coordinator no later than 15 January 2012. 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 2012.

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 will 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 2011) 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 plan is that the Icelandic vessel conducts its survey at the same time and will cover 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 are shown in the text table below.

The following subjects should be targeted:

Herring abundance and distribution

Blue whiting abundance and distribution

Plankton abundance and distribution

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. No intercalibration has taken place since the 2005 survey. It is recommended, that serious effort should be put into intercalibrations at the 2012 survey, as has failed for so many years. 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.
A post-cruise meeting will be held in Reykjavik 26-28 June 2012 where the results will be analyzed and a joint survey report will be compiled.

Ship	Nation	Vessel time (days)	Active survey time (days)	Preliminary dates
G.O. Sars	Norway	30	28	1/5 – 30/5
Fridjof Nansen	Russia	21	21	15/5 – 05/6
Dana	Denmark (EU)	30	23	28/4 – 28/5
Magnus Heinason	Faroes	14	12	4/5 – 18/5
Arni Fridriksson	Iceland	26	23	28/4 – 24/5

Final dates for the surveys will be decided by the end of 2011.

5.3 Workshop on implementing a new TS relationship of blue whiting abundance estimates (WKTSBLUES)

Acoustic abundance estimates of blue whiting have so far tended to be considerably higher than those based on catch data (Godø *et al.*, 2002), probably due to the use of a target strength (TS) that is too low, leading to an overestimate of the number of fish (Heino *et al.*, 2003). New TS measurements of blue whiting and a resulting revision of acoustic survey results are desired, as the TS-length relationship currently used for blue whiting is based on measurements of juvenile cod (Nakken and Olsen, 1977; Foote, 1980). Pedersen *et al.* (2011) conducted TS measurements during the annual blue whiting surveys from 2003 to 2007 using several different observation platforms. They provide a new TS-length relationship for blue whiting based on these high quality *in situ* measurements:

$$TS = 20 \log_{10} L - 65.2$$

Preliminary analyses showed that the use of this relationship will bring the time series of acoustic abundance estimates more in line with the stock size from the assessment (see Figure 5.1.).

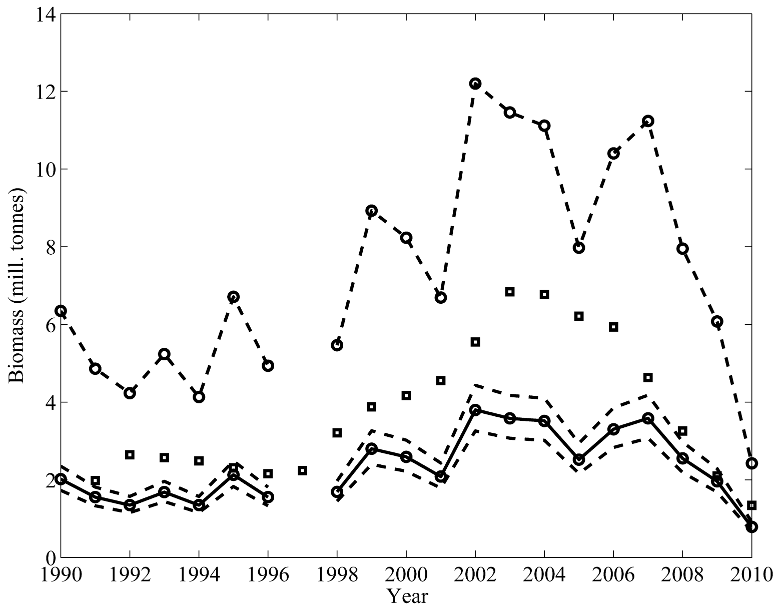

Figure 5.1. Estimated biomass from the international blue whiting spawning stock survey from 1990 to 2010 (dashed line). The solid line (with 95% confidence bands) shows the abundance scaled by the new TS-length relationship (20 $\log_{10}$ L - 65.2) using the mean fish length and weight for each survey. The squares indicate assessment results (ICES, 2010).

In order to fully implement this revised TS relationship to the survey index (i.e. applying the full length-age/weight key observed in the respective years), WGNAPES recommends to hold a workshop in January 2012 (WKTSBLUES; see 'Recommendations' section in this report). Terms of reference for the workshop are presented in Annex 8. In that respect, a timescale of tasks has been developed. This task list includes members of the group submitting all outstanding data to the WGNAPES online database from 2004 onwards. Table 5.1. shows that all countries have already uploaded years from 2006 onwards. Leon Smith has agreed to oversee the uploading of the missing data to the database. It was agreed that only quality controlled data be submitted and that data should be made ready in the current format only (biological, acoustic and logbook). The deadline for submissions to the database is end of October, 2011.

Current and historic calculation of the global biomass estimate has been carried out using the BEAM program by members of the group from IMR. The use of BEAM is limited to experienced members from IMR. The development of an open source, Java based biomass calculation tool by IMR is presently underway and until this is complete the group agrees that to retain consistency across the survey indices the use of BEAM is continued. The release of the new IMR software would allow the responsibility of the global abundance calculation to be spread equally among the group. The group therefore recommends that this work must be prioritized and a provisional date of release is provided by the developers to allow for future planning in this respect.

This considered, the WKTSBLUES will require the re-running of survey data from 2004 onwards and will require an experienced BEAM user. The time scale for this large portion of work is February 2012 prior to the final blue whiting benchmark meeting. At present Oyvind Tangen, IMR is the most experienced user of BEAM and has been a consistent member of the group throughout. It was agreed by the group that the responsibility for this task would be shared by Oyvind Tangen and Valantine

Anthonypillai. The group therefore recommends that time is allowed for the pre-workshop preparation to facilitate this re-working of the survey data.

Table 5.1. Overview of WGNAPES data base content by nation and year (august 2011).

	country				
year	Faroe Isl.	Norway	Netherlands	Ireland	Russia
2004	×	×	×	×	×
2005	×	×	×	×	×
2006	✓	✓	✓	✓	✓
2007	✓	✓	✓	✓	✓
2008	✓	✓	✓	✓	✓
2009	✓	✓	✓	✓	✓
2010	✓	✓	✓	✓	✓
2011	✓	✓	✓	✓	✓

5.4 ICES requests for WGNAPES input to the Marine Strategy Framework Directive Steering Group (MSFDSG) and the Strategic Initiative on Area Based Science and Management (SIASM) as well as for WKCATDAT

In March 2011, ICES requested that all Expert Groups (EG's) should provide input to both MSFDSG and SIASM to meet the challenges of implementing an ecosystem approach. The MSFDSG requested that the following Terms of Reference (TOR) were added to all Expert Groups.

Identify elements of the EGs work that may help determine status for the 11 descriptors set out in the Commission Decision.

Provide views on what good environmental status (GES) might be for those descriptors, including methods that could be used to determine status.

In addition, the following TORs were received from SIASM.

Take note of and comment on the Report of the Workshop on the Science for area-based management Coastal and Marine Spatial Planning in Practice (WKCMSP).

Provide information that could be used in setting pressure indicators that would compliment biodiversity indicators currently being developed by the Strategic Initiative on Biodiversity Advice and Science (SIBAS). Particular consideration should be given to assessing the impacts of very large renewable energy plans with a view to identifying/predicting potentially catastrophic outcomes.

Identify spatially resolved data, for e.g. spawning grounds, fishery activity, habitats, etc.

In order to address some of these TORs, the Workshop on Cataloguing Data Requirements from Surveys for the EAFM (WKCATDAT, ICES CM 2010/SSGESST:09), drafted a table which was subsequently utilised by the International Bottom Trawl Surveys Working Group (IBTSWG).

WGNAPES have taken a similar but slightly simplified approach, identifying the tasks that are already done during the surveys as well as tasks that could be done during future surveys. Table 5.4 identifies elements which could be incorporated into the work of WGNAPES, which might contribute to a broader 'ecosystem approach'. The group has also added two additional tasks referring to the use of multifrequency hydroacoustics that could, in the light of the rapidly developing field of acoustics, also become feasible for other surveys. However, it must be noted that additional tasks are likely to impact the existing surveys, unless sufficient additional resources (staff, ship time, equipment) become available. Even if these resources are available, it must be remembered that these acoustic and trawl surveys already involve the vessels working 24 hours per day, and that the synoptic picture resulting from these surveys will be disrupted if other time demanding tasks are undertaken.

In view of these evaluation WGNAPES recommends to the Working Group for Integrating Surveys for the ecosystem approach (WGISUR) that they need to be aware of the following concerns:

Additional tasks undertaken to address the 'ecosystem approach' are likely to impact the existing surveys, unless sufficient additional resources (staff, ship time, equipment) become available. In fact it is unlikely that most additional tasks will be conducted by WGNAPES participants without these additional resources. However, because of lack of expertise in many of the additional survey tasks it is impossible for WGNAPES to exactly specify additional staff, equipment and financial requirements without consulting experts in the task related research fields.

Furthermore, any additional tasks that require the survey vessels to stop or slow down or divert course from the original survey plan will seriously impact the quasi-synoptic nature of WGNAPES surveys.

It was not possible for the participants of WGNAPES to provide views on what good environmental status (GES) might be for the descriptors in the table. WGNAPES felt that they did not have the required level of expertise within the group to provide an opinion on such a wide range of descriptors and what GES might be for each.

WGNAPES anticipates that it is unlikely that large offshore renewable energy plans will significantly impact the vast oceanic spawning areas of blue whiting. WGMEGS produces spatially (and temporally) resolved data for blue whiting spawning and has done this annually for many years. Some environmental parameters such as sea surface temperature and salinity have been obtained concurrently. Also, full CTD profiles are obtained from selected survey stations. On occasion various other parameters such as Chlorophyll-a fluorescence, turbidity, light attenuation and nutrient concentrations are also measured, which could help to describe the spawning habitat favoured by the species.

Table 5.4: WKCATDAT Data Catalogue, simplified version.

Task	Additional equipment	Data Already Collected	Comments: Is it used now, could it be done better etc.	Data could be collected easily	Comments: Any add. Resources	Data could be collected with major additional work	Comments: Estimate of scale of extra: time, people, tools
Fish							
Organism collection (e.g. for contaminants, fatty acids analysis etc.)	no	no		Yes			
Stomach sampling	no	Yes	Blue whiting survey: stomach fullness index routinely recorded	Yes but processing remains an issue			
Additional biological data (e.g. liver/gonad weight, otoliths, scales, fin-rays, length-weight data of other than standard species)	no	no		Yes for secondary and teritary spp			
Disease/parasite registration	no	no		Yes with training			
Genetic information	no	Ad hoc		Yes			
Lipid content	Fat meter; Calibation series for the species should be available	no	Has been done in the past by some				
Sonar observations pelagic fish	scientific sonar	no	Not all participants have scientific sonar			Expensive capital equipment	
Tagging	Tags and fish handling	no		Yes	Problems exist with shortening trawl times to ensure survival or carrrying additional ring nets etc		
Bioactive materials in marine species	no	no		Yes			
School shapes/schools in surface dead zone	Multi beam echosounder	no		Yes with training		Expensive capital equipment	
Species identification & abundance estimation	Multifrequency echosounder	Yes by some	the more frequencies the better	Yes	at least 4 frequencies between ~10-333kHz needed for reliable identification		
Physical and chemical oceanography [CTD, chlorophyll, oxygen, nutrients, turbidity, etc.]							
Continuous underway measurements	dependent on variables being collected	Yes by some		Yes			
Station measurements	dependent on variables being collected	Yes		Yes			
Autonomic devices (Buoys, AUV, Landers etc.	dependent on variables being collected	no			Depends on type	Expensive capital equipment	
Water movement	ADCP	Yes by some	Problems with interference with EK60				
Nutrient samples	Water sampler	Yes by some		Yes but processing remains an issue			
Biological oceanography							
Microbiological samples	Water sampler	Yes by some		Yes			
Phytoplankton samples	Water sampler	Yes by some		Yes			
Zooplankton samples	Towed samplers	Yes by some		Yes			
Zooplankton samples	Dipped samplers	Yes by some		Yes			
Zooplankton samples	Echosounder at proper frequency	no		Yes			
Species identification & abundance estimation	Multifrequency echosounder	Yes by some	the more frequencies the better	Yes	at least 4 frequencies between ~10-333kHz needed for reliable identification		
Invertebrates							
Infauna	Grab/corer, sieves	not generally		Posisble time penalty			
Epifauna	Beam trawl/dredge/sledge	not generally		Posisble time penalty			
Epifauna	Video	not generally		Posisble time penalty			
Pelagic	Trawl net	no		Yes			
Species identification & abundance estimation	Multifrequency echosounder	Yes by some	the more frequencies the better	Yes	at least 4 frequencies between ~10-333kHz needed for reliable identification		
Megafauna							
ESAS sampling (birds, sea mammals)	Binoculars	Yes by some		Yes	dedicated personnel		
Towed hydrophones	Towed hydrophone	no		Posisble time penalty			
Habitat description							
Towed/dropped camera	Towed/dropped camera	no		Posisble time penalty			
Side-scan sonar	Side-scan sonar	no		Posisble time penalty			
Multi beam echosounder	Multi beam echosounder	no		Yes with training		Expensive capital equipment	
Ground truthing	Grab/corer, sieve	no		Posisble time penalty			
		no		Posisble time penalty			
Pollution							
Floating litter	no	no		Yes	see MMO		
Sinking litter	no	no		Posisble time penalty			
Pollution in the water column	dependent on variables being collected	no		Yes with training			
Pollution in the sediment	Grab/corer	no		Yes with training			
Pollution in organisms		no		Yes with training			
Environmental conditions							
Weather conditions	appropiate sensors	Yes by some		Yes			
Sea state	no	Yes by some		Yes			

(the Excel version of this table can be found on the WGNAPES SharePoint http://groupnet.ices.dk/wgnapes2011/default.aspx , the extended version of the table can also be found as Excel table on the WKCATDAT SharePoint http://groupnet.ices.dk/wkcatdat2010/default.aspx)

5.5 WGMEGS recommendations to WGNAPES

There was a recommendation from WGMEGS that WGNAPES are looking for possibilities to take ichthyoplankton samples for mackerel and horse mackerel eggs during their Blue whiting spawning stock survey in order to

- define the beginning of the spawning time and
- to provide additional information on the Western spawning boundary of mackerel and horse mackerel.

With a start date of 26 March the 2012 survey was judged as too late for defining the beginning of the spawning of mackerel in the survey area. However, Ireland will consider doing ichthyoplankton sampling during their participation in IBWSS in the Rockall Bank area in order to provide information on the Western spawning boundary of mackerel. Sampling positions as well as work up of samples will be liaised between the Irish IBWSS cruise leader (Ciaran O'Donnell, MI) and members of WGMEGS (Brendan O'Hea, MI, and Matthias Kloppmann, vTI-SF).

6 Survey protocol and standardization

Methods currently employed during WGNAPES coordinated surveys are highlighted below. Detailed methods employed during specific surveys are available within individual cruise reports as shown in Annex's 2-5 of this report.

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

Details of trawls used during WGNAPES coordinated surveys are listed in the individual survey reports presented in Annex's 2-4 of this report.

In terms of trawl standardization this has only been considered for use during the International ecosystem summer survey in the Nordic Seas (IESSNS) as a standardization tool for use in swept area surveys. During the Pelagic Complex conference in Tórshavn, august 2010, NO, IS and FO agreed to develop a standard pelagic trawl for use during the IESSNS survey program.

At a meeting in Bergen in January 2011, funded by the Nordic Council of Ministers the outline for the new Multi Purpose pelagic trawl (MULTPELT) was decided. The participants from NO,IS and FO at the meeting consisted of scientists, skippers from the pelagic industry and trawl manufacturers under the chair of John Willy Valdemarsen from IMR, Bergen.

During spring 2011 the trawl was designed, and IS and FO ordered 1 trawl each from local netmakers. By end of June the trawls were delivered.

The MULTPELT trawl was used by FO and IS in the mackerel trawl survey this year. The trawls are performing as expected. Detailed drawings and dimensions of the trawl are available on request.

6.3 PGNAPES exchange format

The database has been changed, to incorporate fluorescens data from the CTD hauls. A new column "Fluorescens" (mg/m^3) has been added in the Hydrography table. The updated database description is uploaded to the sharepoint.

7 PGNAPES database

Internet database

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

12 international surveys have so far been uploaded (63 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 can be 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, where received and uploaded to the database, before the planned post cruise meeting in Copenhagen.

Data from International Ecosystem Surveys in the Nordic Seas

Data were received and uploaded to the database before the WGNAPES meeting in Kaliningrad. Though especially labour intensive sample data, such as age readings and processing plankton samples at the start of the holidays, delayed the data considerably.

Data from International Mackerel Trawl Surveys in the Nordic Seas

In 2009 NO,IS and FO initiated a survey targeting Mackerel in the Nordic Seas. Data from last year surveys in July has been uploaded in the database. The surveys from this July/August 2011 will be uploaded as soon as the surveys are completed.

Species code table

Countries are encouraged to deliver species 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. A copy of ASFIS codes obtained from the FAO webpage has been uploaded to the WGNAPES sharepoint, for the group members convenience.

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.

Assessment calculation application

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.

Future Effort

A new version of Oracle Express Edition (11g) is now available, and the database will be upgraded.

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 up-load 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.

IBWSS data back to 2004 needs to be uploaded by the end of October 2011, to be able to make estimates with the new blue whiting target strength at the WKTSBLUES workshop in Copenhagen January 23-26 2012.

Data overview

COUNTRY	YEAR	VESSEL	CRUISE	LOG	CATCH	BIO	HYDR	ACOUSTIC	ACOUSTICVAL	PL
DK	2008	OXBH	308	193	71	2379	48625	559	850	54
DK	2009	OXBH	200904	124	113	3416	3360	554	554	40
DK	2010	OXBH	201003	167	39	455	4263	645	263	46
DK	2011	OXBH	201103	122	118	1051	2759	587	1174	32
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	22664	
FO	2009	OW2252	932	90	30	1234	3239	1404	7037	23
FO	2010	OW2252	1010	65	30	1358	1980	1219	18054	27
FO	2010	OW2252	1014	77	30	1417	3708	1589	12067	23
FO	2010	XPXP	1051	99	83	4165	1297	2363	30073	30
FO	2011	OW2252	1111	41	23	1016	1359	843	13989	
FO	2011	OW2252	1116	86	36	2716	3250	1382	9045	22
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	
IE	2010	EIGB	BWAS10	69	35	1350	3304	2345	6163	
IE	2011	EIGB	BWAS11	33	21	1050	794	850	1308	
IE	2011	EIGB	BWAS11_2	29	10	600	844	795	1079	
IS	2007	TFEA	B08-2007	50						50
IS	2007	TFNA	A08-2007	130	39	9873	336	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

IS	2010	TFNA	A10-2010	205	255	6365	14420	4615	7322	
IS	2010	TFNA	A7-2010	217	48	4006	5608	4031	9966	144
IS	2011	TFNA	A5-2011	191	76	4932	4491	3621	23471	113
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	
NL	2010	PBVO	BWHTS2010	30	67	250	400	1294	204	
NL	2011	PBVO	BWHTS2011_1	28	17	100	898	616	616	
NL	2011	PBVO	BWHTS2011_2	43	36	350	3157	798	798	
NO	2006	LMEL	2006104	131	53	2576	57741	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	
NO	2010	LIWG	2010807	202	247	9273	2804	3642	104115	62
NO	2010	LMEL	2010104	48	32	617	2238	1753	2271	
NO	2010	LMEL	2010107	179	93	1903	5802	3150	7803	61
NO	2010	LMQI	2010810	318	310	9870	4321	1316	24681	88
NO	2011	LMEL	2011103a	36	25	707	17541	820	15638	
NO	2011	LMEL	2011103b	20	10	182	637	584	2176	
NO	2011	LMEL	2011106	164	90	2816	5202	651	2188	48
RU	2006	UHOB	2006048	102	30	371	699	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
RU	2010	UANA	2010077	86	19	1264	788	1849	2234	
RU	2010	UANA	201078	239	68	2449	2771	569	620	96
RU	2011	UANA	2011082	38	7	462	2053	855	11249	
RU	2011	UANA	2011083	207	140	2264	2400	493	815	72

The table shows number of records in logbook, catch, biology, hydrography, acoustic, acoustic values and plankton tables' per nation, year, vessel and cruise by 17 August 2011.

8 Agreement and Recommendations

Agreements:

- The location of the next post-cruise meeting of the International Blue whiting spawning stock survey (IBWSS) will take place at IMARES, Netherlands from the 24–27 April, 2012.
- The location of the initial post-cruise meeting of the International Ecosystem Survey in the Nordic Seas (IESNS) will take place at Marine Institute, Iceland from the 26–28 June, 2012.
- The next meeting of the WGNAPES group will occur under the new name of WGIPS, this cross over meeting will take place at ICES HQ, Copenhagen from the 16–20 January, 2012. Members who attended the final WGNAPES meeting in 2011 (Kaliningrad) should evaluate their individual participation in the January 2012 meeting in advance of the December 2012 WGIPS meeting.

Recommendations:

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

General recommendations

- This year, the temporal and spatial coverage of the stock during the IBWSS were completed providing a higher quality stock estimate compared to 2010 where a large gap in coverage occurred. In light of this WGNAPES recommends the exclusion of the 2010 survey estimate as the survey is considered incomplete when compared to this years and the previous years of the time series. The 2010 estimate was put forward as the best option from the available survey data.
- Development of standardized set of survey methods for the mackerel/trawl acoustic surveys in the Norwegian Sea. Methods should be developed in association with WGIPS and with input from WGWIDE. Once complete these methods should be included in the updated survey manual.
- The group recommends that a dedicated blue whiting survey workshop [Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES)] be held from the 23-26 January 2012 at ICES HQ to re-evaluate the survey indices in light of the new length to target strength relationship in readiness for the species benchmark meeting in February.
- The group recommends that a dedicated workshop on age reading is required for both herring and blue whiting to address discrepancies across nations highlighted for blue whiting during the EFAN otilith exchange program 2010 and during the May survey.
- WGNAPES recommends that until such a time that a fully functioning crossover database is in place within the ICES datacenter that the systems currently in place within WGNAPES (WGNAPES survey database) be maintained.

Survey recommendations:

- Discrepancies between age readings of participants observed during the IBWSS should be addressed to increase the precision of the global estimate.
- It is recommended that the Rockall Bank be covered annually during the IBWSS.

- 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.

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10 Tables and Figures

Table 1.3.1. Organisational frame of the coordinated herring investigations in the Norwegian Sea, 1995–2009.

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 April-June for the period 1997–2010. 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	2010	2011	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	4.8	4.3	5.6	9.4
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	2.9	6.8	10.4
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	4.8	5.9	6	8.4

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 1998–2011.

Survey year/Age	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008*	2008**	2009	2010	2011
0	0	0	0	0	0	0	0	0	0	0	0		0		
1	24	0	0	0	0	32,073	0	0	3,688	2,058	0	43	202	7,805	619
2	1,404	215	157	1,540	677	8,115	13,735	1,293	35,020	4,122	1,193	381	906	2,330	4,666
3	367	2,191	1,353	8,312	6,343	6,561	1,543	19,679	5,604	15,437	587	199	2,980	1,286	1,593
4	1,099	322	2,783	1,430	9,619	9,985	5,227	1,353	15,894	7,783	8,332	279	2,754	3,329	1,752
5	4,410	965	92	1,463	1,418	9,961	12,571	1,765	1,035	20,292	8,270	5	14,292	2,156	4,550
6	16,378	3,067	384	179	779	1,499	10,710	6,205	1,810	1,261	16,345		9,487	8,282	2,691
7	10,160	11,763	1,302	204	375	732	1,075	5,371	6,336	1,992	1,381		11,629	4,146	8,693
8	2,059	6,077	7,194	3,215	847	146	580	651	7,372	6,781	1,920		1,472	4,519	2,877
9	804	853	5,344	5,433	1,941	228	76	388	558	5,581	3,958		1,253	319	4.828
10	183	258	1,689	1,220	2,500	1,865	313	139	651	647	2,500		2,587	513	572

11	0	5	271	94	1,423	2,359	367	262	171	486	416		1,357	804	897
12	0	14	0	178	61	1,769	1,294	526	344	371	242		267	331	837
13	112	0	114	0	78	0	1,120	1,003	807	403	159		183	45	282
14	0	158	0	0	28	287	10	364	792	1,047	217		60	17	13
15+	415	128	1,135	85	26	45	88	115	324	953	408		258	25	34
Number in '000	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	35,907	34,904
Biomass in '000 tons	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	5,902	7,394

***Norwegian Sea**

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

Table 3.4.1. Total stock biomass and spawning-stock biomass time-series from the International blue whiting spawning stock survey, 2004–2011.

		2004	2005	2006	2007	2008	2009	2010	2011	Change from 2010 (%)
Biomass	Total	11.4	8	10.4	11.2	8	6.07	3.01	4.85	61%
(mill. t)	Mature	10.9	7.6	10.3	11.1	7.9	6.03	2.9	4.383	51%
Numbers	Total	137	90	108	104	68	46.7	19.2	37.1	93%
(10^9)	Mature	128	83	105	102	67	45.8	18.6	28.57	54%
Survey area (nm^2)		149,000	172,000	170,000	135,000	127,000	133,900	109,320	68,851	-37%

Table 3.4.2. Age disaggregated estimate of total stock numbers and biomass from the International blue whiting spawning stock survey, 2004–2011.

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
2010	621	1291	627	931	2426	5258	4838	2608	467	63	67	19,197
2011	629	8255	2890	2786	5009	6997	5389	3740	1317	106		37,118

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
2010	23	91	64	130	394	883	840	466	99	11	15	3,015
2011	27	470	291	357	757	1119	939	635	239	18		4,850

Table 3.4.3. Age disaggregated estimate of total stock numbers and biomass for International blue whiting spawning stock survey in 2011.

	Age in years (year class)										Numbers	Biomass	Mean	Prop.
Length	1	2	3	4	5	6	7	8	9	10+			weight	mature*
(cm)	2010	2009	2008	2007	2006	2005	2004	2003	2002		(*10-6)	(10^6 kg)	(g)	(%)
11.0 – 12.0	9	0	0	0	0	0	0	0	0	0	9	0.1	9	0
12.0 – 13.0	9	0	0	0	0	0	0	0	0	0	9	0.1	10	0
13.0 – 14.0	18	0	0	0	0	0	0	0	0	0	18	0.2	13	0
14.0 – 15.0	9	0	0	0	0	0	0	0	0	0	9	0.1	16	0
15.0 – 16.0	9	0	0	0	0	0	0	0	0	0	9	0.2	20	0
16.0 – 17.0	53	4	0	0	0	0	0	0	0	0	57	1.6	28	0
17.0 – 18.0	31	77	0	0	0	0	0	0	0	0	108	3.2	30	0
18.0 – 19.0	141	184	4	0	0	0	0	0	0	0	329	11.6	35	0
19.0 – 20.0	147	959	4	0	0	0	0	0	0	0	1110	47	42	0
20.0 – 21.0	35	1879	47	0	0	0	0	0	0	0	1961	95.9	49	5
21.0 – 22.0	0	2633	78	11	0	0	0	0	0	0	2722	154.3	57	20
22.0 – 23.0	168	1473	287	18	0	0	0	0	0	0	1946	123.4	63	29
23.0 – 24.0	0	370	146	17	4	0	0	0	0	0	537	39.3	73	52
24.0 – 25.0	0	261	232	32	0	0	0	0	0	0	525	41.9	80	71
25.0 – 26.0	0	255	227	35	9	0	0	0	0	0	526	43.1	83	100
26.0 – 27.0	0	77	203	167	73	7	0	0	0	0	527	49.3	94	100
27.0 – 28.0	0	22	551	297	76	0	0	0	0	0	946	97.8	105	100
28.0 – 29.0	0	61	554	545	168	155	15	46	0	0	1544	185.2	122	100
29.0 – 30.0	0	0	355	778	716	789	549	233	136	6	3562	473.5	134	100
30.0 – 31.0	0	0	202	596	1544	1639	748	544	67	0	5340	768.7	145	100
31.0 – 32.0	0	0	0	210	1312	2098	1091	1174	212	73	6170	982.5	160	100
32.0 – 33.0	0	0	0	20	670	1180	1230	617	258	5	3980	681.3	172	100
33.0 – 34.0	0	0	0	57	404	508	722	626	242	11	2570	469.9	185	100
34.0 – 35.0	0	0	0	3	25	513	515	247	202	0	1505	307.3	206	100
35.0 – 36.0	0	0	0	0	8	67	161	142	127	11	516	116.4	228	100
36.0 – 37.0	0	0	0	0	0	25	130	62	59	0	276	65.5	239	100
37.0 – 38.0	0	0	0	0	0	16	146	0	0	0	162	45	277	100
38.0 – 39.0	0	0	0	0	0	0	49	0	0	0	49	15	304	100
39.0 – 40.0	0	0	0	0	0	0	0	49	14	0	63	19	301	100
40.0 – 41.0	0	0	0	0	0	0	33	0	0	0	33	11.4	341	100
TSN (10^6)	629	8255	2890	2786	5009	6997	5389	3740	1317	106	37118	4849.8		
TSB (10^6 kg)	26.5	470.3	291	357	756.7	1118.5	938.5	634.8	238.7	17.9	4849.9			
Mean length (cm)	19.3	21.5	26.7	29.2	31	31.6	32.5	32.2	33	32.0				
Mean weight (g)	42.2	57.1	101.6	129.3	152.3	161.1	175.3	170.8	182.5	168.4				
% mature*	8	22	84	99	100	100	100	100	100	100				
% of SSB	0	6	8	9	17	24	18	13	4	0				

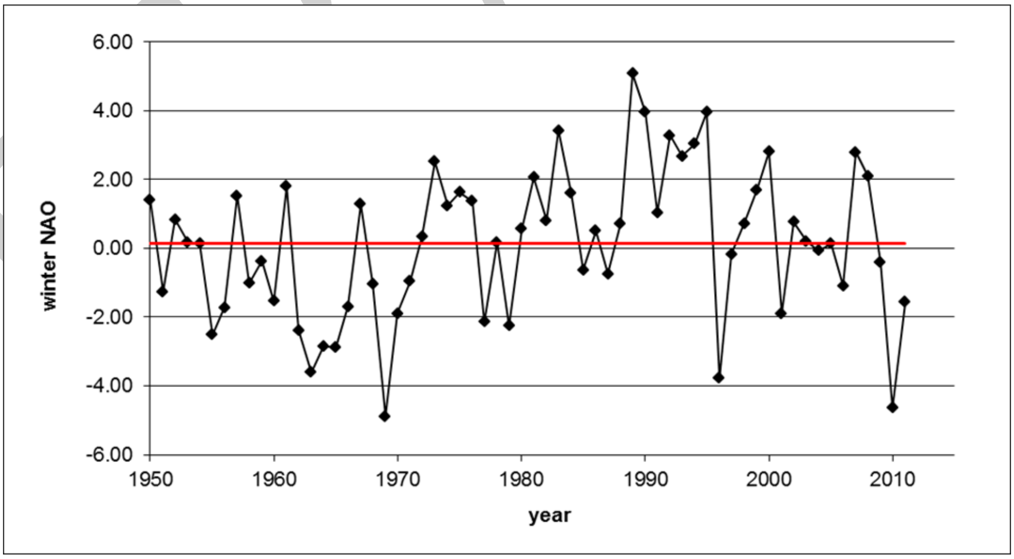


Figure 3.1.1: The winter NAO index between 1950 and 2011, the red line marks the 1950-2011 long term mean value. Data from Hurrel 2011.

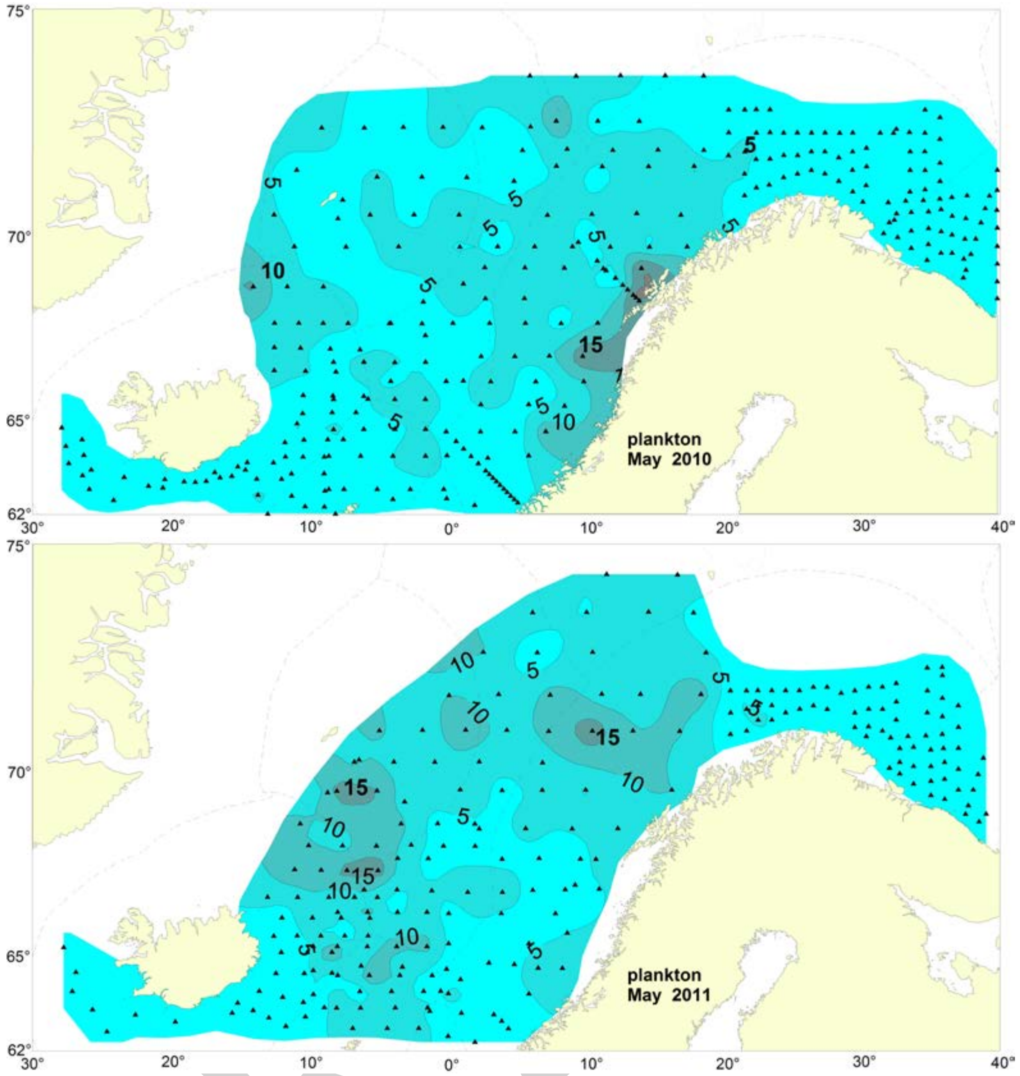


Figure 3.2.1. Zooplankton biomass (g dw m⁻²; 200–0 m) in May 2010 and 2011.

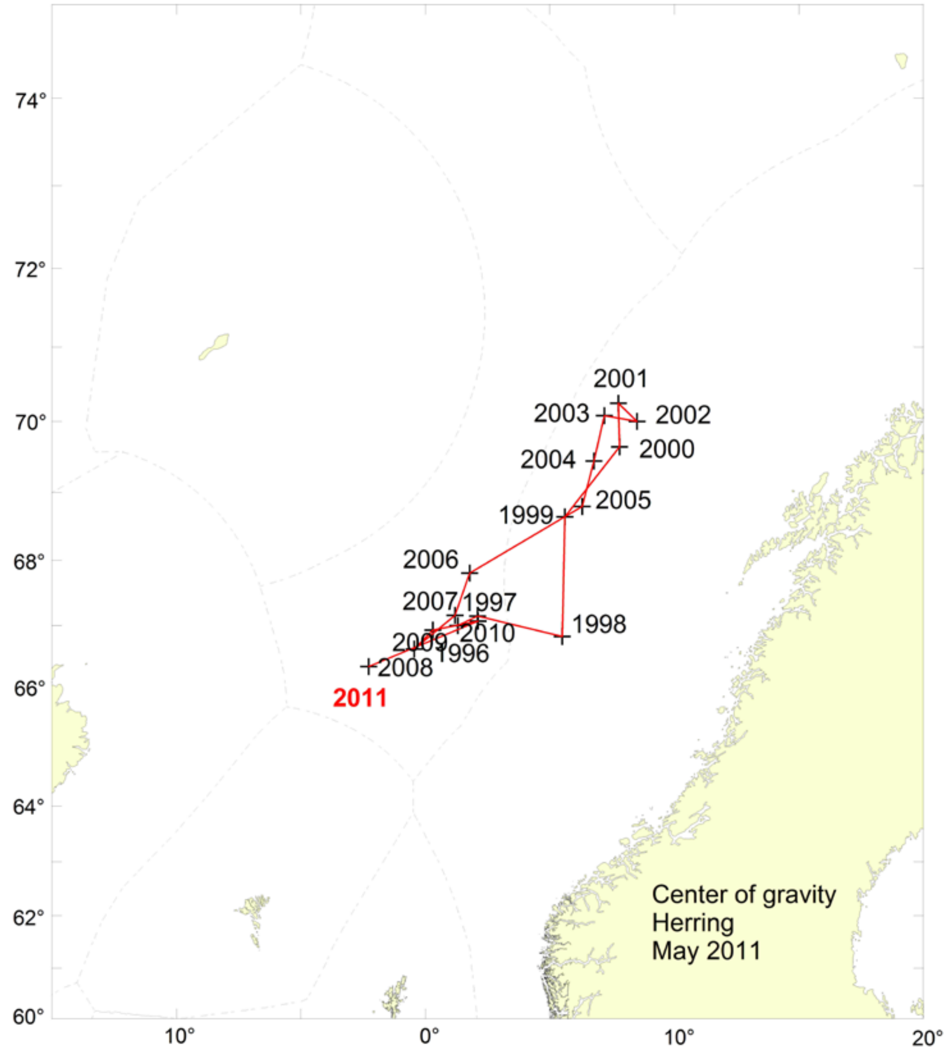


Figure 3.3.1. Centre of gravity of herring during the period 1996–2011 derived from acoustic. Acoustic data from area II and III only, i.e. west of 20°E.

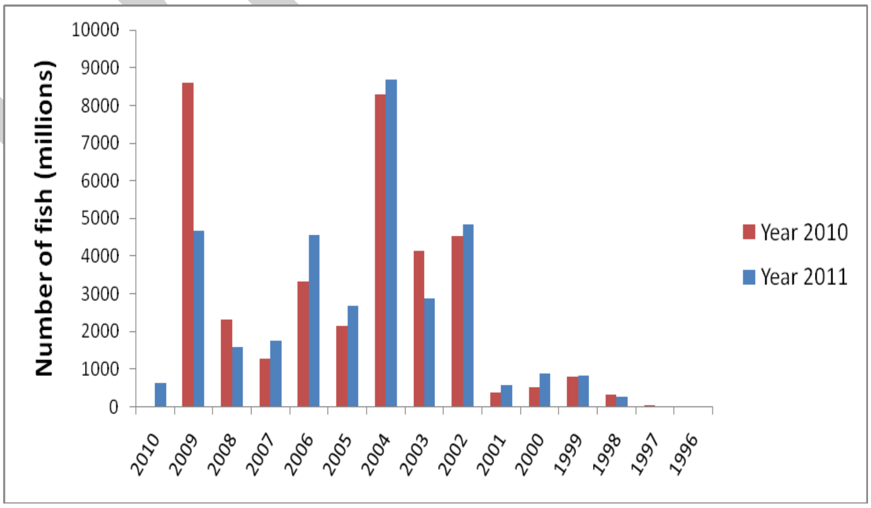


Figure 4.3.1. A comparison of the results of the acoustic measurements of NSSH in May 2010 and May 2011 in the Nordic seas for the different year classes.

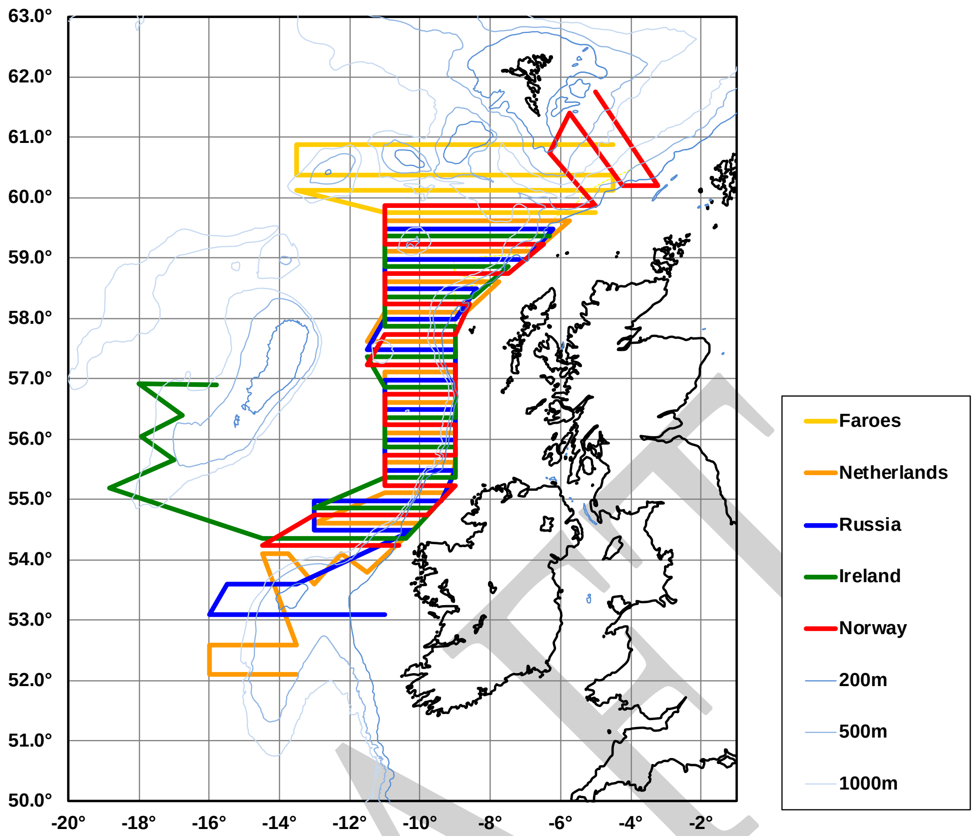


Figure 5.1.1. Preliminary survey tracks for the 2012 International blue whiting spawning stock.

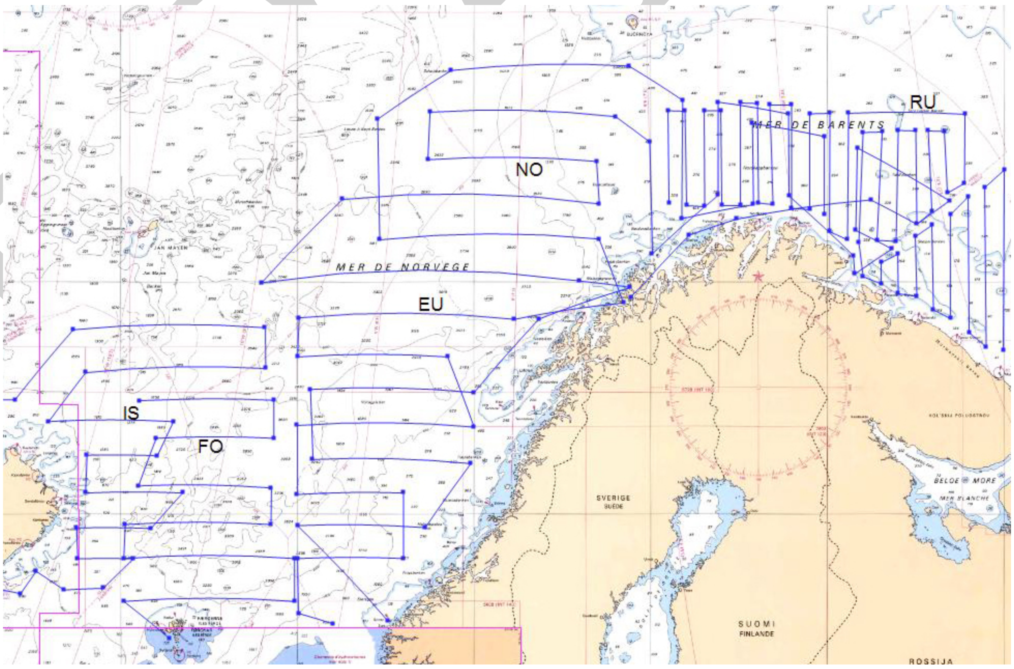


Figure 5.2.1. Preliminary survey tracks for the 2012 International ecosystem survey in the Nordic Seas.

Annex 1: List of participants

NAME	ADDRESS	TELEPHONE	FAX	E-MAIL
Ciaran O'Donnell (Chair)	Marine Institute Rinville Oranmore Co. Galway, Ireland	+353 87 968 1954	+353 9138 7200	ciaran.odonnell@marine.ie
Alexander Krysov	PINRO 6,Knipovich Street, 183763, Murmansk, Russia	+7815247342 4	+47 78910518	a_krysov@pinro.ru
Karl-Johan Staehr (By correspondance)	National Institute for Aquatic Research Technical University of Denmark Nordsoen Forskerpark DK-9850 Hirtshals Denmark	+4533963271	+4533963260	kjs@aqua.dtu.dk
Gudmundur J. Oskarsson	Marine Research Institute Skulagata 4 101 Reykjavik, Iceland	+354 575 2000	+354 575 2001	gjos@hafro.is
Leon Smith	Faroe Marine Research Institute Nóatún 1 PO Box 3051 FO-110 Tórshavn Faroe Islands	+298 353900	+298 353901	leonsmit@hav.fo
Nikolay Timoshenko	AtlantNIRO Kaliningrad Russian Federation	+7401292555 4	+74012219997	timoshenko@atlant.baltnet.ru
Oyvind Tangen	Institute of Marine Research, PO Box 1870, N-5817 Bergen, Norway	+47 55238414 +47 91803405	+47 55238687	oyvind.tangen@imr.no
Age Hoines	Institute of Marine Research, PO Box 1870, N-5817 Bergen, Norway	+47 55238674	+47 55238687	aageh@imr.no
Matthias Kloppmann	vTI Bund Institute of Sea Fisheries, Palmaille 9, 22767 Hamburg, Germany	+49 40 38905 196	+49 40 38905 263	matthias.kloppmann@vti.bund.de
Valentine Anthonypillai	Institute of Marine Research, PO Box 1870, N-5817 Bergen, Norway	+47 55238414	+47 55238687	valantine.anthonypillai@imr.no
Sascha Fässler	IMARES Haringkade 1 1976 CP IJmuiden Netherlands	+31 317487474	+31317487326	sascha.fassler@wur.nl

Annex 2: International blue whiting spawning survey report

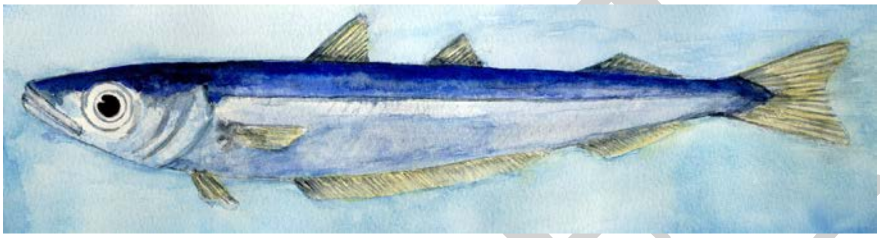
Working Document

Working Group on Northeast Atlantic Pelagic Ecosystem Surveys

Kaliningrad, Russia, 16-19 August 2011

Working Group on Widely distributed Stocks

Copenhagen, Denmark, 23-29 August 2011



INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY SPRING 2011

Sascha Fässler[1^*], Thomas Pasterkamp[1], Kees Bakker[1], Jérôme Chladek[7], Dirk Thijssen[8],
Eric Armstrong[6]

R/V Tridens

Ciaran O'Donnel[5*], Ryan Saunders[5], Eugene Mullins[5], Graham Johnston[5] and Kieran Lyons[5],

R/V Celtic Explorer

Maxim Rybakov[3], Valery Ignashkin[3*], Sergeeva Tatiana[3], Yuri Firsov[3], Velikzhanin Alexey[3], Dolgolenko Ilya[3], Gavrilik Tatiana[3], Krivosheya Pavel[3], Murashko Ekaterina[3].

R/V Fridtjof Nansen

Åge Høines[2*], Valantine Anthonypillai[2*], Øyvind Tangen[2*], Jan de Lange[2], Elna Meland[2], Martin Dahl[2], Asgeir Steinsland[2]

R/V G.O. Sars

Jan Arge Jacobsen[4], Ebba Mortensen[4*], Mourits Mohr Joensen[4], Leon Smith[4*]

R/V Magnus Heinason

1 Institute for Marine Resources & Ecosystem Studies, IJmuiden, The Netherlands

2 Institute of Marine Research, Bergen, Norway

3 PINRO, Murmansk, Russia

4 Faroe Marine Research Institute, Tórshavn, Faroe Islands

5 Marine Institute, Galway, Ireland

6 Marine Scotland Marine Laboratory, Aberdeen, Scotland, United Kingdom

7 Johann Heinrich von Thünen-Institut, Hamburg, Germany

8 Danish Institute for Fisheries Research, Denmark

* Participated in post cruise meeting

^ Survey coordinator

Introduction

In spring 2011, five research vessels representing the Faroe Islands, European Union (Ireland and the Netherlands), Norway and Russia surveyed the blue whiting spawning grounds to the west of the UK and Ireland. 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 eighth 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*: Rybakov et al. 2011; *C. Explorer*: O'Donnell et al. 2011; *M. Heinason*: Jacobsen et al. 2011; *Tridens*: Fässler et al. 2011)

This report is based on correspondence undertaken after the international survey by all participants and during the post cruise meeting held in Copenhagen from April 27-29, with representatives from all participating nations present.

Materials and Methods

Survey planning and Coordination

Coordination of the survey was initiated in the meeting of the Working Group on Northeast Atlantic Pelagic Ecosystem Surveys (WGNAPES, ICES 2010) and continued by correspondence until the start of the survey. Participating vessels together with their effective survey periods are listed below:

Vessel	Institute	Survey period
Fridtjof Nansen	PINRO, Murmansk, Russia	28/3 – 5/4
Celtic Explorer	Marine Institute, Ireland	28/3 – 11/4
G.O. Sars	Institute of Marine Research, Bergen, Norway	23/3 – 4/4
Magnus Heinason	Faroe Marine Research Institute, Faroe Islands	6/4–11/4
Tridens	Institute for Marine Resources & Ecosystem Studies (IMARES), the Netherlands	29/3–11/4

Due to differences in survey coverage and timing resulting from the revised survey methodology described in ICES (2010), 3 individual survey runs, described in Table 1, were considered. These runs were consistent in spatial coverage and timing, delivering full coverage of the respective distribution areas within maximally 2 weeks.

Cruise tracks and trawl stations for each participant vessel are shown in Figure 1. Figure 2 shows combined CTD stations. All vessels, apart from G.O. Sars in survey run II, worked in a northerly direction (Figure 3). Regular communication between vessels was maintained during the survey (via email, internet weblog, InmarSat C and VHF radio) exchanging blue whiting distribution data, echograms, 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. All transducers were calibrated with a standard calibration sphere (Foote et al. 1987) prior to the survey. Acoustic settings by vessel 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. This year, no inter-calibrations were carried out.

Biological sampling

All components of the catch from the trawl hauls were sorted and weighed; fish and other taxa were identified to species level. The level of blue whiting sampling by vessel is shown in Table 5.

Hydrographic sampling

Hydrographic sampling by way of vertical CTD cast was carried out by each participant vessel (Figure 2 and Table 1) up to a maximum depth of 1,100 m 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 4.8) 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 G.O. Sars, 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 backed up every 30 minutes and scrutinized every 24-48 hrs using the Large Scale Survey System LSSS (V 1.50) post processing software. Blue whiting were identified and separated from other recordings based on trawl catch information and characteristics of the recordings.

Acoustic data analysis

The acoustic trawl data were analysed with a SAS based routine called "BEAM" (Totland and Godø 2001) and used to calculate age and length stratified estimates of total biomass and abundance (numbers of individuals) within the survey area as a whole and within 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 200 m.

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

<u>*Inter-calibration results*</u>

No acoustic inter-calibrations were carried out during the 2011 survey due to time and weather restrictions.

<u>*Distribution of blue whiting*</u>

The 2011 survey adopted a revised methodology by aiming to cover the whole survey area twice. Nonetheless, not all participants managed to achieve double coverage of their assigned area and the survey design was adapted during the survey. Due to adverse weather conditions, the Russian RV *Fridjof Nansen* was delayed and only managed a single coverage of the southern area – still, their temporal coverage matched that of the other vessels. As a result, the RV *Tridens* re-allocated their effort in the second survey run in the northern area west of the Hebrides. Based on the commercial fleet distribution and observed acoustic recordings from the Norwegian RV *G.O. Sars* during her first run, most of the stock was concentrated in that area and additional coverage there was justified. Due to consistent bad weather in the second half of the survey period RV *Celtic Explorer* failed to cover the Rockall area. As a result the Rockall subarea was not covered in 2011.

The specific survey design provided a series of 3 possible survey track combinations based on a combination of temporal and spatial area coverages (Table 1). Survey run 3 was selected to provide the final abundance estimate. Selection criteria were based on: (1) best temporal progression of survey tracks (Figure 3); and (2) largest geographical coverage of core spawning grounds (Figure 4). Consequently, unless otherwise stated, all estimates, figures and tables reported here refer to survey run 3.

Blue whiting were recorded in all areas surveyed. In total 6,470 nmi (nautical miles) of survey transects were completed. Respective track lengths were: 2,496 nmi for run 1, 2,520 nmi for run 2 and 4,177 nmi for run 3. The total area of all the sub-survey areas covered was 68,851 nmi^2 (Figure 1, Tables 1 & 3).

Compared to the combined survey in 2010, the survey coverage was down by 37.0% overall. The majority of this reduction can be attributed to the dropped Rockall area. The N. Porcupine and Hebrides areas saw an increase in coverage by 42.8% and 20.6%, respectively, as effort was concentrated in these areas. Missed coverage of the Rockall sub area was due to adverse weather conditions. The weather also affected the coverage of the Faroes/Shetland area (-70.7%).

The absence of the Rockall area from the stock abundance estimation is likely to result in an underestimate of the total stock biomass as the stock was not considered fully contained. The area did contain blue whiting as indicated by the presence of Russian and Norwegian fishing vessels around the southwest corner of the Rockall plateau during the early stages of the survey. IMR reported one of its reference fleet was operating in southwest Rockall using a calibrated echosounder and retained frozen catch samples for aging purposes. It will not be possible to quantify a viable abundance estimate from these acoustic data in line with the research vessel survey data due to the sporadic nature in which it was collected. However, it is important that these data are reviewed during WGNAPES for qualitative purposes both acoustically and biologically.

The highest concentrations of blue whiting were recorded in the Hebrides core area which remains consistent with the results from previous surveys (Figure 8a, Table 3a). Overall the bulk of the stock was centred further north than during the same time in 2010 (Figure 4). Medium and high density registrations were concentrated along the shelf slope and did not extend further into the Rockall Trough as observed in 2010. To the north and south of this region blue whiting registrations of medium to high density were also distributed almost entirely within a narrow band running close the shelf edge.

Stock size

Combined survey

The estimated total abundance of blue whiting for the 2011 international survey was 4.85 million tonnes, representing an abundance of 37.1x10^9 individuals (Figure 7, Tables 3 & 4). Spawning stock was estimated at 4.38 million tonnes and 28.6x10^9 individuals. In comparison to the 2010 survey estimate, there is a significant increase (+61%) in the observed stock biomass and a related increase in stock numbers (+93%).

		2004	2005	2006	2007	2008	2009	2010	2011	Change from 2010 (%)
Biomass	Total	11.4	8	10.4	11.2	8	6.07	3.01	4.85	61%
(mill. t)	Mature	10.9	7.6	10.3	11.1	7.9	6.03	2.9	4.383	51%
Numbers	Total	137	90	108	104	68	46.7	19.2	37.1	93%
(10^9)	Mature	128	83	105	102	67	45.8	18.6	28.57	54%
Survey area (nm^2)		149,000	172,000	170,000	135,000	127,000	133,900	109,320	68,851	-37%

The Hebrides core area was found to contain 76% of the total biomass observed during the survey and is consistent but higher with the results from previous surveys (50% in 2008, 62% in 2009, 58% in 2010 relative to total stock biomass for that year). The Faroes/Shetland and north Porcupine areas ranked second and third highest contributing 18% and 5% to the total respectively. The breakdown of combined survey biomass by sub area is shown below:

		Biomass (million tonnes)				
		2010		2011		
Sub-area			% of total		% of total	Change (%)
I	S. Porcupine Bank	0.1	4	0.04	1	-60%
II	N. Porcupine Bank	0.4	17	0.25	5	-38%
III	Hebrides	1.4	58	3.68	76	163%
IV	Faroes/Shetland	0.3	13	0.88	18	193%
V	Rockall	0.2	8		0	-100%

Stock composition

Individuals of ages 1 to 16 years were observed during the survey. A comparison of age reading between nations was carried out and the results are presented in Appendix 2. Results show good agreement for most participants for all age classes with a broad range of lengths at age observed across readers but less so than in 2010. However, Russian age readings appear out of phase with other nations by between 1-4 years in 2011. The oldest fish observed according to Russian estimates was 16 years when compared to 12 years for Irish and Faroe readers. Older ages were noted for smaller fish in the order of one year.

The stock within the survey area is dominated by age classes 6, 7 and 5-years, of the 2005, 2004 and 2006 year classes respectively, contributing over 59% of spawning stock biomass (Table 4, Figure 9 & 10).

The Hebrides area remains the most productive in the current survey time series and has consistently contributed over 50% to the total SSB (Figure 7). The age profiles of the other sub-areas were additionally represented by younger age classes (2, 3 and 4-year old). The Faroe/Shetland sub area was strongly dominated by 2-year fish.

Juvenile blue whiting were represented to various extents in all sub areas in 2011 (Figure 10). Maturity analysis of combined survey samples indicate that 8% of 1-year old and 22% of 2-year old fish were mature as compared to 2010 estimates of where 10% 1-year old fish and 96% of 2-year old fish were considered mature (Tables 4).

From combined survey data the Faroese/Shetland sub area was found to contain significant proportions of immature blue whiting. The largest proportion of 1-yr old fish representing 0.4% (18,500t) of the total biomass and 1% (367 million individuals) of the total abundance was observed in the Faroese/Shetland area. The Hebrides also contained immature representing 0.1% (6,300t) of total biomass and 0.5% (174 million) of total abundance.

Faroe/Shetland area had a significant contribution of 2-year old fish (2009 year class) representing 85% (400,600t) of the total biomass and 87% (7212 million) of total abundance for this area. The positive signal of this pre-recruiting year class was not observed in any other sub area in the same proportion (Figure 10).

Overall immature blue whiting from the combined estimate represented 8% (397,300t) of the total biomass and 20% (749 million) of the total abundance recorded during the survey.

Hydrography

A combined total of 140 CTD casts were undertaken over the course of the survey. Horizontal plots of temperature and salinity at depths of 10m, 50m, 100 and 200m as derived from vertical CTD casts are displayed in Figures 11-14 respectively.

Concluding remarks

Main results

- The eighth international blue whiting spawning stock survey 2011 shows an increase when compared to the 2010 estimate. The updated survey time series show a decline in the observed stock but that rate of decline is not as abrupt if the 2010 estimate is excluded. The exclusion of the 2010 data is advisable due to the large uncertainties in the estimate.
- Poor weather prevented the Rockall sub area from being covered in 2011. Commercial fishing occurred along the southwest slopes in the early days of the survey when the Celtic Explorer was undertaking her allocated core coverage. A weather induced break of 4 days meant that this supplementary coverage was not possible without sacrificing replicate coverage in the core Hebrides area.
- The stock in the survey area is dominated by 6, 7 and 5-years, of the 2005, 2004 and 2006 year classes respectively. Together these year classes account for 59% of spawning stock biomass.
- Mean length (28.7 cm) and weight (131.5 g) are lower than the previous years. The year on year increases were attributed to the progression of the 3 dominate year classes as they progressed through the stock.
- The contribution of immature fish to the total biomass remains small. However, a positive signal of 2-year old fish was observed in the Faroe/Shetland area and is an encouraging sign in a period of prolonged poor recruitment.
- Maturity analysis indicated that peak spawning in 2011 was later than in previous years due to the proportion of spent fish observed.
- The effort for the selected survey run 3 was carried out over 14 days as compared to 28 days in 2010. The 2010 survey commenced 2 days later than in 2010 so timing is considered comparable. It was planned that the survey should be completed within a 21 day window.

Interpretation of the results

- Non-coverage in the Rockall area resulted in the stock not being fully contained within the survey area and may therefore result in an underestimate of the stock. Spawning aggregations appeared in Rockall early in the survey period as in previous years and this should be considered for future planning. Nonetheless, there is a possibility that portions of the stock present on Rockall early in the survey period were covered later on after migrating into the Faroes/Shetland sub area.
- Due to the revised survey design, there were several possible survey combination options that could be used to make an abundance estimate. This flexibility allowed for a choice of the most 'optimal' design in terms of timing and spatial coverage. The chosen survey run #3 covered the area within 2 weeks with good temporal progression. Compared to previous years, it was the shortest period required to complete the survey.
- The 2011 estimate of abundance for the combined survey can be considered robust for those areas covered. Over 82% of the total biomass was observed in sub areas surveyed by more than one vessel. However, non-coverage of Rockall may have resulted in an under estimate of the stock.

- Survey timing is fixed annually to coincide with peak spawning of the stock. In 2011 as in the two previous years, the time of peak spawning varied. However, in all these years the stock was contained within the survey area due to the extensive survey area and so estimates of abundance are credible.

Recommendations

- The mis-match between age reading results within the survey needs to be addressed and considered in 2012.
- The results of the blue whiting otiliths exchange program should be made available prior to the WGNAPES 2011 meeting in August for discussion at the meeting.
- The Rockall area should be covered during the survey in the future.
- From the three survey options considered all managed to cover the area in 15 days or less. In previous years the minimum time for achieved coverage was 28 days.
- Delivery of survey data in the PGNAPES format to Leon Smith was achieved in a timely fashion.

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Table 1. Survey effort by vessel. March-April 2011.

Vessel	Effective survey period	Length of cruise track (nm)	Trawl stations	CTD stations	Plankton sampling	Aged fish	Length-measured fish	Survey run I	Survey run II	Survey run III
Magnus Heinason	6/4 - 11/4	915	9	16	16	300	610		x	x
Fridtjof Nansen	28/3 - 5/4	848	5	27	0	275	341	x		x
G.O. Sars	23/3 - 28/3	839	8	23	0	212	617	x		
G.O. Sars	31/3 - 4/4	565	2	15	0	57	142			
Celtic Explorer	28/3 - 2/4	889	7	17	0	350	1,050			
Celtic Explorer	7/4 - 11/4	889	4	15	0	200	600		x	x
Tridens	29/3 - 2/4	809	7	12	0	100	100	x		x
Tridens	2/4 - 11/4	716	10	15	0	300	350		x	x
Total		**6,470**	**52**	**140**	**16**	**1,794**	**3,810**			

Table 2. Acoustic instruments and settings for the primary frequency. March-April 2011.

	Fridtjof Nansen	Celtic Explorer	G.O. Sars	Magnus Heinason	Tridens
Echo sounder	Simrad EK60	Simrad EK 60	Simrad ER 60	Simrad EK 500	Simrad EK 60
Frequency (kHz)	**38, 120**	**38**, 18, 120, 200	**38**, 18, 70, 120, 200, 333	**38**	**38**
Primary transducer	ES38B	ES 38B	ES 38B - SK	ES38B	ES 38B
Transducer installation	Hull	Drop keel	Drop keel	Hull	Towed body
Transducer depth (m)	4.5	8.7	8.5	3	7
Upper integration limit (m)	10	15	15	7	15
Absorption coeff. (dB/km)	10	10.1	9.8	10	9.8
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.425	2.43	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	-20.8	-20.9	-20.5
Sv Transducer gain (dB)				25.32	25.3
Ts Transducer gain (dB)	25.72	25.9	26.62	25.38	
s_A correction (dB)	-0.63	-0.64	-0.63	-0.06	-0.75
3 dB beam width (dg)					
alongship:	6.99	6.91	7.09	7.22	6.97
athw. ship:	7.04	6.95	7.07	6.99	7.01
Maximum range (m)	750	750	750	750	750
Post processing software	FAMAS	Sonardata Echoview	LSSS	Sonardata Echoview	LSSS

Table 3. Assessment factors of blue whiting for survey run 3 March-April 2011.

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	7,670	0.24	0.37	66	0.037	0.043	86	115.1	27.2	5.6
II	N. Porcupine Bank	19,625	1.48	2.11	70	0.22	0.25	88	117.6	27.5	12.7
III	Hebrides	35,883	23.25	23.75	98	3.65	3.68	99	155	31.1	102.6
IV	Faroes/Shetland	5,673	3.38	10.66	32	0.48	0.88	54	82.2	23.8	155.1
V	Rockall	0	-	-	-	-	-	-	-	-	-
Tot.		68,851	28.57	37.12	78	4.38	4.85	90	131.5	28.7	70.4

Table 4. Survey run 3 stock estimate of blue whiting, March-April 2011.

Length (cm)	Age in years (year class) 1 (2010)	2 (2009)	3 (2008)	4 (2007)	5 (2006)	6 (2005)	7 (2004)	8 (2003)	9 (2002)	10+	Numbers ($*10^{6}$)	Biomass (10^6 kg)	Mean weight (g)	Prop. mature* (%)
11.0 – 12.0	9	0	0	0	0	0	0	0	0	0	9	0.1	9	0
12.0 – 13.0	9	0	0	0	0	0	0	0	0	0	9	0.1	10	0
13.0 – 14.0	18	0	0	0	0	0	0	0	0	0	18	0.2	13	0
14.0 – 15.0	9	0	0	0	0	0	0	0	0	0	9	0.1	16	0
15.0 – 16.0	9	0	0	0	0	0	0	0	0	0	9	0.2	20	0
16.0 – 17.0	53	4	0	0	0	0	0	0	0	0	57	1.6	28	0
17.0 – 18.0	31	77	0	0	0	0	0	0	0	0	108	3.2	30	0
18.0 – 19.0	141	184	4	0	0	0	0	0	0	0	329	11.6	35	0
19.0 – 20.0	147	959	4	0	0	0	0	0	0	0	1110	47	42	0
20.0 – 21.0	35	1879	47	0	0	0	0	0	0	0	1961	95.9	49	5
21.0 – 22.0	0	2633	78	11	0	0	0	0	0	0	2722	154.3	57	20
22.0 – 23.0	168	1473	287	18	0	0	0	0	0	0	1946	123.4	63	29
23.0 – 24.0	0	370	146	17	4	0	0	0	0	0	537	39.3	73	52
24.0 – 25.0	0	261	232	32	0	0	0	0	0	0	525	41.9	80	71
25.0 – 26.0	0	255	227	35	9	0	0	0	0	0	526	43.1	83	100
26.0 – 27.0	0	77	203	167	73	7	0	0	0	0	527	49.3	94	100
27.0 – 28.0	0	22	551	297	76	0	0	0	0	0	946	97.8	105	100
28.0 – 29.0	0	61	554	545	168	155	15	46	0	0	1544	185.2	122	100
29.0 – 30.0	0	0	355	778	716	789	549	233	136	6	3562	473.5	134	100
30.0 – 31.0	0	0	202	596	1544	1639	748	544	67	0	5340	768.7	145	100
31.0 – 32.0	0	0	0	210	1312	2098	1091	1174	212	73	6170	982.5	160	100
32.0 – 33.0	0	0	0	20	670	1180	1230	617	258	5	3980	681.3	172	100
33.0 – 34.0	0	0	0	57	404	508	722	626	242	11	2570	469.9	185	100
34.0 – 35.0	0	0	0	3	25	513	515	247	202	0	1505	307.3	206	100
35.0 – 36.0	0	0	0	0	8	67	161	142	127	11	516	116.4	228	100
36.0 – 37.0	0	0	0	0	0	25	130	62	59	0	276	65.5	239	100
37.0 – 38.0	0	0	0	0	0	16	146	0	0	0	162	45	277	100
38.0 – 39.0	0	0	0	0	0	0	49	0	0	0	49	15	304	100
39.0 – 40.0	0	0	0	0	0	0	0	49	14	0	63	19	301	100
40.0 – 41.0	0	0	0	0	0	0	33	0	0	0	33	11.4	341	100
TSN (10^6)	629	8255	2890	2786	5009	6997	5389	3740	1317	106	37118	4849.8		
TSB (10^6 kg)	26.5	470.3	291	357	756.7	1118.5	938.5	634.8	238.7	17.9	4849.9			
Mean length (cm)	19.3	21.5	26.7	29.2	31	31.6	32.5	32.2	33	32.0				
Mean weight (g)	42.2	57.1	101.6	129.3	152.3	161.1	175.3	170.8	182.5	168.4				
% mature*	8	22	84	99	100	100	100	100	100	100				
% of SSB	0	6	8	9	17	24	18	13	4	0				

*** Percentage of mature individuals per age or length class**

Table 5. Country and vessel specific details, March-April 2011.

	Fridtjof Nansen	Celtic Explorer	G.O. Sars	Magnus Heinason	Tridens
Trawl dimensions					
Circumference (m)	716	768	600	640	1120
Vertical opening (m)	50	50	30	40	30-70
Mesh size in codend (mm)	16	20	16	40	±20
Typical towing speed (kn)	3.2-4.2	3.5-4.0	3.0-3.5	3.0-4.0	3.5-4.0
Plankton sampling	0	0	0	16	0
Sampling net	-	-	-	WP2 plankton net	-
Standard sampling depth (m)	-	-	-	200	-
Hydrographic sampling					27
CTD Unit	SBE19plus	SBE911	SBE911	SBE911	SBE911
Standard sampling depth (m)	1000	1000	1000	1000	1000

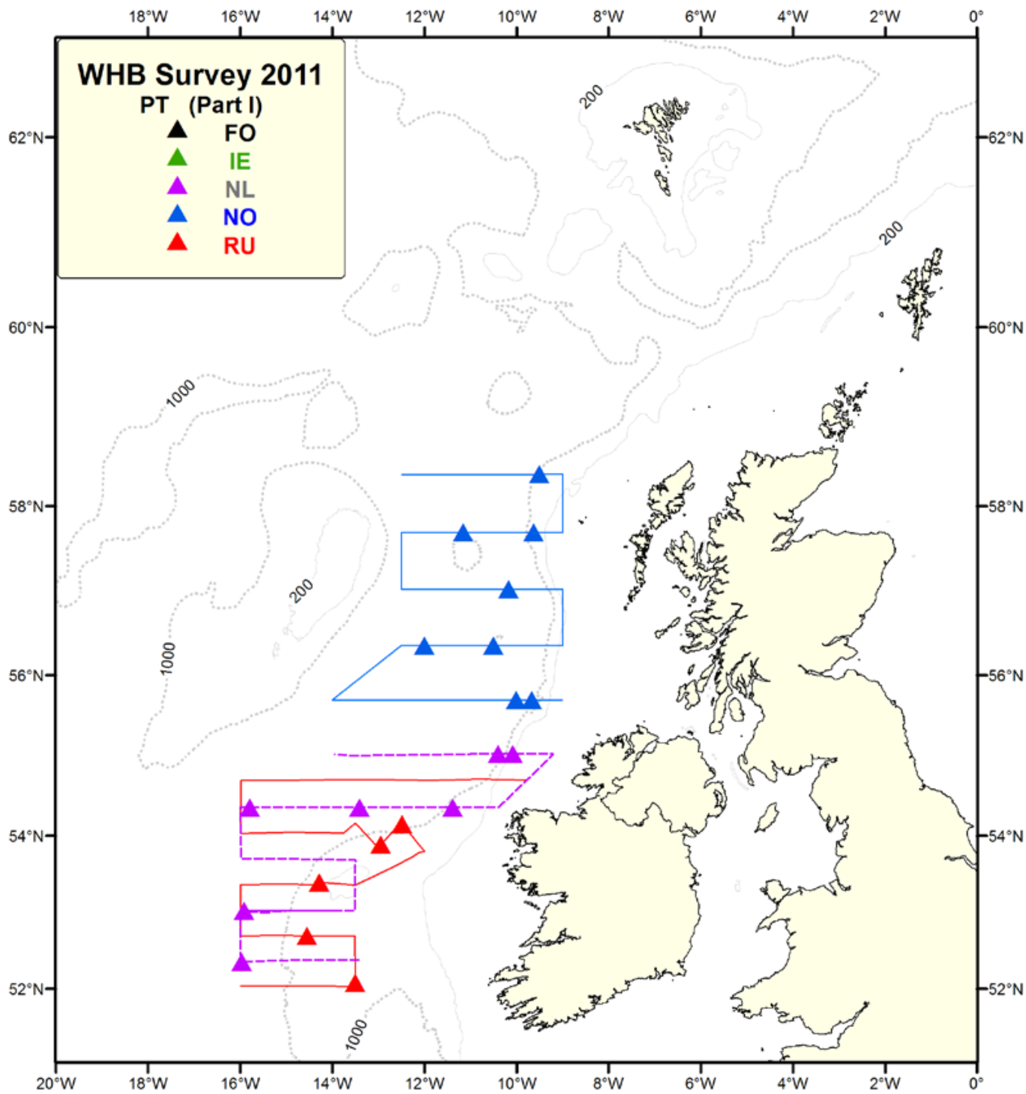


Figure 1a. Vessel cruise tracks and trawl stations of survey run 1. PT: Indicates pelagic trawl station. IE: Ireland (Celtic Explorer); FO: Faroese (Magnus Heinason); NL: Netherlands (Tridens); RU: Russia (Fridtjof Nansen): NO: Norway (G.O. Sars). March-April 2011.

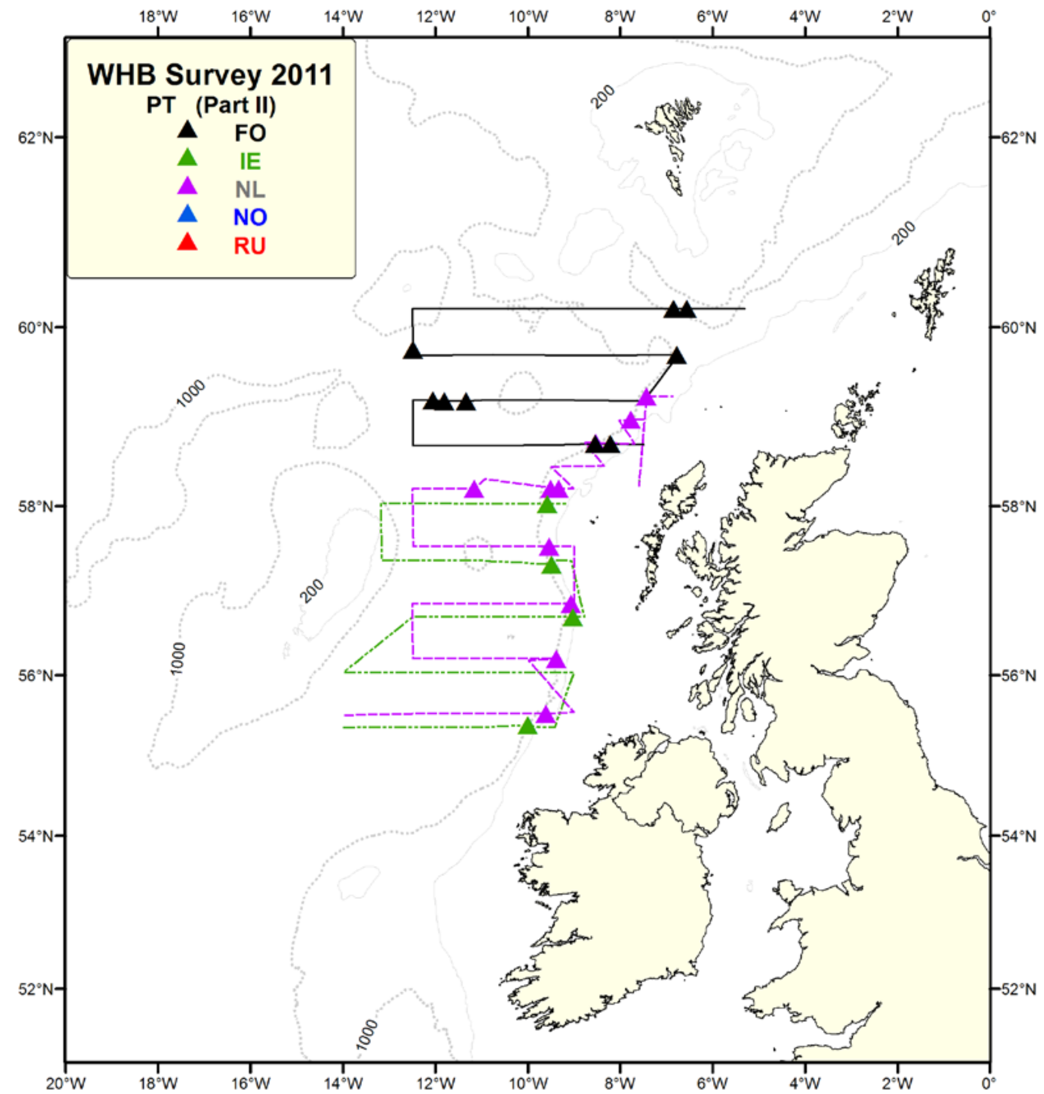


Figure 1b. Vessel cruise tracks and trawl stations of survey run 2. PT: Indicates pelagic trawl station. IE: Ireland (Celtic Explorer); FO: Faroese (Magnus Heinason); NL: Netherlands (Tridens); RU: Russia (Fridtjof Nansen): NO: Norway (G.O. Sars). March-April 2011.

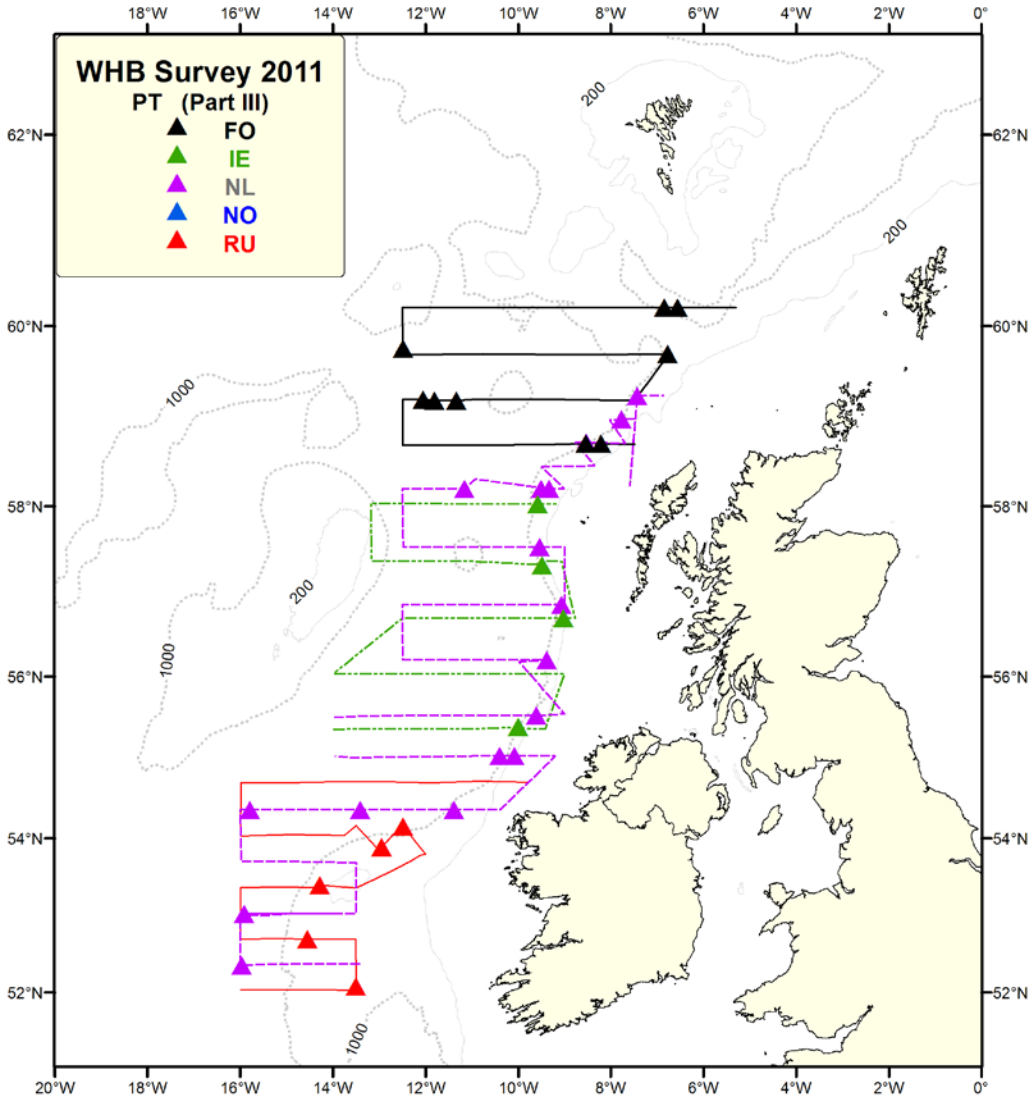


Figure 1c. Vessel cruise tracks and trawl stations of survey run 3. PT: Indicates pelagic trawl station. IE: Ireland (Celtic Explorer); FO: Faroese (Magnus Heinason); NL: Netherlands (Tridens); RU: Russia (Fridtjof Nansen): NO: Norway (G.O. Sars). March-April 2011.

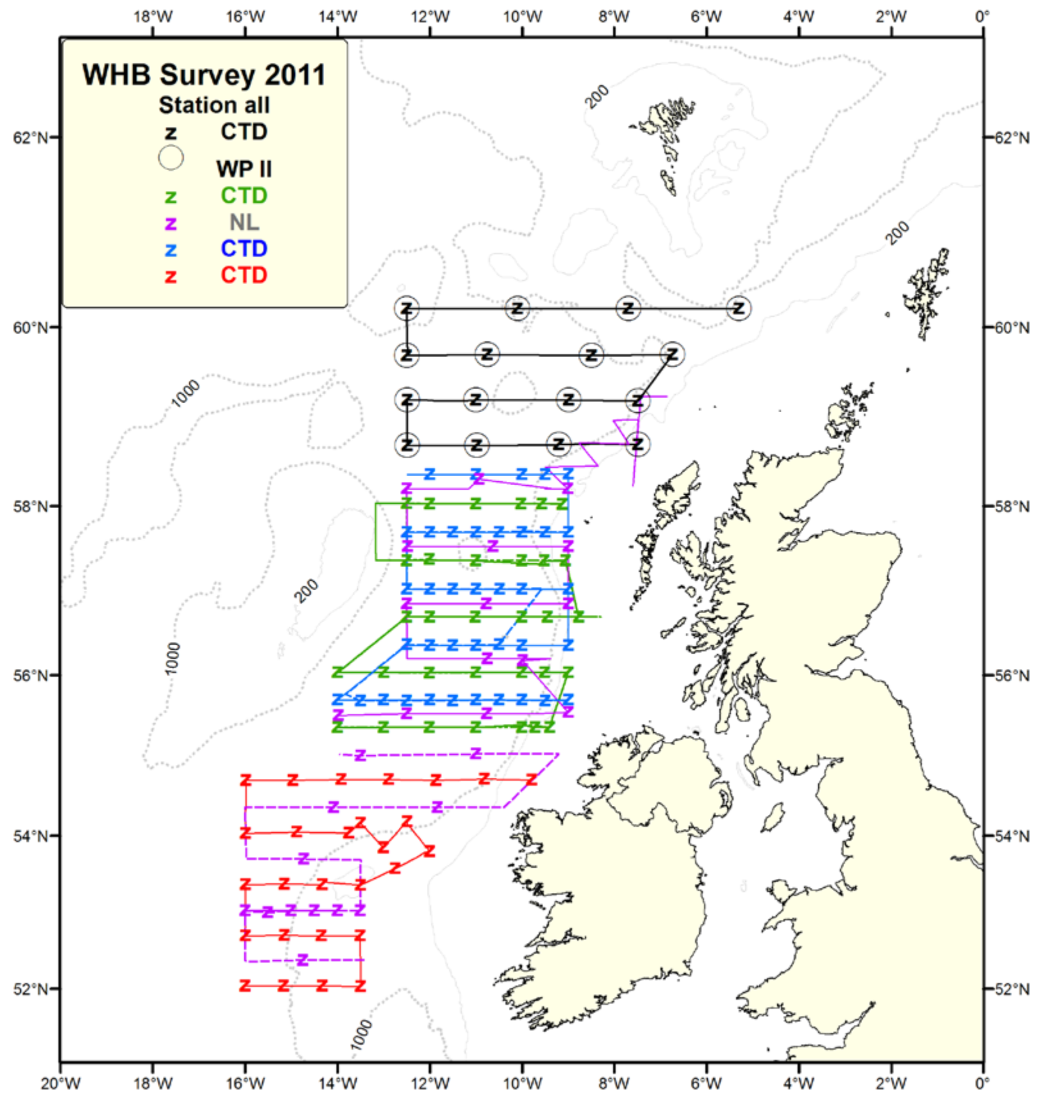


Figure 2. CTD stations overlaid onto vessel cruise tracks for the combined survey. WP II: plankton trawl. green: Celtic Explorer; black: Magnus Heinason; purple: Tridens; red: Fridtjof Nansen: blue: G.O. Sars. March-April 2011.

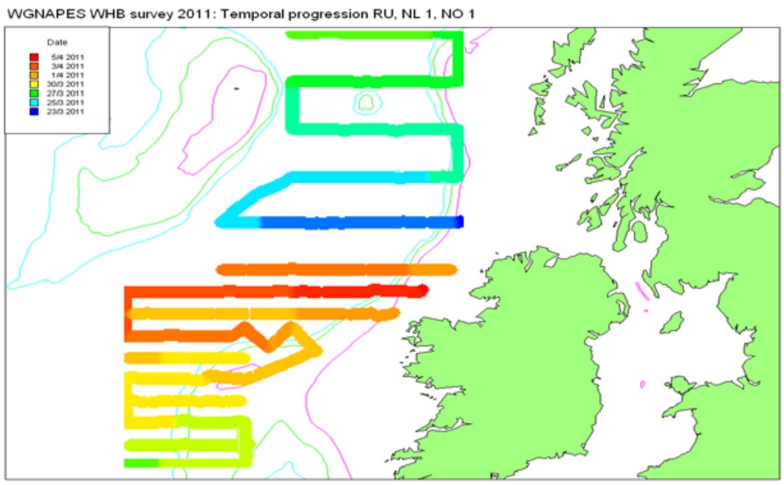


Figure 3a. Temporal progression for survey run 1, 23 March – 5 April 2010.

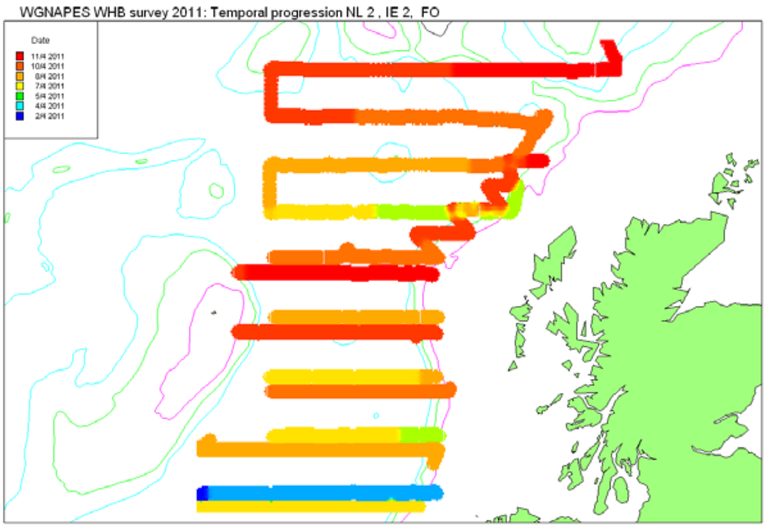


Figure 3b. Temporal progression for survey run 2, 2 April – 11 April 2010.

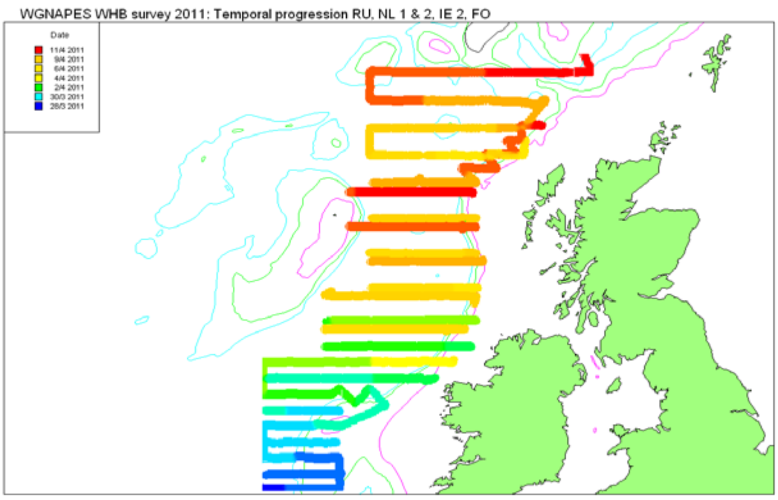


Figure 3c. Temporal progression for survey run 3, 28 March – 11 April 2010.

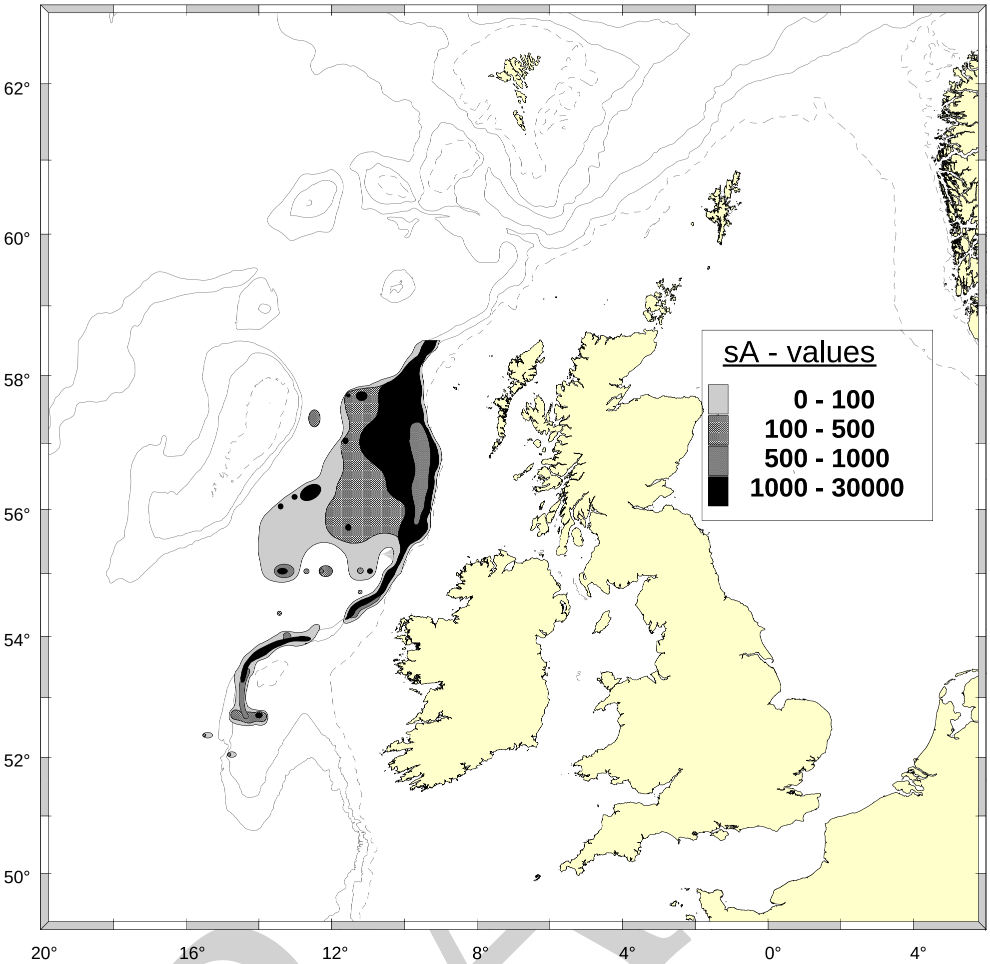


Figure 4a. Map of blue whiting acoustic density (s_A, m^2/nm^2) for survey run 1.

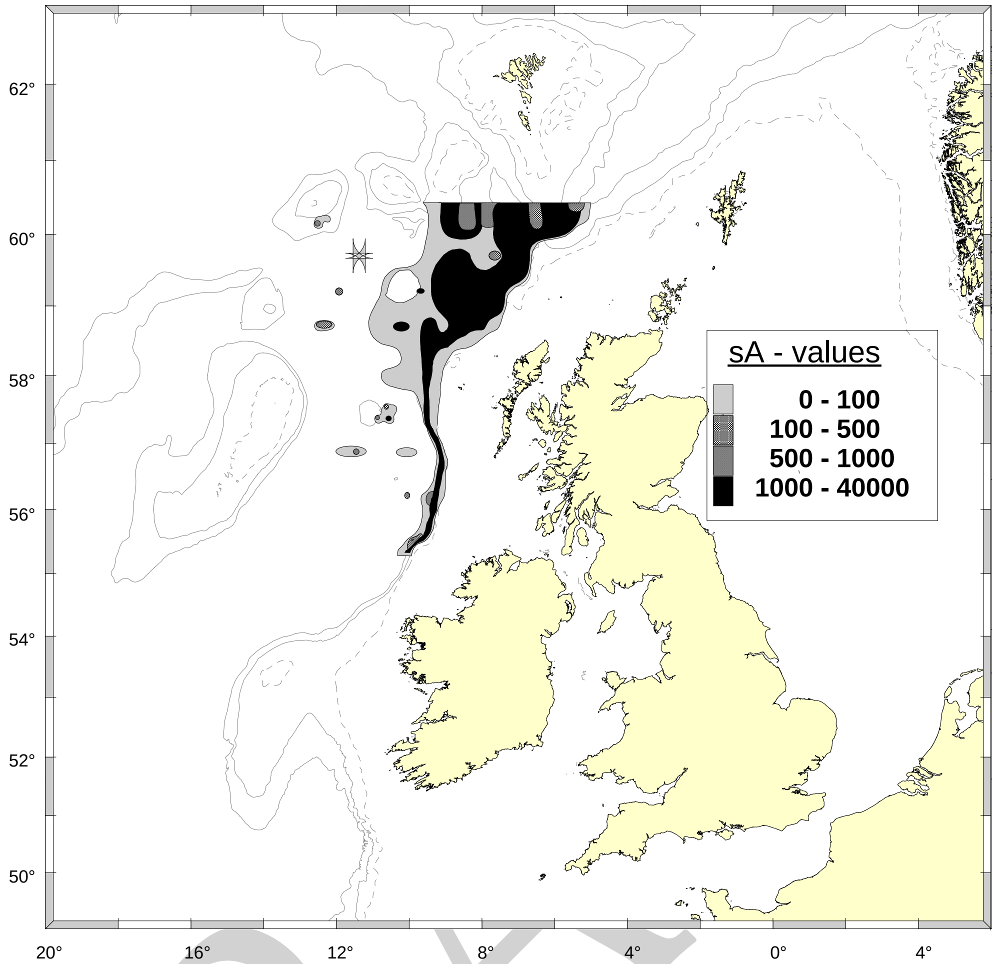


Figure 4b. Map of blue whiting acoustic density (s_A, m²/nm²) for survey run 2.

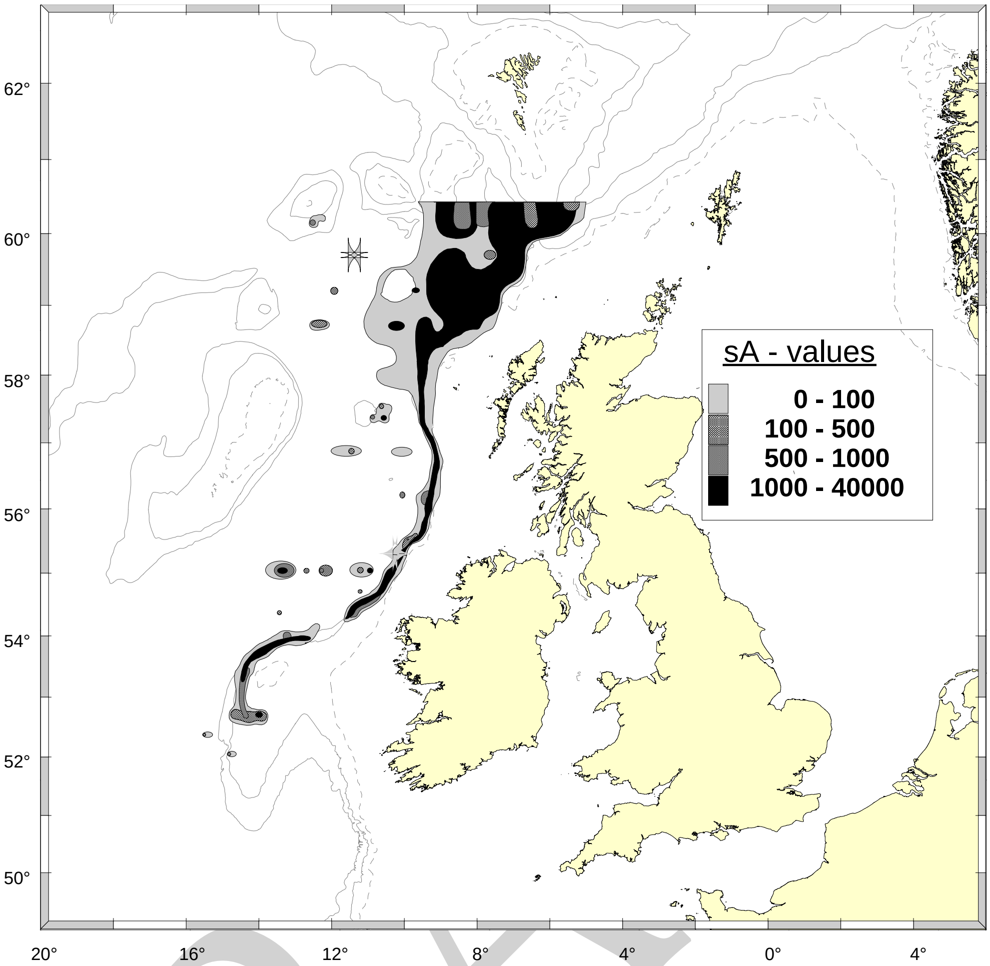


Figure 4c. Map of blue whiting acoustic density (s_A, m^2/nm^2) for survey run 3.

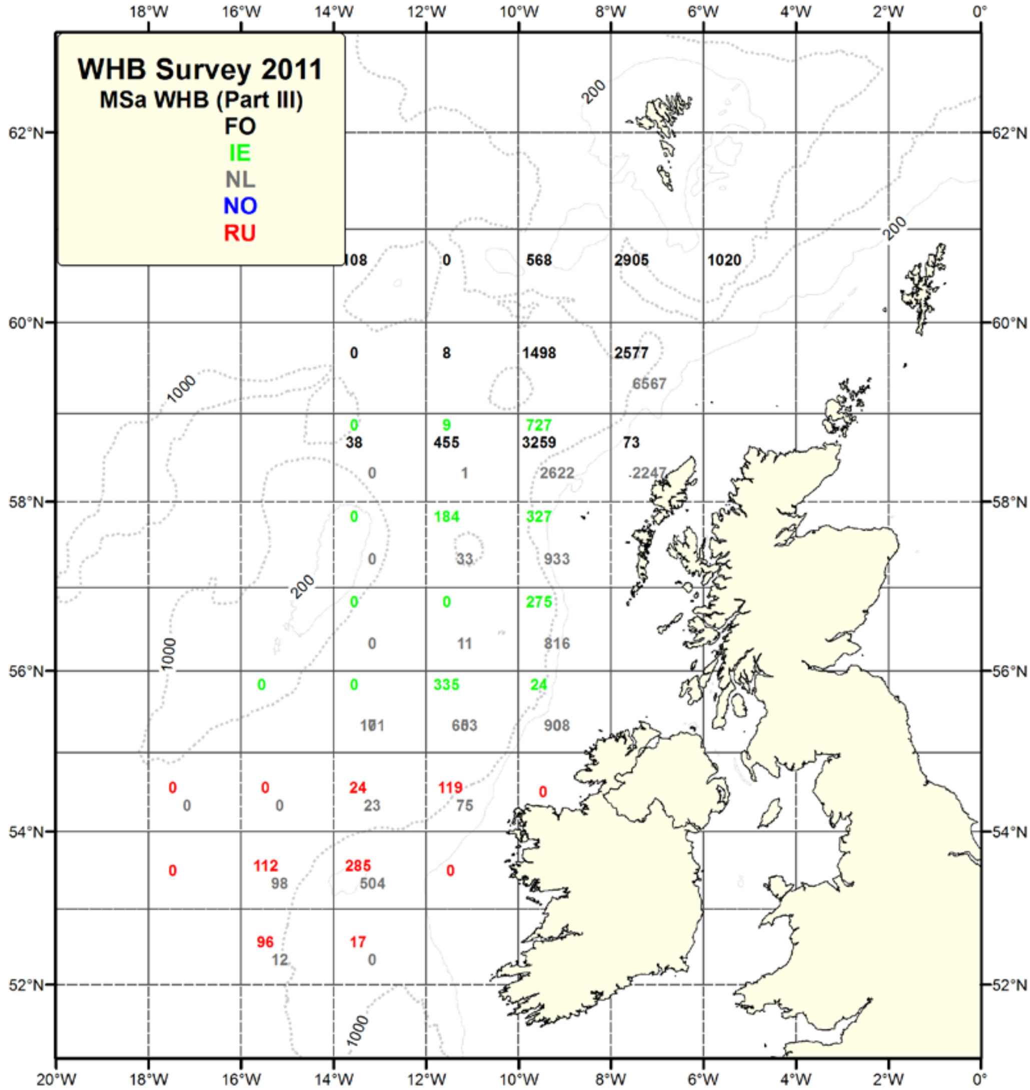


Figure 6. Mean blue whiting acoustic density (s_A, m^2/nm^2) for survey run 3 by individual vessel: Celtic Explorer: green, Magnus Heinason: black, Tridens: grey, Fridtjof Nansen: red. March-April 2011.

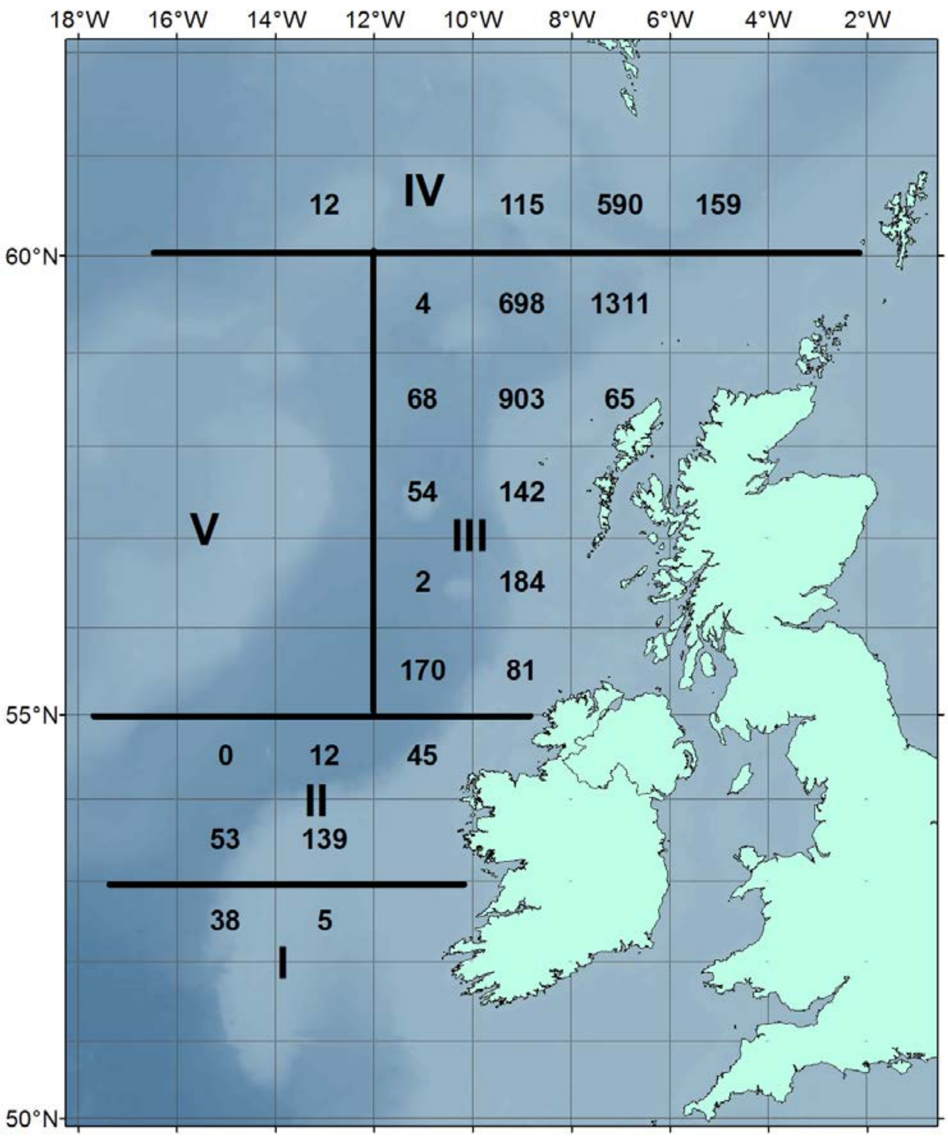
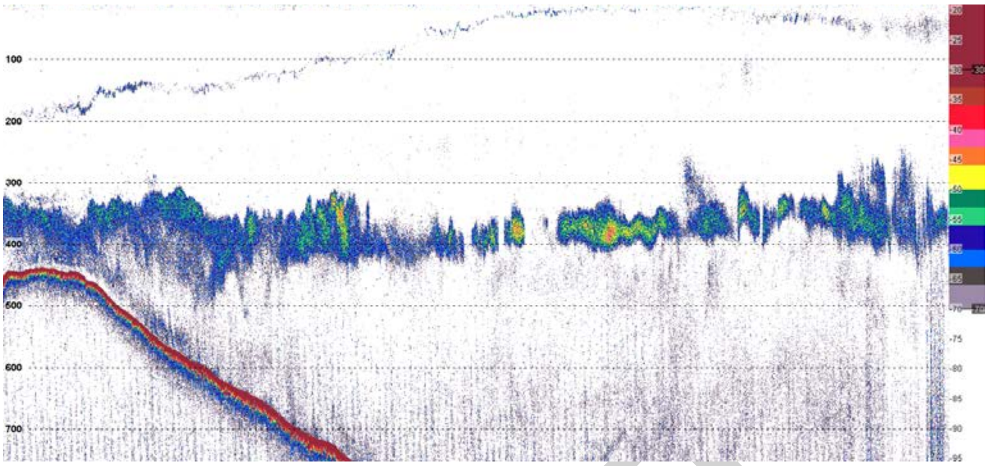


Figure 7. Blue whiting biomass by sub-area as used in the assessment.



a). *High density schools of blue whiting recorded by the RV Tridens. Located on shelf slopes to the northwest of the Hebrides (Sub area III). Depth scale (m) shown on left of image.*

Figure 8. Echograms of interest encountered during the combined International blue whiting survey in March-April 2011.

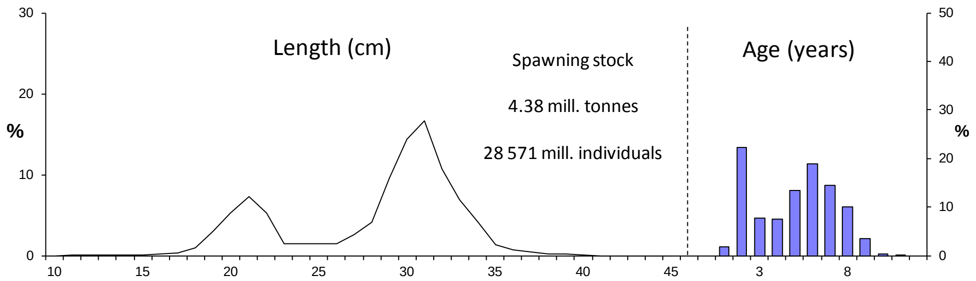


Figure 9. Length and age distribution as total and spawning stock biomass of blue whiting. March-April 2011.

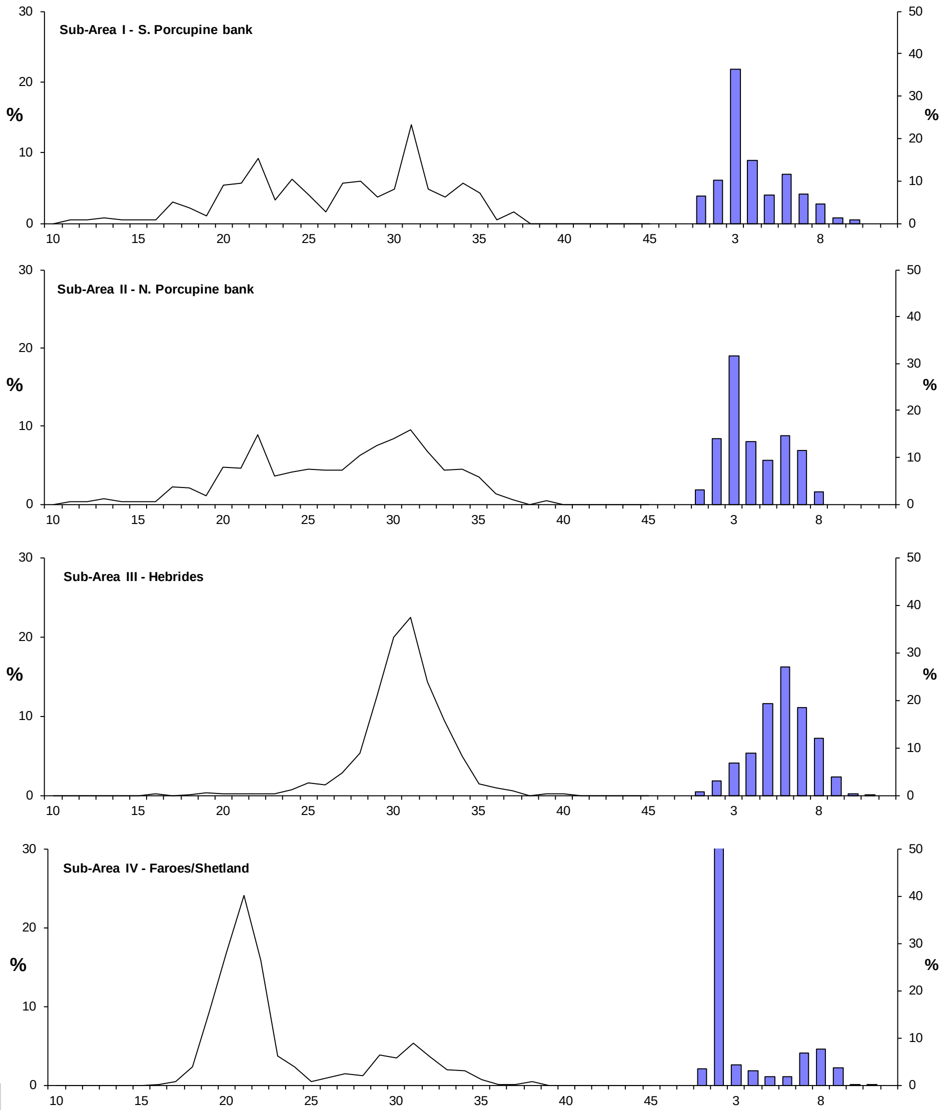
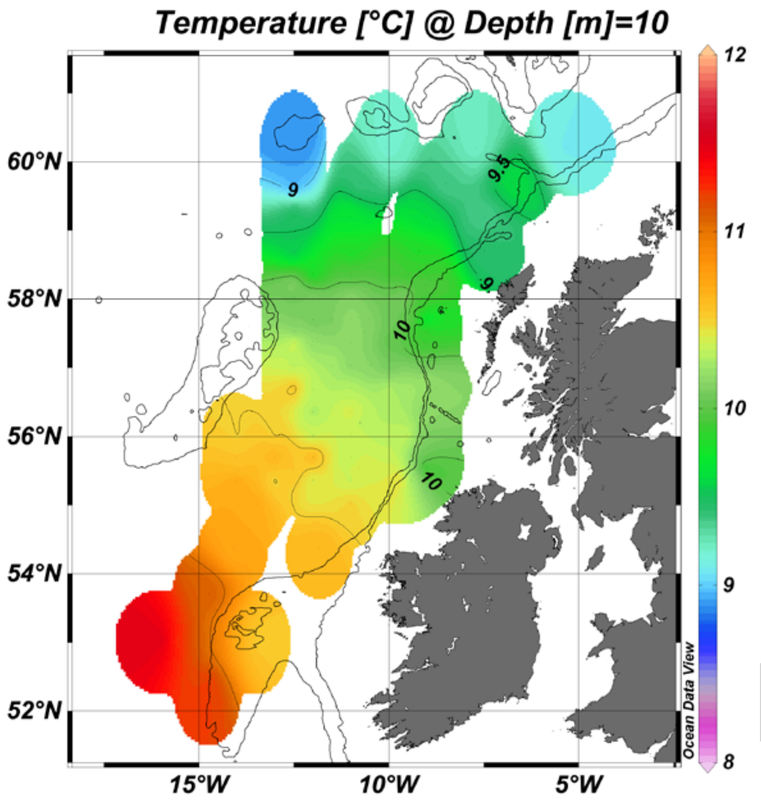


Figure 10. Length and age distribution (numbers) of blue whiting by covered sub-area (I–IV). March-April 2011.



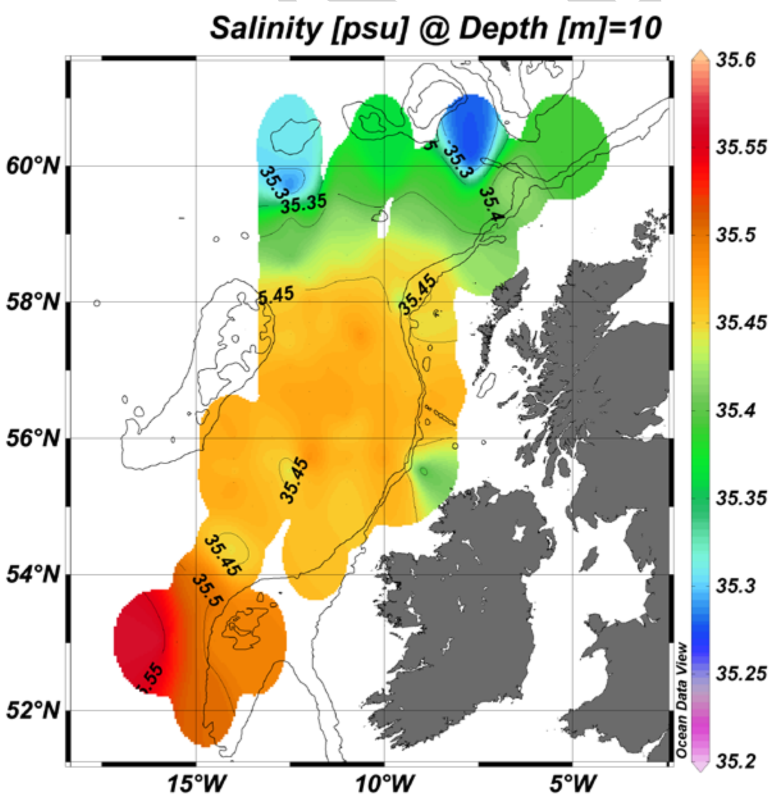


Figure 11. Horizontal temperature (top panel) and salinity (bottom panel) at 10m subsurface as derived from vertical CTD casts. March-April 2011.

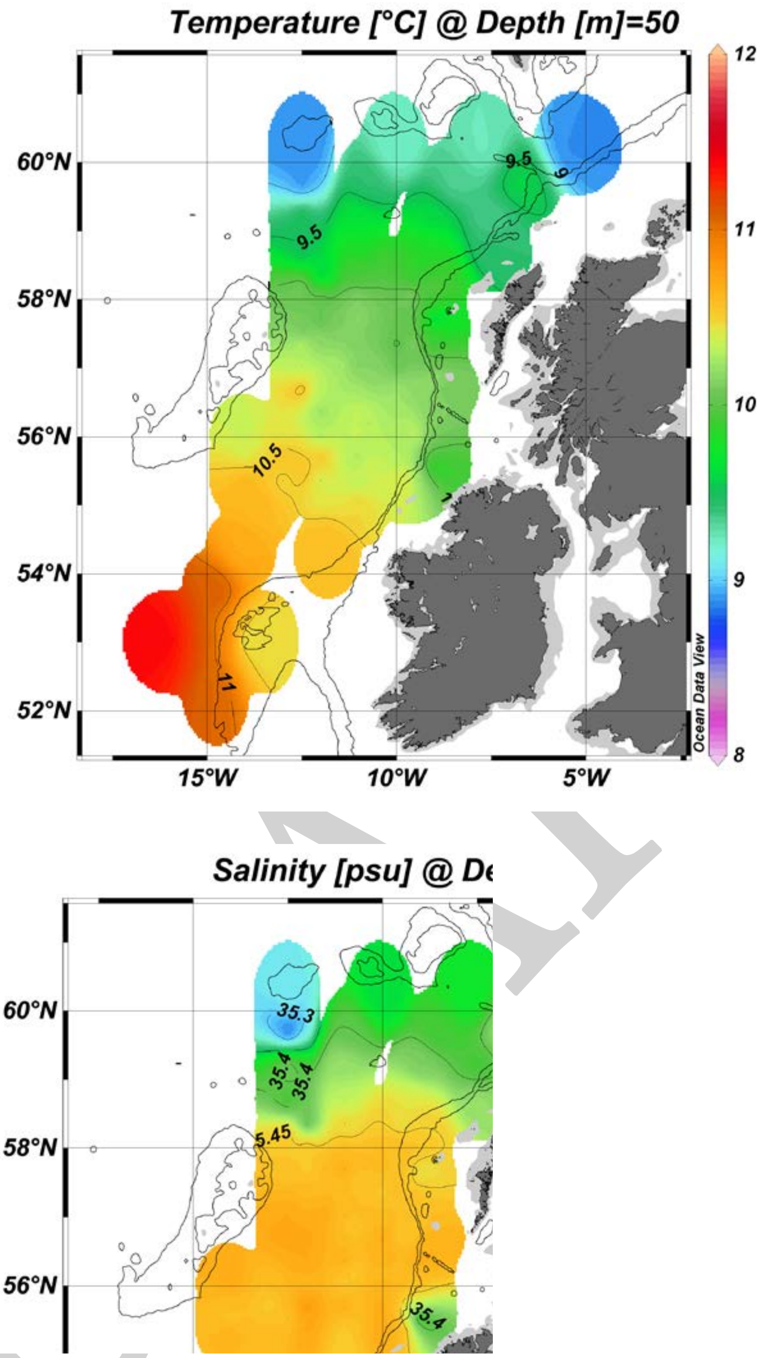


Figure 12. Horizontal temperature (top panel) and salinity (bottom panel) at 50m as derived from vertical CTD casts. March-April 2011.

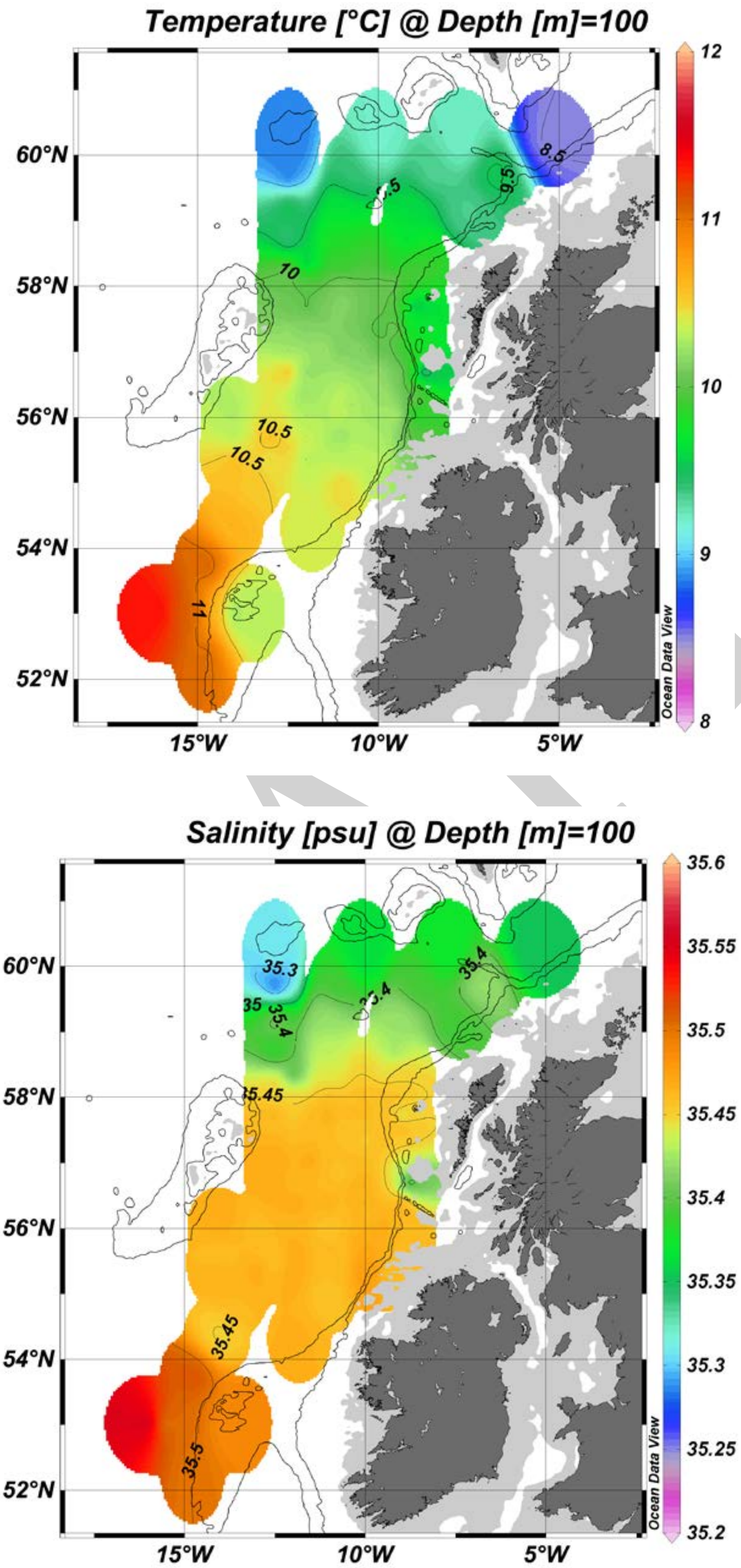


Figure 13. Horizontal temperature (top panel) and salinity (bottom panel) at 100m as derived from vertical CTD casts. March-April 2011.

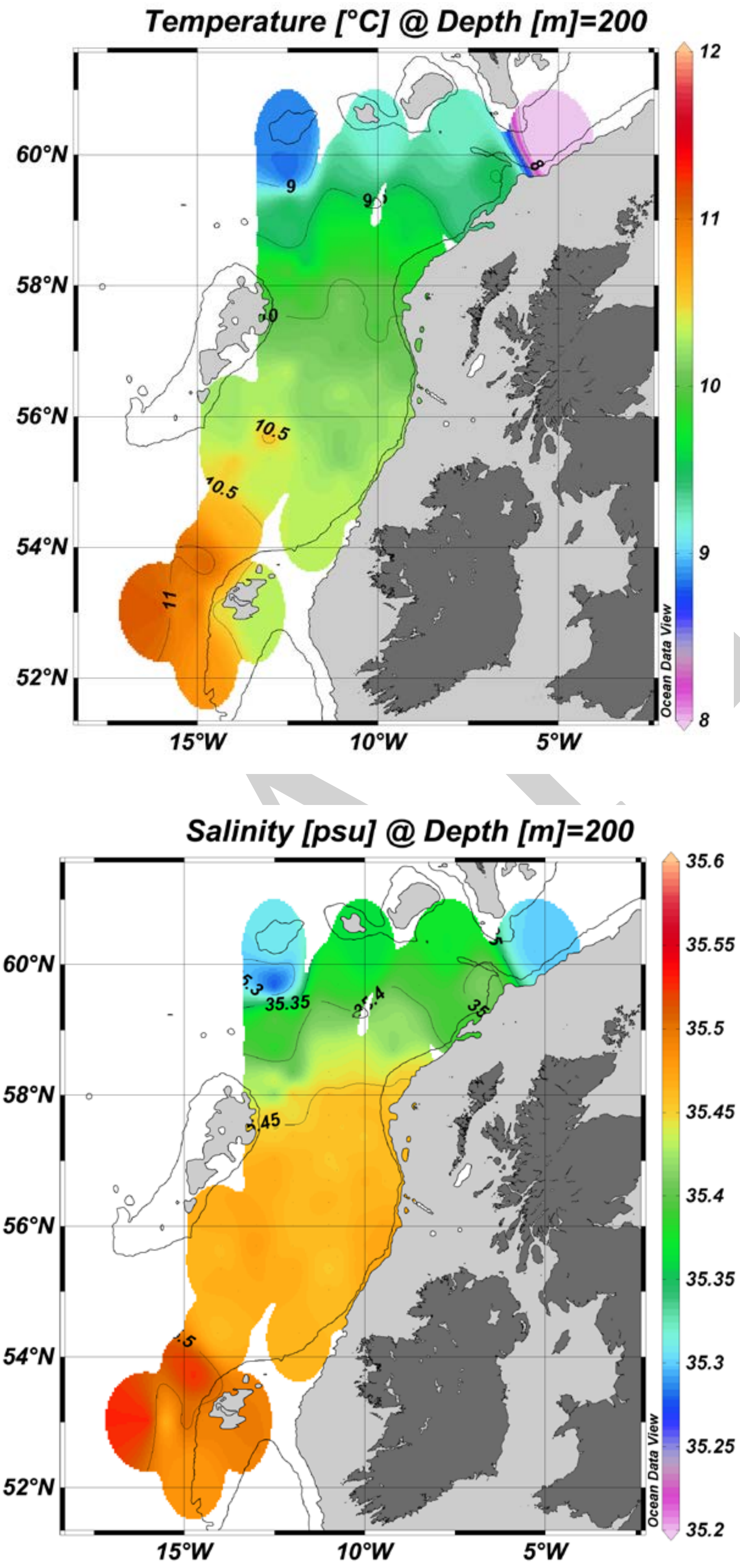


Figure 14. Horizontal temperature (top panel) and salinity (bottom panel) at 200m as derived from vertical CTD casts. Yellow circles indicate CTD positions. March-April 2011.

Appendix 1. Uncertainty in the acoustic observations and its implications on the stock estimate

Sascha Fässler and Ciaran O'Donnell

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).

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 1 nmi ESDU (elementary sampling distance units). 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 1 nmi). 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 2011 survey as well as eight earlier international surveys. Mean acoustic density over the survey area is 562.8 m^2/nm^2 (as compared to 174.2 m^2/nm^2 in 2010) with 95% confidence interval being 506.4 (lower) and 621.8 (upper) m^2/nm^2. Relative to the mean, the approximate 95% confidence limits are –10.0% and +10.5%, and 50% confidence limits are –3.9% and +3.8%. This level of acoustic uncertainty is similar as observed in previous years with the exception of 2007. Overall mean acoustic density has shown a consistent decrease annually since 2007 to 2010 and is now shown at an increased level during 2011.

Figure 2 summarizes the results and puts them in the biomass context. The overall trend indicates a continued decrease year-on-year in biomass from 2007 - 2010 for this stock. The uncertainty around the decline in biomass from 2008 to 2010 is more than could be accounted for from spatial heterogeneity alone and is regarded as statistically significant. The biomass estimate from 2010 was formulated using interpolated mean NASC values applied from surrounding rectangles to those rectangles not covered during the survey. Although the interpolation was carried out using established and routinely used methods for acoustic abundance estimation it was felt that the estimate was not representative of the stock as a whole. This considered, the 2011 estimate shows a continuation of the decline of the stock as determined from survey data. Excluding the 2010 estimate the rate of decline is not as pronounced but nonetheless still evident.

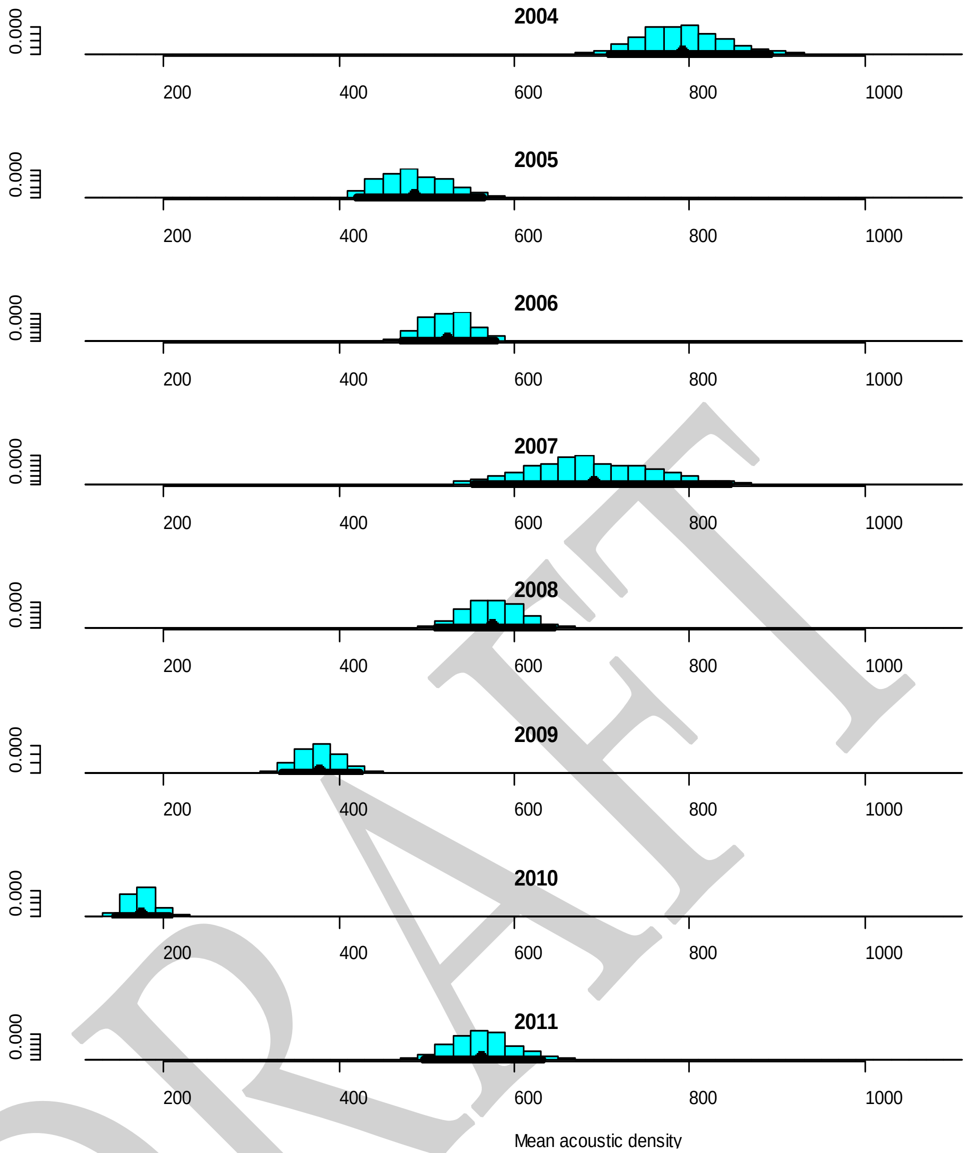


Figure 1. Distribution of mean acoustic density (in m²/nm²) by year based on 1000 bootstrap replicates of acoustic data from blue whiting surveys. Mean acoustic density is indicated with a black dot on the x-axis, while the horizontal bar shows 95% confidence limits.

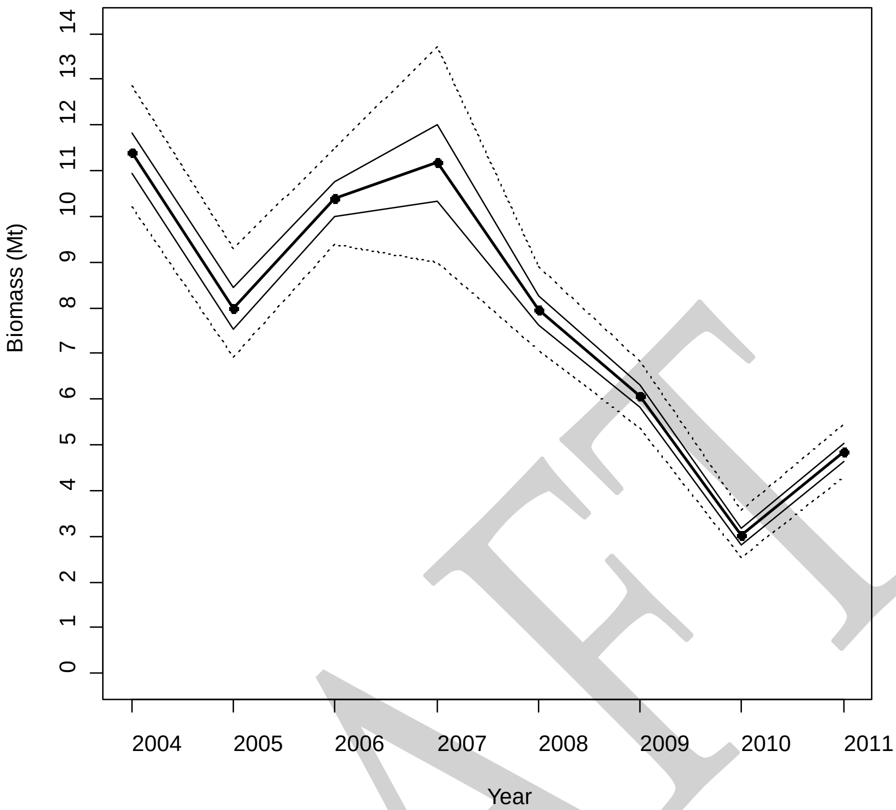
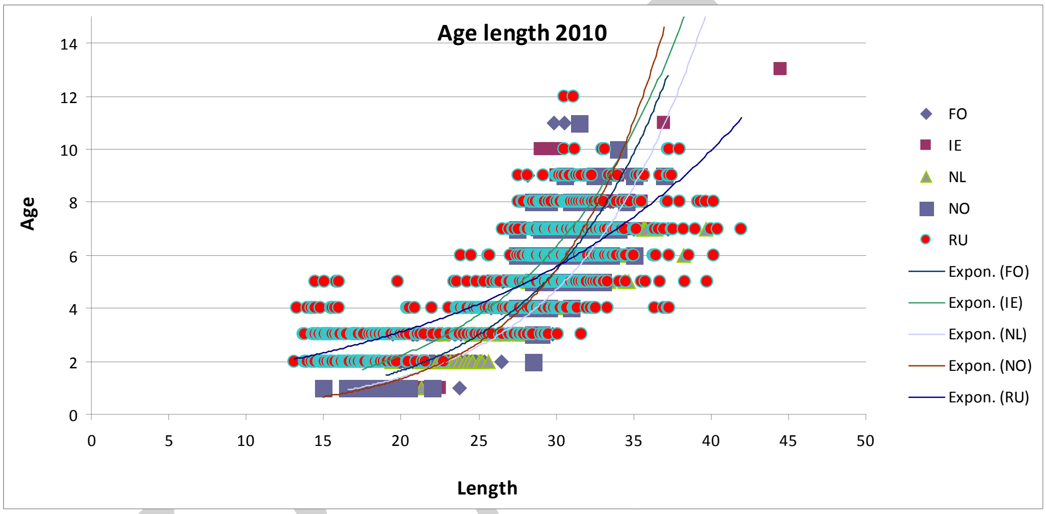


Figure 2. Approximate 50% and 95% confidence limits for blue whiting biomass estimates. The confidence limits are based on the assumption that confidence limits for annual estimates of mean acoustic density can be translated to confidence limits of biomass estimates by expressing them as relative deviations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

Appendix 2. Review of age determination of blue whiting by national participants.

Ciaran O'Donnell and Åge Høines

A review of consistency of age readings was carried out using data collected during the 2011 combined survey from participant nations. Results show good agreement for the majority of participants across age classes. A broad range of lengths at age was observed across readers as in 2010. Russian age readings appear out of phase with other nations in 2011 as in 2010. The oldest fish observed according to Russian estimates was 16 years when compared to 12 years for Irish and Faroe readers. Older ages were noted for smaller fish in the order of one year.



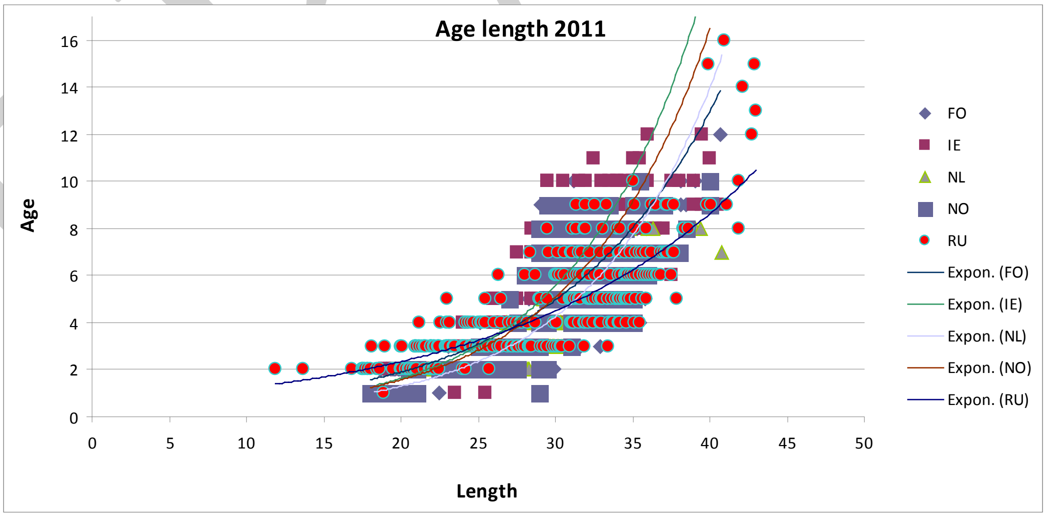


Figure 1. Profile of national age estimates as determined from otolith reading of trawl samples carried out over all individual blue whiting surveys in 2010- 2011 (FO; Faroes, IE; Ireland, NL: Netherlands, NO; Norway and RU; Russia).

Appendix 3. Agreed v's actual survey coverage and survey effort for the 2011 blue whiting survey program.

Ciaran O'Donnell

Presented below are the relevant planning sections from the WGNAPES report, section 5, 2010.

Survey timing and design were discussed in detail during the meeting. The group decided that in 2011 the survey area would be divided in two components (north and south) covering core spawning sub-areas with the dividing line occurring at 55.30ºN. This revised survey methodology would see each participant vessel covering their allocated area twice in opposing directions. The aim of this modified design is to analyse the potential effects of migration by means of survey replication. Overall this would provide a two survey biomass estimate for the combined area while maintaining the integrity of the survey index.

It was decided that the Tridens and F. Nansen would co-survey the southern sub-area and C. Explorer and G.O. Sars would cover the northern sub-area. Survey extension in terms of coverage (52-61ºN) would be maintained, ensure containment of the stock and survey timing would also remain fixed as in previous years.

Vessels should use the reciprocal cruise track on the secondary coverage, repeating CTD stations in the original positions. This will allow for temporal changes to be monitored between surveys. Biological sampling should be carried out following methods normally applied to sampling acoustic registrations, again to provide detailed information on the progress of spawning between coverages.

Individual vessels would maintain a transect spacing of 20nmi. Coverage in the western extreme in southwest of Rockall, will work on an annual rotation between survey vessels. This will be decided at the next WGNAPES meeting in 2012. In 2011 the C. Explorer volunteered to cover southwest Rockall.

Table 1 Planned area allocation by vessel for 2011

Ship	Primary Coverage	Secondary Coverage	Area Component	Supplementary
Celtic Explorer	North - South	South - North	Hebrides	SW Rockall (2011)
Tridens	South - North	North - South	Porcupine N & S	
G.O. Sars	South - North	North - South	Hebrides	
F. Nansen	North - South	South - North	Porcupine N & S	
Magnus Heinason	North - South	South - North	Faroes/Shetland	

Table 2 Planned vessel effort by vessel for 2011

Ship	Nation	Vessel time (days)	Active survey time (days)	Preliminary survey dates	Primary target area [secondary]
Celtic Explorer	EU (Ireland)	21	18	25/3–14/4	1 [2b]
G.O. Sars (TBC)	Norway	15	12	21/3–5/4	1 [2b]
Magnus Heinason	The Faroes	14	11	30/3–14/4	2c [1]
Tridens	EU (Netherlands)	21	14	22/3–12/4	2a [1,3a]
F. Nansen	Russia	30	21	22/3-13/4	2a [1,3a]

Table 3 Actual area coverage by vessels in 2011.

Ship	Primary Coverage	Completed as planned	Secondary Coverage	Completed as planned	Area Component	Supplementary	Completed as planned
Celtic Explorer	North - South	Y	South - North	Y	Hebrides	SW Rockall (2011)	N
Tridens	South - North	Y	North - South	N	Porcupine N & S		
G.O. Sars	South - North	Y	North - South	Y	Hebrides		
F. Nansen	North - South	N	South - North	Y	Porcupine N & S		
Magnus Heinason	North - South	N	South - North	Y	Faroes/Shetland		

Table 4 Actual area coverage by vessel in 2011.

Note: Poor weather played a large part in the temporal differences observed between planned and actual start dates.

Ship	Nation	Preliminary survey dates	Actual dates	Temporal difference from start
Celtic Explorer	EU (Ireland)	25/3–14/4	28/03–11/04	3 days
G.O. Sars (TBC)	Norway	21/3–5/4	23/03–04/04	2 days
Magnus Heinason	The Faroes	30/3–14/4	06/04–11/04	7 days
Tridens	EU (Netherlands)	22/3–12/4	29/03–11/04	7 days
F. Nansen	Russia	22/3-13/4	28/03–05/04	6 days

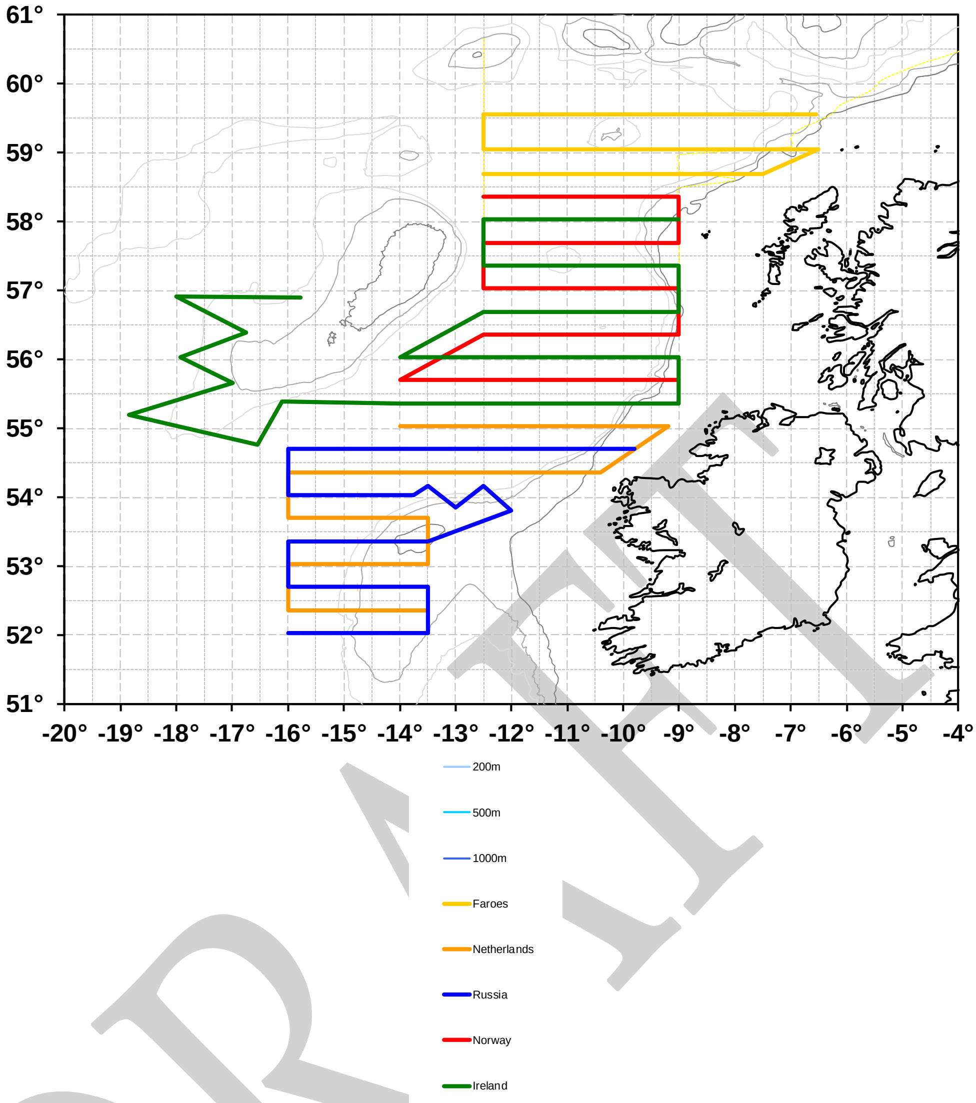


Figure 1. Pre agreed survey tracks for the 2011 International blue whiting spawning stock.

Annex 3: International ecosystem survey in the Nordic Seas

Working Document

Working Group on Northeast Atlantic Pelagic Ecosystem Surveys

Kaliningrad, Russia, 16–19 August 2011

Working Group on Widely distributed Stocks

ICES, Copenhagen, 23-29 August 2011

INTERNATIONAL ECOSYSTEM SURVEY IN NORDIC SEA IN April – June 2011

Alexander Krysov[4], Yriy Firsov[4], Tatiana Sergeva[4], Irina Prokopchuk[4]

RV Fridtjof Nansen

Øyvind Tangen[2], Valentine Anthonypillai[2], Webjørn Melle[2], Erling Kåre Stenevik[2], Åge Høines[2], Kjell Arne Mork[2]

RV G. O. Sars

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

RV Dana

Guðmundur J. Óskarsson[7], Sveinn Sveinbjörnsson[7]
RV Árni Friðriksson
Leon Smith[5*], Høgni Debes[5], Mourits Mohr Joensen[5], Fróði Skúvadal[5]

RV Magnus Heinason

1 Marine Institute, Galway, Ireland

2 Institute of Marine Research, Bergen, Norway

3 DTU-Aqua, Denmark

4 PINRO, Murmansk, Russia

5 Faroese Marine Research Institute, Tórshavn, Faroe Islands

6 IMARES, IJmuiden, The Netherlands

7 Marine Research Institute, Reykjavik, Iceland

8 vTI-SF, Hamburg, Germany

Introduction

In April-June 2011, 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, RV G. O. Sars, Norway and RV Fridtjof 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 2011a, Magnus Heinason: FAMRI 2011, Arni Friðriksson: Oskarsson and Sveinbjornsson 2011, Fridtjof Nansen: PINRO 2011 and G. O. Sars: not (yet) available.

Material and methods

Coordination of the survey was initiated at the meeting of the Working Group on Northeast Atlantic Pelagic Ecosystem Surveys (WGNAPES) in August 2010 (ICES CM 2011/SSGESST:16), 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	30/4–26/5
G. O. Sars	Institute of Marine Research, Bergen, Norway	29/4-29/5
Fridtjof Nansen	PINRO, Russia	14/5–4/6
Magnus Heinason	Faroese Fisheries Laboratory, Faroe Islands	5-16/5
Arni Friðriksson	Marine Research Institute, Island	26/4–18/5

Figure 2 shows the cruise tracks and the CTD/WP-2 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.

In general, the weather condition did not affect the survey even if there were some days that were not favourable. In the eastern area the weather conditions were generally excellent during the survey.

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	G. O. Sars	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, 70, 120, 200, 333	**38**, 18, 120, 200	**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	LSSS	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).

Generally, acoustic recordings were scrutinized with the different software (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	G. O. Sars	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 30–100 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 70–250 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 (sA) 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 and plankton stations by survey are shown in Figure 2. All vessels collected hydrographical data using a SBE 911 CTD. Maximum sampling depth was 1000 m. Zooplankton was sampled by a WPII on all vessels except the Russian vessel which used a Dyedi net, according to the standard procedure for the surveys. Mesh sizes were 180 or 200 µm. The net was hauled vertically from 200 m or the bottom to the surface. All samples were split in two and one half was preserved in formalin while the other half was dried and weighed. On the Danish, the Icelandic and the Norwegian vessels the samples for dry weight were size fractionated before drying. Data are presented as g dry weight m^2.

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 > 9°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 it turned north-eastwards and intersected the boundary of the survey area at about 5°E. The front was discernible throughout the observed water column but was most pronounced below 100 m depth (Figures 7 – 9).

With depth, temperatures decreased to values < 0°C particularly north and west of the polar front because here it is located in Arctic water masses while south and east of it the drop in temperature was not as pronounced as it is more influenced by Atlantic water masses. The warmer North Atlantic water formed a broad tongue that stretched far northwards along the Norwegian coast with temperatures > 6 °C in the surface layers. In the surface layers this water mass was warmer in the south compared to last year. However, with increasing depth this core of warm Atlantic water had about similar temperatures as last year. Relative to a 16 years long-term mean, from 1995 to 2010, temperatures below the surface east of the 0° Meridian in the Norwegian Sea were slightly higher in 2011 compared to the long-term mean. At 100 m depth the difference is about 0-0.4°C, dependent on the area, but at 10 m this difference could be 1°C. In the western areas, west of the 0° Meridian, however, a cooling is observed compared to the mean and to 2010. In the southwestern area, the temperature reduction at 100 m is 0-0.8°C compared to the long-term mean. Compared to 2010 the temperature reduction could even be up to -1.5°C north and northeast of the Faroese. The increased eastern extension of the East Icelandic Current in 2011 can be observed by comparing the e.g. 3°C isoline. At 100 m depth the isoline reached about 8°W in 2010 while in 2011 it reached about 4°W at 64°N.

In the Barents Sea the water temperature reduced at the surface and 20 m depth, in some areas by 1°C, compared to 2010. Thus, the last year warming at the surface compared to the long-term mean reversed. At deeper depths the temperature in 2011 was almost like in 2010, which was in the category of warm years for the Barents Sea (Figures 4 – 9).

Zooplankton

Zooplankton

Biomass of zooplankton and sampling stations are shown in Figure 10. Sampling stations were relatively evenly spread over the area, and most oceanographic regions were covered. The highest zooplankton biomasses were observed in the western and northern Norwegian Sea, but in general biomass was low in all areas. Recorded zooplankton biomass in the two areas west and east of 2°W equaled 6.8 and 6 g dry weight m^{-2}, while total mean was 6.4 g dry weight m^{-2}.

In the Barents Sea zooplankton biomass was low in all areas. Mean biomass of the Barents Sea was 1.1 dry weight m^{-2}.

Norwegian Spring-spawning herring

Survey coverage in the Norwegian Sea was considered adequate in 2011 and in line with previous years. There were some differences in the herring distribution this year (Figure 11) compared to 2010. In 2010, the herring was distributed throughout most of the surveyed area while in 2011 the herring was more concentrated in the central part of the Norwegian Sea. The highest values in 2010 were also recorded in the central Norwegian Sea although somewhat more to south, at the eastern edge of the cold waters of the East Icelandic Current. Moreover, in last year herring were also found in the northern part of the surveyed area, while in this year almost no herring were observed north of 70°N. Because of this, the center of gravity of the acoustic recordings shifted in a southwesterly direction compared to 2010.

As in previous years the smallest fish were found in the northeastern area where size and age were found to increase to the west and south (Figure 12). Correspondingly, it was mainly older herring that appeared in the southwestern areas (area III), especially the 2002 year class. An exception of this general pattern was that in 2011 some bigger herring were observed in the southeastern area close to the Norwegian coast.

The herring stock is now dominated by 7 year old herring (2004 year class) in numbers but 9, 8 year old herring (2002 and 2003 year classes) are also numerous (Table 2). The three year classes 2002, 2003 and 2004 contribute to 18%, 10% and 29%, respectively, of the total biomass.

There was an unexpected drop in the biomass estimate in the survey in 2010 compared to 2009 (from 10.7 million tons to 5.8 million tons). The abundance estimate from the 2011 survey (7.4 million tons) is higher than in last year. The past estimates of the 2002 year class indicate that it is very strong but the 2010 survey gave a less optimistic estimate of its size. The results from the 2011 survey gave a minor increase in the estimates of the 2002 and 2004 year classes while the 2003 year class was reduced compared to 2010.

The investigations of herring in the Barents sea carried out in the area from 40°E to the 20°30′ E from 15 May to 30 June. During the survey herring spread in the southwest part of Russian zone, south part of Grey area and along 12-miles Norwegian zone. Maximum sA values observed there reached 4360 square meters per square miles with a vertical extension of up to 10-40 m. Herring with length of 9.0-24.0 cm at the age of 1-3 were found in catches. Weight of herring was, on average, 24.0 g. It was immature fish. Feed rate was weak (Mean fullness of stomach was 0.9). Euphausiids dominated in the diet of herring (56.6%).

The total number of herring recorded in the Norwegian Sea was 22.7 billion in the northeastern area and 7.9 billion in the southwestern area, compared to 18.1 billion and 8.8 billion in last year, respectively.

Blue whiting

The total biomass of blue whiting registered during the May 2011 survey was 0.84 million tons (Table 3), which is very low (the corresponding estimates from 2006, 2007, 2008 and 2009 were 6.2, 2.4, 1.1, 0.9 and 0.26 mill. tons, respectively). The stock estimate in number for 2011 is 9.2 billion, which is more than 5 times the 2010 estimate. The main reason for an increased estimate is better recruitment of blue whiting and 1- and 2-group constitute ca 50% of the total estimate in terms of biomass and 74% in terms of numbers. Such values have not been seen since 2005/2006. But still the values of young fish are well below the rich year classes recruiting in the first half of the decade.

An estimate was also made from a subset of the data or a “standard survey area” between 8°W–20°E and north of 63°N, which has been used as an indicator of the abundance of blue whiting in the Norwegian Sea because the spatial coverage in this area provides a coherent time-series with adequate spatial coverage. This standard survey area estimate is used as an abundance index in WGWIDE. The age-disaggregated total stock estimate in the “standard area” is presented in Table 4, showing that the blue whiting in this index area was dominated by young fish, age groups 1 and 2 years old.

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. The edge of the distribution has also been found progressively further north and west. In 2011 the mackerel was found up to 64°N west of around 0°W but all the way to 69°N further east (Figure 15). The mean length was 34-36 cm in most catches and no clear geographical pattern was in mean length of the fish.

Discussion

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

Concluding remarks

- The estimate of NSSH was higher compared to last year
- NSSH was dominated by the 2004 year class
- No strong year classes of NSSH were observed in the Barents Sea indicating poor recruitment since 2004.
- The amount of blue whiting measured in the survey area was higher than previous years but still very low.
- The blue whiting stock show signs of improved recruiting year classes.
- Total biomass estimate of blue whiting was higher now than in 2010 mainly due to recruiting year classes (age 1-2), which have hardly been seen in the most recent years.
- The increasing trend in the abundance of mackerel and the widening of its northern and western distribution limits during summer seem to continue in 2011.

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Table 1. Survey effort by vessel.

Vessel	Effective survey period	Length of cruise track (nm)	Trawl stations	CTD stations	Plankton station
Dana	30/4–25/5	1.414	22	34	66
GO Sars	6/5–2/6	3.831	38	63	52
Fridjof Nansen	14/5–1/6	2.331	34	91	82
Magnus Heinason	29/4–12/5	1.292	14	36	36
Arni Friðriksson	26/4–18/5	3.919	36	58	58
Total	26/4–2/6	12.787	144	282	294

Table 2. Age and length-stratified abundance estimates of Norwegian spring-spawning herring in April-June 2011 for total area and abstracts of estimates for subareas II and III

Length	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Number	Biomass	Weight
10	108															108	0.7	6.3
11	455															455	3.5	7.6
12	36															36	0.4	10.3
13	20	99														119	1.8	15
14		141														141	2.5	17.5
15		895														895	18.9	21.1
16		1292														1292	32.1	24.8
17		959														959	27.7	28.9
18		545														545	21.5	39.4
19		238	4													242	12.2	50.4
20		192	6													198	11.5	57.9
21		91	3													94	6.2	66.9
22		102	1													103	8.2	80.1
23		54	1													55	4.8	87.7
24		52	57	1												110	11.3	103.2
25		0	270	0												270	31.3	116.3
26		1	299	0												300	38.8	129.5
27		3	225	0												228	34.7	152.8
28		0	9	248	41											298	49.5	166.2
29		2	60	209	415											686	126.9	185
30			82	390	971	364	202	0	0	0	0	0	0	0	0	2009	408.6	203.4
31			370	499	2396	966	1279	0	0	0	0	44	0	0	0	5554	1224.9	220.5
32			159	265	521	853	3486	365	311	0	0	0	27	0	0	5987	1425.3	238.1
33			47	114	180	311	2597	908	1524	43	107	86	21	0	0	5938	1532.4	258
34				26	26	165	951	1171	2084	182	169	93	0	0	0	4867	1329.5	273.2
35						28	178	380	768	253	340	311	84	0	0	2342	684.7	292.2
36						4	0	53	137	71	238	239	88	9	21	860	272.3	316.1
37									4	23	43	51	35	4	8	168	55.2	331.4
38												13	26	0	5	44	15.6	355.6
39													1	0	0	1	0.8	391
40																0		
41																0		
42																0		
N mill.	619	4666	1593	1752	4550	2691	8693	2877	4828	572	897	837	282	13	34	34904	7394	

Table 2. (cont'd)

Area I

Age	1	2	3	4	5	6	7	8	9	10	11	12+	Number	Biomass
Biomass 10^3	4.8	90	1										95.8	95.8
Length cm	11.4	16.5	21.6											15.8
Weight g	7.7	25	58.5											22.6

Area II

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Number	Biomass
Biomass 10^3 t		61.1	116.2	246.8	929.2	556.1	1776.8	452.2	685.1	45.2	80.5	128.9	33.6			5112	5111.8
Length cm		20.2	26.5	30.4	31.2	32	32.8	33.9	34.1	35.1	34.8	34.9	35				31.8
Weight g		58.6	132.6	199.6	213.9	227	240.4	258.2	262.2	279	273.9	275.1	279.6				224.7

Area III

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Number	Biomass
Biomass 10^3 t		1.3	164.2	128.1	53.3	65.6	347	316.7	623	120.8	183.4	114.9	52.2	4	11.5	2186	2185.9
Length cm		22.6	31.6	32.3	33.1	33.8	33.5	34.4	34.4	35.3	35.7	36.1	36.6	36.8	37		34.1
Weight g		93.1	235.7	248.4	260.7	271.1	266.6	281.2	281.1	294.8	303.9	311.5	320	324.5	330		276.1

Total

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Number	Biomass
Biomass 10^3 t	4.8	152.5	281.4	374.9	982.5	621.7	2123.8	768.9	1308.1	166	263.9	243.8	85.8	4	11.5	7394	7393.6
Length cm	11.4	17.4	28.7	30.9	31.3	32.1	32.9	34.1	34.3	35.2	35.4	35.4	35.9	36.8	37		30.4
Weight g	7.7	32.7	177	213.9	216	231	244.3	267.2	270.9	290.3	294.1	291.1	302.9	324.5	332		211.8

Table 3. Age and length-stratified abundance estimates of blue whiting in April-June 2011, west of 20°E for total area and abstracts of estimates for subareas II and III.

Length	1	2	3	4	5	6	7	8	9	10	11	12+	Number	Biomass	Weight
10													0		
11													0		
12													0		
13													0		
14													0		
15													0		
16													0		
17													0		
18	30	45	0	0	0	0	0	0	0	0			75	2.4	32.3
19	218	316	0	0	0	0	0	0	0	0			534	20.2	37.9
20	525	900	0	0	0	0	0	0	0	0			1425	63.4	44.5
21	628	805	0	0	0	0	0	0	0	0			1433	74.1	51.7
22	912	453	0	0	0	0	0	0	0	0			1365	82.5	60.4
23	259	857	0	0	0	0	0	0	0	0			1116	79	70.7
24	0	672	0	0	0	0	0	0	0	0			672	54.6	81.2
25	0	167	0	0	0	0	0	0	0	0			167	15.5	92.8
26	0	0	54	0	0	0	0	0	0	0			54	5.9	110.5
27	0	0	0	17	0	0	0	0	0	0			17	1.9	113.6
28	0	0	0	8	4	4	0	0	62	0			78	8.9	115.1
29	0	0	0	31	37	68	37	7	0	0			180	27.4	152.8
30	0	0	0	6	34	23	234	28	56	0			381	63.8	167.6
31	0	0	0	56	56	107	231	68	17	0			535	93	173.6
32	0	0	0	0	38	48	177	38	0	0			301	61.7	204.8
33	0	0	0	0	45	68	136	401	45	0			695	144.9	208.2
34	0	0	0	0	22	33	38	0	11	0			104	25.9	250.8
35	0	0	0	11	11	0	2	0	11	11			46	12	274.5
36													0		
37													0		
38													0		
39													0		
40													0		
41													0		
42													0		
43													0		
Number 10^6	2572	4215	54	129	247	351	855	542	202	11	0	0	9178	837	

Total area

	1	2	3	4	5	6	7	8	9	10	11	12+	Number	Biomass
Biomass 10^3	139.3	252.4	5.9	20.7	48.2	67.2	164	100.3	36.2	2.9			837	837.3
Length cm	21.6	22.3	26.5	30.6	32	31.8	31.8	33	31.1	35.5				24.6
Weight g	54.2	59.9	110.5	161.8	195.6	191.9	191.7	185.2	179.2	276.8				91.2

Area II

Age	1	2	3	4	5	6	7	8	9	10	11	12+	Number	Biomass
Biomass 10^3	98.1	145.1	0.2	9.3	36.8	51.5	137.3	30.7	36.2	2.9			548.1	548
Length cm	21.5	21.3	26.5	30.1	32.3	32.1	31.8	31.9	31.1	35.5				24
Weight g	52.2	50.9	107.7	167.1	210.7	204.6	197.5	195.2	179.2	276.8				87.3

Area III

Age	1	2	3	4	5	6	7	8	9	10	11	12+	Number	Biomass
Biomass 10^3	41.2	107.4	5.7	11.3	11.5	15.8	26.7	69.7					289.3	289.3
Length cm	22.1	24.2	26.5	31	31.1	31.1	31.6	33.4						. 25.9
Weight g	59.6	78.5	110.6	157.7	159.1	159.7	166.4	181.1						99.8

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
10													0		
11													0		
12													0		
13													0		
14													0		
15													0		
16													0		
17													0		
18	30	45	0	0	0	0	0	0	0				75	2.4	32
19	211	316	0	0	0	0	0	0	0				527	19.9	38
20	320	1040	0	0	0	0	0	0	0				1360	60.1	44
21	342	856	0	0	0	0	0	0	0				1198	60.3	50
22	311	543	0	0	0	0	0	0	0				854	50.6	59
23	233	233	0	0	0	0	0	0	0				466	32.8	71
24	0	105	0	0	0	0	0	0	0				105	8	76
25	0	0	1	0	0	0	0	0	0				1	0.1	96
26	0	0	0	0	0	0	0	0	0				0	0.1	110
27	0	0	0	8	0	0	0	0	0				8	1	125
28	0	0	0	0	44	0	0	0	0				44	5	113
29	0	0	0	23	23	46	23	0	0				115	17.7	156
30	0	0	0	0	29	0	117	29	29				204	37.7	184
31	0	0	0	0	0	62	83	41	21				207	39.7	192
32	0	0	0	0	28	28	85	28	0				169	36.1	213
33	0	0	0	0	44	66	87	22	22				241	58.3	243
34	0	0	0	0	24	24	36	0	0				84	22.2	268
35	0	0	0	12	12	0	0	0	12				36	10.5	291
36													0		
37													0		
38													0		
39													0		
40													0		
41													0		
42													0		
43													0		
Number 10^6	1447	3138	1	43	204	226	431	120	84	0	0	0	5694	462.5	

Age	1	2	3	4	5	6	7	8	9	10	11	12+	Number	Biomass
Biomass 10^3	75.1	159	0.1	8	40.4	47.3	89.7	24.6	18.2				462.4	462.4
Length cm	21.5	21.3	25.9	30.8	31.6	32.1	32	31.9	32.2					23.4
Weight g	51.9	50.7	101.3	188.3	198.2	210.1	208.8	204.3	216.8					81.2

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

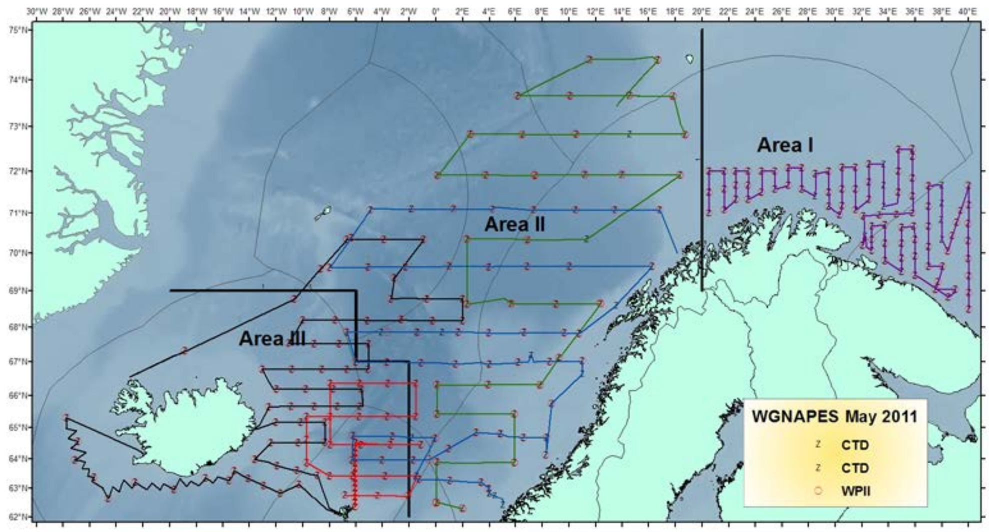


Figure 2. Cruise track and CTD stations by country for the International ecosystem survey in the Nordic Seas in April-June 2011.

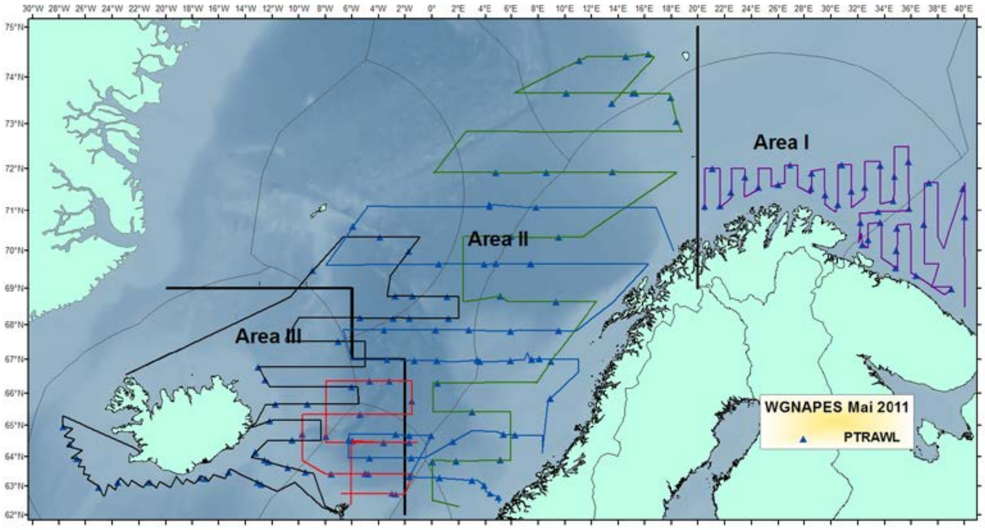


Figure 3. Cruise tracks during the International North East Atlantic Ecosystem Survey in April-May 2011 and location of trawl stations.

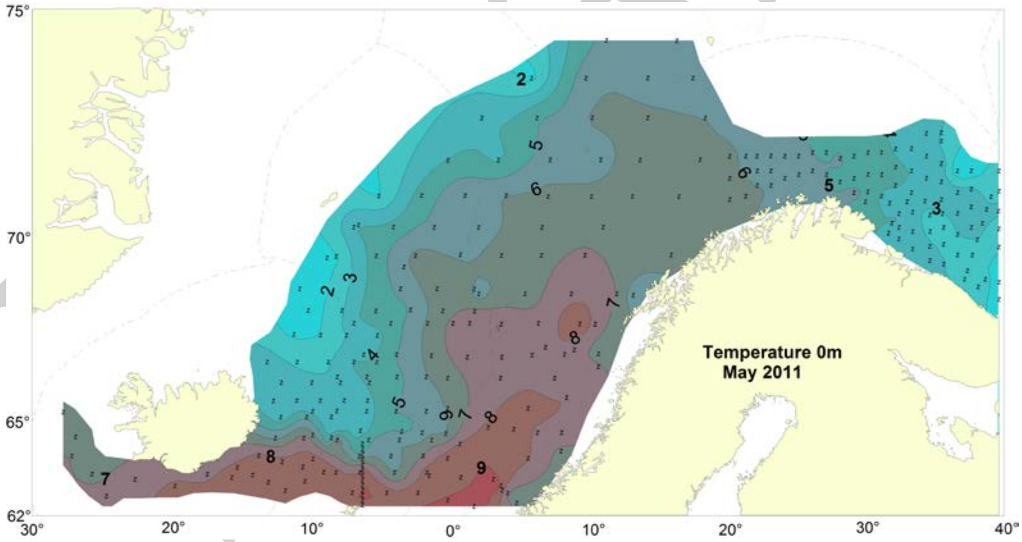


Figure 4. The horizontal sea surface temperature distribution in April-June 2011.

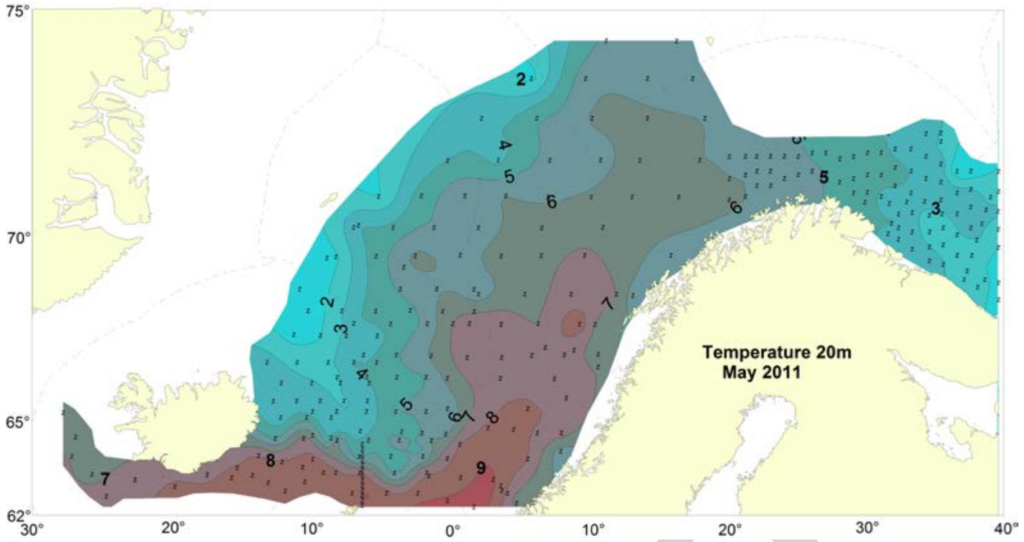


Figure 5. The horizontal distribution of temperatures at 20 m depth in April-June 2011.

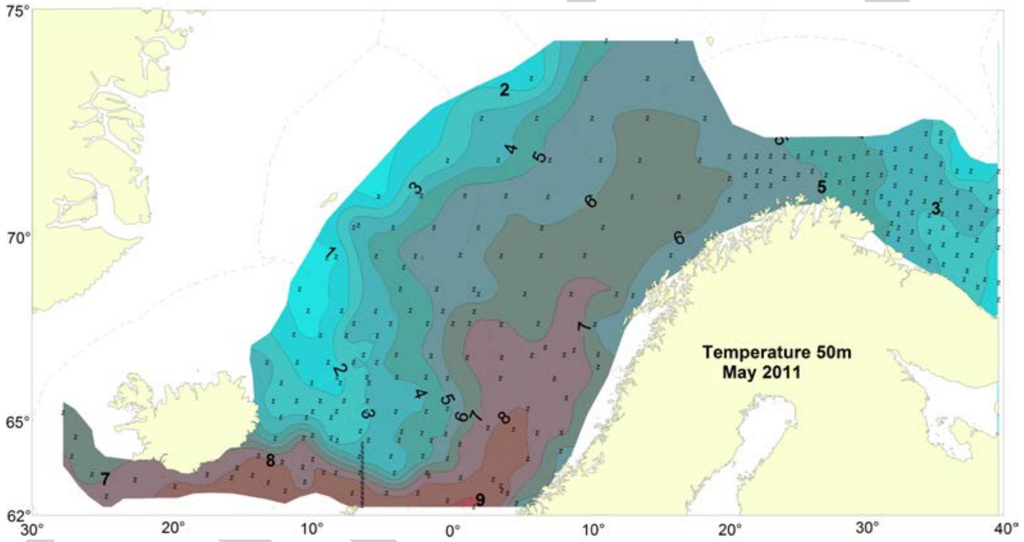


Figure 6. The horizontal distribution of temperatures at 50 m depth in April-June 2011.

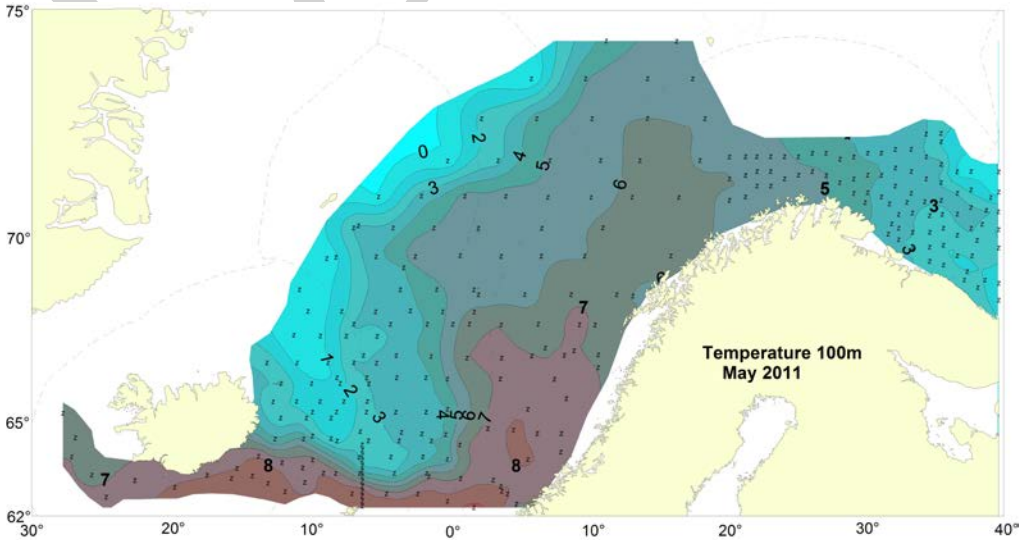


Figure 7. The horizontal distribution of temperatures at 100 m depth in April-June 2011.

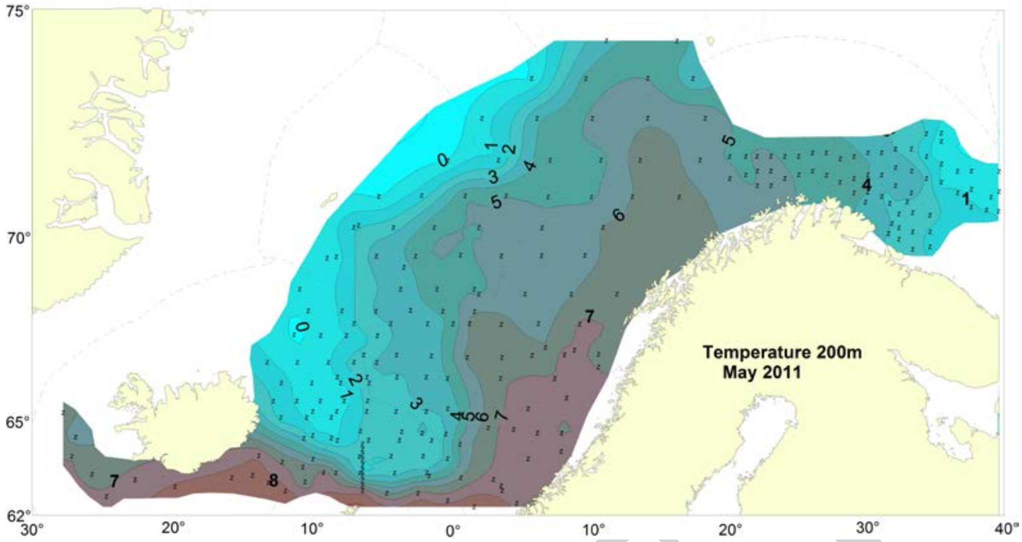


Figure 8. The horizontal distribution of temperatures at 200 m depth in April-June 2011.

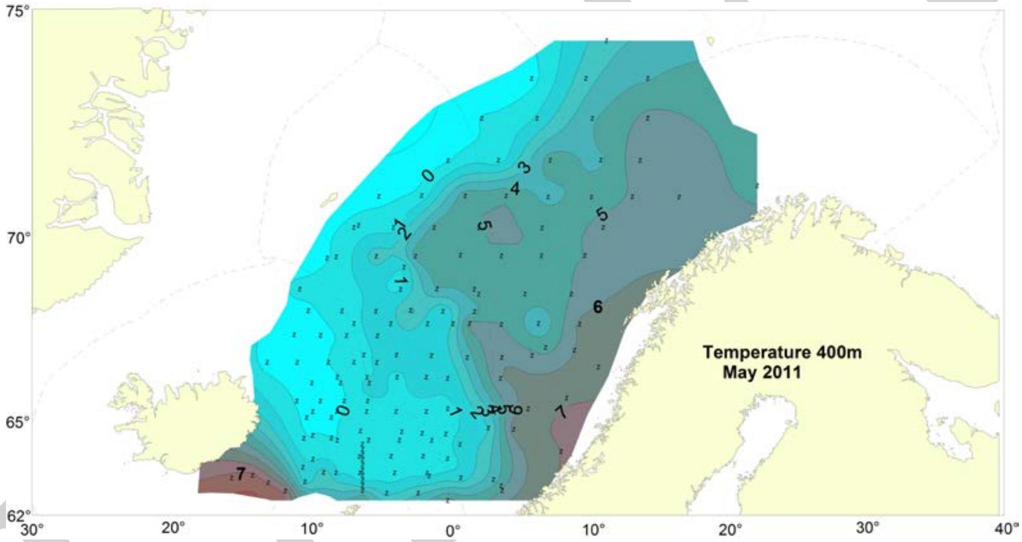


Figure 9. The horizontal distribution of temperatures at 400 m depth in April-June 2011.

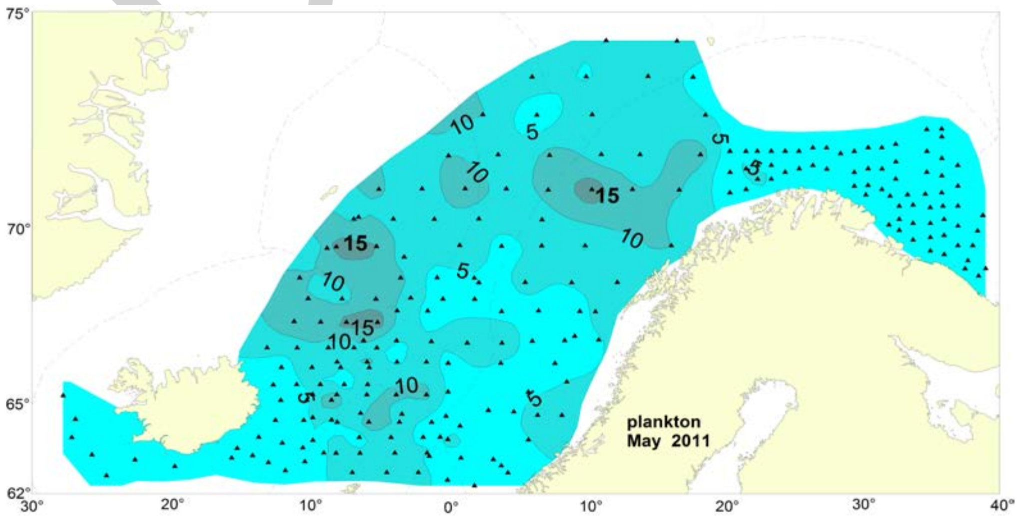


Figure 10. Zooplankton biomass (g dw m-2; 200–0 m in April-June 2011.

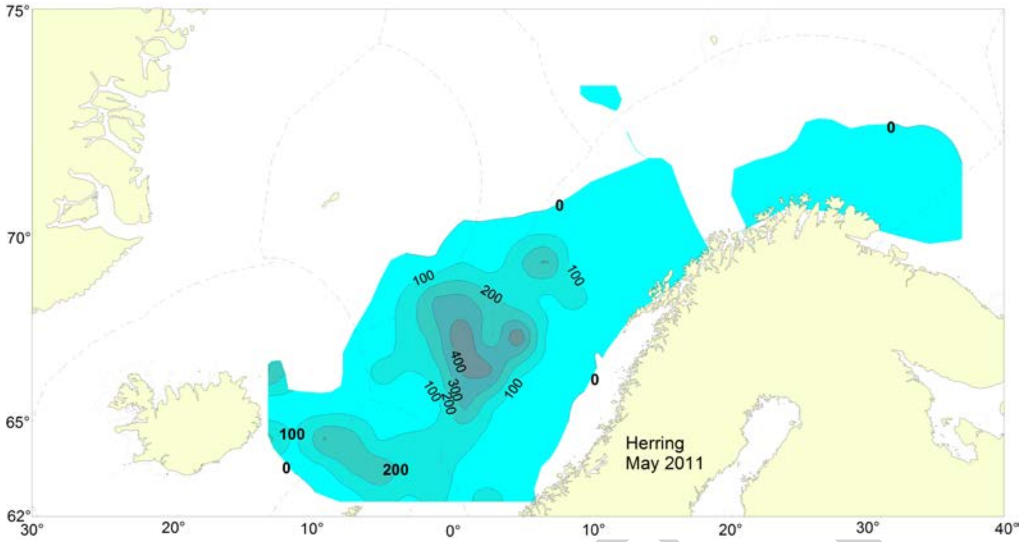


Figure 11. Distribution of Norwegian spring-spawning herring as measured during the International survey in April-June 2011 in terms of sA-values (m²/nm²) based on combined 5 nm values.

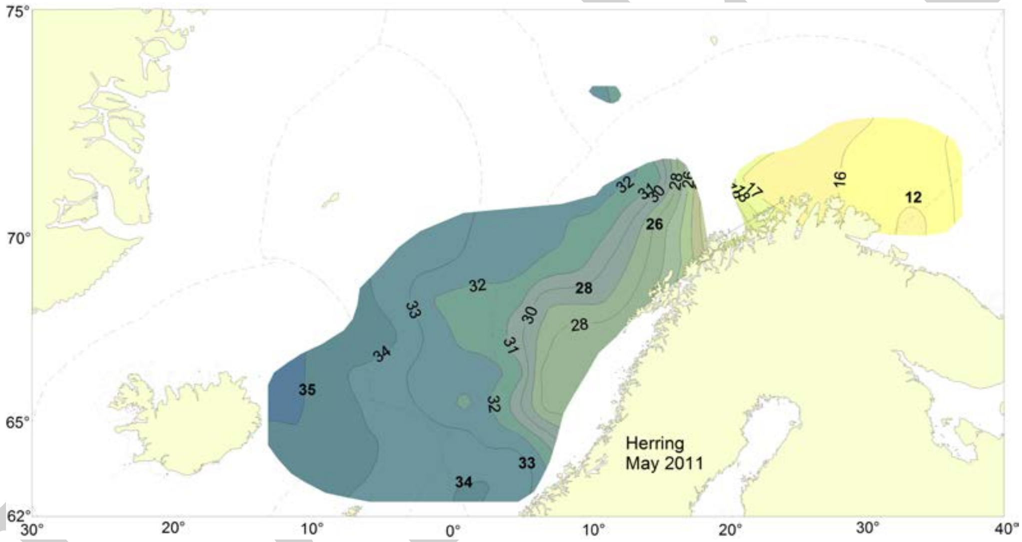


Figure 12. Distribution of Norwegian spring-spawning herring as measured during the International survey in April-June 2011 in terms of sA-values (m²/nm²) based on combined 5 nm values.

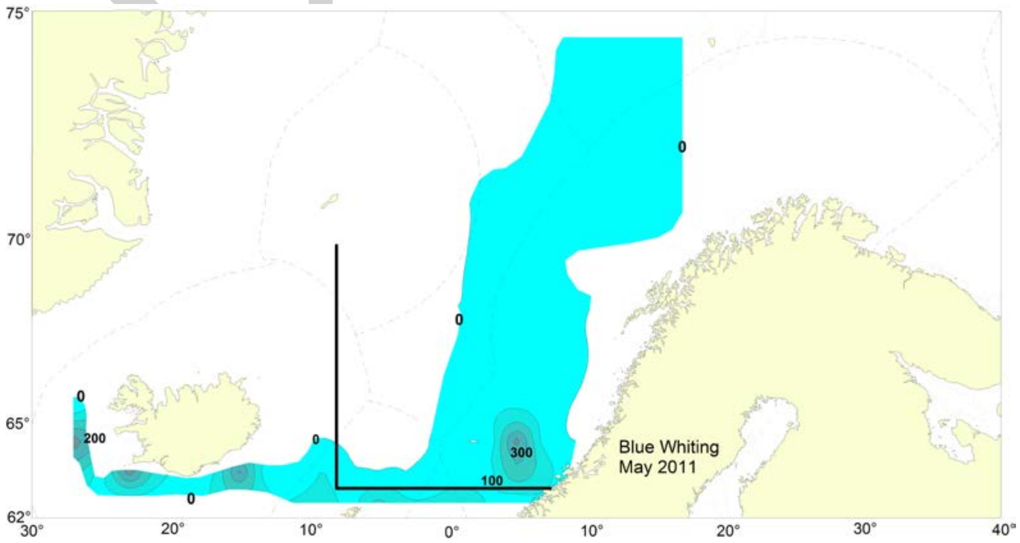


Figure 13. Distribution of blue whiting as measured during the International survey in April-June 2011 in terms of s_A-values (m²/nm²) based on combined 5 nm values. The standard area used in assessment (NPBWWG) is shown on the map.

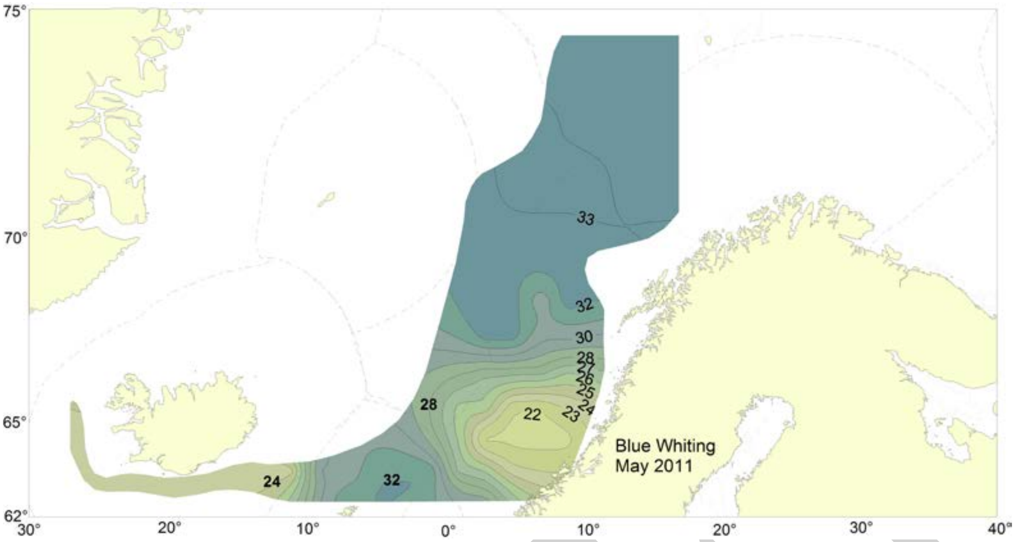


Figure 14. Mean length (cm) of blue whiting recorded in the North-east Atlantic Ecosystem Survey in April–June 2011.

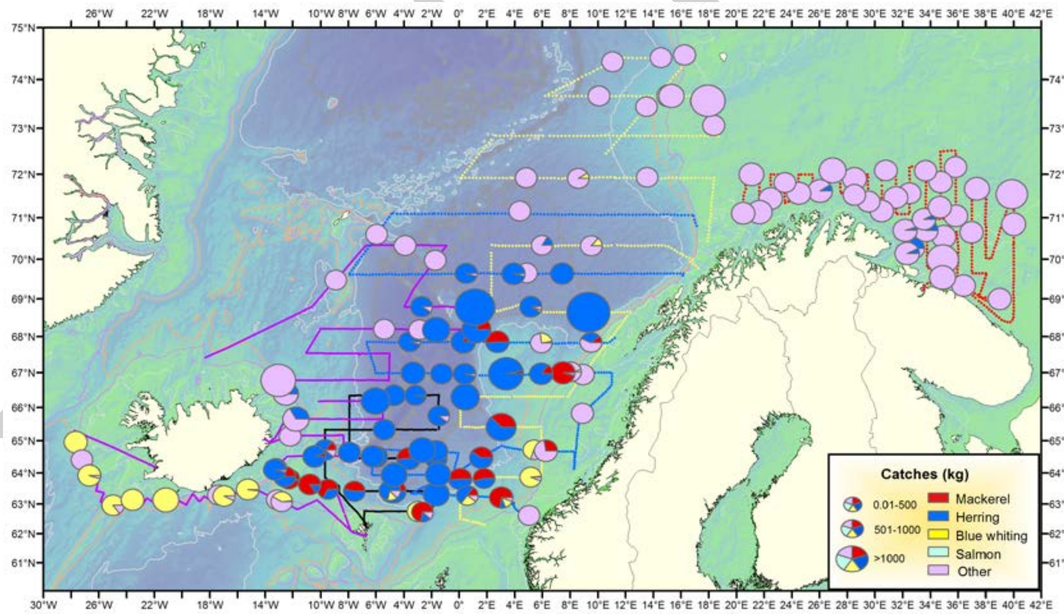


Figure 15. Distribution and spatial overlap between mackerel (red), herring (blue), blue whiting (yellow) and salmon (violet) according to trawl catches of the vessels participating in the survey during April-June. Note that "other" in the Barents Sea indicates juvenile herring.

Annex 4: International Ecosystem Summer Survey in the Nordic Seas in July-August (IESSNS)

Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) with M/V "Libas" and M/V "Brennholm", M/V "Finnur Fridi" and R/V "Arni Fridriksson" in the Norwegian Sea and surrounding waters, 9 July- 20 August 2010

By:	Norway (Nøttestad et al.), Faroes (Jacobsen et al.) and Iceland (Sveinbjørnsson et al.)
Cruise report:	Survey number 2010 810 (Libas) and 2010 807 (Brennholm), 1051 Finnur Fridi and Arni Fridriksson
Period:	9 July – 20 August 2010
Vessels:	M/V"Libas" (LMQI) (15 July-20 August), M/V "Brennholm" (LIWG) (15 July-6 August), M/V "Finnur Fridi" (XPXP) (9-23 July) and R/V "Arni Fridriksson" (TFNA) (20 July–12 August)
Area:	Nordic Seas (60º00-78º00N, 32º00E-20º00W)
Main purpose:	Study abundance, spatiotemporal distribution, aggregation and feeding ecology of Northeast Atlantic mackerel, Norwegian spring-spawning herring, blue whiting and other pelagic species in relation to oceanographic conditions, prey communities and marine mammals.

Sub-goals:

- Map concentration and distribution of non-targeted species such as horse mackerel, Atlantic salmon and lumpsucker.
- Systematic marine mammal sightings for species identification, group size and behaviour. Concurrent digital filming and photo for scientific purposes and validation.
- Quantify migration speed and direction of tracked herring and mackerel schools at different spatial scales on multibeam sonars (SH80 and SX 90) in the upper water masses (0-50m).
- Ecological studies on predator-prey interactions and avoidance behaviour of pelagic fish, krill and marine mammals using acoustics, visual observations and sampling.

CONTENT

1) Summary

Two chartered Norwegian fishing vessels M/V "Libas" and M/V "Brennholm", one chartered Faroese vessel M/V "Finnur Fridi" and the research vessel R/V "Arni Fridriksson" performed an ecosystem survey from 9 July until 20 August 2010 in the Norwegian Sea and adjacent waters. 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. The total acoustical estimate of biomass of mackerel was 12.1 million tons, while swept area estimate from trawl catches was 4.5 million tons. Mackerel was distributed over larger areas than previously documented for the Nordic Seas in July-August. Furthermore, a central and western distribution was pronounced in July 2010. Repeated off-shore catches of two year's old individuals indicate that the Norwegian Sea is increasingly showing to be an important nursery and feeding ground for immature mackerel. The 2005- and 2006 year classes dominated with 24% and 31% of total catches, respectively. Large mackerel ate the squid *Gonatus fabricii* northeast of Iceland. Estimated biomass of herring was 10.7 million tons. Herring had rather periphery distribution in the Norwegian Sea and surrounding waters, and the majority of individuals were distributed feeding in the colder and frontal waters in the western, northwestern and northeastern parts of the Norwegian Sea. Herring also ate adult capelin, representing new scientific knowledge. The 2002 and 2004 year classes were most abundant representing 20% and 27% of the acoustical estimates, respectively. Estimated biomass of blue whiting was 3.46 million tons in the Norwegian Sea in July. The 2004 year class dominated with 36 % of the *acoustical estimates* followed by the 2003 year class with 23% of the acoustical estimates. No major young year classes less than four years of age were found during the survey. A total of nine salmon were caught in the epi-pelagic trawl hauls. Lumpsucker were caught in vast areas of the covered areas. Horse mackerel were caught in the southernmost area of the Norwegian Sea.

Surface waters in the eastern, central and northern Norwegian Sea were colder compared to the last year, but still warmer than average temperature the last two decades. Extremely warm temperatures were found in the southern and southwestern part off Iceland.

Zooplankton concentrations including *Calanus finmarchicus*, krill and amphipods were generally low, except a few locations in the southernmost areas.

Fewer marine mammals were generally present in the Norwegian Sea in July 2010, compared to previous years, based on dedicated whale observations on Libas and Brennholm. 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.

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

2) Introduction

Ecosystem survey

We aim to use these coordinated cruises with chartered and scientific 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 and surrounding waters during summer. It is of great importance and interest for our understanding of the functioning of the Norwegian Sea ecosystem, how the 3-D and 4-D 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 RDI instrument, plankton samples from WP 2 nets, and full biological analyses of pelagic fish species for each station applying epi-pelagic trawling at surface and deeper in the water column, both from pre-determined stations and trawling on registrations. Acoustic measurements and registrations were performed using multi-frequency acoustics from Simrad ER60 echosounder, as well as high-frequency medium range Simrad SH 80 (Libas and Brennholm), and low-frequency long-range Simrad SX 90 (Libas) and Simrad SP70 (Brennholm)) multi-beam sonars. A new software developed by Ruben Patel at the Institute of Marine Research in Bergen, Norway were used to analyse fish schools on Simrad SH80 sonar and methodology tested on a large scale for the second time. The aim here in the medium term is to be able to automatically count number of fish schools along the cruise track and record relevant data on school size, swimming speed and direction.

The seven weeks coordinated cruises are 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 "Brennholm", both fulfilling the required scientific specifications set for this ecosystem study. Faroe Marine Research Institute in the Faroe Islands chartered the modern commercial fishing vessel M/V "Finni Fridur", whereas the Marine Institute in Iceland applied the research vessel, R/V "Arni Fridriksson" as their operating survey vessel. A scientific quota consisting of mackerel, capelin and blue whiting was provided to IMR from the Directorate of Fisheries and accepted by the Ministry of Fisheries and Coastal Affairs as an economical compensation for the chartered vessels operating as platforms for the scientific activities performed.

3) Material and Methods

Calibration of echosounder transducers

Libas and Brennholm were calibrated after standard hydro-acoustic calibration-procedure for each frequency prior to the cruise from 13-14 July 2010 (Foote, 1987). The transducers are placed in the drop keel onboard Libas, but not onboard Brennholm. The calibration on Libas and Brennholm took place inside a wind and wave protected area at Sandviksflaket, just outside the harbour of Bergen, Norway. The frequencies calibrated involved 18, 38, 70, 120 and 200 kHz on Libas and 38 and 200 kHz on Brennholm. We calibrated 38 kHz and 200 kHz transducers with 60 mm copper sphere (Cu 60). CTD measurements with a SAIV SD200W instrument were taken in order to get the correct sound velocity as input to the echosounder calibration settings.

Finni Fridur and Arni Fridriksson were also calibrated after standard hydro-acoustic procedure for each operating frequency (Foote, 1987).

Cruise tracks

Libas, Brennholm, Finni Fridur and Arni Fridriksson followed predominantly predetermined survey lines with pre-selected pelagic trawl stations and occasionally performed pelagic trawl stations on registration from acoustics (Figure 1). An adaptive survey design was also adopted, due to uncertain geographical distribution of our main pelagic planktivorous schooling fish species. Some modifications in the southwestern regions, and central and western part in between Icelandic, Jan Mayen and Greenland waters were performed due to higher concentrations of herring and mackerel in these areas. The cruising speed was between 10-12.0 knots if the weather permitted it, otherwise 10.0 knots. CTD stations (0-500 m) using a SEABIRD and SAIV SD200 CTD sensor in combination with WP2 net samples (0-200 m) were taken systematically on every pelagic trawl station on all vessels, except onboard Arni Fridriksson, which did not perform any plankton sampling (Figure 1).

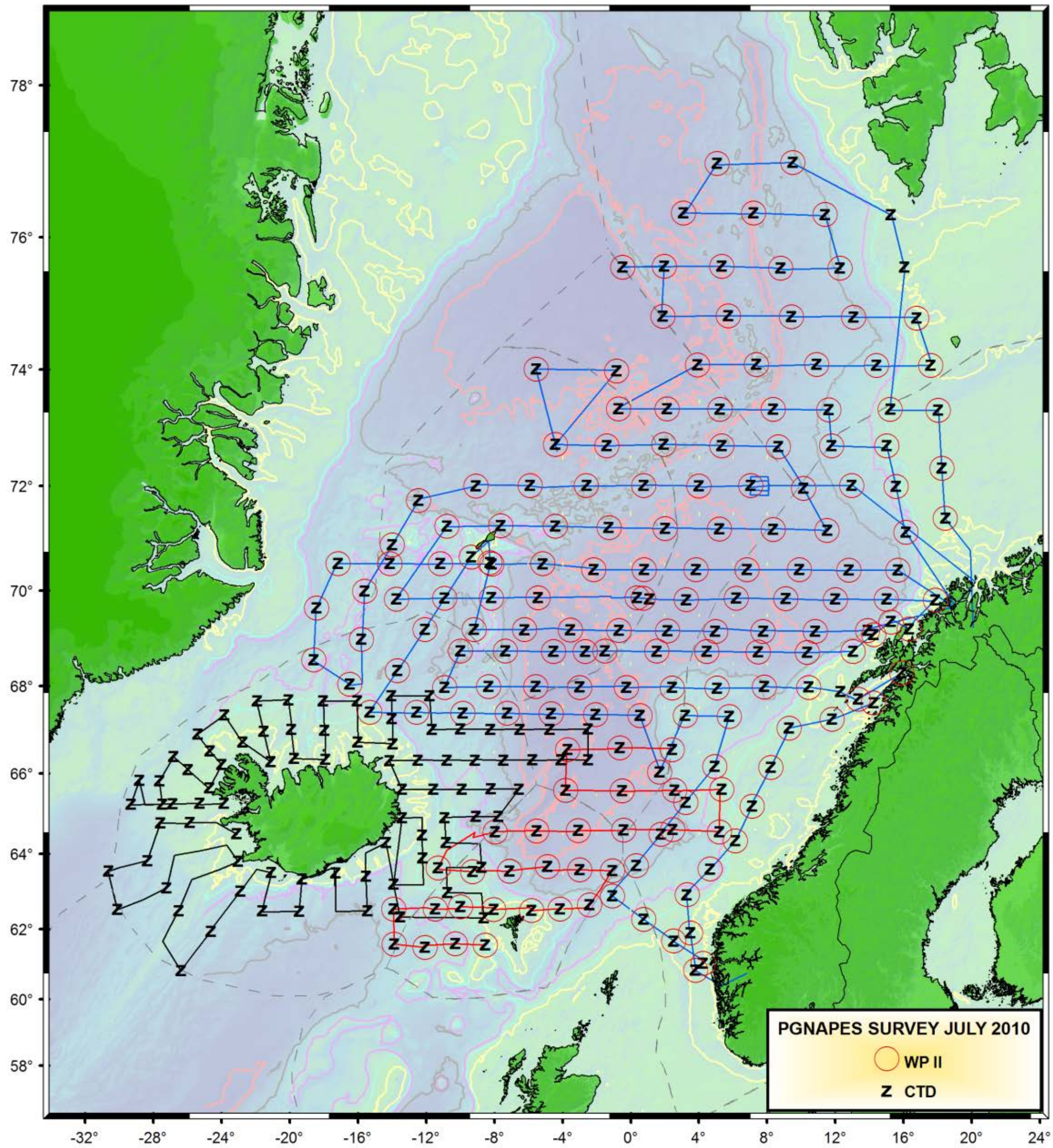


Figure 1. Survey lines along the cruise tracks with pre-defined CTD stations (0-500 m) and WP2 samples (0-200 m) for M/V"Libas", M/V"Brennholm", M/V "Finni Fridur" and R/V "Arni Fridriksson" 9 July – 20 August 2010. This large ocean area included the following Eco-

nomical Exclusive Zones (EEZ): Norwegian EEZ, United Kingdom EEZ, Faeroe Island EEZ, Iceland EEZ, Jan Mayen fishery protection zone, Spitzbergen protected area and International waters.

Biological sampling

Pelagic planktivorous fish species

Trawling was done with a rather large pelagic trawl from a blue whiting /capelin trawl with a trawl opening between 30-35 m, spread of 55-65 m using 160-200 m wire length on Brennholm and Libas. 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 maximum 30 minutes. When large schools or aggregations of fish were detected on the trawl sonde, the towing duration was reduced accordingly in order to avoid too large catches. Targeted herring and blue whiting trawl hauls on registrations were performed with a capelin/herring trawl from 10-250 m depth. 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. Towing speed at depths varied between 3.5-5.2 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 enable to study 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.

The salmon was photographed, measured and weighted. The specimen was labeled and stored immediately in the freezer to avoid contamination.

The biological sampling on Arni Fridriksson diversed from the above description in the way that the trawl used was smaller, or Wide Body 512, with vertical opening of 16.5m and horizontal of 23m. Furthermore, the full biological sampling included otoliths of up to 50 mackerels and blue whiting, and 100 herring in addition to length and weight measurements of at least 100 specimen and stomach samples of 10-15 individual per species.

The Faroese vessel used at Vónin 640m trawl with floats on the wingtips and a „floating sausage“ attached to the entire headline. The towing speed was on average 4.4 knots (3.8-4.6). The doors used were 5.5 m^2 and weighted 750 kg. In addition to length, weight, sex and maturation otolith and stomach samples were taken from 15 fish of each species during each haul, and further 100 fish were measured and weighted.

Hydrography

Libas, Brennholm and Finnur Fridi were 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. The SAIV sensor was programmed to record data every 2 seconds and the speed of the wire during measurements was set to 0.5 m/s providing data approximately every 1 m in the water column. The sensor was positioned at about 1 m depth for 1 min at each station in order to let the instrument sensors adapt to the seawater from being stored dry between stations on the vessel. 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. Libas and Arni Fridriksson had also a SEABIRD CTD sensor with a water rosette, that was applied during the entire cruise from 0-500 m depth. The SEABIRD in Libas was properly tested by IMR instrument people prior to the survey when the vessel was in the harbour at Nykirkekaien.

ADCP current speed and direction were measured continuously onboard Libas and Brennholm. These data are not yet analyzed for inclusion in this report.

Plankton sampling

Zooplankton sampling was performed at 90 stations on Libas, 62 stations on Brennholm and 30 stations on Finnur Fridi. A WP-2 net with 180 μ m mesh size was towed from 200 m depth to the surface at a speed of 0.5 m/s.

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

Plankton hauls were collected with a WP-2 plankton net, 56 cm in diameter and a mesh size of 180 µm on M/V "Libas", M/V "Brennholm" and M/V "Finnur Fridi". 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 vertical deviation on the wire should not exceed 30º and all plankton samples were repeated if this situation appeared. The plankton net is each time flushed with seawater to collect plankton from the net itself inside the cup, while the net is still hanging outside the railing. Furthermore, the area above the cup is flushed on deck to secure that the whole plankton sample is properly collected. The cup is detached from the net inside a bucket, to avoid losing part of the plankton sample. The plankton sample is divided in to fractions; 1) taxonomic analyses (taxonomic species, size, and stadium composition, and 2) biomass estimates. The WP-2 samples were split into two equal parts, one for formaldehyde preservation, the second part for dry weighing. This part was separated into three size categories by filtering at 2000, 1000 and 180 mesh size sieves. The biomass in each size fraction was transferred into alumina trays for drying. The content of 2000 um fraction was identified, dependent upon species group the organisms were length measured and the various groups transferred to individual trays for drying. Weighing of trays took place at IMR laboratory after ended survey.

Acoustics

Sonar data collection system configuration and data storage

The Simrad sonar available in Brennholm were SP90 and SH90, and onboard Libas were a SX90 and a SH80. The characteristics of the scientific output available for this sonar models

are the following:

Frequency	Model	.dat file	.dat file	.raw file
		Screen data	Beam data	Beam data
Low (20-30 kHz)	SP90	✓		
	SX90		✓	✓
High (110-120 kHz)	SH80		✓	
	SH90		✓	✓

The synchronization between the sonar an echo sounder was not operational during the first leg of the survey. Due to the sonar interference in the echo sounder, sonar data was collected during selected trawl stations. A technician from Simrad determined that the COM port from the EK60 system was not working properly; therefore no output trig signal was send to the sonars. The COM port was changed and the synchronization was re-established, allowing a continuous data collection of data from the SH80 sonar.

Onboard Brennholm, continuous scientific data was collected only from the SH90 during the whole survey, in a .dat file format. Onboard Libas was stored scientific data from the SH80 in the .dat file format during all the second leg and from the SX90 with a .raw format during selected periods during the first and second legs.

The SX90 data storage onboard Libas experienced problems due to increased periods loosing contact with the NAS storage device where the .raw files were stored, resulting in a hang-up of the sonar PC. This was solved changing the storage place destination to the local hard disk and later transferred the files to the massive storage device NAS.

Data processing

One of the objectives in this survey was to test the software module in LSSS "Processing system for fisheries omnidirectional sonar, PROFOS". This module is in development phase and already has the capabilities for semi-automatic school growing. First, the software reads the .dat files from the SH80 sonar, which are displayed together with the echo sounder data. Once a school is identified, manually it is selected in one of all the pings which are detected by the sonar. This selection is made in the center of the school, process we called "seed" the school, and later the software automatically will find the boundaries of the school in the present ping, and also in previous and later pings. The number of pings used for the automatic growing can be set by the user and will depend in the noise level and the number of pings the school is detected along the ship track.

The manual seeding and automatic growing of the individual school is a very time demanding process, and this particular data, it took roughly two working days for scrutinizing one day sonar data. This time was determined by the noise level and the number of schools, which in this survey was characterized by a large number and in some cases quite noisy data.

Once scrutinized the school data can be exported in two text files, one with the information including all the data per ping for each school (Table 1), and the second with the aggregated information for each school (Table 2). The data per school also includes the swimming speed and direction of the schools, calculated primarily based in the geographical positions of the first and last detection.

Id	StartDate	Time	Box.lon	Box.lat.	Depth	Sv.mean	Area	Ship lon.	Ship lat.	Ship speed	Ship heading	Tilt angle
5	26/07/2010	19:56:34	17.5452	69.7346	3.59	-40.69	61.3	17.548	69.74	5.56	322	-0.03
5	26/07/2010	19:56:39	17.5453	69.7347	3.35	-44.27	29.3	17.547	69.74	5.56	322	-0.03
5	26/07/2010	19:56:40	17.5454	69.7346	3.32	-41.58	55.4	17.547	69.74	5.56	322	-0.03
5	26/07/2010	19:56:41	17.5455	69.7346	3.35	-44.15	22.4	17.547	69.74	5.56	322	-0.03
5	26/07/2010	19:56:45	17.5455	69.7347	3.58	-44.14	26.9	17.546	69.74	5.61	322	-0.03
5	26/07/2010	19:56:46	17.5455	69.7346	3.68	-41.6	121.1	17.546	69.74	5.56	322	-0.03
5	26/07/2010	19:56:47	17.5457	69.7346	3.71	-42.69	94.5	17.546	69.74	5.50	322	-0.03
11	26/07/2010	19:59:31	17.5246	69.7418	8.08	-43.92	77.4	17.531	69.74	5.50	322	-0.03
11	26/07/2010	19:59:32	17.5245	69.7418	8.03	-43.96	130.5	17.53	69.74	5.50	322	-0.03
11	26/07/2010	19:59:33	17.5246	69.7418	7.77	-43.94	77.7	17.53	69.74	5.56	322	-0.03
11	26/07/2010	19:59:34	17.5246	69.7418	7.64	-44.45	51.0	17.53	69.74	5.56	322	-0.03

Table 1. Example of the file output with the school information for each ping, with some selected fields. Id, unique identifier of school; , Box.lon and Box.lat., geographical position of square which contains each school detection; Depth, mean school depth (m); Sv mean, mean school s_v (m^{-1}); Area, mean school area (m^2); Ship lon. and Ship lat., geographical position of the vessels; Ship heading, vessel heading (deg); Tilt angle, tilt angle of sonar (deg).

Id	StartDate	StartTime	StopDate	StopTime	Box.lon	Box.lat.	Depth	Sv.mean	Area	Pings	Speed	Heading
1	26/07/2010	19:52:13	26/07/2010	19:52:35	17.570	69.726	3.3	-33.6	578	23	1.46	85
2	26/07/2010	19:53:24	26/07/2010	19:54:07	17.560	69.730	7.35	-38.0	1242	44	1.01	64.8
5	26/07/2010	19:56:14	26/07/2010	19:56:47	17.545	69.734	4.39	-41.0	123	23	0.85	90.5
11	26/07/2010	19:59:31	26/07/2010	19:59:45	17.524	69.742	7.12	-43.8	86	8	0.59	68.5
13	26/07/2010	20:02:10	26/07/2010	20:02:41	17.511	69.747	5.32	-40.0	450	29	0.95	83.9
16	26/07/2010	20:06:28	26/07/2010	20:06:30	17.487	69.758	6.72	-42.7	159	3	1.16	227.1
17	26/07/2010	20:07:24	26/07/2010	20:08:01	17.479	69.761	7.29	-38.0	625	38	1.22	60.4

Table 2. Example of the file output with the school information for each ping, with some selected fields. Id, unique identifier of school; StartDate and StartTime, date and time of the first school detection, StopDate and StopTime, date and time of the last school detection, Box.lon

and Box.lat., geographical position of square which contains all school detections, Depth, mean school depth (m); Sv. mean, mean school s_v (m^{-1}); Area, mean school area (m^2); Pings, number of pings of detected school, Speed, school speed (knots); Heading, school heading (deg).

Selected period from the SH80 sonar data collected onboard Libas were scrutinized. First a transect between the Norwegian coast up to Greenland (26 to 30 July), and later a minisurvey designed specifically to study the school distribution beyond the transect sampling. The minisurvey included 5 transects of 20 nmi separated by 5 nmi, and started at 12:00 am on the 03 August ending on the 00:50 am of the 04 August.

In Figure 2 is showed a screen dump of the SH80 visualization window in which several small shallow schools were detected in 400 m range. Each red dot represents the central position of a detected school in each ping, and all detections in each school were delimited inside a red square assigned with a unique ID. The ship survey track is showed as a dotted grey line, and in this example the vessel was sailing from west to east. Also two buffers zones (white continuous lines); a circle around the vessel and two lines behind the vessel, to avoid the automatic school growing in these noisy regions.

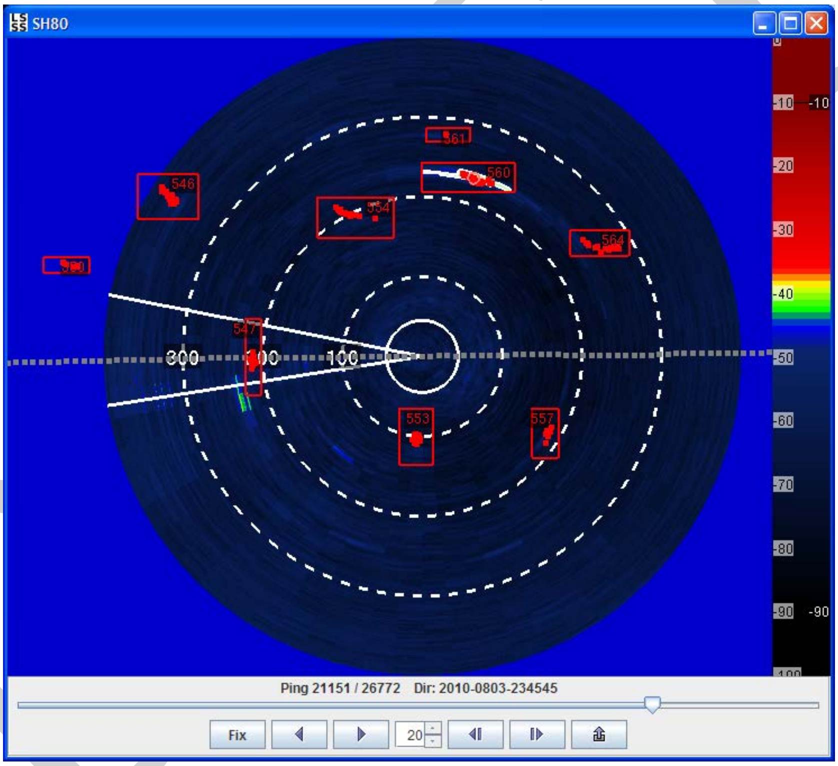


Figure 2. Example of the SH80 visualization window. School detections for each ping are noted with a red dot. Scale in the right is showing s_v values in dB. The lower panel is showing the tool bar for the replay of the sonar data. More details of the figure are explained in the text.

Sonar detection and acoustic measurements of marine mammals

Simrad SH80 omnidirectional sonar calibration

The need to increase the sampling volume in standard fishery surveys for better biomass estimation of major pelagic fish stocks brought the attention of the scientific community to apply omnidirectional sonars, previous used for fish school visualization during fishing activities.

Sonar cover considerable wider areas than traditional echosounder, and in large marine ecosystems such as the Norwegian Sea, there is clear advantages of also covering the water layers close to the surface, where a major part of the biomass of pelagic fish concentrate during summer due to the availability of suitable food, good light conditions and a strong thermocline.

With this in mind, it became clear the need of quantify the output of this class of sonars. Since 2007 we have studied the Simrad SH80 high frequency omnidirectional sonar data output. Good results were achieved in the attempt of calibrating the unit. A fast *in situ* calibration protocol is a proposed prospect for the dedicated ICES SGCAL (Study Group on Calibration of Acoustic Instruments in Fisheries Science) which proposed a deadline in April 2012 for publication of new guidelines on this subject.

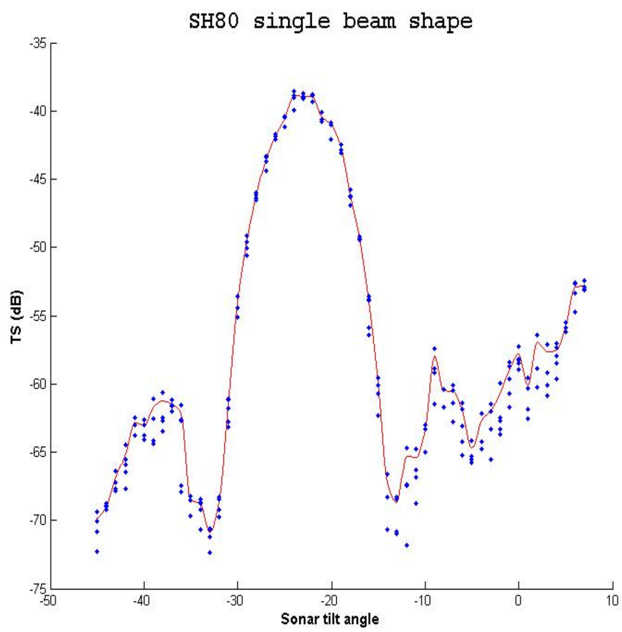


Figure 31: Beam shaping obtained using the tilt angle control of the sonar unit during the 2008 calibration experiment.

For the 2010 calibration we used a custom 75 mm tungsten carbide sphere as a reference target. This sphere was chosen for its ready availability and for the good results obtained in a similar experiment in 2008. The sphere was suspended from the side of the ship (Libas) in front of the sonar transducer (depth of 8.5 m) and moved trough 8 different individual sonar beams using an electric controlled reel system connected to a pulley suspended to a crane at a horizontal distance of approximately 25 m from the transducer in the far field of the sonar. The sphere was moved in both the vertical plane, by the electric reel system, and in the horizontal plane, by operating the crane at the minimum speed. That procedure allowed us moving the target through the beam with centimeter steps for a better coverage of the acoustic beam, compared to the calibration obtained in 2008 (Figure 3).

In 2008 we limited our effort in placing the sphere in front of different beams at the axis center and scanning it electronically. The objective of the 2010 calibration was to verify the variance from the main axis of the acoustic beam and its peripheral areas in both horizontal and vertical plane and test how tilt angle settings could influence the shape of single beams. The reason for the particular attention given to the tilt angle setting stand in its constant adjustment need during the survey operation to obtain the optimal performance in terms of range.

Some electronic scan of the reference target were also performed as done previously in for a comparison of the 2008 material (see figure 1). From this calibration experiment we expected a better understanding of the sonar detection dynamicc. A dedicated Calibration SH80 Monitor, written in Java and Matlab languages, has been developed to read and extract fast and directly the single beam received dB level (Figure 4).

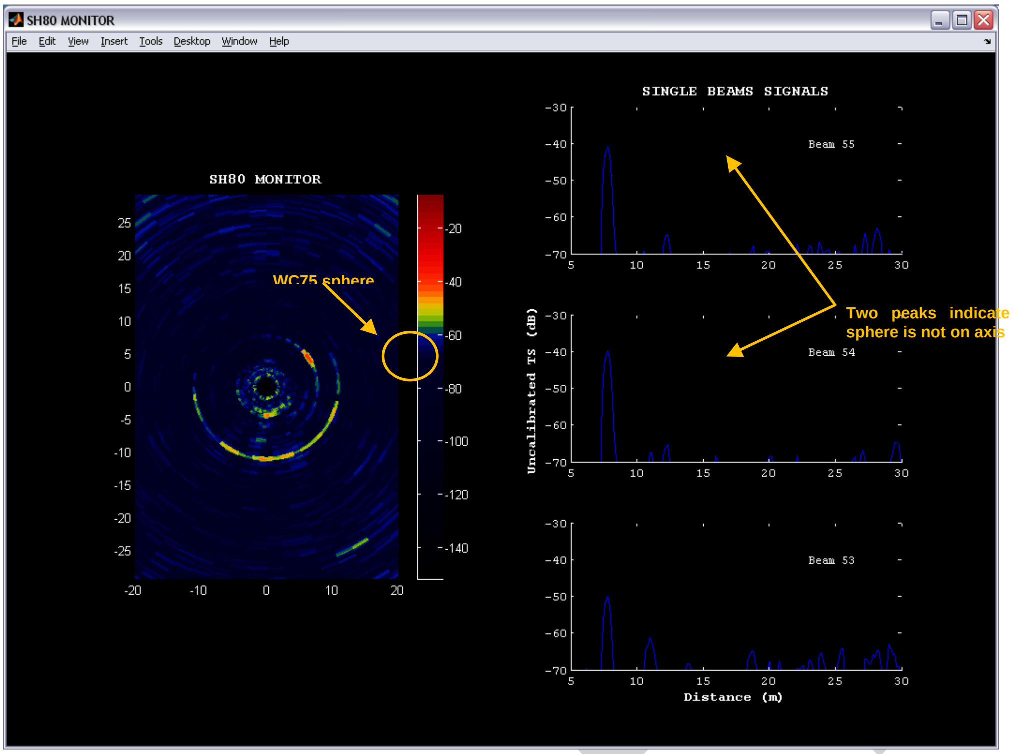


Figure 4: Screen shot of the Simrad SH80 Monitor developed in the last two years used to process, extract and analyze sonar signal directly from the raw data stored by the Simrad Winson software. From the energy plot in the left is possible to notice how the calibration sphere is not positioned exactly at the center of the beam 54, but is off axis between beam 54 and 55.

SH80 performance evaluation using the Lybin ray trace model

During the survey the different physical conditions of the water encountered may strongly influence the performance of the acoustic instrumentations. When transducers are facing downwards these variations do not affect consistently the perception of the observed volume of the water column. A strong influence can instead be observed when sonars are directed horizontally. The travelling acoustic wave can suddenly bend and channeled, misleading the operator judgment about what is really on sight and its 3D position in the water column. What is visualized on the sonar screen as a school close to the surface in reality can be a school placed at hundred meters depth (Figure 5).

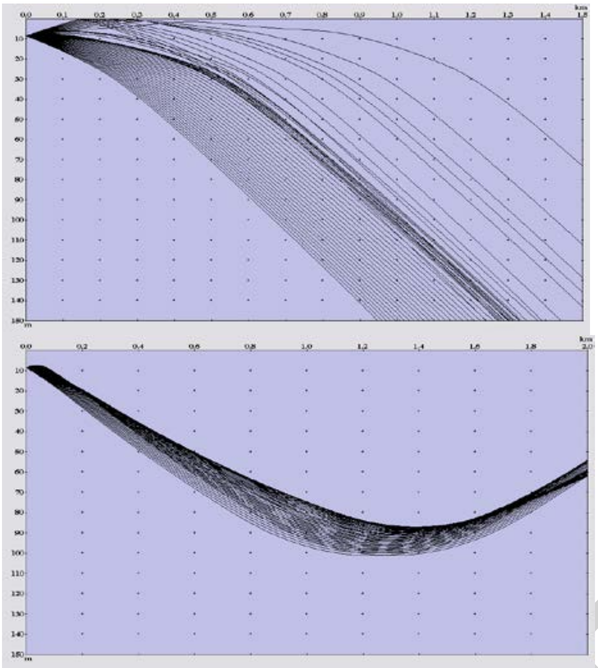


Figure 5: Ray trace simulations for two CTD stations for the Simrad SH80 unit operating at 110 kHz with a tilt angle setting of 0° and a pulse duration of 6 ms. In the two examples we can observe a typical bending that reduce the horizontal range of the sonar, and the most extreme situation encountered with the sound drastically channeled by fresh water masses close to Greenland.

The ray bending itself is not the only phenomenon to consider while navigating in different areas of the oceans. The constant consciousness of the maximum detection range is another important indication for the operator. Avoiding the over interpretation is at this stage of the instrument development our primary objective. We collected information about water masses with a SAIV SD204 CTD unit and use the data to run simulations through the acoustic ray trace model LYBIN. This model is a well established and frequently used sonar prediction model owned by the Norwegian Defence Logistic Organisation. The model is used onboard navy vessels as well as in training situations on shore. The choice of the SAIV SD204 unit for this purpose was made considering the capability of the SAIV Minisoft SD200W. This software generate directly, with an easy interface .xml files ready to be process with the Lybin 4.0 software that was use to update constantly the sonar setting during the survey.

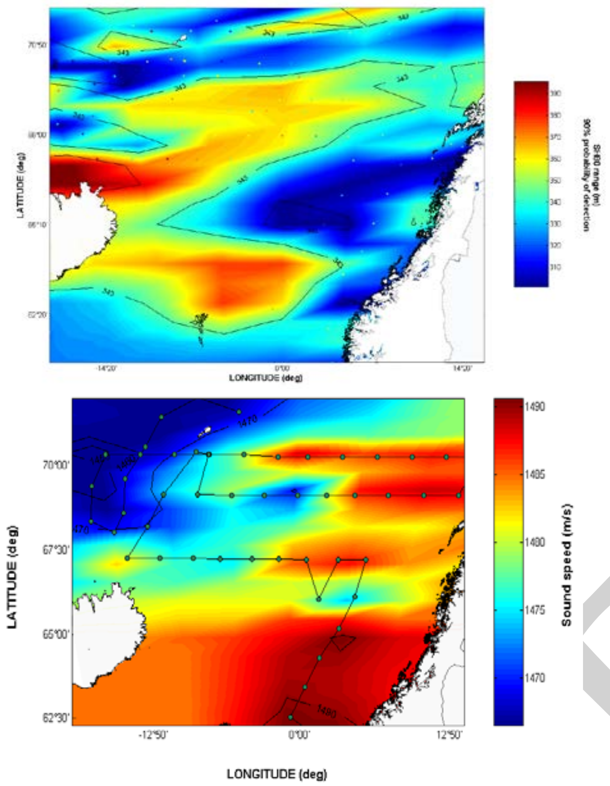


Figure 6: plots of the SH80 detection range evaluated using the Lybin model with the sonar set to look target at the surface and map of the sound speed of the first 40 m of the water column.

The maps in Figure 6 show the average sound velocity of the first 40 m of the water column along the coordinated ecosystem survey of the Norwegian Sea and the Simrad SH80 performance using a tilt angle setting of 0° and a pulse duration of 6 ms in term of range based on over 100 CTD samples and 500 Lybin simulations. From a preliminary qualitative analysis is clear that will be very important in a near future to develop the use of such probability model to operate and collect sonar data for a concrete and reliable biomass estimation of fish stock and capitalize the potential of omnidirectional sonar units.

Whale TS measurements and conservation issues

The effect that seismic survey could have on endangered whale species is a concern. Currently passive acoustic and visual observations are the common ways use to detect whales during seismic operations; however these methods clearly face strong limits due to the impossibility to detect silent animals and the effect generated by bad weather conditions. There are thus limitations to both presently used techniques, limitations that could fail to prevent conflict between human activities and cetaceans. For this reason with an opportunistic approach, a unique project to develop

Figure 7. *In situ* TS measurements of marine mammals were possible for the extreme tranquility showed by the animals once approached by the vessel. As we have experienced in the past years, it seems that the running acoustic equipments do not generate any notable reaction even if the operating frequencies overlap with the ones used by the whales to communicate as in the case of killer whale that we could observe during typical feeding activities at close range.

a whale sonar detector has been carried on in the past three years as a subgoal in the development of omnidirectional sonar for fish abundance estimation. The particular aim of the project is to avoid breaking security ranges imposed as a stop to seismic operation in presence of cetaceans indicated by international guidelines and regulations. There are thus limitations to both presently used techniques, limitations that could fail to prevent conflict between human activities and cetaceans.

There is still a lot of concern appointing sonar as an eventual cause of stress and disturbance for the cetaceans, but our close encounters and the possibility of having good sonar recordings speeds lower than 4 knots seems to give us different indications than the one hypothesize by many popular science article that using the sonar word talk about military system that works at lower frequency with longer pulse and higher source level.

We want to take the advantage of active sonar for conservation purposes, giving to the operator in charge of detecting whales an instrument on which he has the choice of most parameters of the sonar equation (Eq. 1) except TS, the target strength (relative amount of sound reflected back to the receiver), define as:

$$TS=dBl-SL+TVG+Cal \qquad (1)$$

where dBl is the received dB level at the transducer; SL is the source level of the sonar; TVG is time varied gain corresponding to $40\log_{10}R+2\alpha R$ (with R the range and α the absorption coefficient); Cal is a correction value obtained in a dedicated calibration experiment.

Active acoustic detection of whales, is still an unexplored field, and could offer an alternative approach to damage mitigation associated with seismic operations, providing real-time detection capabilities. The long-term goal of exploring the possibility of using fishery omnidirectional sonars to detect cetaceans during seismic operations and to use such detections as triggers to stop potentially harmful seismic shooting imply the need to gather consistent informations about different cetacean species TS as it has been done for years for many commercially important fish species.

We collected very good data about this parameter for different species. A detailed paper about fin whale (*Balaenoptera physalus*) TS has been recently submitted to the Journal of the Acoustical Society of America. In this manuscript we described TS for fin whale at all side from head to tail describing *in situ* what was observed before just *ex situ* for a dolphin by Au (1996). The recorded values had a span of 14 dB, not uncommon for such stochastic parameter with a maximum of - 4 dB and a minimum of - 14 dB. Our preliminary results also point in the direction of the variation of such parameters due to recognizable behavioural swimming pattern that we could notice since our first attempt of whale sonar detection. In figure 6 is possible to observe how whales leave well marked print on the screen while surfacing to breath. In figure X the sequence of red mark are the print that the animal leave behind and that were quantified in 7 dB less than the actual whale represented by the first print in the sequence.

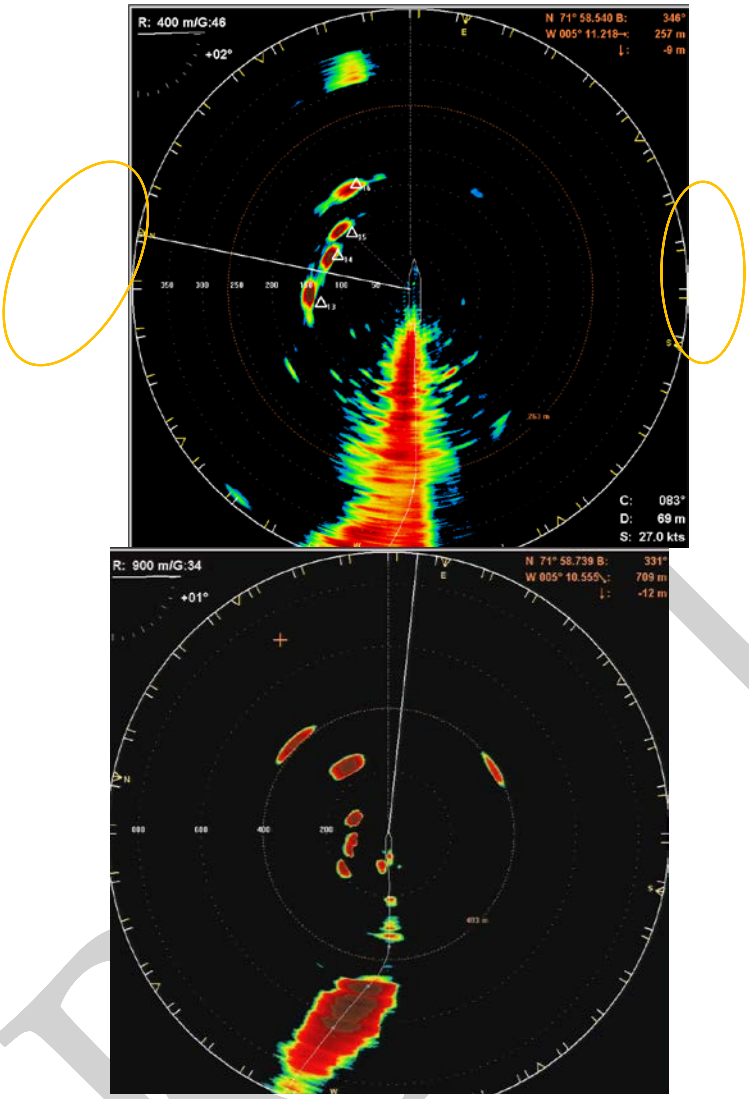


Figure 8: Within the circles we see typical marks left on the sonar screen by a fin whale swimming at the surface. We could quantify in term of 7 dB the difference between the actual whale (first mark of the series) and the prints left behind. The first screen capture is from the Simrad SH80 unit, the second from the new Simrad SX90, sonar we believe will be the optimal to adopt for marine mammals detections.

As a last note it has to be mention that in 2010 we could test the new low frequency sonar unit Simrad SX90. It seems it will be convenient in the future to adopt this sonar unit to detect marine mammals, not just for its longer detection range but for the better response that cetaceans body seems to have at frequencies between 20 and 30 kHz.

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 Brennholm, 38 and 200 kHz on Finni Fridur and 18, 38, 120 and 200 kHz on Arni Fridriksson. 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/) onboard Libas and Brennholm, with Echoview software package (http://www.echoview.com/) onboard Finni Fridur and BI500 onboard of Arni Fridriksson. 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 two Norwegian vessels, Libas and Brennholm, conducted observations of marine mammals. Two dedicated marine mammal observers were present on board Libas and Brennholm, respectively. 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, behavior, 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 and Brennholm 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 onboard.

Meteorology

Wind conditions as derived from the Baufort scale, air temperature, weather, cloud coverage and sea state were monitored and noted in the cruise logger program at each station for both vessels.

Digital photos and filming

Digital photography with Nikon D70 digital filming with Sony TCR TRV50 were done throughout the cruise for documentation of trawl catches, various scientific activities and visual observations of marine mammals and seabirds along the cruise tracks on board Libas and Brennholm.

Data management

All collected data onboard Libas and Brennholm were stored on a server PC installed on each vessel under the area P:\\nas\HI-Libas\Tokt Name\20108180 on Libas and P:\\nas\HI-Brennholm\Tokt Name\2010807 on Brennholm. Collected data originating from echosounders, multibeam sonars, epi-pelagic and pelagic trawling, krill trawling, CTD stations, WP2 net sampling, sea surface temperatures, marine mammal observations, weather station, diary, cruise logger and digital photos were all stored on this server with advanced backup system. A timestamp synchronized the clock on all essential instrumentation and for all activities onboard each vessel and between the two vessels in order to ensure correct temporal comparison between different data sources collected during the cruise. All data were copied to two external hard drives for proper backup.

All collected data onboard Finnur Fridi and Arni Fridriksson were also stored on a server PC. After the surveys were finished the survey data were stored in the WGNAPES database located in the Faroes.

4) Results

Hydrography

There were considerable changes in the temperature regime in the Norwegian Sea and adjacent waters in July 2010 compared to previous periods (Figure 9). However, it must be mentioned that the these NOAA sea surface measurements are sensitive to the weather condition (i.e. wind and cloudiness) prior to and during the observations and do therefore not necessarily reflect the oceanographic condition of the watermasses in the areas.

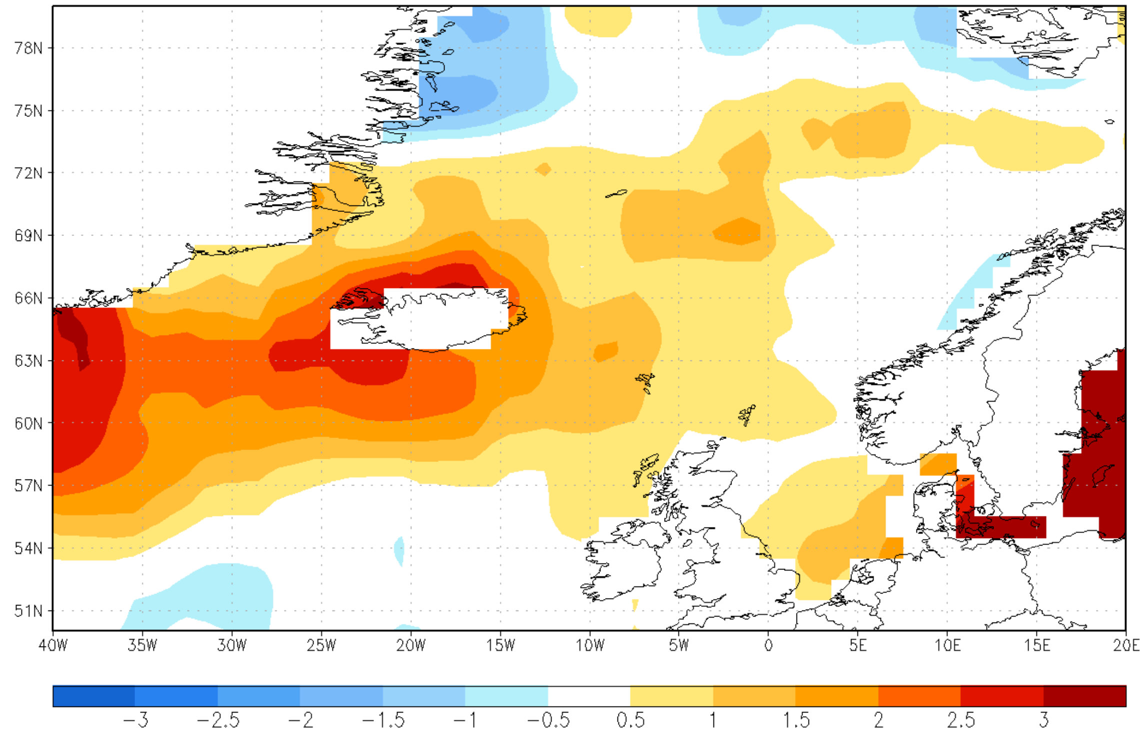


Figure 9. Sea surface anomalies (centered in week 21 July 2010) showing warm and cold conditions in comparison to a 20 year average.

Sea surface temperatures taken from the NOAA database in mid July 2010 (Figure 10).

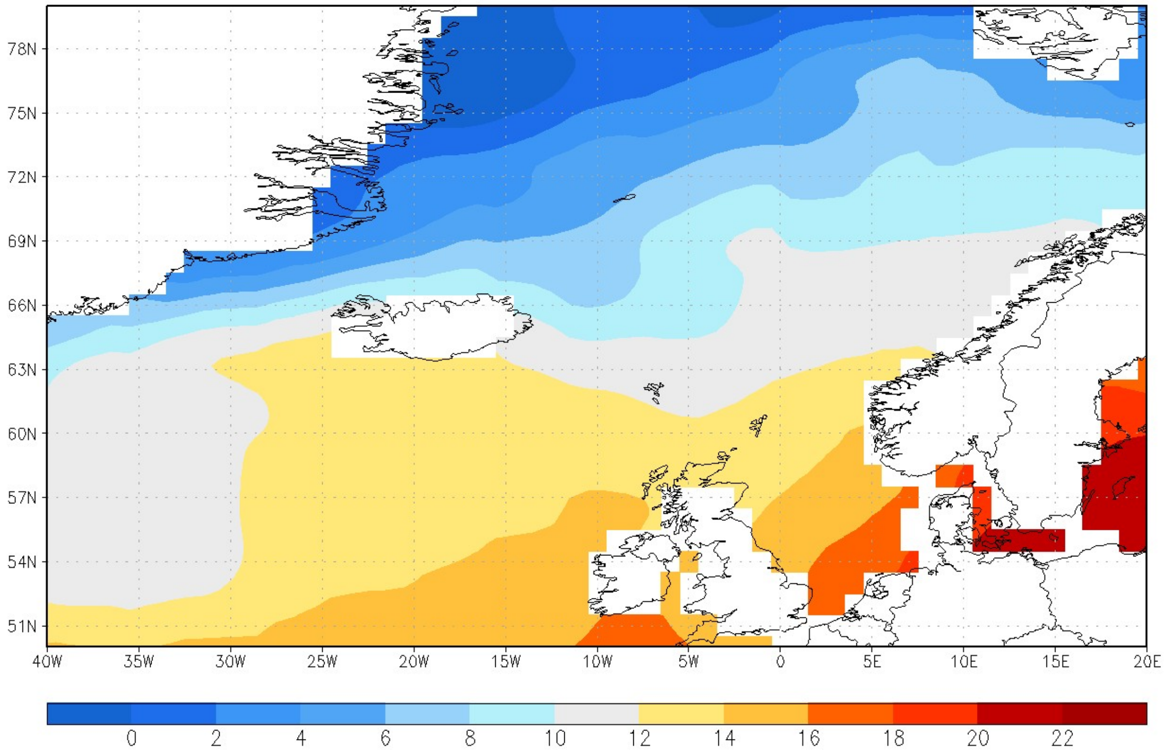


Figure 10. Sea surface temperature (SST) centred around 21 July 2010 in the Norwegian Sea and surrounding waters.

Temperature maps were produced in Surfer 9.0 and ArcGis 10.0 based on 278 CTD casts from Libas (90) and Brennholm (58) Finni Fridur (30) and Arni Fridriksson (100). Surface waters in the northwestern part of the Norwegian Sea in the Jan Mayen zone and in Icelandic waters were still warmer compared to the last two decades, and coincided with increased presence and concentrations of large herring and mackerel in the area. The eastern and northernmost areas were in contrast colder than previous years (Figure 13), although not limiting the extent of northern migration by herring and mackerel. We found a new record northerly distribution of large mackerel north up to 76.30°N. Coastal waters off Norway were also colder than recorded previous years (Figures 11, 12 and 13).

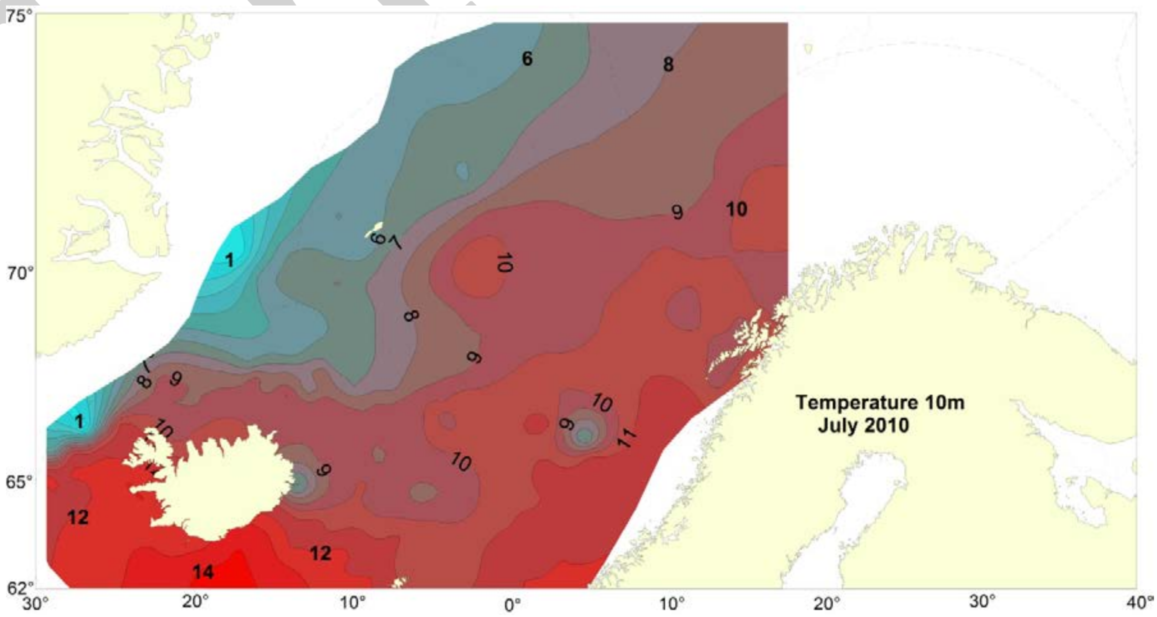


Figure 11. Temperature at 10 m depth in the Norwegian Sea and surrounding waters, 9 July - 20 August 2010.

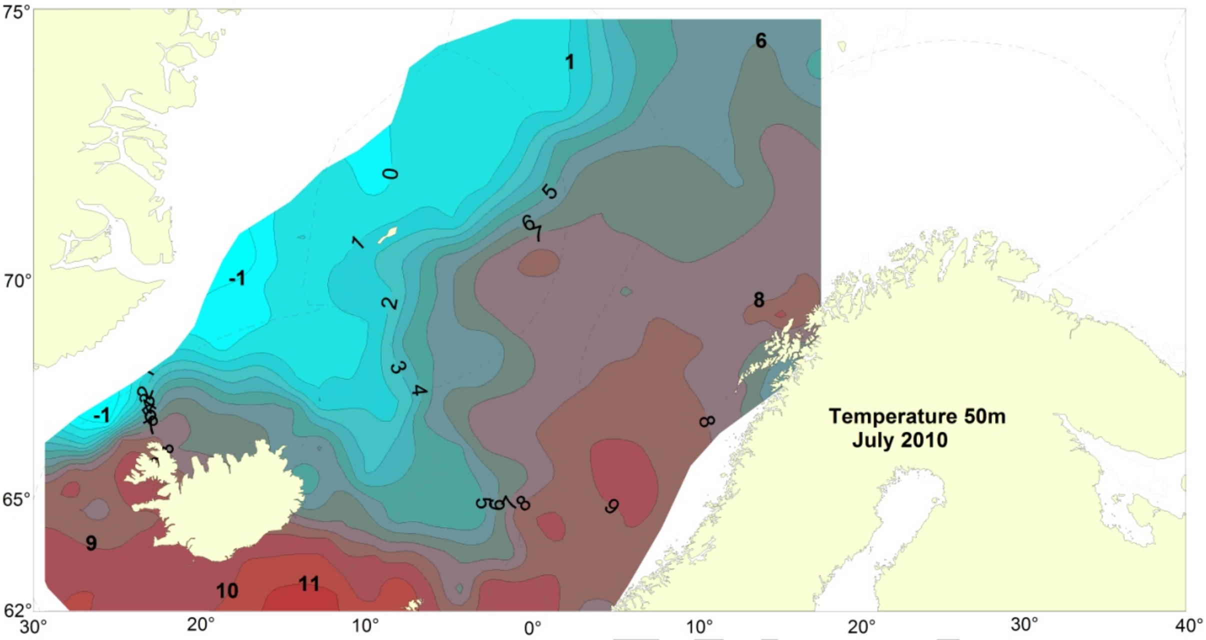


Figure 12. Temperature at 50 m depth in the Norwegian Sea and surrounding waters, 9 July - 20 August 2010.

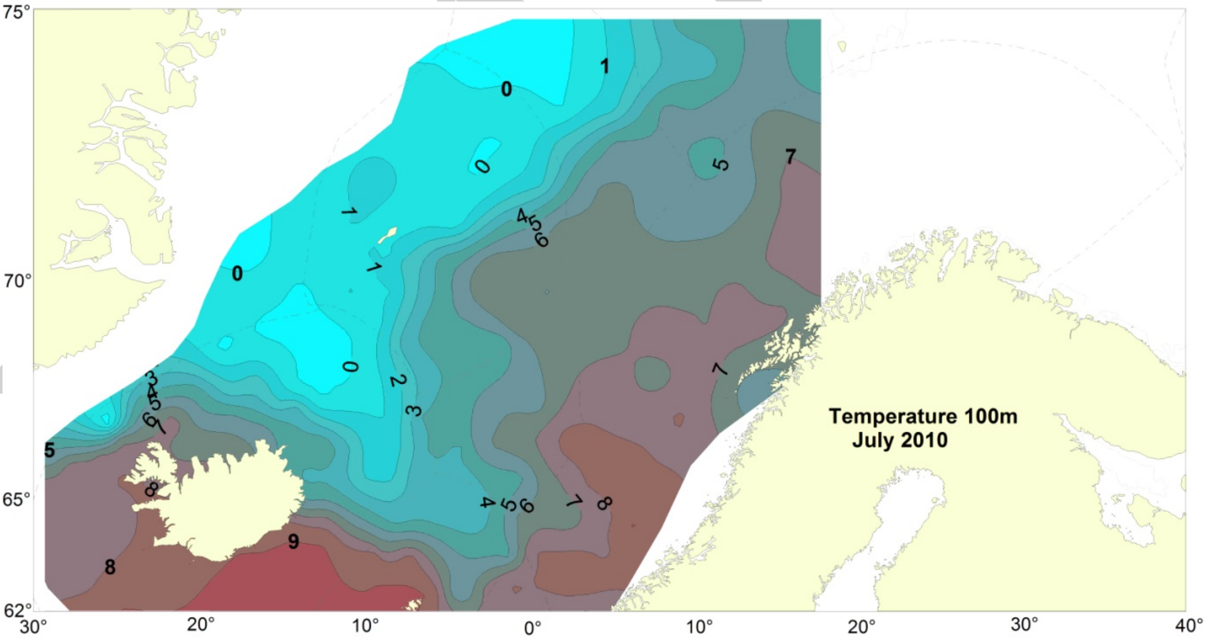


Figure 13. Temperature at 100 m depth in the Norwegian Sea and surrounding waters, 9 July -20 August 2010.

Acoustic doppler current profiler (ADCP)

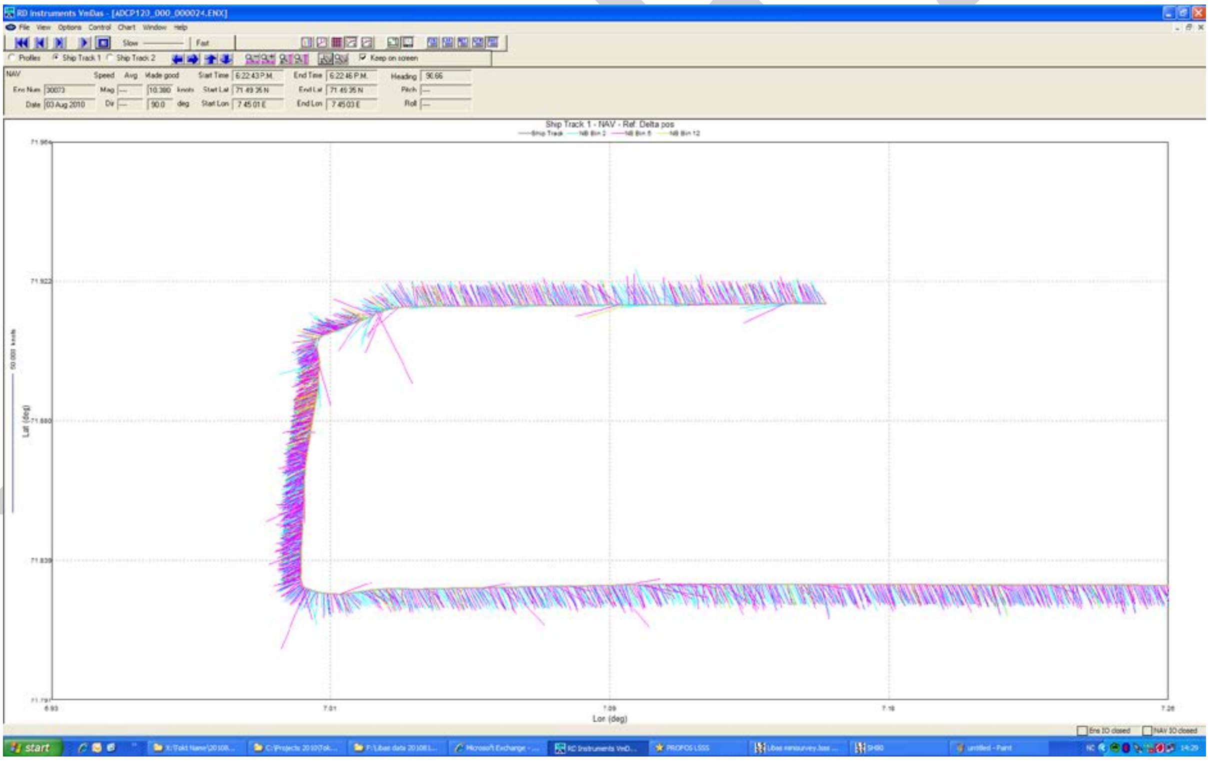
The bottom mounted RDI ADCP was not working properly during the first leg and at the start of the 2nd leg of the survey. After the initial installation of the equipment back in 2004, the original PC has been replaced. Originally the gyro telegram was read from a RS422 serial line. The new PC only has RS232 serial ports. For the ADCP software to be able to read the gyro telegram the serial connection was reconfigured from RS422 to RS232 and the gyro telegram was successfully received.

Two of the PC COM-ports had connection problems and failed at times. This was due to the fact that the COM-port card does not fit properly into the card slot of the new PC. External USB-RS232 converters was used instead and worked without problems.

The ADCP received external trigger pulses from the ER60 echo sounder. An adjustable delay circuit was used to prevent interference from the ADCP on the echo sounder recordings. This worked very well.

It was discovered that the measured current direction was always ca. 45 deg to the side of the ship heading. Current magnitude was also far too high and correlated with the vessel speed. An example of this wrong data is showed in figure 6, where is clear how the current direction changes with the vessel heading. The reason for this problem was that the transducer misalignment was set to 0 deg .

A short calibration “survey” was performed to get the exact value for the misalignment. The analysis of the calibration survey provided with suitable data and a true misalignment of 40.98 deg. All the collected ADCP data have to be reprocessed before they can be included in any analysis. This has so far not been done, however technical expert from RDI have supervised all these works, and looked at some of the data and verified that the data quality after reprocessing is good, and confirmed that the ADCP system now is working properly. A sample of data reprocessed is also showed in figure 14.



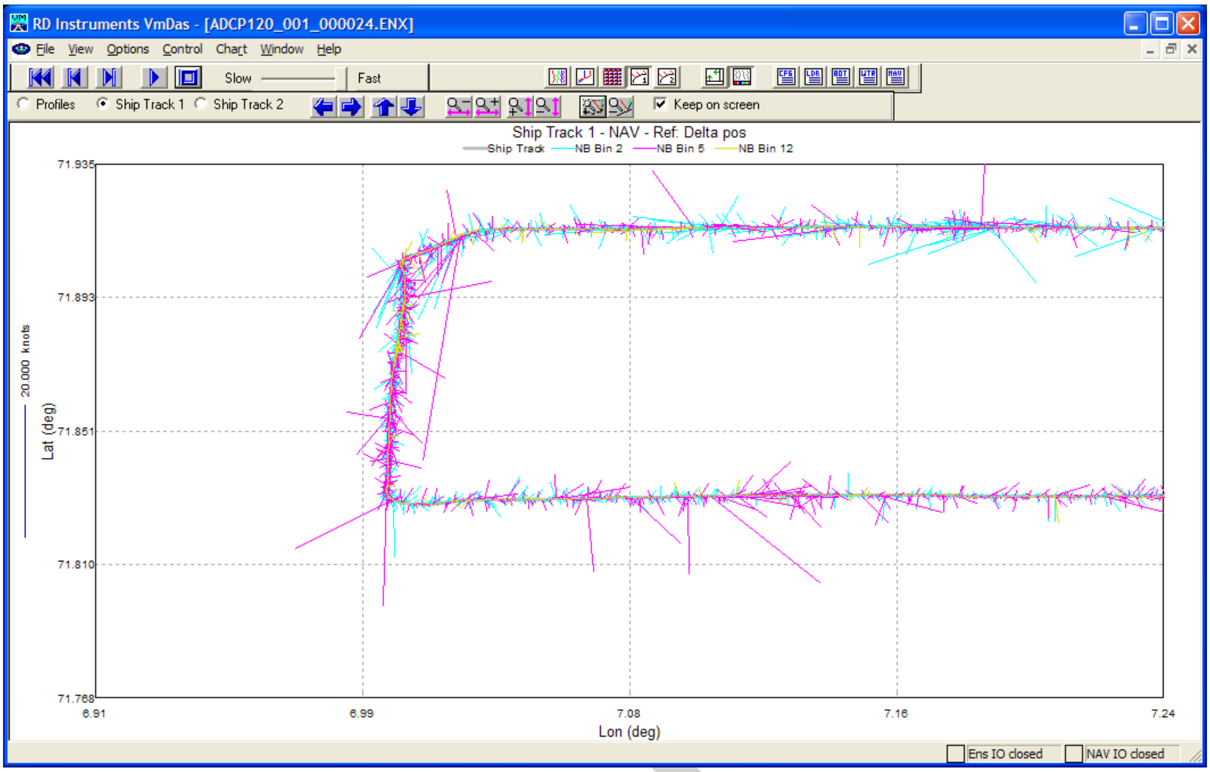


Figure 14. Example of ADCP data collected onboard Libas. Upper panel, data with wrong ADCP transducer alignment, where the current direction is influenced by the vessel heading. Lower panel, corrected data, reprocessed for misalignment correction.

Weather conditions

The weather conditions were mostly favourable for acoustic recordings and visual sightings with low wind speed (Baufort scale: 0-3): However, wind speed reached Baufort scale 8-10 some days within the survey tracks for Libas, Brennholm, Finni Fridur and Arni Fridriksson in the Norwegian Sea and surrounding water from 9 July to 20 August 2010. Low precipitation and limited rainfall provided good visibility throughout the cruise. Fog and fogbanks were mostly experienced in the westernmost area in the Greenland Sea, north and west of Iceland and around Jan Mayen.

Biological samples

Libas performed 90 pelagic trawl stations, Brennholm performed 58 pelagic stations, Finnur Fridi performed 30 trawl samples, whereas Arni Fridriksson performed 100 pelagic trawl stations (Figure 15).

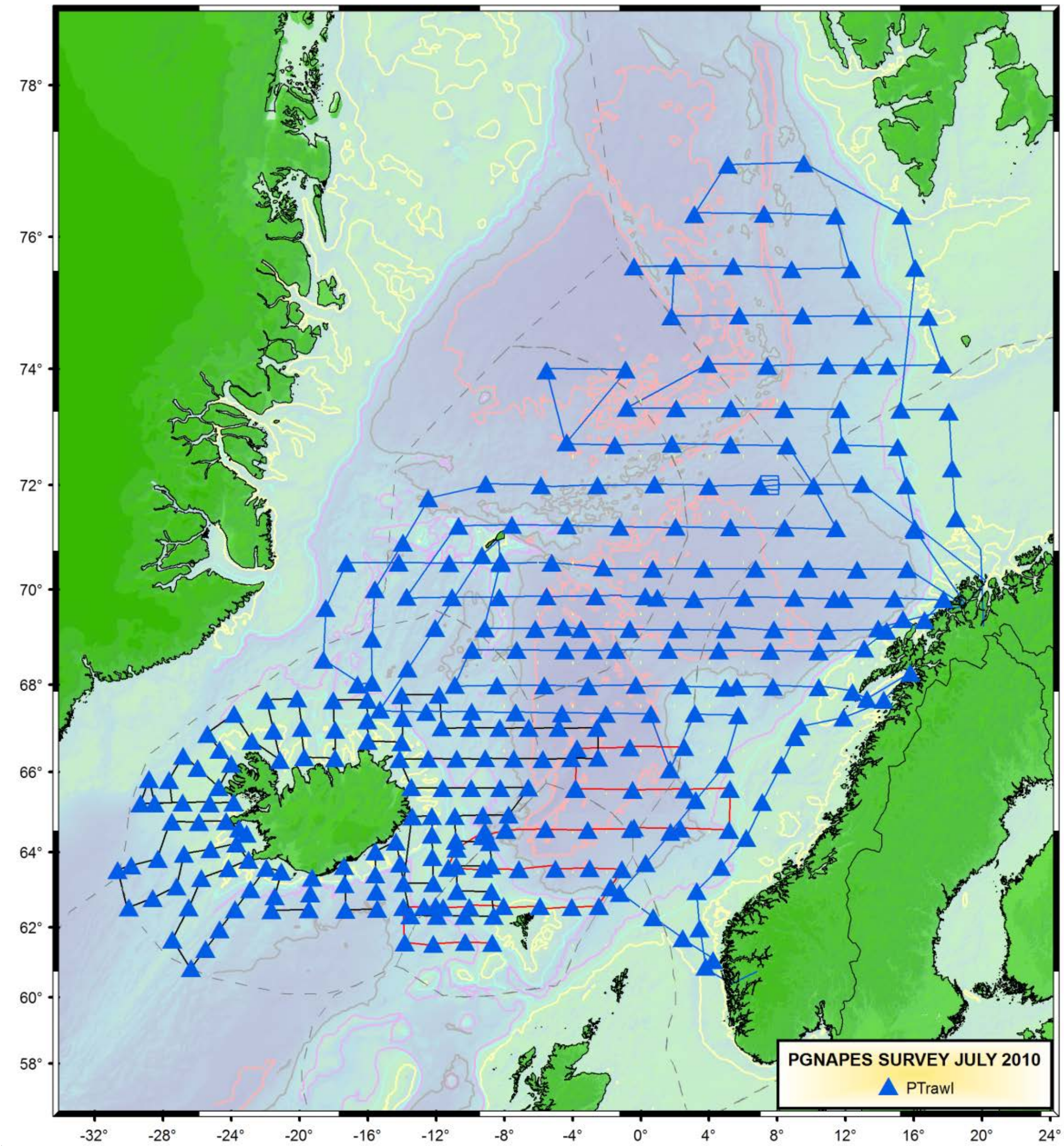


Figure 15. Map showing pelagic trawl hauls taken on Brennholm, Libas, Finni Fridur and Arni Fridriksson and survey tracks during the ecosystem survey 9 July to 20 August 2010.

Salmon

Totally 9 salmon were caught during the ecosystem survey in the Norwegian Sea. A total number of 1 salmon were caught on M/S Brennholm within the survey area. The largest salmon caught was 5.4 kg. In total, 6 salmon were caught in the survey areas covered by M/S Libas. Finni Fridur caught 2 small salmon. None of the salmon were classified as escaped farmed fish. The salmon were caught in different parts of the survey area (see figure 16). The northernmost catches of salmon were done at 74°N. The southernmost catch was a single individual caught at 64.5°N. This distribution of catches indicates that the survey area covered by M/S Libas probably only overlapped with postsmolt distribution during the most northerly transects. All salmon were measured. Lice were observed on all individuals originating from the Greenland Sea and northern waters.

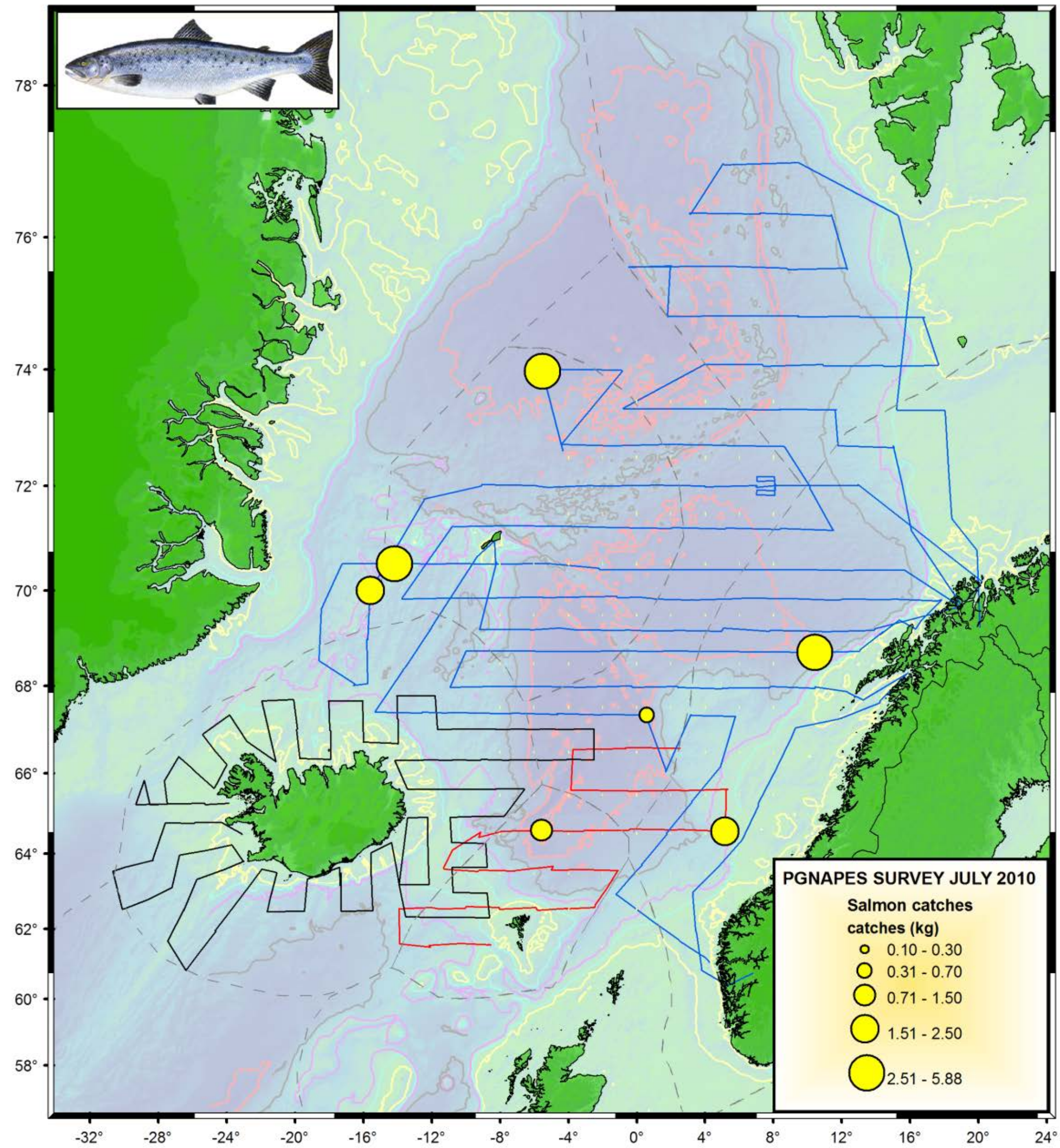


Figure 16. Salmon catches (kg) taken on epi-pelagic trawl hauls along the cruise tracks for Libas and Brennholm combined.

Mackerel caught in the pelagic trawl hauls on Libas, Brennholm, Finnur Fridi and Arni Fridriksson varied from 22 cm to 46 cm in length with the individuals between 33-35 cm dominating in the abundance. The mackerel weight (g) varied between 100 to 925 g (Figure 17). The 2005-year class of mackerel together with the 2006-year class dominated the mackerel population in the Norwegian Sea with more than 50% in number (Figure 18).

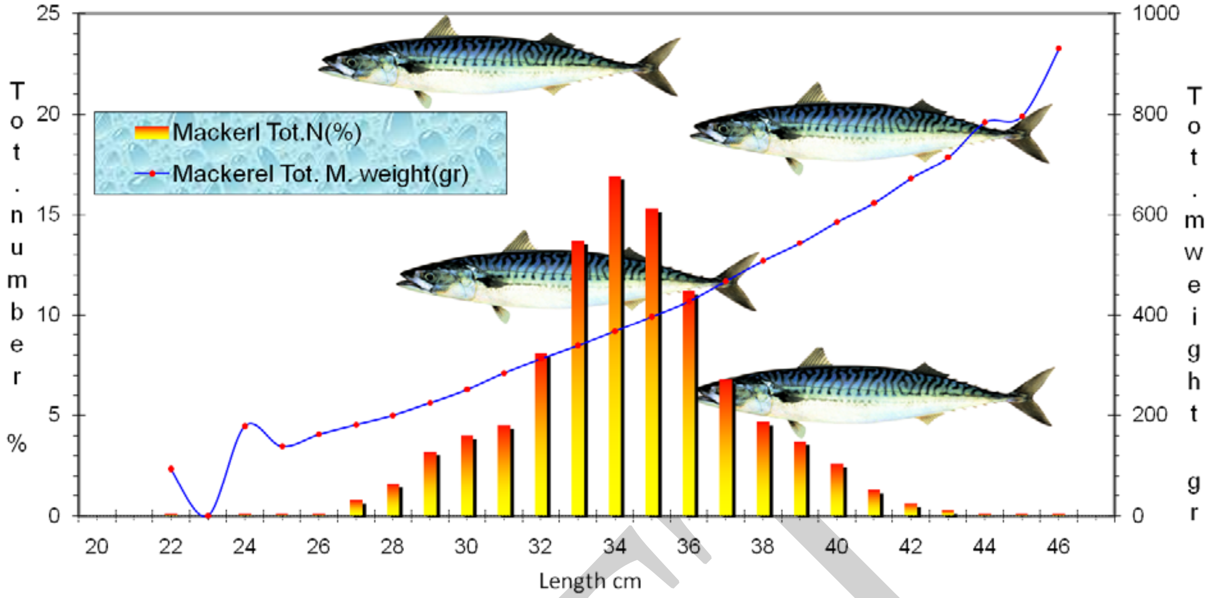


Figure 17. Total length (cm) and weight (g) distribution in percent (%) for mackerel in all catches.

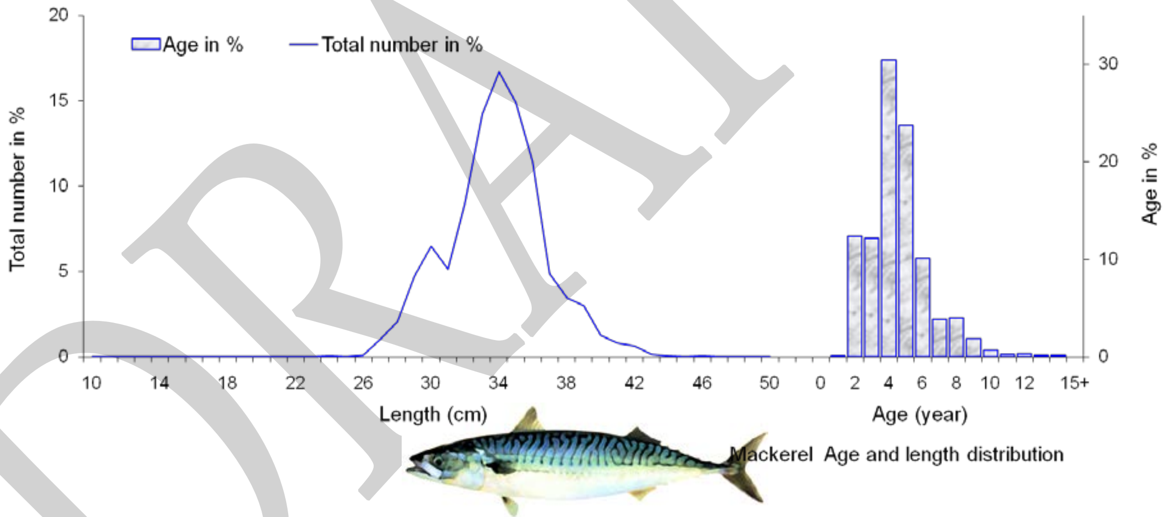


Figure 18. Age and length distribution in percent (%) of Atlantic mackerel in the Norwegian Sea.

Norwegian spring-spawning herring had a length distribution from 16-43 cm with a peak at 35-37 cm, and a weight ranging from 20-470 gram (Figure 19).

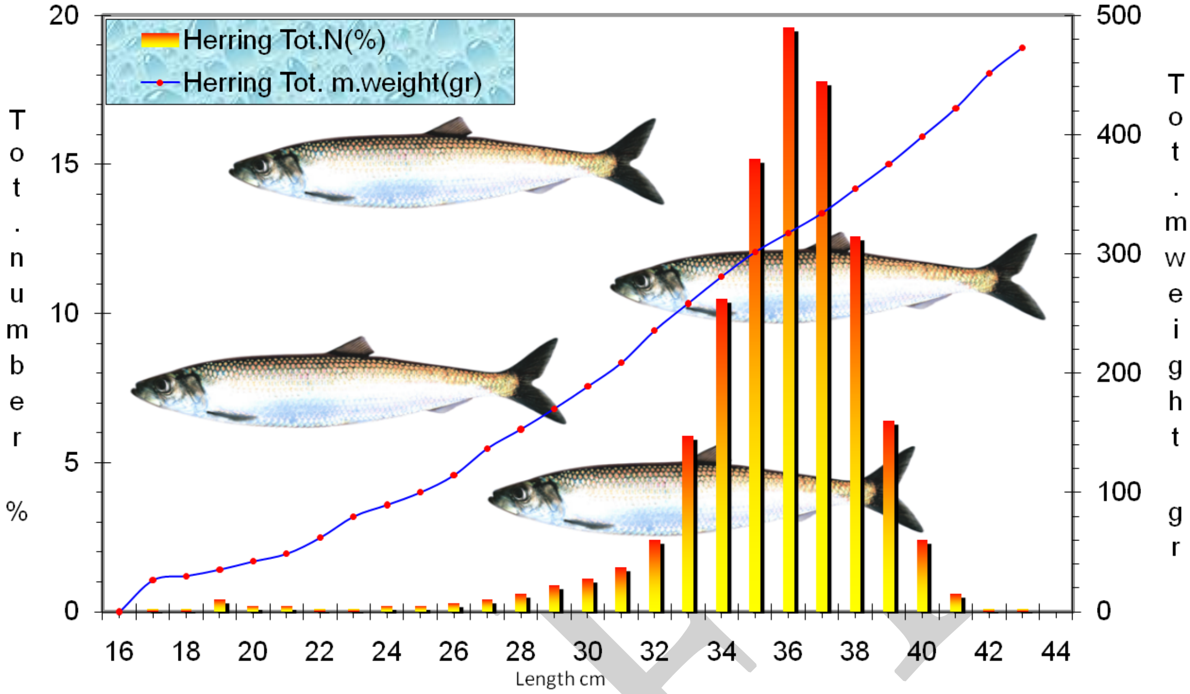


Figure 19. Length and weight distribution of herring in the pelagic trawl catches.

The age distribution in herring shows dominance of the 2002 year class. They constitute 27% of the total population in number. The 2004- (22%) and 2003 (15%) year classes are the second and third most numerous herring year classes, respectively. Younger herring than 3 years was practically absent in the trawl catches (Figure 20).

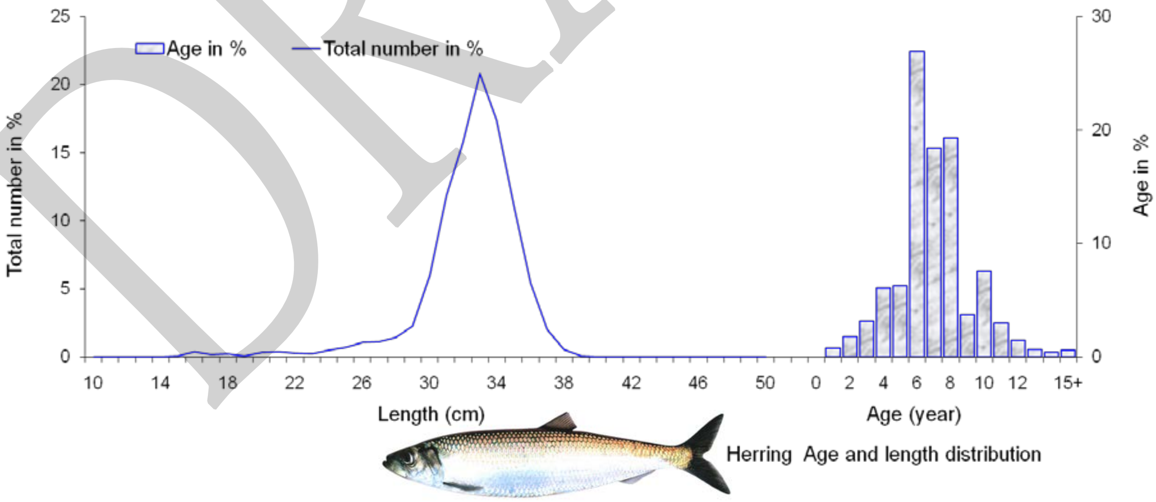


Figure 20. Herring age and length distribution in the pelagic trawl catches.

Blue whiting length distribution was from 27-36 cm and individual weight distribution was 100-240 gram. Blue whiting between 33-37 cm dominated the catches (Figure 21).

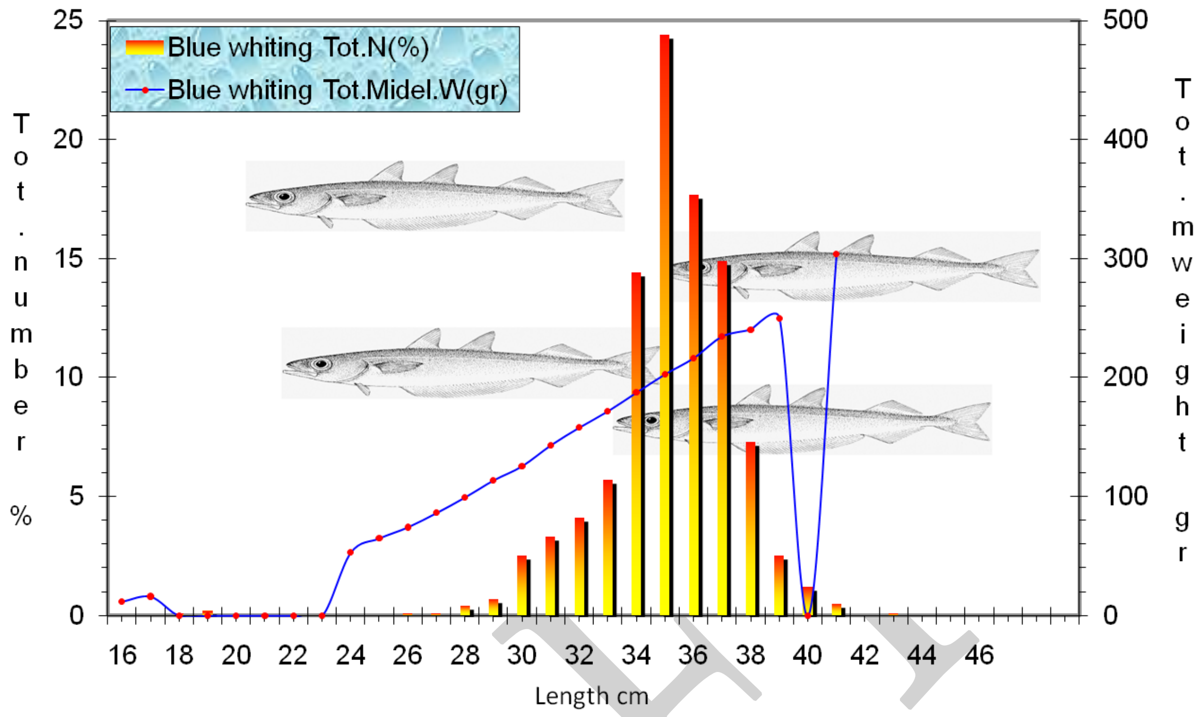


Figure 21. Length and weight distribution of blue whiting in the pelagic trawl catches.

The age distribution of blue whiting showed a dominance of 2004 year class (36%) followed by the 2003 year class (23%) and 2005 year class (17%). Blue whiting younger than 4 years of age was in low number in the trawl catches or less than 10% (Figure 22).

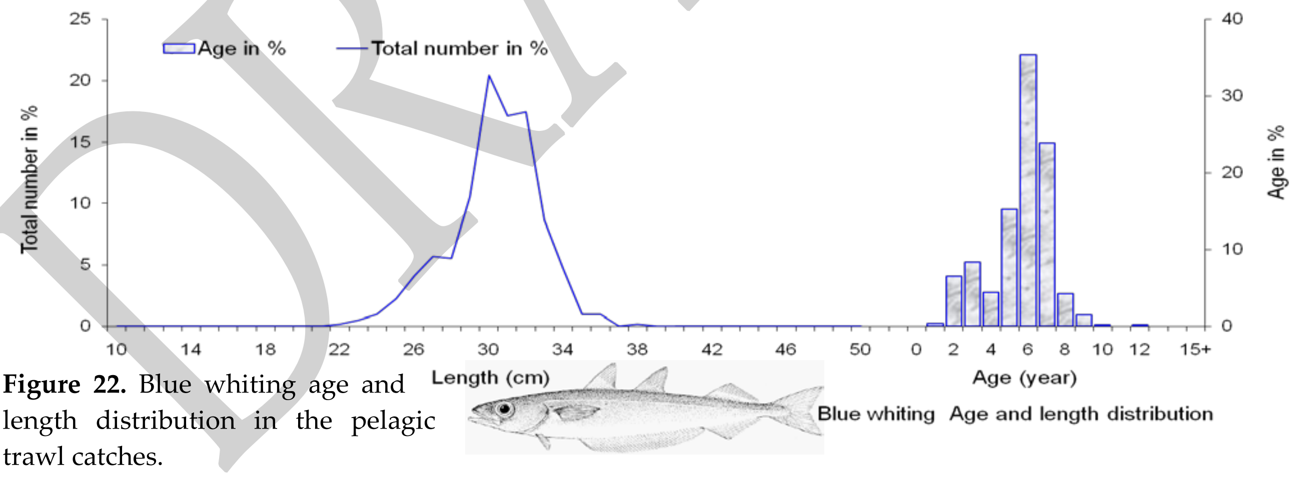


Figure 22. Blue whiting age and length distribution in the pelagic trawl catches.

Highest mackerel catches (kg/nmi) dominated in the western and central Norwegian Sea and adjacent areas from 62ºN to 68ºN in the northwestern and northern areas with Arctic water masses (Figure 23).

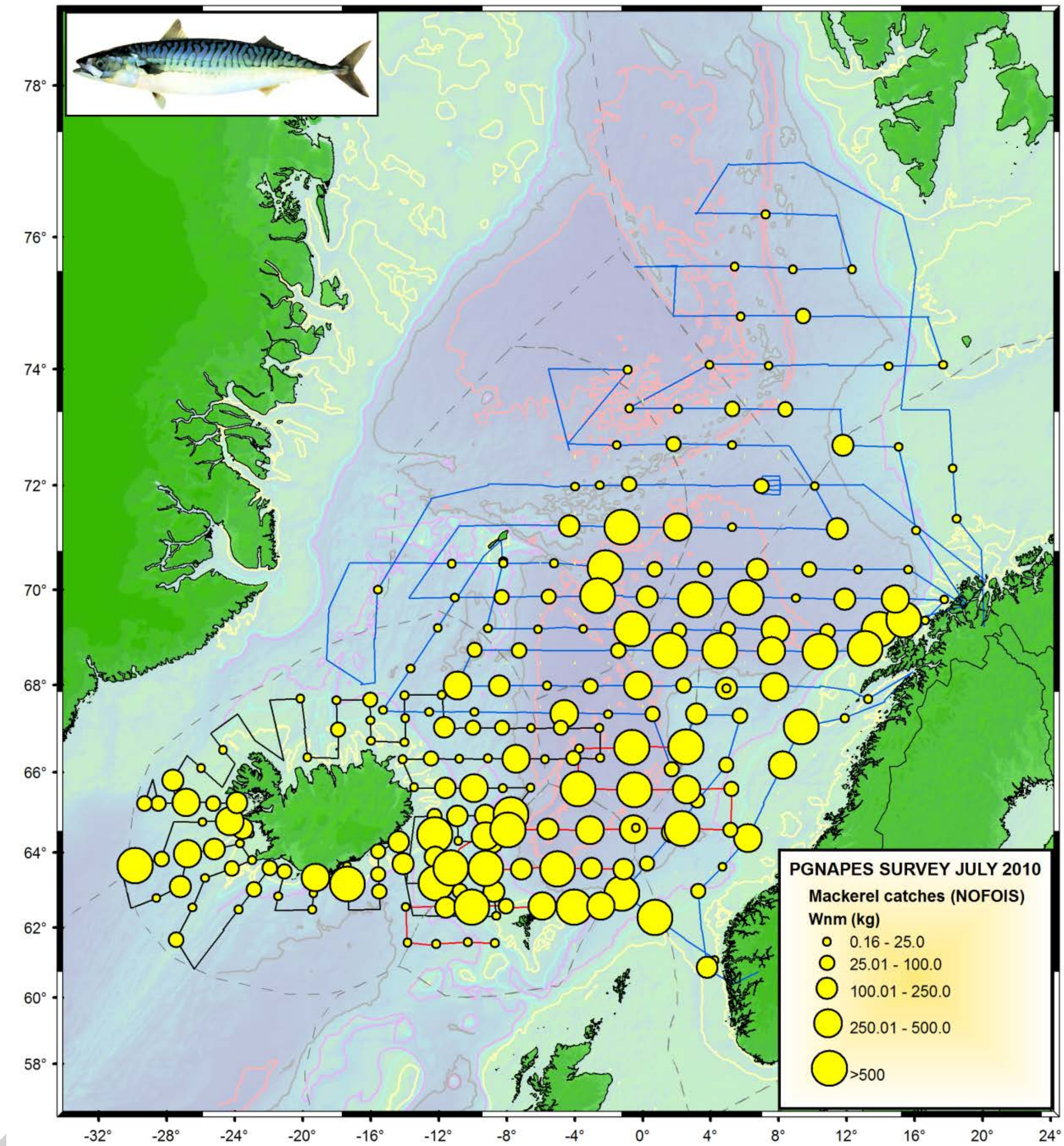


Figure 23. Mackerel catches (kg/nmi) from Libas and Eros combined in the Norwegian Sea and surrounding waters, 9 July- 20 August 2009.

Mean mackerel weight (g) within a category is shown for each biological station (Figure 24). A general trend is that the largest mackerel is found in the western and northwestern part of the Norwegian Sea.

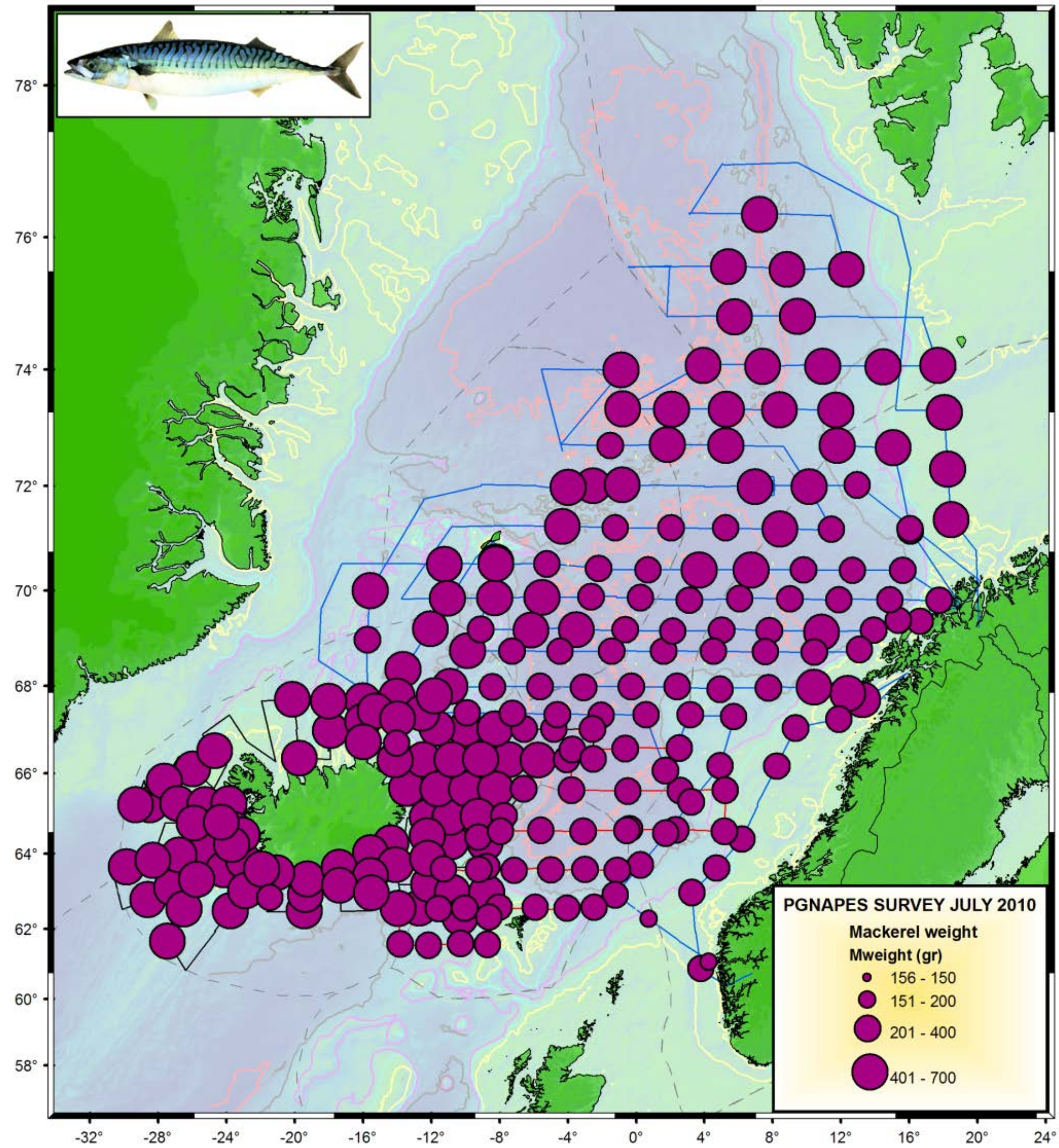


Figure 24. Mean mackerel weight (g) represented for each station within the categories shown. No catch of mackerel is indicated as a blank along the cruise track.

Mean mackerel length (cm) within each category is shown for each biological station (Figure 25). A general trend is that the longest mackerel is found in the western and northwestern part of the Norwegian Sea.

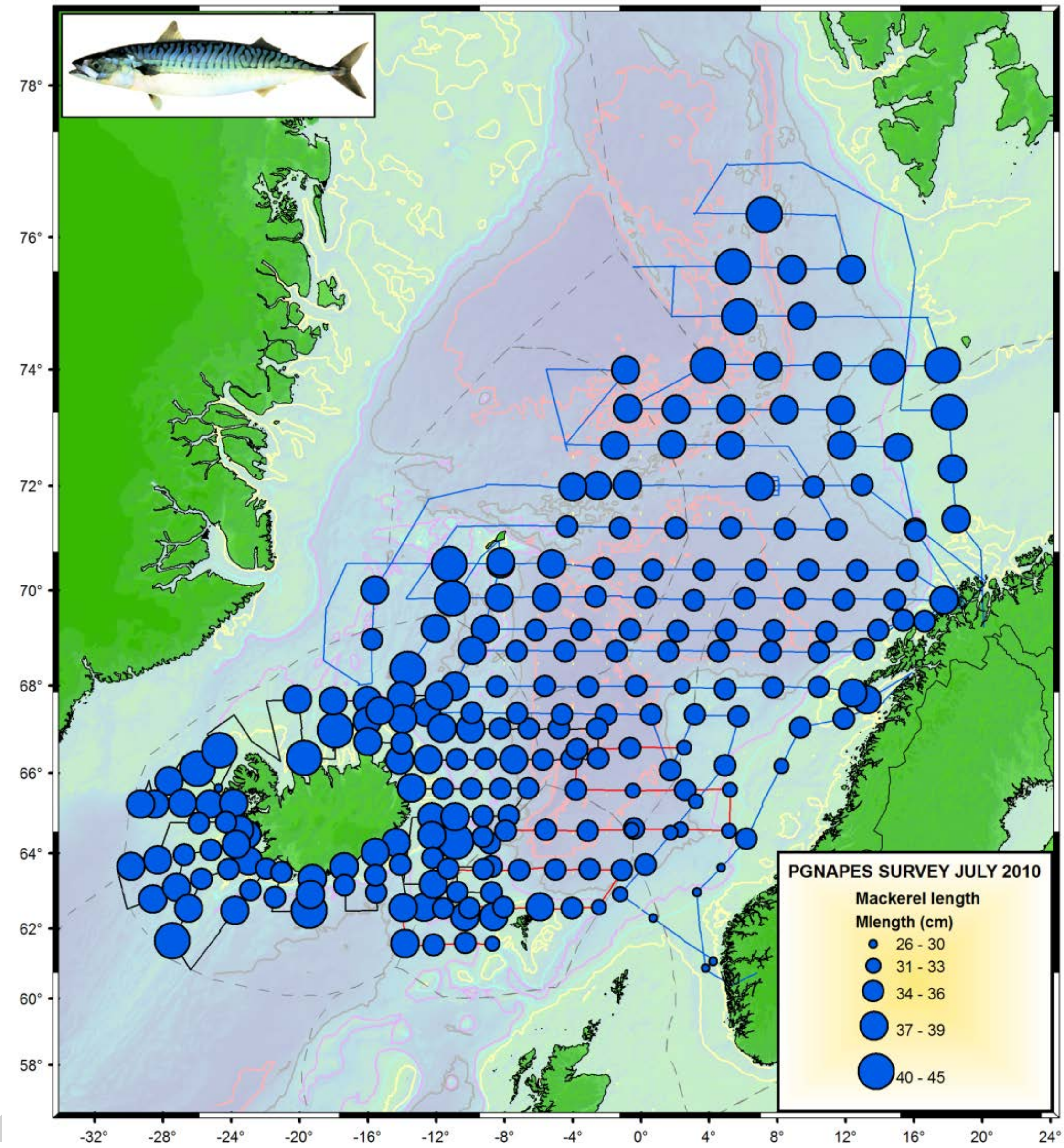


Figure 25. Mean mackerel length (cm) represented for each station within the categories shown. No catch of mackerel is indicated as a blank along the cruise track.

Mean herring weight (g) is shown in figure 26. We can see from the figure that herring is distributed over a substantial feeding area within the peripheral parts (donout shaped) of the entire study area. The largest herring were found in the northern and western areas, with a relatively clear weight dependent migration pattern was found.

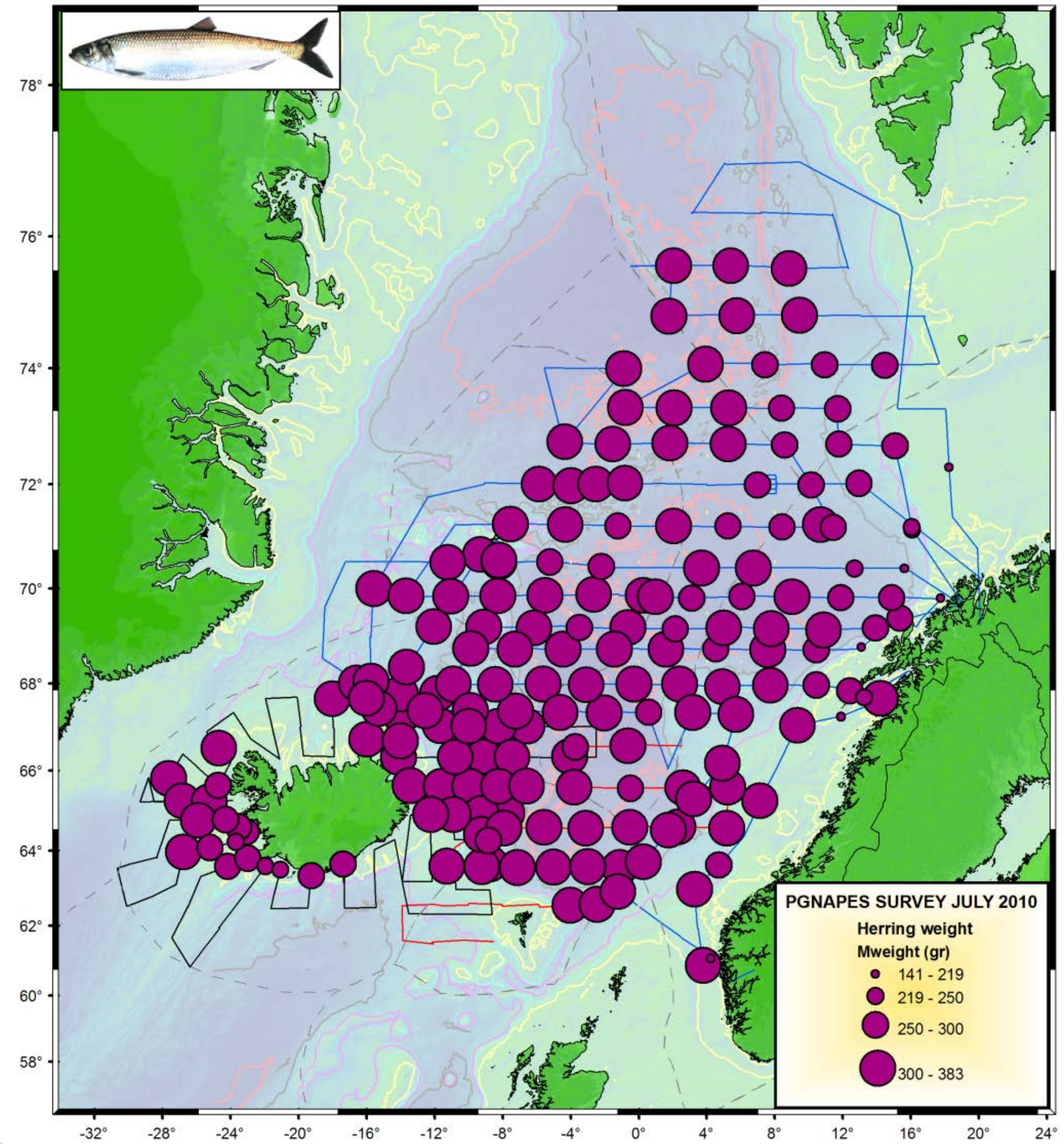


Figure 26. Mean herring weight (g) for herring represented for each station within the categories shown. No catch of mackerel is indicated as a blank along the cruise track.

We can see from Figure 27 that herring was distributed over a large feeding area within the study area. The largest herring were normally found in the western and northern part indicating a clear length-dependent herring migration pattern (Figure 27).

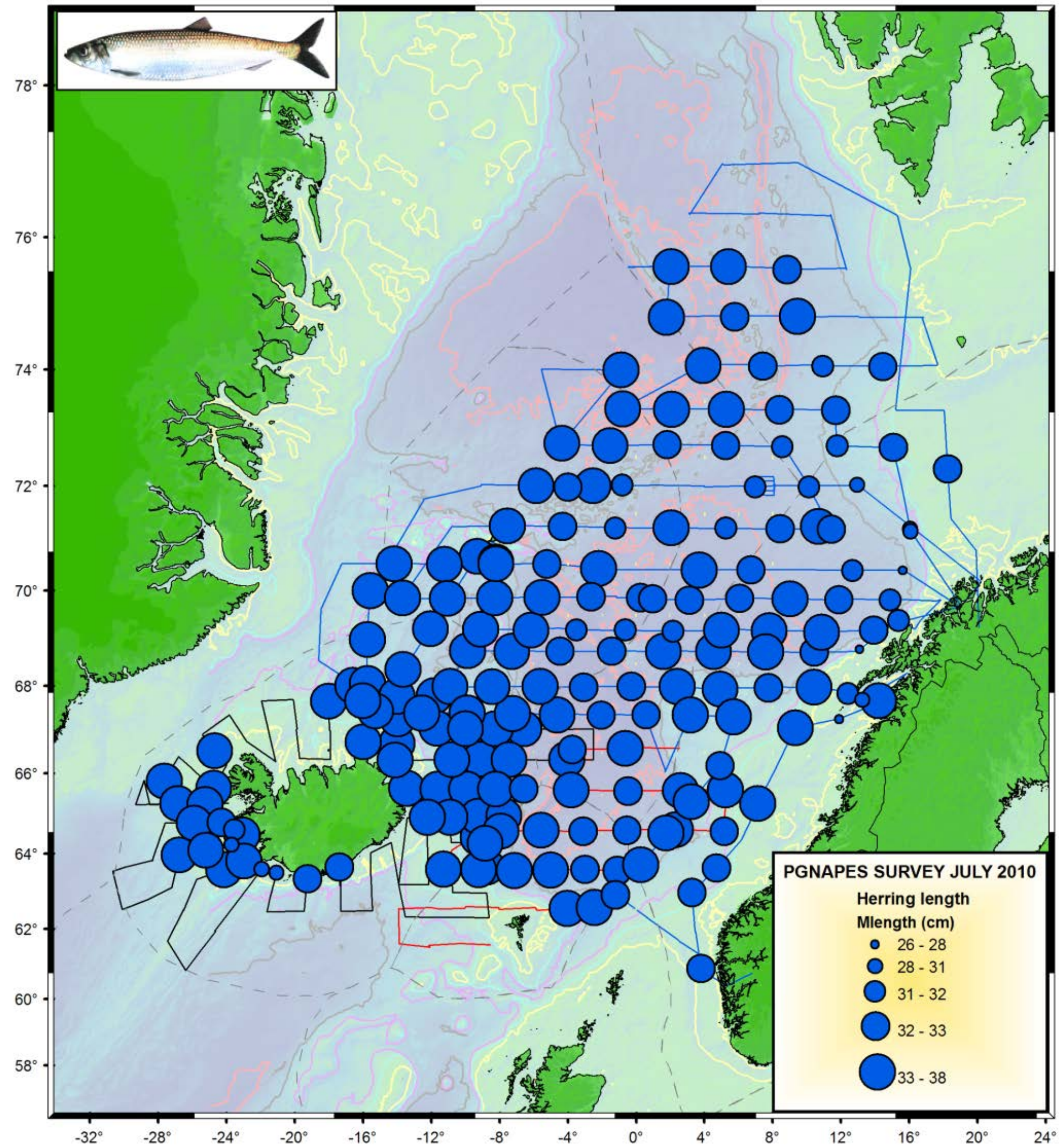


Figure 27. Mean herring length (cm) for each station within the different categories shown.

In order to illustrate and visualize the spatial and temporal overlap between mackerel, herring, blue whiting and other species such as salmon, horse mackerel and lumpsucker 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 28).

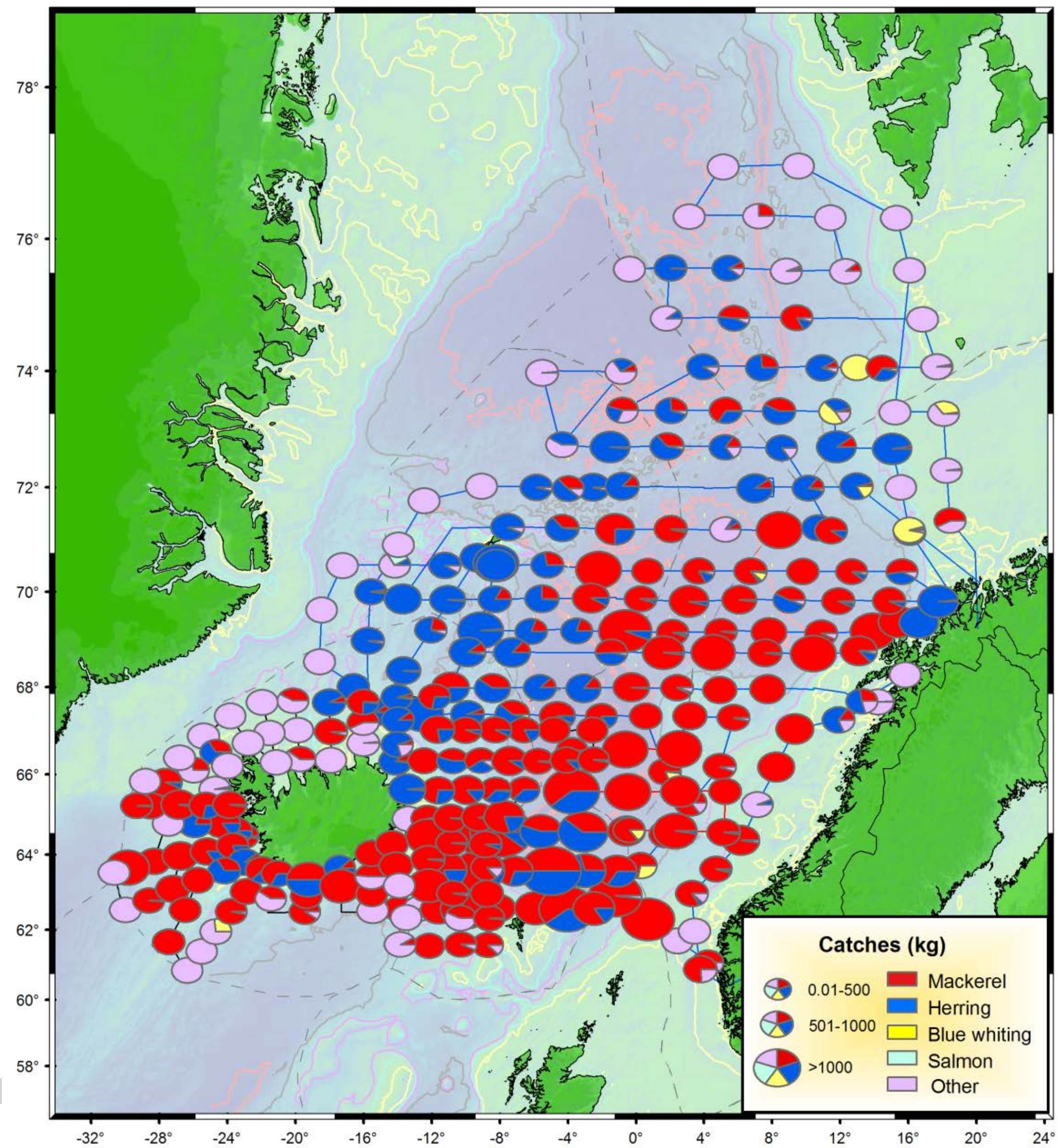


Figure 28. Distribution and spatial overlap between mackerel (red), herring (blue), blue whiting (yellow) and salmon (violet) from Libas and Brennholm in the Norwegian Sea between 15 July and 6 August 2010.

The spatial overlap between mackerel and herring were mostly found in the southern, southwestern and northern parts of the Norwegian Sea. Altogether 24 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, central part of the Norwegian Sea and in several catches west, south and southeast off Iceland. 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. The herring caught off west and south Iceland belonged entirely to the Icelandic summer-spawning stock.

Acoustics

Omnidirectional fisheries sonar

The results of the scrutinizing process of the sonar data showed that along all transects, either North or South of the central line (which correspond to the original survey line), a large number of schools were present. A North-South gradient in the number of school can be observed, with lower number of schools in the NE and SW corners of the sampled area. These results indicates that schools were distributed in this region more than 10 nmi from the central survey line. A comparative and integrated analysis with the data collected with the echo sounder and ADCP data will be done in a later stage.

From these preliminary results is also possible to observe the general swimming direction of the schools detected (Figure 29). In a selected region of the northernmost transect of the mini-survey the schools presented an east- south east direction, in the same direction of the vessel.

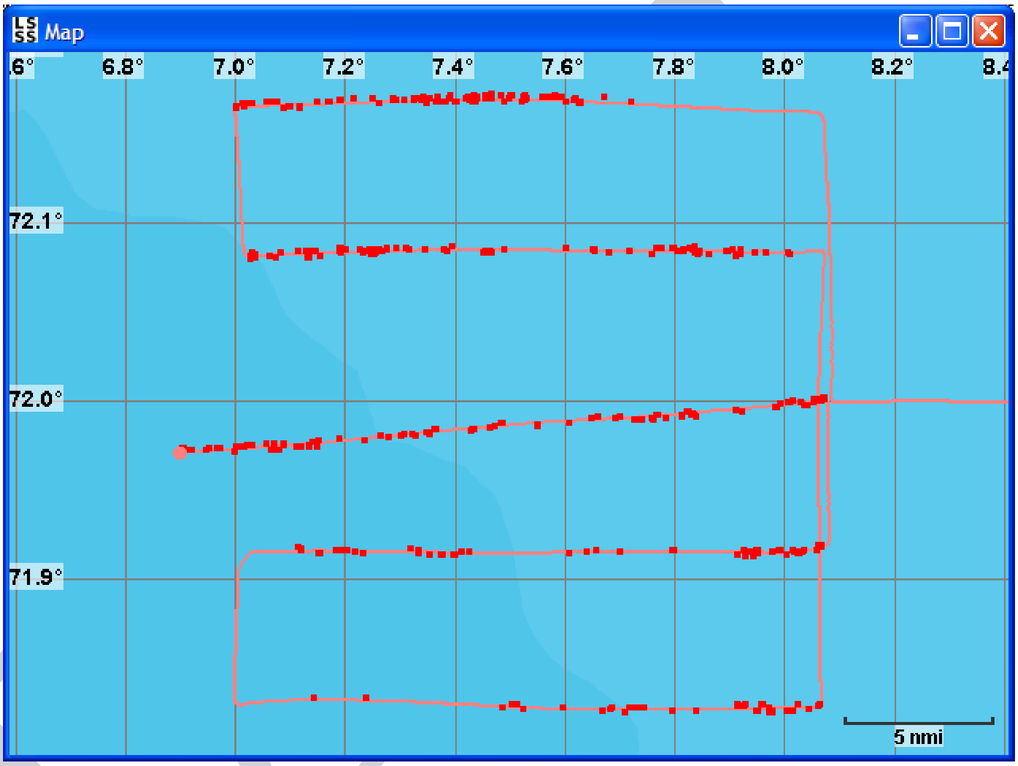


Figure 29. Schools detected by the SH80 sonar during the minisurvey. Each red dot represents the single detections for each school in every ping. The central line (*ca*. 72.0° N) corresponds to the original survey track line.

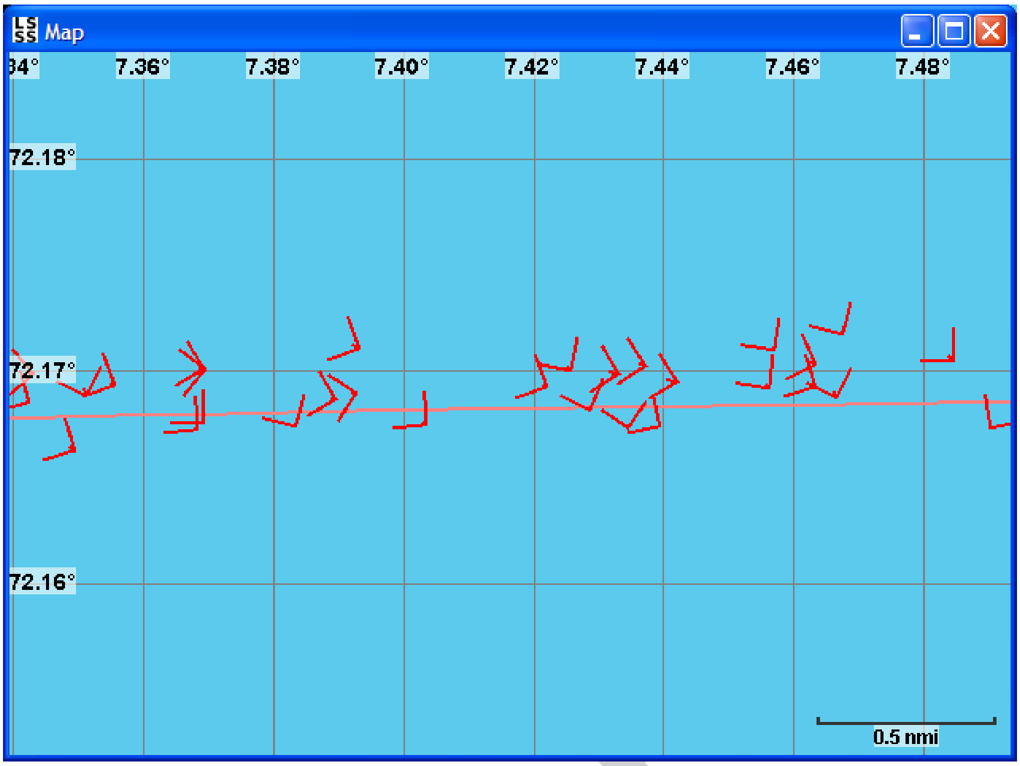


Figure 30. Detail of one of the survey lines in the minisurvey. Each arrow head is showing the mean school direction. In this particular transect the vessel was sailing from west to east, and the schools were swimming in a general east-southeast direction.

From the processing of the sonar data from one of the survey transects from the Norwegian coast to Greenland is possible to observe schools all along the transect, with relative more schools over the continental shelf off Tromsø. A detail of the first part of the transect showed that most of the schools have a swimming direction NE, similar to the prevailing currents in that area.

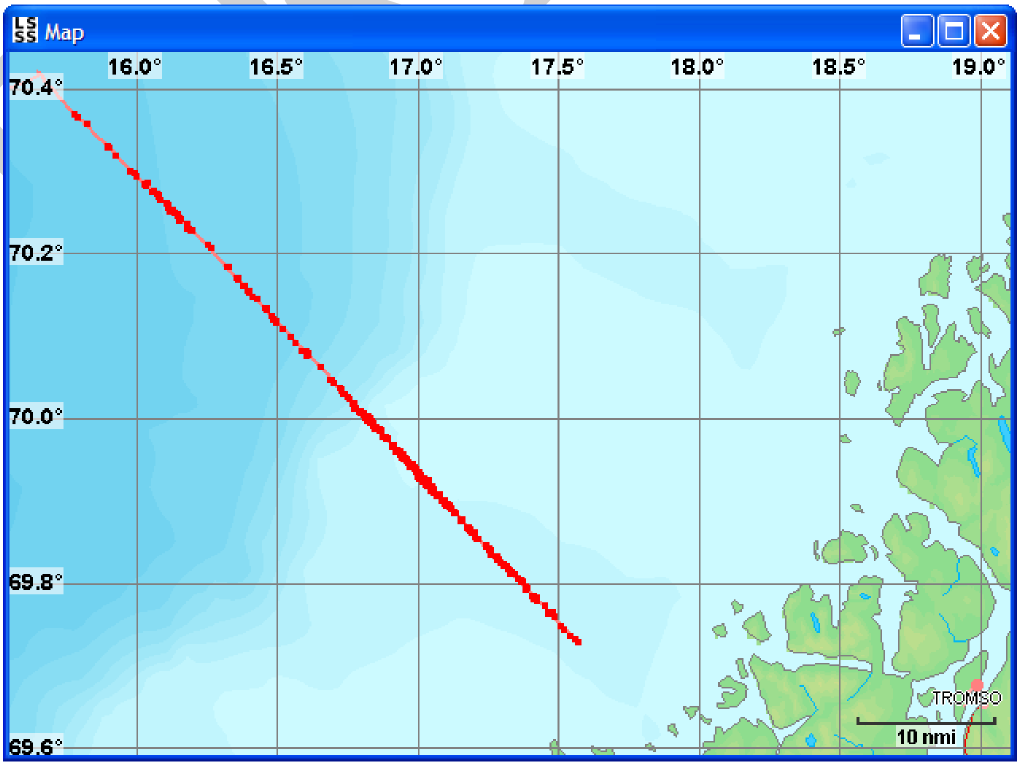


Figure 31. Schools detected by the SH80 sonar during the first survey transect during the second leg (26.07.2010). Each red dot represents the single detections for each school in every ping.

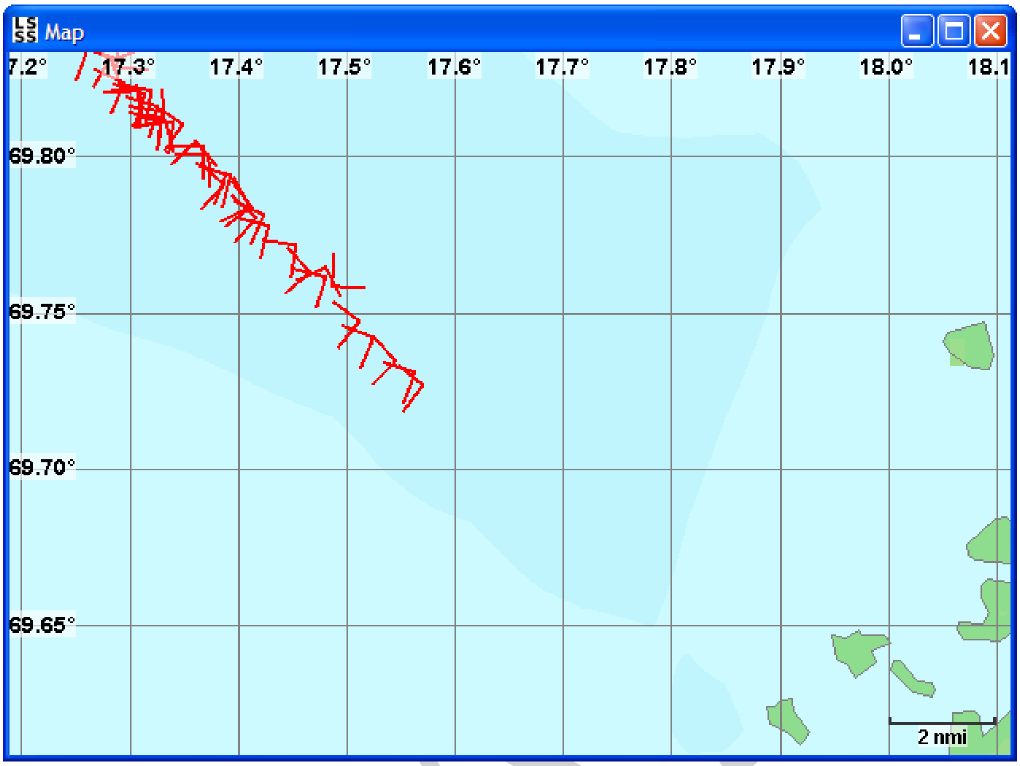


Figure 32. Detail of the first survey transect during the second leg (26.07.2010). Each arrow head is showing the mean school direction.

Also, was tried to process some of the files collected onboard Brennholm with the SH90 sonar. However, problems reading some .dat files was observed, and no explanation is yet found. Most likely, the .dat file format stored with the SH90 sonar is not exactly the same as the .dat format stored by the SH80 which was used to develop the PROFOS module. This problem is now investigated and already communicated to Simrad.

From the experience gained during the survey is clear that one of the main aspects that need to be solved is to improve the school growing process. For this, is crucial to perform the semi-automatic growing process in a more noise free and smoothed sonar image. Actually, the PROFOS module is working with the raw data files with no smoothing or noise filtering, making the automatic growing process inaccurate, and requiring manual corrections. The aim is to be able to filter the raw data to produce an image similar to the sonar screen, with the school very strong enhanced and low noise level. If this is accomplish, a full automatic school detection procedure will be tested, if successful with reduce significantly the scrutinizing time.

Another important problem is related with the data handling. Actually the .dat file format is structured in a way that the files corresponding to each sonar ping are stored inside a folder, every *ca*. 30 s. This procedure creates a large number of folders of small byte size, which in a large survey generates a problem for handling (storing, copying, etc) by the computer operating system and the PROFOS system. Has been communicated by Simrad that the new .raw format that will be available in the SH90 and SX90 sonars, will have a format similar to the EK60 data format. This format will allow an easier and faster handling of the sonar files.

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.
Multi-frequency patterns between 38 and 200 kHz (Brennholm and Finni Fridur) and 18, 38, 70 120 and 200 kHz (Libas and Arni Fridriksson), were also used actively to allocate acoustic targets to species. Judging of the acoustic data was performed daily by two experienced scientists applying the post processing system Large Scale Survey System (LSSS) and http://www.marec.no/, Echoview (http://www.echoview.com/) and BI 500 (see above).

Abundance 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 10.7 million tons consisting of 35.6 billion individuals. The average weight of herring was 300.7 gram and mean length was 32.6 cm. Altogether 15 different year classes were present in the catches, whereas only six year classes constituted to more than 5% of the catches.

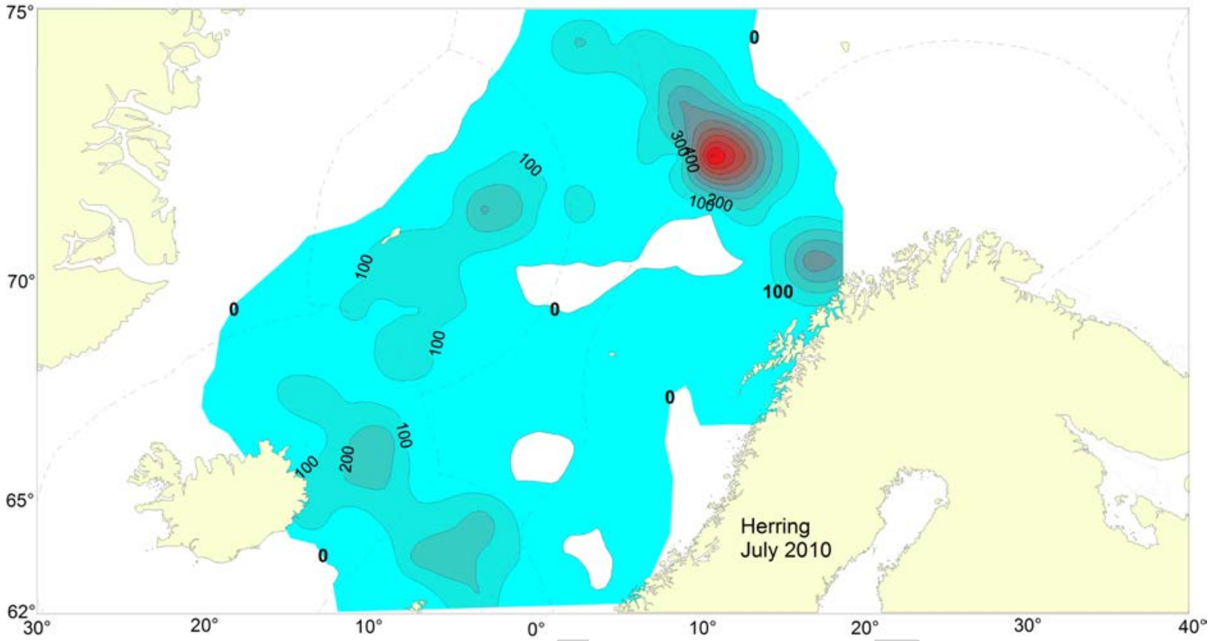


__Figure 33.__ Sa or Nautical Area Scattering Coefficient (NASC) values of herring along the cruise track.

A swept area analyses was performed for Norwegian spring-spawning herring for Libas, Brennholm, Finni Fridur and Arni Fridriksson from 9 July to 20 August 2010. The input data for the calculation was as follows: a horizontal opening of 23 m was applied for Arni Fridriksson based on the trawl dimensions and performance geometry. A horizontal opening of 50 m was applied for the pelagic trawl onboard the chartered vessel Finni Fridur from Faroe Islands and Libas and Brennholm from Norway. Only surface trawl hauls were used in the analyses. The same six geographical areas were used for the swept area calculations as for the acoustic estimation. Based on these assumptions an overall biomass estimate for Norwegian spring-spawning herring from the swept area method came to 2.28 mill. tons (figure 34).

Figure 34. Swept area estimates for Norwegian spring-spawning herring based on pelagic trawl haul catches at the surface onboard Libas, Brennholm, Finni Fridur and Arni Fridriksson from 9 July to 20 August 2010.

Acoustic detection of and NASC allocation to Atlantic mackerel were done based on the multi-frequency 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 (figure 31). The allocation of NASC values to mackerel on Arni Fridriksson was however incomplete and were given a low priority during the survey because the methodology was considered to be too subjective and therefore unreliable by the scientists onboard, especially on the continental shelf. Consequently, the area covered by Arni Fridriksson should be considered with a caution with regards to the NASC values (Figure 35).

The mackerel population within the covered cruise tracks and areas was estimated to be 12.1 million tons consisting of 31.8 billion individuals. The average weight of mackerel was 382.1 gram and mean length was 34.7 cm. Altogether 13 different year classes were present in the catches, whereas five year classes constituted more than 5% of the catches.

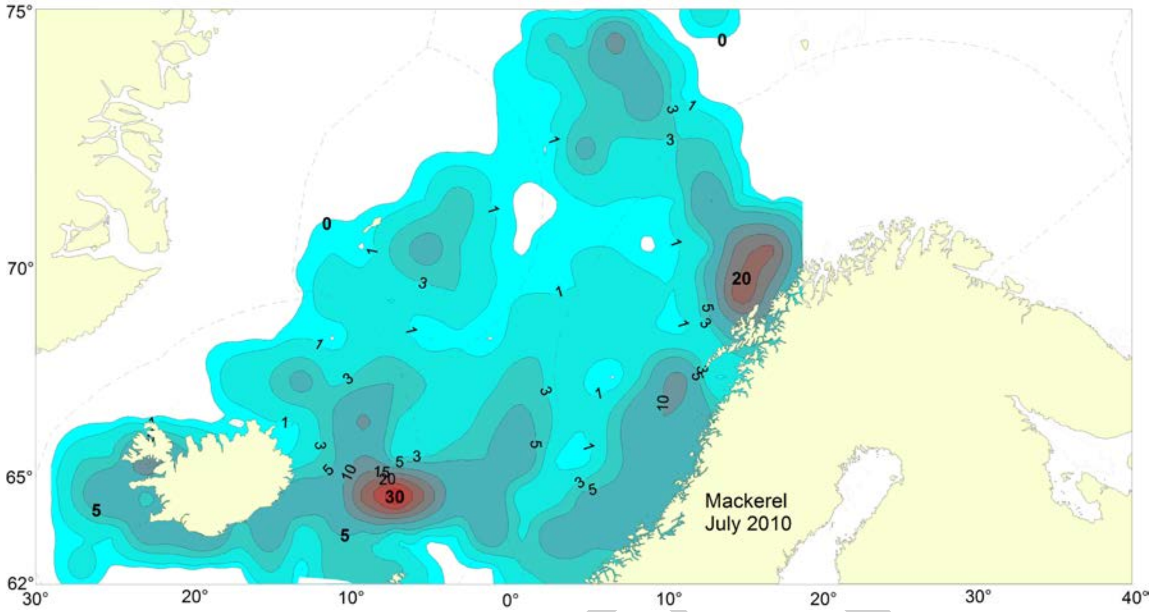


Figure 35. Sa or Nautical Area Scattering Coefficient (NASC) values of mackerel along the cruise track.

A swept area analyses was also performed for Northeast Atlantic mackerel for Libas, Brennholm, Finni Fridur and Arni Fridriksson from 9 July to 20 August 2010. The input data for the calculation was as follows: a horizontal opening of 23 m was applied for Arni Fridriksson based on the trawl dimensions and performance geometry. A horizontal opening of 50 m was applied for the pelagic trawl onboard the chartered vessel Finni Fridur from Faroe Islands and Libas and Brennholm from Norway. Only surface trawl hauls were used in the analyses. The same six geographical areas were used for the swept area calculations as for the acoustic estimation. Based on these assumptions an overall biomass estimate of 4.46 mill. tonnes was found for Northeast Atlantic mackerel from this swept area analysis(figure 36).

Figure 36. Swept area estimates for Northeast Atlantic mackerel based on pelagic trawl haul catches at the surface onboard Libas, Brennholm, Finni Fridur and Arni Fridriksson from 9 July to 20 August 2010.

The blue whiting population within the covered cruise tracks and areas was estimated to be 3.46 million tons consisting of 21.1 billion individuals (figure 37). However, the targeted trawling for verification of acoustic values were somewhat scarce in part of the distribution area. In particular in the western and northern areas (Figure 37b). The average weight of blue whiting was 164 gram and mean length was 29.6 cm. Altogether 10 different year classes were present in the catches, although five year classes constituted more than 5% of the catches.

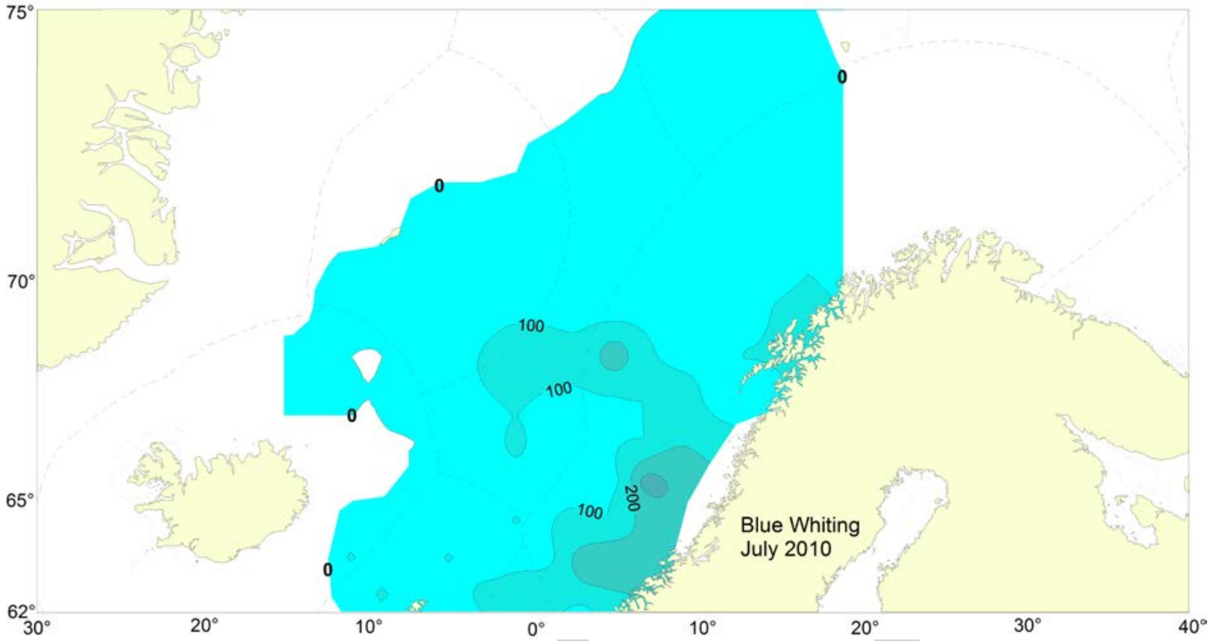


Figure 37. *Map of blue whiting distribution and aggregation showing the Sa or Nautical Area Scattering Coefficient (NASC) values estimated acoustically in the Norwegian Sea ecosystem.*

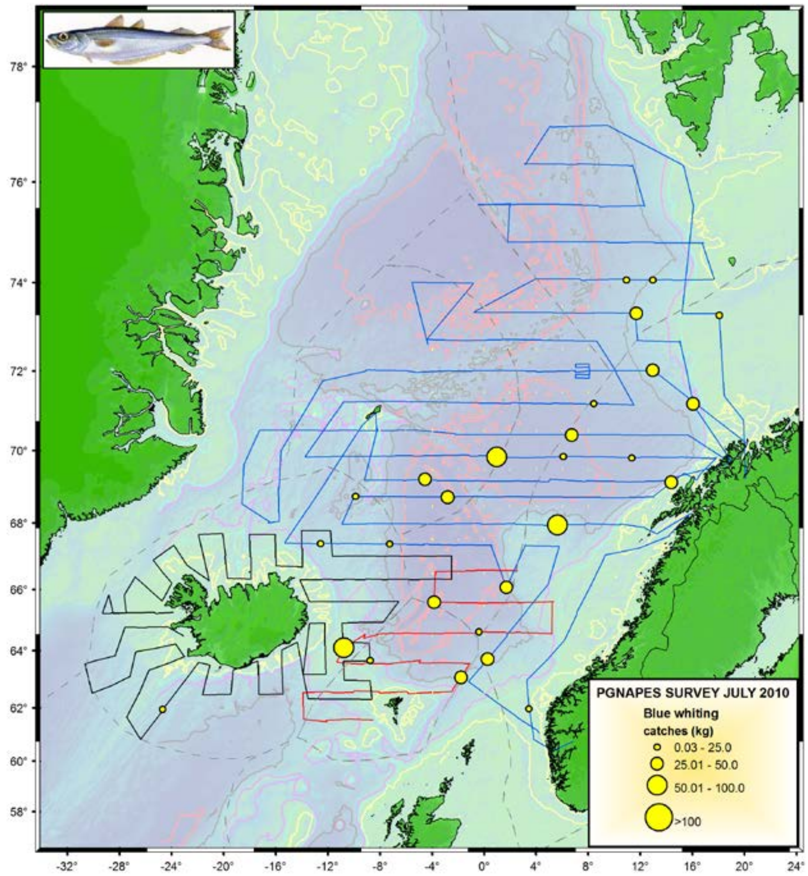


Figure 37b. Distribution and catches of blue whiting in the Norwegian Sea and surrounding waters, 9 July – 20 August 2009.

Lumpsucker

Lumpsucker was caught in most of the trawl hauls north of 64°N of the Norwegian Sea (Figure 38). The wide distribution and the range in size distribution from very small individuals to large adults could indicate that this species is in a healthy state in the Nordic Seas. Based on swept area calculations from epi-pelagic trawl hauls, an abundance of 53 000 tons of lumpsucker was calculated.

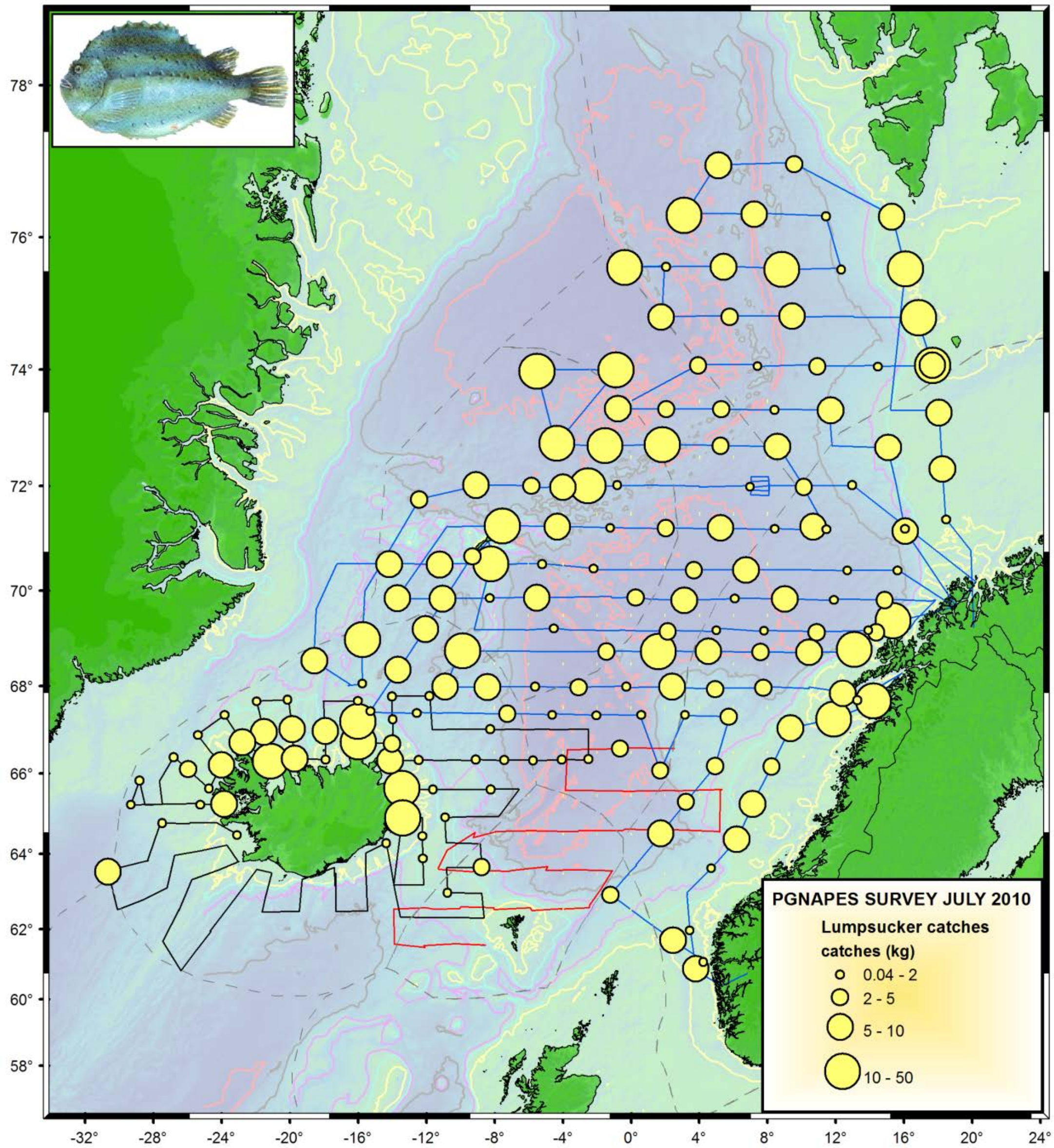


Figure 38. Distribution and catches of lumpsucker in the Norwegian Sea and surrounding waters, 9 July – 20 August 2009.

Plankton

Plankton samples from the WP2 nets from Libas, Brennholm and Finni Fridur showed generally very low plankton concentrations (Figure 39). Summer 2010 showed the lowest plankton concentrations since we started these measurements.

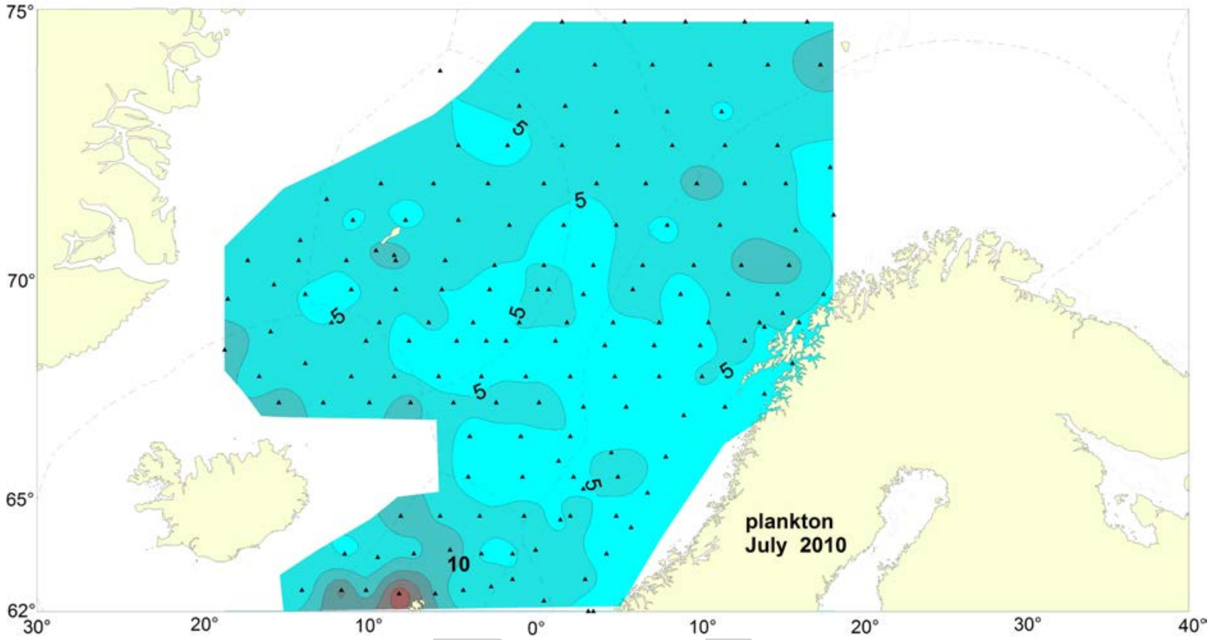


Figure 39. Map of total zooplankton concentrations (g/m^2) from WP2 net samples (0-200 m) at pre-selected stations.

Marine mammals

The weather conditions were good and calm during the majority of the scientific cruise. However, dedicated observations were done from the bridge and not from the roof according to marine mammal sighting procedure. Result on marine mammal sightings are given in figure 40.

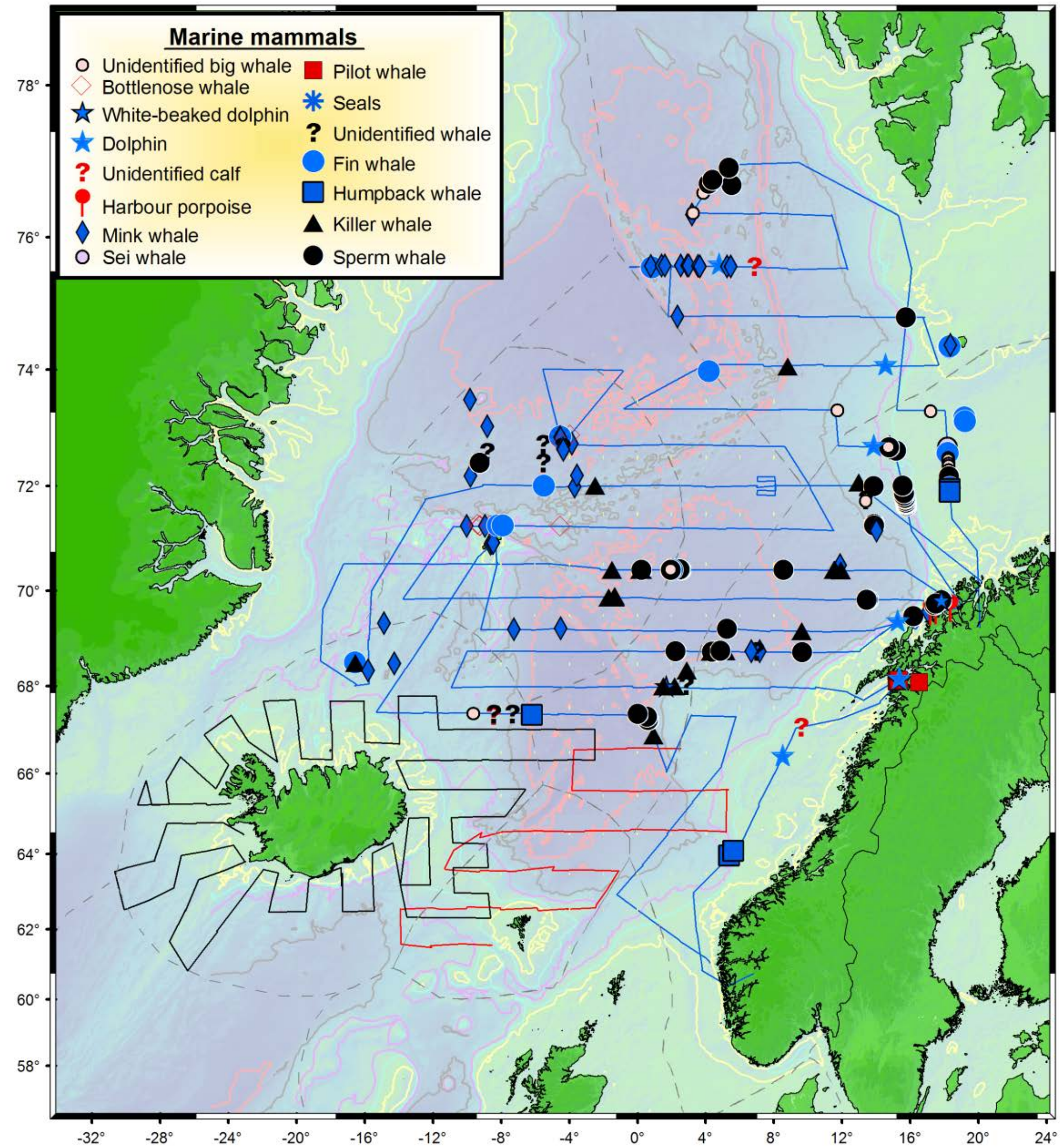


Figure 40. Marine mammals observed in the Norwegian Sea onboard "Libas" and "Brennholm" between stations in daylight hours, 15 July –20 August 2010.

5) Discussion

The ecosystem survey is considered to have covered 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 for all the three major planktivorous species and during the time they have their maximum geographical distribution. One of the main aim of this study was to map the distribution of the entire populations of mackerel, herring and blue whiting in the Norwegian Sea and adjoining waters. Based on the continuous acoustic recordings from hydro-acoustics and extensive pelagic trawling near the surface and midwater, we believe that we managed to cover the vast majority of these species and consequently their maximum spatial distribution. These ecosystem surveys in summer basically date back to 2004 and have been gradually expanded in geographical coverage and scientific complexity (Skaret et al. 2004; Nøttestad et al. 2005, 2006, 2007, 2009; Holm et al. 2008). Prior to 2004 the surveys were dedicated to northeast Atlantic mackerel alone.

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. Since both Libas and Eros has drop keel the vessels can be used for abundance estimation using hydro-acoustic recordings with scientific echosounders and multibeam sonars. This combined methodology, in addition to the pre-defined surface trawling 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, and in some areas 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 multi-frequency 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 inter-specific feeding competition, spatiotemporal overlap and migration patterns of mackerel, herring and blue whiting in the Norwegian Sea.

Acknowledgement

We thank skippers and crew members onboard Libas, Brennholm, FInnur Fridi and Arni Fridriksson for outstanding collaboration and practical assistance on the ecosystem cruise in the Norwegian Sea and surrounding waters.

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ANNEX 1:

Addendum to:

Cruise report from the coordinated ecosystem survey with M/V ”Libas” and M/V ”Brennholm”, M/V “Finnur Fridi” and R/V “Arni Fridriksson” in the Norwegian Sea and surrounding waters, 9 July- 20 August 2010

By

Iceland (Sveinbjørnsson et al.), Norway (Nøttestad et al.), and Faroe Island (Jacobsen et al.)

Prologue

This document shows a revised swept area biomass estimate for mackerel in the coordinated ecosystem survey in July-August 2010 in the Nordic Seas. The estimates presented here were done for the different exclusive economical zones (EEZ) in a more appropriate manner than the previous estimates, which were calculated under an improper time pressure to be able to include them in the WGWIDE report, and there the focus was mainly on the total estimate of mackerel in the area. Thus, the content of this addendum should replace the information that is shown in Figure 36, and the associated text, in the *Cruise Report from the coordinated ecosystem survey 2010* and also Figure 2.5.1.1.2 in the WGWIDE 2010 report. It should be noted that the total biomass estimate of mackerel from the swept area methods is similar in both cases, or 4.85 million tons now instead of 4.46 million tons in the reports. Thus, the relevance of all conclusions and discussions in the two reports referring to the total area swept biomass estimate of mackerel remains.

This presented Addendum has been accepted by all the WGWIDE members that participated in this coordinated ecosystem survey in 2010.

Swept area estimate of mackerel biomass in the different economical zones of the Nordic Seas in July-August 2010

The data originate from the four vessels from Faroe Islands (1), Iceland (1) and Norway (2) that participated in the coordinated ecosystem survey in July-August 2010 in the Nordic Seas. The data were gathered from the common WGNAPES database located in the Faroe Islands. The swept area biomass estimates were based on average catches of mackerel within rectangles of 1° latitude and 2° longitude and their area (Figure A1). Where the EEZ boundaries bisect or trisect, the rectangles were apportioned across boundaries according to the percentage used for blue whiting distribution of catches in the *Report of the NEAFC workshop on mackerel and blue whiting –Thorshavn, February 1999*. The NEAFC report gives the proportions of ICES rectangles of 1° longitude by 30' latitude, these proportions were converted to area within EEZs, and aggregated to rectangles of 2° longitude by 1° latitude. Islands and land area were as well subtracted from the area estimates with a mix of polygon clipping, finding the convex hull of coastlines or by drawing approximate outlines of complex coasts (Figure A2). The approximate area of the rectangles where mackerel occurred or were assumed to have is shown in Figure A3.

An interpolation was only done for rectangles that had adjacent rectangles with one or more tows on all their sides, meaning that rectangles on the edges of the survey area were not interpolated. Total number of rectangles interpolated was 31. The interpolation was done by taking the average values of all tows within the four nearby rectangles. When two or more adjacent rectangles had no tows but were within the general distribution of mackerel, the average from less than four sampled rectangles was used.

In this swept area biomass calculation, only the horizontal opening of the trawl was used as was done in the rough estimations in the *Cruise Report from the coordinated ecosystem survey*

2010. However, there are differences in the trawl parameters used between the calculations now and in the report: (a) The Icelandic trawl; 23 m instead of 25 m horizontal opening; (b) The Faroese trawl; 50 m (as before); (c) The Norwegian trawl, 60 m instead of 50 m. The revision of the trawl size was done to reflect better the actual measured size of the trawls as provided in the report section on *Biological sampling, Pelagic planktivorous fish species*.

Catch data from all surface trawl hauls were used in the calculations except for five trawl stations taken by the Icelandic vessel within the Faroese EEZ as they overlap trawl stations taken by the Faroese vessel two week earlier. The same was done in the former calculations. The calculated average mackerel catch per square km towed is shown in Figure A4 for all rectangles and more graphically on Figure A5.

The results of the calculations are given in Table A1. The total biomass estimate of mackerel is similar to the estimate obtained from the rough calculations previously done and shown on Figure 36 in the *Cruise Report from the coordinated ecosystem survey 2010.* However, there is a difference between them in quantity for the different areas, which is due to several reasons and they include: (1) The former estimate was simply divided according to individual vessels' coverage and not according to EEZs. (2) The former estimates were based on different measures of the trawls sizes. (3) The former estimate was not based on gridded calculations (i.e. on rectangles) but on the total area covered by each vessel and its average catch. Thus, the estimate presented here is considered to be more appropriate and to reflect the mackerel distribution and abundance better than the former estimate.

As can be noted in Figure A1, there was an incomplete coverage in various areas, including the EU waters where only area equivalent to two rectangles were covered, southern parts of the Faroe Island EEZ and Icelandic EEZ, and coastal areas in mid Norway EEZ.

The calculations and allocation to the different EEZs was done with R and S-plus scripts. Now when it has been developed it can easily be used in the coming years for these area swept estimates.

Table A1. The swept area estimates of mackerel biomass in the different exclusive economical zones (EEZ) according to the coordinated ecosystem survey in July-August 2010.

	Area (10^3 km^2)	Biomass (thous. tons)	Biomass %
EU EEZ	24	407	8.4
Faroese EEZ	175	768	15.8
Greenland EEZ	22	1	0.0
Jan Mayen EEZ	215	607	12.5
Iceland EEZ	511	1111	22.9
Norway EEZ	421	1370	28.2
Svalbard EEZ	110	24	0.5
International waters	264	564	11.6
Total	1750	4852	100.0

Figures

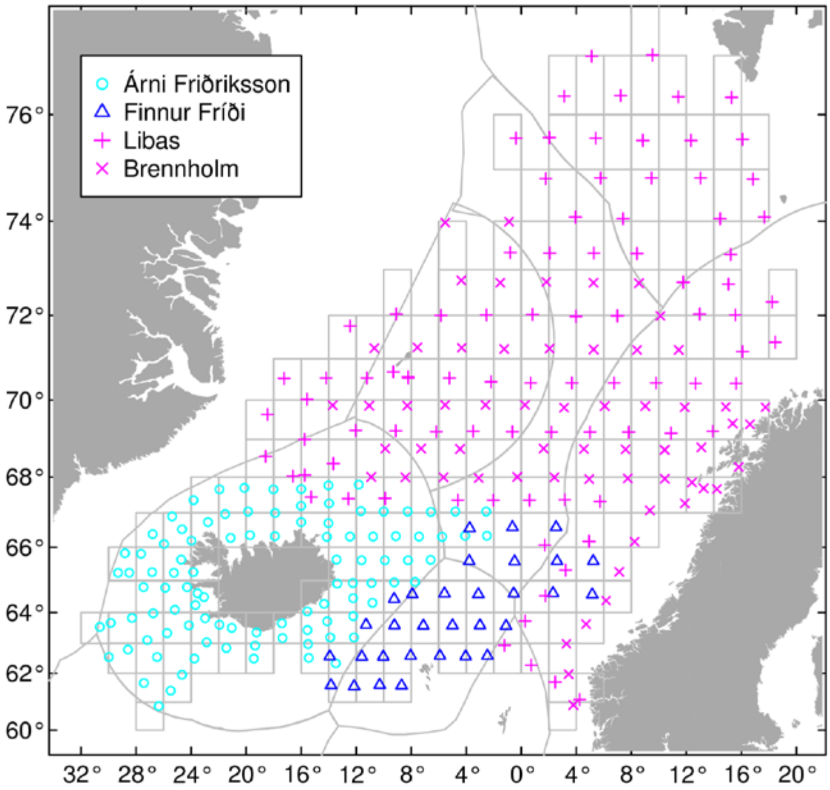

Figure A1. The location of the trawl stations of the different vessels used in the swept area estimates of mackerel biomass and all the rectangles that included trawl hauls.

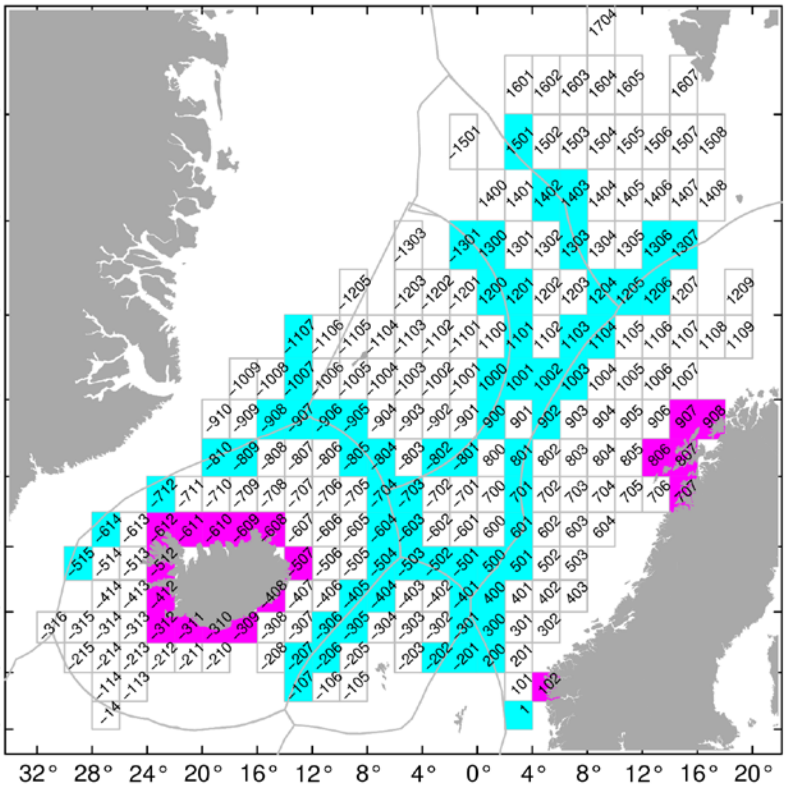

Figure A2. Rectangle codes and rectangles with area corrected for land (magenta) and on EEZ boundaries (cyan). All covered rectangles are shown.

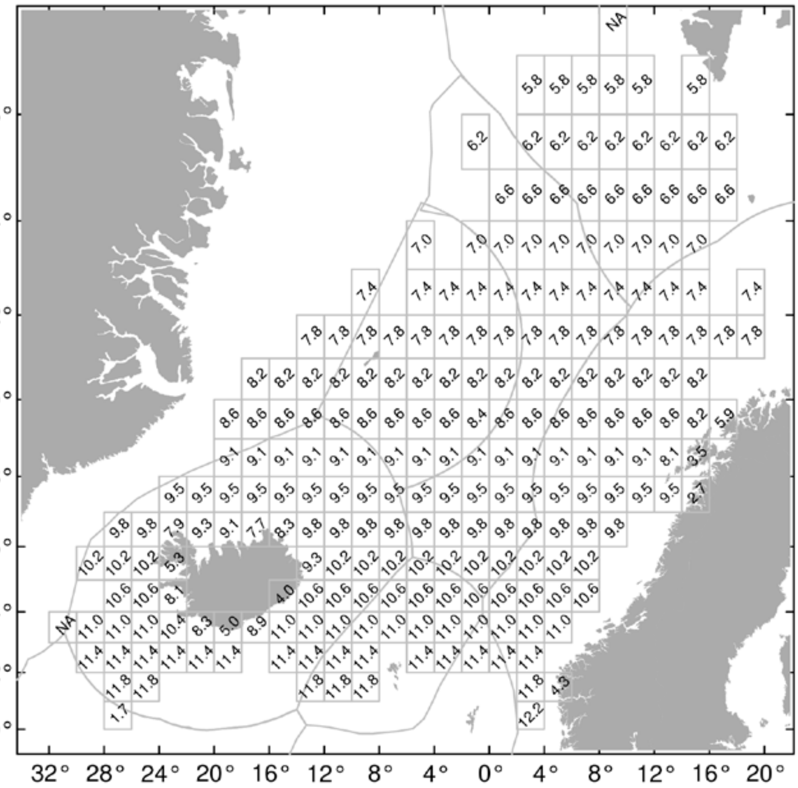

Figure A3. Approximate sea area (10^3 km^2) of 1° latitude by 2° longitude rectangles, *i. e.* corrected for land and islands. NOTE Lofoten roughly approximated. All covered rectangles are shown.

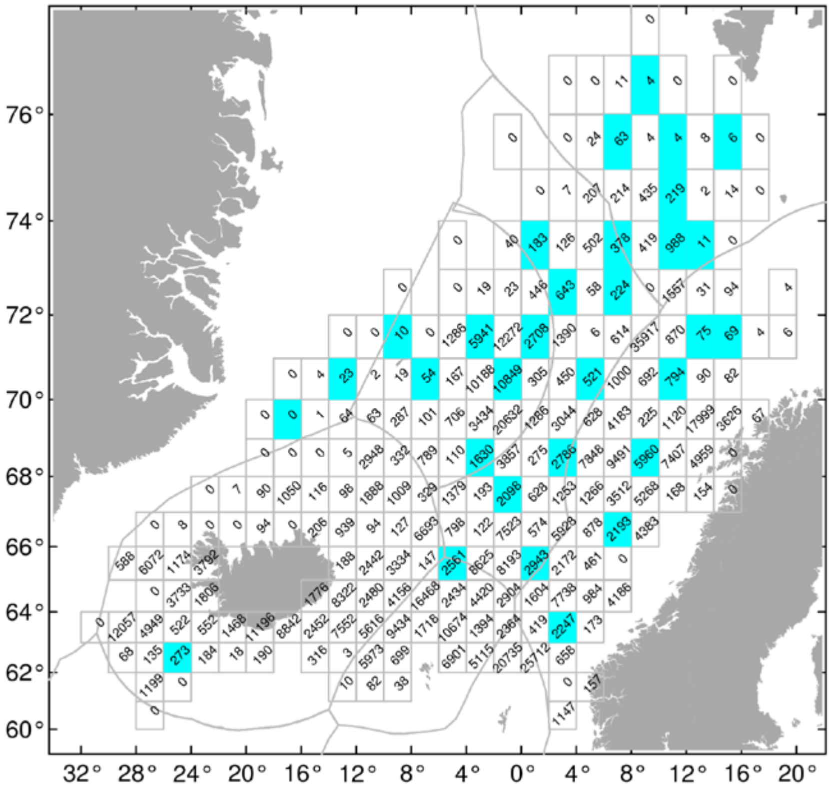

Figure A4. Mean swept area estimate (kg/km²) by rectangle of mackerel, either based on tow means within rectangle or interpolated with average of adjacent rectangles (colored rectangles). All covered rectangles are shown.

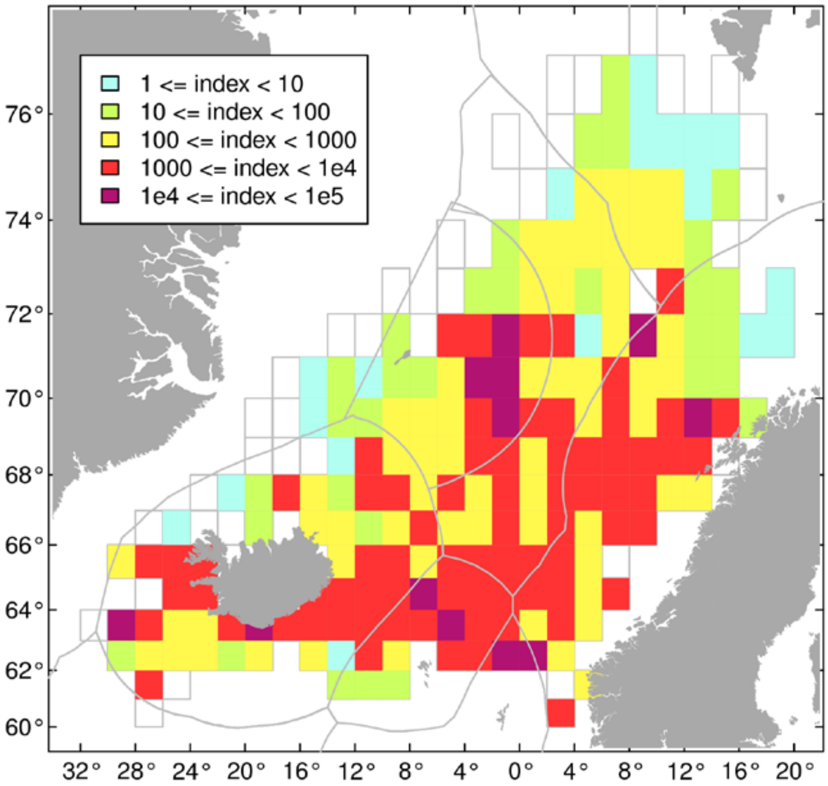

Figure A5. Graphical representation of the swept area estimates of mackerel (kg/km²) in the rectangles in the July-August 2010 survey.

Annex 5: Boarfish acoustic survey cruise report

FSS Survey Series: 2011/03

Boarfish Acoustic Survey
Cruise Report

07 July – 28 July, 2011

MFV Felucca

Ciaran O'Donnell[1], Edward Farrell[2], Ryan Saunders[1] and Andy Campbell[1]

[1]The Marine Institute, Fisheries Science Services

[2]Killybegs Fisherman's Organisation

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1 Introduction

This survey represents the first dedicated exploratory research survey for boarfish (*Capros aper*) undertaken along the western seaboard. The commercial fishing vessel the MFV *Felucca,* an active participant in the fishery was equipped with a calibrated scientific echo-sounder. A consultant biologist from the Killybegs Fisherman's organisation (KFO) and a Marine Institute scientist headed the biological and acoustic research respectively during the cruise.

Exploratory fishing for boarfish by Irish vessels began in the late 1980s when commercial quantities were encountered during the spring horse mackerel (*Trachurus* trachurus) and mackerel (*Scrombrus scomber*) fishery in northern Biscay. Several landings were made into Ireland for fishmeal during this time but due to logistical problems related to handling (prominent dorsal spines) this species was not favoured by processors. Interest increased again around the mid 1990s when Dutch pelagic vessels landed frozen samples to determine if a market could be developed for human consumption. From the early 1970s onwards the abundance of boarfish was seen to increase density and distribution as the observed marks spread northwards along the western seaboard (Blanchard and Vandermeirsch, 2005). With this increase in abundance boarfish were taken as bycatch in both the pelagic and demersal fisheries in increasing quantities and this caused serious problems relating to damaged target species due to the dorsal spines.

During the early 2000s the Irish landings were relatively small (<700t per yr) and it wasn't until 2006 that the directed fishery developed in earnest. Fishing was undertaken primarily by vessels from the Castletownbere and Killybegs based RSW fleets (refrigerated seawater vessels) which targeted boarfish from northern Biscay to the southern Celtic Sea. In 2007-08 Scotland and Denmark also began targeting boarfish. Irish landings are primarily landed into fishmeal plants in Denmark and the Faroe Islands with increasing amounts being landed in Killybegs. The boarfish fishery bridged an important gap between the short season fisheries for horse mackerel, mackerel and blue whiting (*Micromesistius poutassou*) affectively extending the fishing season for the RSW fleet from late August through to May.

A precautionary interim management plan was adopted in November 2010 covering ICES Divisions VI, VII and VIII and an EU TAC of 33,000t was set. Of this the Irish allocation for 2011 was 22,000t. This precautionary TAC was based on 50-75% of total landings from the period 2007-2009 which peaked at over 83,400t (2009). Landings in 2010 reached over 137,000t in a scramble to build up a track record in the fishery prior to a fixed quota allocation. In 2010 Sweden now also shares the TAC allowance with those actively involved in the fishery. In addition to the TAC control, seasonal closures were also implemented; from March 15–August 31 when mackerel is frequently encountered as a large bycatch, and this closure is extended to October 31 in VIIg to protect herring feeding and pre spawning aggregations. A bycatch limit of 5% was also implemented within the fishery where boarfish are taken with other TAC controlled species.

Data from this survey, in addition to the extensive biological research carried out on this species forms part of a larger program aimed at increasing the knowledge of the population dynamics of this species. Data from this survey will be presented to the ICES Planning Group meeting for North Atlantic Pelagic Ecosystem Surveys in August 2011 (WGNAPES) and to the ICES assessment Working Group for Widely Distributed Stocks (WGWIDE) also meeting in August 2011.

2 Materials and Methods

2.1 Scientific Personnel

Organisation	Name	Capacity
FSS	Ciaran O'Donnell	Acoustics (SIC)
KFO	Edward Farrell	Biologist
Contractor	Jason Clarke	Biologist
Contractor	John Cunningham	Contractor

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives of the survey are listed below:

- Collect acoustic data on boarfish (*Capros aper*) aggregations within the pre-determined survey area
- Determine the biomass and abundance of boarfish within the survey area
- Collect biological samples from directed trawling on insonified echotraces to determine age structure and maturity state of survey stock
- Determine the extent and behaviour of boarfish aggregations within the survey area to aid the design of future surveys
- Dovetail with the RV Celtic Explorer in the northern area to ensure close tempo-spatial alignment and increase effective area coverage

2.2.2 Area of operation and survey design

The survey was carried out starting with the Porcupine Bank before moving to complete the shelf area from north to south following a pre-determined cruise plan (Figure 1). Timing was closely linked to coincide with the arrival of the RV *Celtic Explorer* in the survey area and to ensure the seamless flow from north to south coverage between both surveys.

In total 3,160nmi (nautical miles) of cruise track was undertaken by the MFV *Felucca* over 32 transects relating to an area coverage of over 89,490nmi^2. Coverage extended from the 50m contour to the shelf slope (250m). Transect spacing was set at 15nmi throughout.

2.3 Sampling protocols and equipment specifications

2.3.1 Acoustic equipment

Equipment settings were determined before the start of the survey and are based on established settings employed on previous herring surveys (O'Donnell *et al.,* 2004).

Acoustic data were collected using a Simrad EK60 scientific echosounder topside unit. A Simrad ES-38B (38 KHz) split-beam transducer was mounted within a towbody frame and deployed on the port side via a towing boom to a working depth of 2.5-3m (Appendix 2).

Cruising speed was determined by the weather and the affects on the quality of acoustic data output. The cruising speed was maintained, where possible at 10-11 Kts.

2.3.2 Calibration of acoustic equipment

The EK60 was calibrated in Killybegs Harbour on 05 July prior to the start of the survey. The results of the calibration are presented in Table 1.

2.3.4 Acoustic data acquisition

Acoustic data were observed and recorded onto the hard-drive of the processing unit. The "RAW files" are logged via a continuous Ethernet connection as "EK5" files to laptop and a HDD hard drive as a backup in the event of data loss. Sonar Data's Myriax Echoview® Echolog (Version 4.9) live viewer was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of target schools. A member of the scientific crew monitored the equipment continually. Time and location are recorded for each transect start/end position within each strata. This log is used to monitor "off track events" during fishing operations and hydrographic stations.

2.3.5 Echogram scrutinisation

Acoustic data is backed up every 24 hrs and scrutinised using Sonar data's Echoview® (V 4.9) post processing software. Selection criteria are based primarily upon the species composition of trawl samples as well as target strength (TS) information and the experience of the scientist viewing the echograms.

The NASC (Nautical Area Scattering Coefficient) values from each herring region were allocated to one of 4 categories after inspection of the echograms. Categories identified on the basis of trace recognition were as follows:

1. "Definitely boarfish" echo-traces or traces were identified on the basis of captures of boarfish from the fishing trawls which had sampled the echo-traces directly, and on large marks which had the characteristics of "definite" boarfish traces (i.e. very high intensity (red), located high in the water column (day) as intense circular schools.

2. "Probably boarfish" were attributed to smaller echo-traces that had not been fished but which had the characteristic of "definite" boarfish traces.

3. "Boarfish in a mixture" were attributed to NASC values arising from all fish traces in which boarfish were thought to be contained, owing to the presence of a proportion of boarfish within the nearest trawl haul or within a haul which had been carried out on similar echo-traces in similar water depths. Boarfish are often present in mixed species layers during the hours of darkness.

4. "Possibly boarfish" were attributed to small echo-traces outside areas where fishing was carried out, but which had the characteristics of definite boarfish traces.

The "EK5" files were imported into Echoview for echo post-processing. The echograms were divided into transects. . Echo integration was performed on a region which were defined by enclosing selecting marks or scatter that belonged to one of the four categories above. The echograms were analysed at a threshold of -70 dB and where necessary plankton was filtered out by thresholding at –65 dB.

The allocated echo integrator counts (NASC values) from these categories were used to estimate the herring numbers according to the method of Dalen and Nakken (1983).

The following TS/length relationships used were those recommended by the acoustic survey planning group (Anon, 1994):

Herring TS = 20logL – 71.2 dB per individual (L = length in cm)

Sprat TS = 20logL – 71.2 dB per individual (L = length in cm)

Mackerel TS = 20logL – 84.9 dB per individual (L = length in cm)

Horse mackerel TS = 20logL – 67.5 dB per individual (L = length in cm)

The TS length relationship used for gadoids was a general physoclist relationship (Foote, 1987):

Gadoids TS = 20logL – 67.4 dB per individual (L = length in cm)

For boarfish (*Capros aper*) the TS coefficient for gadoids (Foote *et al.* 1987) was applied in place of a known TS. It was decided to apply a gadoid TS as an interim measure as no alternative verified TS was available for morphometrically or taxonomically similar species (Appendix 1).

Boarfish TS = 20logL – 67.4 dB per individual (L = length in cm)

2.3.6 Biological sampling

A single pelagic midwater trawl with the dimensions of 296m in length (LOA) with a 78m brailer. The net spread was approximately 90m at the wing ends. Mesh size in the wings was 12.8m through to 2cm in the cod-end liner used during the survey. The net was fished with a vertical mouth opening of approximately 45m, which was observed using a cable linked Simrad FS 900 netsonde (200 kHz). The net was fitted with a Marport catch sensors to limit the amount of catch taken during surveys trawls.

All components of the catch from the trawl were sorted and weighed; fish and other taxa were identified to species level. Fish samples were divided into species composition by weight. Species other than boarfish were weighed as a component of the catch and length and weight measurements were taken for 100 individuals in addition to a 300 fish length frequency sample. Age, length, weight, sex and maturity data were recorded for individual boarfish within a random 50 fish sample from each trawl haul with a further 100 random length/weight measurements in addition to a 300 fish length frequency sample. Due to the complexity of aging boarfish no aging was carried out onboard and samples will be analysed back in the lab. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul.

Decisions to fish on particular echo-traces were largely subjective and an attempt was made to target marks in all areas of concentration not just high density shoals.

2.3.7 Target strength modeling sample collection

As a component of the project biological samples were collected for further analysis into formulating a dedicated target strength (TS) length relationship for this species. The results presented in this survey were compiled using the existing TS relationship used for gadoids.

The collection of quality samples for TS modelling was hampered due to the size of the fishing gear used by the vessel. The vessel used a commercial sized boarfish trawl during the surveying (>270m LOA). Hauling on average took around 15mins and was done very quickly and efficiently. Samples once caught were often severely squeezed during the hauling process and no opportunity existed to collect live samples for acclimatisation in an aerated water tank stored on the deck. Individuals that were selected for freezing were those that after visual inspection looked to be in the best shape and showed the least signs external damage.

Samples were frozen as quickly as possible once retrieved from the trawl deck. Each fish was laid flat on grease proof paper and left untouched for a period in excess of 48hrs at -19°C. After this time the fish were carefully removed then dipped in a cold freshwater bath (glazing) before quickly being returned to the freezer. Once the glaze had taken fish were measured and bagged according to length class for ease of identification later on. The number of fish per bag was kept low and bags were then carefully stored within a rigid cardboard box to protect from damage. Samples collected will be combined with those collected during the RV Celtic Explorer survey.

2.4 Analysis methods

2.4.1 Abundance estimates

Total abundance, N_T, is given by $\sum_{m}^{Mark-types} N_{T,m}$, the sum over the total abundance by mark-types.

$$N_{T,m} = \sum_{s}^{strata} N_{m,s}$$

Suppressing the mark-type index, m, the stratum abundance is

$$N_s = area_s \sum_{l}^{transects} \bar{n}_{s,t} l_{s,t} \Big/ \sum_{j} l_{s,j}$$

,where *l* is the transect length and $\bar{n}$ is the transect mean abundance n.mi^{-2} which is given by

$$\sum_{j}^{track\cdot fragments} n_{s,t,j} d_{s,t,j} \Big/ l_{s,t}$$

, where d is the distance of the track fragment and $n_{s,t,j}$ is the mean abundance n.mi^{-2} for the jth track fragment.

Because hauls are assigned with there own stratification that will not necessarily coincide with the acoustic strata, the conversion of NASC into mean density is done at the track fragment level, usually a 1 n.mi segment, but these could be just for the schools themselves. The haul assigned, $h_{m,s,t,j}$, depends strongly on the mark-type (m) and since more than one school can be in a track fragment it needs to be specified. Since age and maturity length-keys are to be applied, the basic estimation is mean density by length bins. The $n_{s,t,j}$ is found by summing over the $n_{s,t,j}$.

$$n_{t,j,i} = \frac{NASC_{t,j}}{\bar{\sigma}_{h_{m,t,j}}} p_{i,h_{m,t,j}}$$

, where *i* indexes length bins, p_i is the proportion of herring in the i^{th} length bin, and is given by $\sum_{spe}^{species} \sum_{i} p_{spe,i} 10^{(a+b\log10(L_{spe,i}))/10}$

, where $p_{spe,i}$ applies over all species considered in the haul, $L_{spe,i}$ is the length to use for the i^{th} length bin and the data comes from the haul (of combination of hauls) assigned, $h_{m,t,j}$. For non-mix mark-types, the later simplifies to

$$\sum_{i} p_{herring,i} 10^{(073+20\log10(L_{herring,i}))/10} .$$

For biomass, a mean weight is also applied to the $n_{t,j,i}$ using the estimated regression relationship, a L_i^b.

For abundance by age and maturity, the abundance by length bin, $n_{t,j,i}$, is averaged over track fragments and then transects to give a strata (and mark-type) mean. The age and maturity keys are applied to the results.

$V_s = area_s^2 s_s^2 W_s$, where $W_s = \sum_{l}^{transects} {l^2}_{s,t} \Big/ \left(\sum_j l_{s,j}\right)^2$ and s^2 is the sample variance.

The variance for the total is the sum of strata variances.

The total biomass can be obtained directly from the track fragment mean biomass by

$B_T = \sum_{k}^{track \cdot fragment} \overline{n}_k w_k$, where w_k is a factor that takes into account the factors for transect

and strata averaging, i.e., $w_k = \frac{1n.mi}{l_{t_k}} \frac{l_{t_k}}{\sum_t^{stratum.s_k} l_{s_k,t}} area_{s_k} = \frac{1}{\sum_t^{stratum.s_k} l_{s_k,t}} area_{s_k}$

, where the 1 n.mi is the length of the track fragment. This ignores the mark-type since that is already accounted for in the $\overline{n}_k$. The $\overline{n}_k w_k$ is the biomass from a track fragment and they can then be used to map the biomass at a fine spatial scale.

Estimates are made for SSB, total abundance and biomass, abundance by age (ring counts), and abundance by age x length bins. A cv (based on strata standard error divided by the strata mean) is estimated for SSB, total abundance and biomass, and abundance by age.

For boarfish total abundance and biomass for the standing stock only will be calculated at this time due and will not be available by age due to the ongoing development of the age/length key.

3 Results

3.1.1 Boarfish abundance and distribution

The results presented here are a composite of data collected during this survey and on the northwest herring survey (RV *Celtic Explorer*). Both surveys were timed to link up and were carried out over 33 days from north (59°N) to south (47°30N). Both surveys used calibrated echosounders but no inter-vessel acoustic or fishing intercalibration exercises were carried out. Acoustic and biological data were compiled for both surveys to provide a picture of boarfish distribution throughout the range covered.

Twenty hauls were carried out during the boarfish survey of which 12 contained boarfish. A further four hauls from the C. Explorer survey yielded boarfish which were used during the analysis (Figure 2, Table 2). Combined over 4,500 lengths, 1,600 length/weight measurements were taken in addition to the 600 individual boarfish otiliths which were collected for aging.

3.1.2 Boarfish biomass and abundance

A full breakdown of the survey stock structure is presented by strata, age, length, biomass, abundance and area in Tables 4, 5 & 6 and Figures 3 & 4.

Boarfish	Millions*	Biomass (t)*	% contribution
Total estimate			
Definitely	9,322	520,985	86.4
Probably	1,495	82,024	13.6
Total estimate	**10817**	**603,009**	100
Possibly	79	3,510	
SSB Estimate			
Definelty	9,283	520,219	86.4
Probably	1,485	81,816	13.6
SSB estimate	**10768**	**602,035**	100

*Biomass derived using an gadiod TS to L conversion coefficient (-67.4dB)

3.1.3 Boarfish distribution

A full breakdown of school categorisation, number and biomass by ICES statistical rectangle is provided in Table 9.

During the survey boarfish shoals were primarily distributed along the shelf edge (Figure 2), which is in contrast to the on-shelf distribution of commercial catches. The commercial fishery for boarfish operates primarily during Q4 and Q1, with some landings during September (end of Q3). From 2007-2010 approximately 20% of Irish catches have been taken in each of two rectangles, 29E0 and 30E0 (Figure 2). During the acoustic survey these two rectangles accounted for a relatively small proportion of the total boarfish abundance (Table 9). Survey data compared to fishery data indicates seasonal spawning movements of boarfish from shelf seas to the shelf edge. The distribution of acoustic densities shows two main areas of concentration; one localised in the west of Ireland and another area stretching along the shelf edge in the southern Celtic Sea. Within these two areas clusters of numerous high density schools dominated. Outside of these areas boarfish were widely distributed and occurred mainly as numerous small schools of mixed medium and high density.

Along the west coast high density schools were located high in the water column within the first 50m subsurface (Figure 6b-c). In southern areas schools were observed closer to the bottom within 30-50m of the seafloor (Figure 6d-e). This may be related to hydrographic conditions along the western seaboard. Sea surface temperatures along the west coast as determined from moored weather buoys was in the order of 1.5°C lower than mean July temperatures and some of the lowest recorded at this time since buoy deployment in 2003 (Lyons *pers communication*). Waters along the west coast during this period were also described as weakly stratified. In the southern Celtic Sea, sea surface temperatures were again lower than average but most interestingly the depth of the thermocline increased greatly towards the shelf edge (Van Der Kooij, *pers communication*). This may account for the distribution of schools closer to the seabed in the southern areas. As boarfish are considered a southerly species that have extended their distribution northwards in recent years their distribution will likely be affected by temperature at the latitudes covered by this survey.

July is the peak of the spawning period as determined from histological analysis of catch samples. It can be inferred from distribution observed during the survey that movements to the shelf edge are part of an annual spawning pattern. During the survey all mature individuals were observed to be spawning i.e. in either a ripe or running state.

Very few immature (< 9.7 cm TL) boarfish we observed during the survey and those encountered formed part of larger aggregations of mature spawning fish at the shelf edge or to a lesser extent as aggregations occurring on shelf. Survey data did not indicate the presence of aggregations of juveniles or potential hotspots of juvenile distribution.

3.1.4 Boarfish age structure

An age length key compiled primarily from commercial samples collected during 2010 was applied during the analysis of survey data. The ALK is considered comprehensive covering a wide range of lengths (2.5-18cm) including those encountered during this survey (7.5-17.5cm). Age readings from this survey were not available during the analysis.

Age distribution as determined from survey samples indicate that the standing stock is dominated by the following age classes in terms of abundance: 6, 7, 20+ and 9 year old fish and 20+, 9, 7 and 10 years in terms of biomass respectively (Figure 3). Immature fish from 0-2 years were poorly represented in survey catches and this is consistent with a spawning movement of mature stock away from feeding grounds on the shelf. Juveniles are most frequently encountered during the IBTS surveys on the shelf.

3.2 Other pelagic species

3.2.1 Herring

Few herring registrations were observed during the survey and only two trawl samples yielded herring in the Celtic Sea (Table 2). No biomass or abundance calculation was made for this species.

A total of 357 herring were measured and 109 length and weights were recorded. The modal length of herring was 24.5cm (range 15.5-29.5cm) and mean weight was 123g.

The distribution of the herring catches and registrations was consistent with the distribution of summer feeding aggregations of the winter spawning component of the Celtic Sea herring stock (Haul 9, Table 2). The occurrence of a small amount of herring south of 50°N (haul 13, Table 2) is unusual this far south. The survey track covered areas which are known summer feeding grounds of the Celtic Sea stock, for example around the Kinsale gas rigs and Labadie Bank, but no large shoals were encountered. The absence of large feeding aggregations is not considered an indication of the absence of herring from the area but is nonetheless unusual considering the current size of the stock.

3.2.2 Horse mackerel

Horse mackerel were the encountered in 50% of survey hauls and were most frequently encountered in deeper waters often where boarfish were encountered, (>80m) Table 2. No biomass or abundance calculation was made for this species.

A total of 201 horse mackerel were measured and 341 length and weights were recorded. The modal length of horse mackerel was 30cm (range 18-39cm) and mean weight was 233g.

Horse mackerel registrations were widely spaced and in general in low density with the exception of 2 areas; one off the southwest coast of Ireland where two Dutch pelagic freezer trawlers reported moderate but consistent catches over several weeks and another area on the shelf edge north of 48°N an area associated with the horse mackerel fishery by Irish and Dutch vessels.

3.2.3 Mackerel

Mackerel were encountered in 9 of 20 trawls (Table 2). No biomass or abundance calculation was made for this species and reliable acoustically derived estimates of mackerel abundance are not possible at this time.

A total of 439 mackerel were measured and 265 length and weights were recorded. The modal lengths of mackerel occurred at 12cm and 34cm (range 11-40cm) and mean weight was 209g.

The distribution of the mackerel was widespread ranging from shelf seas to the shelf edge. Three hauls yielded high numbers of juvenile 0-group mackerel (11-13cm) and haul 15 in particular (Table 2) occurred in an area of high 0-group mackerel abundance. Outside of this large mature individual were well spread throughout the survey area as would be expected at this time during the feeding phase.

4 Discussion and conclusions

4.1 Discussion

Overall, the survey can be considered a success with all components of the work program completed as planned. A total of 97 hours was lost due to weather, mechanical and technical issues. The cruise track was adapted at sea to account for real time observations. Easterly extension in the southern Celtic Sea was reduced and effort was reallocated further south following the shelf edge, where the bulk of the stock was located.

A strong diurnal difference in behaviour was noted during the survey. Daytime behaviour being the most optimal for acoustic surveying due to the position of high density monospecific schools in the water column which were distinct from the heavy plankton layer. During the hours of darkness schools were not as easily seen having dispersed and migrated towards the seabed forming loose mixed species scattering layers. As a result acoustic detection was not considered as effective at night and so a daylight hours survey should be considered in the future. The day/night effect in terms of biomass detection was not considered to be very large as core areas were covered predominantly during daylight hours.

The stock was considered to be sufficiently contained within the survey area in the south but more so north. Communications with IFREMER scientists who carry out their annual PELGAS acoustic survey in the Bay of Biscay (mid May to mid June) reported only a single occurrence of boarfish on the shelf edge at 47°N. Geographical overlap was therefore achieved but with a temporal gap of over one month. A CEFAS acoustic survey in the Celtic Sea and Western approaches in mid June (48-51°N) also observed high density aggregations of boarfish along the shelf edge south around 50°N which is in agreement with the observations on this survey.

4.2 Conclusions

The availability of the boarfish to both acoustic detection and biological sampling was considered good. As a result it is expected that when a specific TS model is available, that this survey can be used as an abundance index in the assessment. This survey should therefore be treated as this first point in the development of a time series.

It is important to note that as no specific target strength to length relationship currently exists for boarfish, for the purposes of producing an interim abundance estimate an existing gadoid TS was applied in the interim. It was decided to use a gadoid TS coefficient for boarfish as it was considered the best available (Appendix 1). The estimates of biomass derived using the gadoid TS are should be treated with a high degree of caution as they are not species specific.

One of the components of this project is to determine a species specific TS for boarfish from acoustic data collected *in-situ* and also from theoretical TS modelling in the laboratory. Once a more robust TS in place then this can be retrospectively applied to survey data. As a result the abundance estimate calculated during this survey should take this into consideration which will no doubt change and maybe revised downwards when a more precise TS length relationship is applied.

4.3 Recommendations

The following recommendations are based on observations made during the survey and are provided as a means of improving the precision of future surveys.

- Boarfish detection by acoustic means at night is not considered as effective as during daylight hours and therefore future surveys should be conducted during daylight hours (04:00-23:00). Adopting methods currently used for herring surveys at this time of year.
- The use of a commercial sized trawl and brailer for routine survey sampling is not necessary and can in fact be limiting in terms of sample quality. It is recommended that a dedicated survey trawl be used or that a smaller brailer, for example a sprat brailer is used for future surveys to ensure the quality of samples.
- The timing of the survey should continue to be aligned with the northwest herring survey to extend the area coverage in the northern area and ensure northern containment of the stock.

Acknowledgements

We would like to express our thanks and gratitude to Peter Mogan (Captain) and crew of the FV *Felucca* for their good will and professionalism during the survey. The help and knowledge imparted during the survey was invaluable in helping to understand the behaviour of this species.

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Table 1. Survey settings and calibration report (38kHz) for the Simrad EK60 echosounder.

Echo Sounder System Calibration

Vessel :	F/V Felucca	Date :	19/6/2010
Echo sounder :	EK60 Tow Body	Locality :	Killybegs
Type of Sphere : CU 64	**TS**$_{Sphere}$: -33.50 dB (**Corrected for soundvelocity or t,S**)	Depth(Sea floor) :	16 m

Calibration Version 2.1.0.11

Comments:
05.07.11

Reference Target:

TS	-33.50 dB	Min. Distance	15.00 m
TS Deviation	5 dB	Max. Distance	25.00 m

Transducer: ES38B Serial No.

Frequency	38000 Hz	Beamtype	Split
Gain	26.50 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	7.10 deg	Along. Beam Angle	6.99 deg
Athw. Offset Angle	-0.07 deg	Along. Offset Angl	-0.15 deg
SaCorrection	-0.62 dB	Depth	3.00 m

Transceiver: GPT 38 kHz 009072033933 1 ES38B

Pulse Duration	1.024 ms	Sample Interval	0.190 m
Power	2000 W	Receiver Bandwidth	2.43 kHz

Sounder Type:
ER60 Version 2.2.0

TS Detection:

Min. Value	-50.0 dB	Min. Spacing	100 %
Max. Beam Comp.	6.0 dB	Min. Echolength	80 %
Max. Phase Dev.	8.0	Max. Echolength	180 %

Environment:

Absorption Coeff.	9.1 dB/km	Sound Velocity	1505.9 m/s

Beam Model results:

Transducer Gain =	26.21 dB	SaCorrection =	-0.62 dB
Athw. Beam Angle =	7.02 deg	Along. Beam Angle =	6.96 deg
Athw. Offset Angle =	0.07 deg	Along. Offset Angle=	-0.15 deg

Data deviation from beam model:
RMS = 0.11 dB
Max = 0.42 dB No. = 277 Athw. = -2.1 deg Along = 3.7 deg
Min = -0.45 dB No. = 76 Athw. = 1.8 deg Along = 4.8 deg

Data deviation from polynomial model:
RMS = 0.08 dB
Max = 0.37 dB No. = 277 Athw. = -2.1 deg Along = 3.7 deg
Min = -0.28 dB No. = 78 Athw. = -0.4 deg Along = 2.8 deg

Comments :
Flat calm conditions
Wind Force : 5 kn. **Wind Direction :** SW (270 degrees)
Raw Data File: C:\Program files\Simrad\Scientific\EK60\Data\Calibration 05.07.11
Calibration File: C:\Program files\Simrad\Scientific\EK60\Data\Calibration 05.07.12

Calibration : Ciaran O'Donnell

Table 2. Catch composition and position of hauls undertaken by the MFV *Felucca* (numbers 1-20) and for the Celtic Explorer (4-26).

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target btm (m)	Bulk Catch (Kg)	Boarfish %	Mackerel %	Herring %	H Mack %	Others^ %
1	10.07.11	52 40.23	013 32.96	09:11	310	100	2000.0	97.5	0.7		1.8	
2	11.07.11	53 39.00	011 46.75	08:26	282	70-90	2500.0	95.6	1.4		3.0	
3	11.07.11	53 39.06	011 15.15	11:42	184	0-50	1000.0	29.7	46.6		21.1	2.6
4	12.07.11	53 11.74	010 14.04	11:00	98	0-50	2500.0		0.8			98.2
5	12.07.11	52 55.72	010 34.00	15:19	108	15	1500.0					100.0
6	13.07.11	52 25.26	011 29.55	11:52	150	0-40	1500.0	14.4	48.1		37.4	
7	13.07.11	52 09.78	010 47.52	18:32	119	0-15	150.0					100.0
8	14.07.11	51 25.83	011 13.10	08:35	195	50-90	2500.0	90.9			9.1	
9	14.07.11	51 10.06	008 24.40	20:36	103	30	1500.0			88.8		11.2
10	15.07.11	50 55.60	009 47.65	11:33	122	0-25	500.0	91.2	6.9		3.0	
11	19.07.11	50 26.34	010 14.43	09:46	146	80	2500.0	97.0	0.4		2.6	
12	19.07.11	50 10.72	010 59.13	16:46	237	133	0.0					
13	20.07.11	49 55.29	008 31.02	11:51	130	0-40	500.0		7.7	2.0	17.8	72.6
14	21.07.11	49 26.00	008 08.84	15:10	125	80	2000.0	99.0			1.0	
15	22.07.11	49 26.03	010 48.71	07:51	155	50-70	2000.0		62.4			37.6
16	22.07.11	49 11.86	010 27.05	14:20	137	20-70	4000.0	100.0				
17	23.07.11	48 56.43	009 31.09	07:46	162	60-100	2000.0	100.0				
18	23.07.11	48 40.98	009 43.15	15:52	217	120	2000.0	100.0				
19	24.07.11	48 18.35	009 24.75	19:35	144	100	1500.0					100.0
20	25.07.11	47 57.05	007 34.87	12:47	191	100	1500.0	96.6				3.4
4*	23.06.11	58 1.433	008 46.30	05:25	158	152	114.2	70.2	6.3	29.8		
17*	30.06.11	55 45.381	008 49.42	07:25	108	103	1000.0	49.5	10.8	39.7		
19*	01.07.11	55 38.23	009 01.25	08:15	94	84	185.0	66.6	33.4		3.8	
26*	07.07.11	53 31.263	011 32.60	15:46	200	100	1500.0	100.0				

^ Includes non target pelagic/demersal species and other taxa

* Celtic Explorer Survey trawls

Table 3. Age length key compiled from commercial catch samples collected during 2010 (Hussy *et al*. 2011). This ALK was applied to boarfish samples collected during the survey.

Length (cm)	Age (years) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
4.5																				
5																				
5.5																				
6																				
6.5	0.75	0.25																		
7	0.63	0.38																		
7.5	0.57	0.43																		
8		0.83	0.17																	
8.5		0.74	0.26																	
9	0.06	0.39	0.50	0.06																
9.5		0.15	0.55	0.30																
10		0.03	0.19	0.53	0.22	0.03														
10.5		0.04	0.04	0.52	0.37	0.04														
11				0.35	0.41	0.19	0.05													
11.5			0.08	0.08	0.33	0.29	0.17	0.04												
12					0.12	0.56	0.12	0.20												
12.5				0.04	0.08	0.21	0.33		0.17	0.13	0.04									
13						0.15	0.15	0.20	0.20	0.10	0.05	0.05	0.05			0.05				
13.5							0.15	0.15	0.10	0.15	0.05	0.05	0.10		0.05	0.05			0.05	0.10
14									0.26	0.20	0.06	0.20		0.06		0.06				0.13
14.5							0.06		0.12	0.12		0.12	0.12	0.18				0.12		0.18
15										0.10				0.10	0.10		0.10	0.10		0.50
15.5										0.08	0.08	0.25		0.08		0.08			0.08	0.33
16																			0.33	0.67
16.5															0.16			0.16		0.67
17																	0.11	0.11		0.78
17.5																				1.00
18																				1.00
18.5																				
19																				
19.5																				
20																				

Table 4. Boarfish length at age (years) as abundance (millions) and biomass (000's tonnes).

Length (cm)	Age (years) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+	Abundance (millions)	Biomass (000s t)	Mn wt (g)
4.5																							
5																							
5.5																							
6																							
6.5																							
7																							
7.5	6.47	4.85																			11.33	0.12	10.6
8		0.18	0.04																		0.22		12.7
8.5		5.81	21.29	11.61																	38.71	0.8	20.6
9		0.94	5.61	15.9	6.55	0.94															29.93	0.71	23.9
9.5		3.11	3.11	43.5	31.07	3.11															83.9	2.3	27.4
10				45.46	52.45	24.48	6.99														129.37	4.05	31.3
10.5			41.36	41.36	165.9	145.5	86.71	20.93													501.81	17.82	35.5
11					129.2	602.8	129.2	215.3													1076.44	43.15	40.1
11.5				74.33	148.8	372.2	595.5		297.8	223.3	74.33										1786.35	80.45	45
12						261.5	261.5	348.7	348.7	174.3	87.17	87.17	87.17			87.17					1743.45	87.83	50.4
12.5							251.6	251.6	167.8	251.6	83.88	83.88	167.8		83.88	83.88			83.88	167.8	1677.55	94.13	56.1
13									319.7	243.5	73.78	243.5		73.78		73.78				159.9	1187.87	73.95	62.3
13.5							58.76		117.5	117.5		117.5	117.5	176.4				117.5		176.4	999.19	68.78	68.8
14										65.42				65.42	65.42		65.42	65.42		327.1	654.17	49.62	75.8
14.5										42.66	42.66	127.3		42.66		42.66			42.66	169.7	510.24	42.51	83.3
15																			81.46	163	244.41	22.3	91.2
15.5															17.55			17.55		72.39	107.48	10.71	99.7
16																	3.77	3.77		26.38	33.92	3.68	108.6
16.5																				0.87	0.87	0.1	118
17																							
17.5																							
18																							
18.5																							
19																							
19.5																							
20																							
TSN																					10,817.2		
TSB																						603.0	
SSN		5.87	57.16	217.7	529.6	1410	1390	836.5	1252	1118	361.8	659.3	372.5	358.3	166.8	287.5	69.19	204.3	208	1263	10,768.0		
SSB		0.142	1.828	7.711	20.31	60.13	66.63	41.06	68.39	64.73	20.59	42.95	21.89	25.25	11.42	17.25	5.371	15.21	15.69	95.5		602.0	
Mn wt (g)	10.6	18.9	29.8	34.7	38.2	42.6	47.9	49.1	54.6	57.9	56.9	65.1	58.8	70.5	68.4	60	77.6	74.5	75.5	75.6			
Mn L (cm)	7.8	9.3	11	11.6	12	12.5	13	13.1	13.6	13.9	13.8	14.4	13.9	14.9	14.7	14	15.4	15.1	15.1	15.2			

*Biomass derived using an gadiod TS to L conversion coefficient

Table 5. Boarfish biomass (000's tonnes) at age (years) by ICES statistical rectangle.

Strata	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+	Total
36D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36D8	0	0	0	0.3	0.8	3.2	4.4	3	4.9	4.6	1.5	3	1.6	1.7	0.9	1.3	0.4	1	1.3	6.9	40.5
36D6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2
35D8	0	0	0	0.2	0.5	2.1	3.2	2.1	4.3	4.4	1.4	3.4	1.5	2.2	0.9	1.3	0.5	1.4	1.3	8.5	39.2
35D7	0	0	0	0	0	0.2	0.3	0.2	0.4	0.4	0.1	0.3	0.1	0.2	0.1	0.1	0	0.1	0.1	0.7	3.2
35D6	0	0	0	0	0	0.2	0.2	0.2	0.4	0.4	0.1	0.3	0.1	0.2	0.1	0.1	0	0.1	0.1	0.7	3.2
35D5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.3
34D9	0	0	0	0	0.1	0.3	0.4	0.3	0.6	0.6	0.2	0.5	0.2	0.3	0.1	0.2	0.1	0.2	0.2	1.2	5.5
34D8	0	0	0	0.1	0.2	1	1.5	1	2	2.1	0.6	1.6	0.7	1	0.4	0.6	0.2	0.6	0.6	4	18.4
34D7	0	0	0	0	0.1	0.2	0.3	0.2	0.5	0.5	0.2	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.9	4.3
34D6	0	0	0	0	0	0.1	0.2	0.1	0.3	0.3	0.1	0.2	0.1	0.1	0	0.1	0	0.1	0.1	0.4	2.1
34D5	0	0	0	0	0.1	0.7	1.2	0.9	1.8	1.8	0.6	1.5	0.6	0.9	0.3	0.5	0.2	0.5	0.5	3.2	15.4
33D9	0	0	0	0	0	0.1	0.1	0.1	0.1	0.1	0	0.1	0	0	0	0	0	0	0	0.1	1.1
33D8	0	0	0	0.2	0.7	2.8	3.6	2.3	3.7	3.2	1	1.8	1.2	0.9	0.5	0.8	0.1	0.5	0.6	3.2	27.4
33D6	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0	0.1	0	0.1	0	0	0	0	0	0.2	1
33D5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
32D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
31D9	0	0	0	0.1	0.2	0.7	0.8	0.6	0.9	0.8	0.3	0.5	0.3	0.3	0.2	0.2	0.1	0.2	0.3	1.7	8.1
31D8	0	0	0	0.2	0.5	1.9	2.4	1.6	2.5	2.2	0.7	1.2	0.8	0.6	0.3	0.6	0.1	0.3	0.4	2.2	18.5
30D9	0	0	0	0	0.1	0.3	0.3	0.2	0.3	0.3	0.1	0.2	0.1	0.1	0.1	0.1	0	0.1	0.1	0.5	2.6
30D8	0	0	0	0.1	0.2	0.8	1	0.7	1	0.9	0.3	0.5	0.3	0.2	0.1	0.2	0	0.1	0.2	0.9	7.6
29D9	0	0	0	0.2	0.5	1.7	1.7	1.1	1.6	1.4	0.4	0.8	0.5	0.5	0.2	0.4	0.1	0.3	0.3	1.6	13.2
29D8	0	0	0.2	0.8	2.3	7.3	7	4.5	6.7	5.8	1.9	3.6	2	2	0.7	1.5	0.3	1.1	1.3	7	56
28D9	0	0	0	0	0	0.1	0.1	0.1	0.1	0.1	0	0.1	0	0	0	0	0	0	0	0.1	1.1
28D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27D9	0	0.1	0.4	1.3	3.8	10.1	9.2	4.7	6.6	5.3	1.8	2.3	1.4	0.9	0.7	1.2	0.1	0.7	0.4	3.7	54.7
27D8	0	0	0	0	0.1	0.2	0.2	0.1	0.1	0.1	0	0	0	0	0	0	0	0	0	0.1	0.9
26D9	0	0	0.1	0.2	0.6	1.5	1.4	0.7	1	0.8	0.3	0.4	0.2	0.2	0.1	0.2	0	0.1	0.1	0.6	8.5
27E4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26E4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25E4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27E3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26E3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25E3	0	0	0	0.2	0.7	2.4	3.1	2	4.2	4.5	1.3	3.5	1.5	2.3	0.9	1.2	0.6	1.3	1.4	8.6	39.7
31E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29E2	0	0	0.2	0.4	0.8	1.6	1.1	0.6	0.6	0.5	0.2	0.2	0.1	0.1	0.1	0.1	0	0.1	0.1	0.4	7.3
28E2	0	0	0	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0	0	0	0	0	0	0	0	0	0.1	1
27E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25E2	0	0	0	0.1	0.1	0.3	0.3	0.2	0.4	0.4	0.1	0.3	0.1	0.2	0.1	0.1	0	0.1	0.1	0.7	3.6
31E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28E1	0	0	0.2	0.4	0.8	1.6	1.1	0.6	0.6	0.5	0.2	0.2	0.1	0.1	0.1	0.1	0	0.1	0.1	0.4	7.2
27E1	0	0	0.2	0.5	1	2	1.4	0.8	0.8	0.6	0.2	0.2	0.2	0.1	0.1	0.1	0	0.1	0.1	0.5	9.1
26E1	0	0	0	0	0.1	0.2	0.2	0.1	0.1	0.1	0	0.1	0	0	0	0	0	0	0	0.1	1.3
25E1	0	0	0	0.1	0.3	0.9	1.2	0.8	1.6	1.7	0.5	1.3	0.6	0.8	0.3	0.5	0.2	0.5	0.5	3.1	14.9
31E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27E0	0	0	0.1	0.3	0.8	2.1	1.9	1	1.4	1.2	0.4	0.6	0.3	0.3	0.2	0.3	0	0.2	0.1	1	12.2
26E0	0	0	0.1	0.3	0.8	2.5	2.7	1.6	2.9	3	0.9	2.1	1	1.4	0.6	0.8	0.3	0.8	0.7	4.9	27.2
25E0	0	0	0	0.1	0.2	0.5	0.6	0.4	0.7	0.8	0.2	0.6	0.3	0.4	0.2	0.2	0.1	0.2	0.2	1.3	6.9
24E2	0	0.1	0.5	1.7	3.4	8.3	10.3	6.2	11.2	11.7	3.7	8.8	4.2	5.6	2.3	3.3	1.1	3.2	3.3	19.8	108.7
24E3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40E0	0	0	0	0	0	0.2	0.3	0.3	0.5	0.4	0.1	0.3	0.1	0.1	0.1	0.1	0	0.1	0.1	0.6	3.4
39E0	0	0	0	0	0	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0	0.1	0	0	0	0.3	1.6
39D9	0	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0.1	0.6
37D9	0	0	0	0	0.1	0.2	0.3	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0	0.1	0	0	0.1	0.3	2.2
36D8	0	0	0	0.1	0.3	1.4	2	1.4	2.6	2.6	0.8	1.9	0.9	1.2	0.5	0.7	0.3	0.7	0.8	4.7	23.2
40E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39E3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0.1	0.3	2.1	8	20.4	60.1	66.6	41.1	68.4	64.7	20.6	42.9	21.9	25.3	11.4	17.2	5.4	15.2	15.7	95.5	603
%	0	0	0.4	1.3	3.4	10	11.1	6.8	11.3	10.7	3.4	7.1	3.6	4.2	1.9	2.9	0.9	2.5	2.6	15.8	100

Table 6. Boarfish abundance (millions) at age (years) by ICES statistical rectangle.

Strata	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+	Total
36D9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36D8	0.0	0.0	0.9	7.0	19.6	72.4	88.5	58.4	89.1	79.4	26.2	45.9	28.0	23.5	12.7	21.7	5.1	13.3	17.0	90.9	699.5
36D6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35D9	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.2	0.3	0.3	0.1	0.2	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.5	2.6
35D8	0.0	0.0	0.7	3.6	11.6	46.8	63.1	41.8	77.0	73.2	23.0	51.2	25.0	30.8	13.2	20.2	6.8	18.2	16.3	109.9	632.6
35D7	0.0	0.0	0.1	0.3	0.9	3.8	5.1	3.4	6.2	5.9	1.9	4.1	2.0	2.5	1.1	1.6	0.6	1.5	1.3	8.9	51.0
35D6	0.0	0.0	0.0	0.2	0.7	3.4	4.8	3.4	6.6	6.2	2.0	4.5	2.1	2.6	1.0	1.8	0.5	1.4	1.4	8.8	51.4
35D5	0.0	0.0	0.0	0.0	0.1	0.3	0.5	0.4	0.7	0.6	0.2	0.5	0.2	0.3	0.1	0.2	0.1	0.1	0.1	0.9	5.3
34D9	0.0	0.0	0.1	0.5	1.6	6.5	8.8	5.8	10.7	10.2	3.2	7.1	3.5	4.3	1.8	2.8	1.0	2.5	2.3	15.3	88.2
34D8	0.0	0.0	0.3	1.7	5.4	22.0	29.6	19.6	36.1	34.3	10.8	24.0	11.7	14.4	6.2	9.5	3.2	8.6	7.7	51.5	296.7
34D7	0.0	0.0	0.1	0.4	1.3	5.1	6.9	4.6	8.4	8.0	2.5	5.6	2.7	3.4	1.4	2.2	0.7	2.0	1.8	12.0	69.1
34D6	0.0	0.0	0.0	0.1	0.5	2.3	3.2	2.3	4.4	4.2	1.3	3.1	1.4	1.8	0.7	1.2	0.3	0.9	0.9	5.9	34.5
34D5	0.0	0.0	0.1	1.0	3.4	16.2	22.9	16.6	31.6	30.0	9.4	21.9	10.2	12.6	4.9	8.5	2.5	6.7	6.7	42.2	247.4
33D9	0.0	0.0	0.0	0.2	0.7	2.5	2.9	1.8	2.7	2.3	0.8	1.2	0.8	0.5	0.3	0.6	0.1	0.3	0.3	1.8	19.8
33D8	0.0	0.0	0.8	6.0	17.9	63.7	73.4	46.6	68.7	58.1	19.0	29.3	20.9	12.7	7.7	15.0	1.7	6.9	8.6	44.6	501.7
33D6	0.0	0.0	0.0	0.1	0.2	1.1	1.5	1.1	2.1	2.0	0.6	1.4	0.7	0.8	0.3	0.6	0.2	0.4	0.4	2.8	16.2
33D5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32D9	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.4
32D8	0.0	0.0	0.0	0.0	0.1	0.3	0.3	0.2	0.3	0.3	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.2	2.4
31D9	0.0	0.2	0.4	1.7	5.1	16.1	17.5	11.1	15.8	14.0	4.6	7.6	5.0	3.7	2.8	3.7	0.9	2.9	3.7	20.7	137.5
31D8	0.0	0.0	0.5	4.1	12.1	43.0	49.5	31.5	46.4	39.2	12.8	19.8	14.1	8.6	5.2	10.1	1.1	4.7	5.8	30.2	338.8
30D9	0.0	0.0	0.1	0.6	1.8	5.9	6.2	4.0	5.6	4.9	1.6	2.6	1.7	1.2	0.8	1.3	0.2	0.8	1.1	5.8	46.3
30D8	0.0	0.0	0.2	1.7	5.0	17.7	20.4	13.0	19.1	16.2	5.3	8.2	5.8	3.5	2.1	4.2	0.5	1.9	2.4	12.4	139.7
29D9	0.5	0.4	1.2	4.9	13.8	40.4	35.1	22.2	29.6	24.3	8.1	13.3	8.3	6.7	2.5	6.2	1.0	3.5	4.2	21.9	248.0
29D8	2.0	1.7	5.1	20.8	58.4	171.0	148.6	94.0	125.4	103.1	34.2	56.5	35.0	28.3	10.4	26.3	4.3	14.9	17.7	92.9	1050.7
28D9	0.0	0.0	0.1	0.4	1.1	3.2	2.8	1.8	2.4	2.0	0.7	1.1	0.7	0.5	0.2	0.5	0.1	0.3	0.3	1.8	20.0
28D8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27D9	3.1	3.5	12.7	35.8	98.6	241.7	201.2	100.3	128.7	100.1	34.8	37.8	25.7	13.0	10.5	21.3	1.6	8.1	7.1	51.0	1136.9
27D8	0.1	0.1	0.2	0.6	1.7	4.1	3.4	1.7	2.2	1.7	0.6	0.6	0.4	0.2	0.2	0.4	0.0	0.1	0.1	0.9	19.5
26D9	0.5	0.5	1.9	5.3	14.6	36.0	30.1	15.1	19.7	15.5	5.3	6.1	4.1	2.3	1.7	3.3	0.3	1.4	1.2	8.8	173.8
27E4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26E4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25E4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27E3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26E3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25E3	0.0	0.1	1.0	5.9	17.4	55.2	61.6	40.9	72.3	73.6	21.9	51.7	25.0	32.6	13.5	19.3	7.5	18.4	17.5	112.8	648.1
31E2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30E2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29E2	0.0	1.1	5.8	14.1	22.7	40.3	25.9	14.0	12.7	9.5	3.4	3.1	2.3	1.1	0.9	1.9	0.2	0.8	1.2	5.6	166.6
28E2	0.0	0.1	0.8	1.9	3.1	5.4	3.5	1.9	1.7	1.3	0.5	0.4	0.3	0.2	0.1	0.3	0.0	0.1	0.2	0.8	22.5
27E2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26E2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25E2	0.0	0.1	0.6	1.7	3.1	6.5	7.0	4.2	6.7	6.5	2.1	4.4	2.3	2.6	1.1	1.7	0.5	1.5	1.4	8.7	62.8
31E1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30E1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29E1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28E1	0.0	1.1	5.7	14.0	22.6	40.1	25.8	14.0	12.6	9.5	3.4	3.0	2.3	1.1	0.9	1.9	0.2	0.8	1.2	5.6	165.8
27E1	0.0	1.3	7.2	17.6	28.4	50.5	32.4	17.6	15.9	12.0	4.2	3.8	2.9	1.4	1.1	2.4	0.3	1.0	1.4	7.1	208.6
26E1	0.0	0.0	0.2	0.9	2.1	4.9	4.1	2.0	2.7	2.2	0.7	1.0	0.6	0.6	0.3	0.5	0.1	0.4	0.2	1.6	25.0
25E1	0.0	0.1	0.9	3.3	7.9	22.1	24.4	15.8	27.3	27.5	8.3	19.1	9.4	11.9	5.0	7.2	2.6	6.7	6.4	40.9	246.9
31E0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30E0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29E0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28E0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27E0	0.4	0.5	2.4	8.2	21.1	50.6	42.3	20.8	27.6	21.9	7.5	9.0	5.9	4.0	2.4	4.6	0.6	2.5	1.6	13.5	247.5
26E0	0.0	0.1	1.8	8.6	22.0	58.2	56.3	32.5	52.5	49.9	15.3	31.3	16.1	19.2	8.2	12.2	4.2	11.1	9.5	64.8	473.8
25E0	0.0	0.2	0.9	2.8	5.1	11.8	12.8	7.8	12.8	12.6	3.9	8.6	4.4	5.2	2.2	3.3	1.0	2.9	2.8	17.5	118.7
24E2	0.0	3.7	18.1	52.4	91.9	196.1	211.4	125.3	201.2	195.9	62.3	131.2	69.7	78.5	33.3	52.0	14.2	44.1	43.3	262.1	1886.8
24E3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40E0	0.0	0.0	0.0	0.2	0.6	4.2	5.8	4.9	8.2	7.0	2.3	4.5	2.2	2.1	1.1	2.1	0.6	1.1	1.4	8.5	56.7
39E0	0.0	0.0	0.0	0.1	0.3	2.0	2.7	2.3	3.8	3.2	1.1	2.1	1.0	1.0	0.5	1.0	0.3	0.5	0.6	3.9	26.3
39D9	0.0	0.0	0.0	0.0	0.1	0.7	0.9	0.8	1.3	1.1	0.4	0.7	0.4	0.3	0.2	0.3	0.1	0.2	0.2	1.4	9.2
37D9	0.0	0.0	0.1	0.5	1.3	4.8	5.6	3.7	5.1	4.4	1.5	2.2	1.6	0.9	0.6	1.2	0.2	0.5	0.9	4.0	39.3
36D8	0.0	0.0	0.5	2.6	8.0	31.3	40.8	27.0	47.0	43.9	14.0	29.3	15.1	17.0	7.7	12.1	3.8	10.0	9.7	61.7	381.5
40E1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40E2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39E1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39E2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39E3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39E0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38E0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38E1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37E0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37E1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37D9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37D8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36D9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36D8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	6.5	14.9	71.4	232.2	534.0	1410.5	1390.3	836.5	1251.5	1118.4	361.8	659.3	372.5	358.2	166.8	287.5	69.2	204.3	208.0	1263.3	10817
%	0.1	0.1	0.7	2.1	4.9	13.0	12.9	7.7	11.6	10.3	3.3	6.1	3.4	3.3	1.5	2.7	0.6	1.9	1.9	11.7	100
Cv (%)	35.9	28.7	27.1	23.3	20.8	18.3	17.6	16.8	16.8	17.7	17.6	19.4	17.8	20.3	19.4	17.7	21.1	20.3	19.5	20.3	NA

Table 7. Boarfish biomass (000's tonnes) at maturity by ICES statistical rectangle.

Strata	Imm	Mature	Spent	Total
36D9	0	0	0	0
36D8	0	40.5	0	40.5
36D6	0	0	0	0
35D9	0	0.2	0	0.2
35D8	0	39.2	0	39.2
35D7	0	3.2	0	3.2
35D6	0	3.2	0	3.2
35D5	0	0.3	0	0.3
34D9	0	5.5	0	5.5
34D8	0	18.4	0	18.4
34D7	0	4.3	0	4.3
34D6	0	2.1	0	2.1
34D5	0	15.4	0	15.4
33D9	0	1.1	0	1.1
33D8	0	27.4	0	27.4
33D6	0	1	0	1
33D5	0	0	0	0
32D9	0	0.1	0	0.1
32D8	0	0.1	0	0.1
31D9	0	8.1	0	8.1
31D8	0	18.5	0	18.5
30D9	0	2.6	0	2.6
30D8	0	7.6	0	7.6
29D9	0	13.2	0	13.2
29D8	0.1	56	0	56
28D9	0	1.1	0	1.1
28D8	0	0	0	0
27D9	0.2	54.5	0	54.7
27D8	0	0.9	0	0.9
26D9	0	8.4	0	8.5
27E4	0	0	0	0
26E4	0	0	0	0
25E4	0	0	0	0
27E3	0	0	0	0
26E3	0	0	0	0
25E3	0	39.7	0	39.7
31E2	0	0	0	0
30E2	0	0	0	0
29E2	0.1	7.2	0	7.3
28E2	0	1	0	1
27E2	0	0	0	0
26E2	0	0	0	0
25E2	0	3.6	0	3.6
31E1	0	0	0	0
30E1	0	0	0	0
29E1	0	0	0	0
28E1	0.1	7.1	0	7.2
27E1	0.1	9	0	9.1
26E1	0	1.3	0	1.3
25E1	0	14.9	0	14.9
31E0	0	0	0	0
30E0	0	0	0	0
29E0	0	0	0	0
28E0	0	0	0	0
27E0	0	12.1	0	12.2
26E0	0	27.2	0	27.2
25E0	0	6.9	0	6.9
24E2	0.3	108.4	0	108.7
24E3	0	0	0	0
40E0	0	3.4	0	3.4
39E0	0	1.6	0	1.6
39D9	0	0.6	0	0.6
37D9	0	2.2	0	2.2
36D8	0	23.2	0	23.2
40E1	0	0	0	0
40E2	0	0	0	0
39E1	0	0	0	0
39E2	0	0	0	0
39E3	0	0	0	0
39E0	0	0	0	0
38E0	0	0	0	0
38E1	0	0	0	0
37E0	0	0	0	0
37E1	0	0	0	0
37D9	0	0	0	0
37D8	0	0	0	0
36D9	0	0	0	0
36D8	0	0	0	0
Total	1	602.0	0	603
%	0.2	99.8	0	100

Table 8. Boarfish abundance (millions) at maturity by ICES statistical rectangle.

Strata	Imm	Mature	Spent	Total
36D9	0.0	0.0	0	0.0
36D8	0.0	699.5	0	699.5
36D6	0.0	0.0	0	0.0
35D9	0.0	2.6	0	2.6
35D8	0.0	632.6	0	632.6
35D7	0.0	51.0	0	51.0
35D6	0.0	51.4	0	51.4
35D5	0.0	5.3	0	5.3
34D9	0.0	88.2	0	88.2
34D8	0.0	296.7	0	296.7
34D7	0.0	69.1	0	69.1
34D6	0.0	34.5	0	34.5
34D5	0.0	247.4	0	247.4
33D9	0.0	19.8	0	19.8
33D8	0.0	501.7	0	501.7
33D6	0.0	16.2	0	16.2
33D5	0.0	0.0	0	0.0
32D9	0.0	1.4	0	1.4
32D8	0.0	2.4	0	2.4
31D9	0.2	137.3	0	137.5
31D8	0.0	338.8	0	338.8
30D9	0.1	46.2	0	46.3
30D8	0.0	139.7	0	139.7
29D9	1.1	246.9	0	248.0
29D8	4.5	1046.2	0	1050.7
28D9	0.1	19.9	0	20.0
28D8	0.0	0.0	0	0.0
27D9	9.7	1127.1	0	1136.9
27D8	0.2	19.3	0	19.5
26D9	1.4	172.3	0	173.8
27E4	0.0	0.0	0.0	0.0
26E4	0.0	0.0	0.0	0.0
25E4	0.0	0.0	0.0	0.0
27E3	0.0	0.0	0.0	0.0
26E3	0.0	0.0	0.0	0.0
25E3	0.2	648.0	0	648.1
31E2	0.0	0.0	0	0.0
30E2	0.0	0.0	0	0.0
29E2	4.3	162.2	0	166.6
28E2	0.6	21.9	0	22.5
27E2	0.0	0.0	0	0.0
26E2	0.0	0.0	0	0.0
25E2	0.5	62.3	0	62.8
31E1	0.0	0.0	0	0.0
30E1	0.0	0.0	0	0.0
29E1	0.0	0.0	0	0.0
28E1	4.3	161.5	0	165.8
27E1	5.4	203.2	0	208.6
26E1	0.0	25.0	0	25.0
25E1	0.5	246.4	0	246.9
31E0	0.0	0.0	0	0.0
30E0	0.0	0.0	0	0.0
29E0	0.0	0.0	0	0.0
28E0	0.0	0.0	0	0.0
27E0	1.4	246.2	0	247.5
26E0	0.4	473.5	0	473.8
25E0	0.7	118.0	0	118.7
24E2	13.6	1873.2	0	1886.8
24E3	0.0	0.0	0	0.0
40E0	0.0	56.7	0	56.7
39E0	0.0	26.3	0	26.3
39D9	0.0	9.2	0	9.2
37D9	0.0	39.3	0	39.3
36D8	0.0	381.5	0	381.5
40E1	0.0	0.0	0	0.0
40E2	0.0	0.0	0	0.0
39E1	0.0	0.0	0	0.0
39E2	0.0	0.0	0	0.0
39E3	0.0	0.0	0	0.0
39E0	0.0	0.0	0	0.0
38E0	0.0	0.0	0	0.0
38E1	0.0	0.0	0	0.0
37E0	0.0	0.0	0	0.0
37E1	0.0	0.0	0	0.0
37D9	0.0	0.0	0	0.0
37D8	0.0	0.0	0	0.0
36D9	0.0	0.0	0	0.0
36D8	0.0	0.0	0	0.0
Total	49.1	10,768	0	10,817
%	0.5	99.5	0	100

Table 9. Boarfish biomass and abundance by ICES statistical rectangle.

Category Stratum	No. transects	No. schools	Def schools	Prob schools	% zeros	Def Biomass	Prob Biomass	Biomass (000't)	SSB (000't)	Abundance millions
36D9	1	0	0	0	100	0	0	0	0	0.0
36D8	1	71	71	0	0	40.5	0	40.5	40.5	699.5
36D6	1	0	0	0	100	0	0	0	0	0.0
35D9	2	4	0	4	50	0	0.2	0.2	0.2	2.6
35D8	2	88	77	11	0	36.8	2.4	39.2	39.2	632.6
35D7	2	7	4	3	50	1.6	1.6	3.2	3.2	51.0
35D6	2	27	0	27	50	0	3.2	3.2	3.2	51.4
35D5	2	1	0	1	50	0	0.3	0.3	0.3	5.3
34D9	2	6	1	5	0	4.7	0.8	5.5	5.5	88.2
34D8	2	31	27	4	50	12.1	6.3	18.4	18.4	296.7
34D7	2	6	6	0	50	4.3	0	4.3	4.3	69.1
34D6	2	8	8	0	0	2.1	0	2.1	2.1	34.5
34D5	2	15	6	9	0	2.2	13.2	15.4	15.4	247.4
33D9	2	12	12	0	50	1.1	0	1.1	1.1	19.8
33D8	2	50	50	0	0	27.4	0	27.4	27.4	501.7
33D6	1	2	1	1	0	0.4	0.6	1	1	16.2
33D5	1	0	0	0	100	0	0	0	0	0.0
32D9	2	2	0	2	0	0	0.1	0.1	0.1	1.4
32D8	2	2	0	2	50	0	0.1	0.1	0.1	2.4
31D9	2	16	12	4	0	5.9	2.1	8.1	8.1	137.5
31D8	2	15	15	0	0	18.5	0	18.5	18.5	338.8
30D9	2	9	9	0	0	2.6	0	2.6	2.6	46.3
30D8	1	4	4	0	0	7.6	0	7.6	7.6	139.7
29D9	2	27	27	0	0	13.2	0	13.2	13.2	248.0
29D8	1	6	6	0	0	56	0	56	56	1050.7
28D9	2	4	4	0	50	1.1	0	1.1	1.1	20.0
28D8	1	0	0	0	100	0	0	0	0	0.0
27D9	2	59	52	7	0	45.8	8.9	54.7	54.5	1136.9
27D8	2	2	0	2	50	0	0.9	0.9	0.9	19.5
26D9	2	20	4	16	0	2.1	6.4	8.5	8.4	173.8
27E4	0	0	0	0		0	0	0	0	0.0
26E4	0	0	0	0		0	0	0	0	0.0
25E4	0	0	0	0		0	0	0	0	0.0
27E3	0	0	0	0		0	0	0	0	0.0
26E3	0	0	0	0		0	0	0	0	0.0
25E3	2	35	15	20	50	31.5	8.2	39.7	39.7	648.1
31E2	1	0	0	0	100	0	0	0	0	0.0
30E2	2	0	0	0	100	0	0	0	0	0.0
29E2	2	1	0	1	50	0	7.3	7.3	7.2	166.6
28E2	2	5	5	0	50	1	0	1	1	22.5
27E2	1	0	0	0	100	0	0	0	0	0.0
26E2	2	0	0	0	100	0	0	0	0	0.0
25E2	2	26	8	18	50	1.5	2.2	3.6	3.6	62.8
31E1	1	0	0	0	100	0	0	0	0	0.0
30E1	2	0	0	0	100	0	0	0	0	0.0
29E1	2	0	0	0	100	0	0	0	0	0.0
28E1	2	36	17	19	0	4.3	2.9	7.2	7.1	165.8
27E1	2	17	17	0	50	9.1	0	9.1	9	208.6
26E1	2	4	4	0	50	1.3	0	1.3	1.3	25.0
25E1	2	38	29	9	50	9.4	5.5	14.9	14.9	246.9
31E0	1	0	0	0	100	0	0	0	0	0.0
30E0	2	0	0	0	100	0	0	0	0	0.0
29E0	2	0	0	0	100	0	0	0	0	0.0
28E0	2	0	0	0	100	0	0	0	0	0.0
27E0	2	18	11	7	0	9.2	2.9	12.2	12.1	247.5
26E0	2	61	59	2	0	27	0.2	27.2	27.2	473.8
25E0	2	21	4	17	0	1.8	5.2	6.9	6.9	118.7
24E2	2	68	57	11	50	108	0.7	108.7	108.4	1886.8
24E3	2	0	0	0	100	0	0	0	0	0.0
40E0	1	2	2	0	0	3.4	0	3.4	3.4	56.7
39E0	3	6	6	0	33	1.6	0	1.6	1.6	26.3
39D9	1	1	1	0	0	0.6	0	0.6	0.6	9.2
37D9	3	11	11	0	33	2.2	0	2.2	2.2	39.3
36D8	3	125	125	0	0	23.2	0	23.2	23.2	381.5
40E1	1	0	0	0	100	0	0	0	0	0.0
40E2	1	0	0	0	100	0	0	0	0	0.0
39E1	4	0	0	0	100	0	0	0	0	0.0
39E2	1	0	0	0	100	0	0	0	0	0.0
39E3	1	0	0	0	100	0	0	0	0	0.0
39E0	2	0	0	0	100	0	0	0	0	0.0
38E0	2	0	0	0	100	0	0	0	0	0.0
38E1	2	0	0	0	100	0	0	0	0	0.0
37E0	1	0	0	0	100	0	0	0	0	0.0
37E1	1	0	0	0	100	0	0	0	0	0.0
37D9	1	0	0	0	100	0	0	0	0	0.0
37D8	2	0	0	0	100	0	0	0	0	0.0
36D9	4	0	0	0	100	0	0	0	0	0.0
36D8	1	0	0	0	100	0	0	0	0	0.0
Total	131	969	767	202	52	521	82	603	602	10,817.2
Cv (%)	-	-	-	-	-	-	-	17.6	NA	17.6

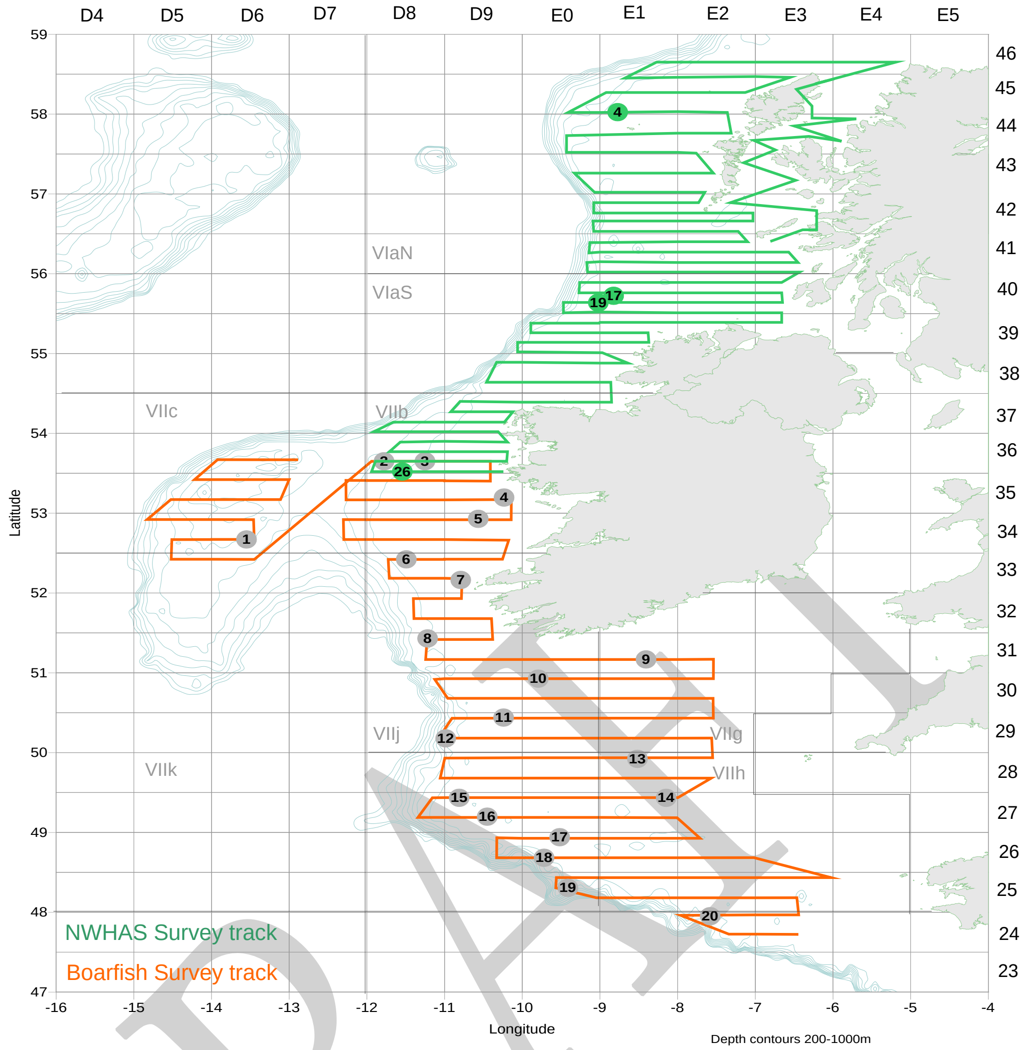


Figure 1. Cruise tracks and haul positions for the FV *Felucca* (orange) and RV *Celtic Explorer* (green). Note: Only hauls containing boarfish are shown for Celtic Explorer.

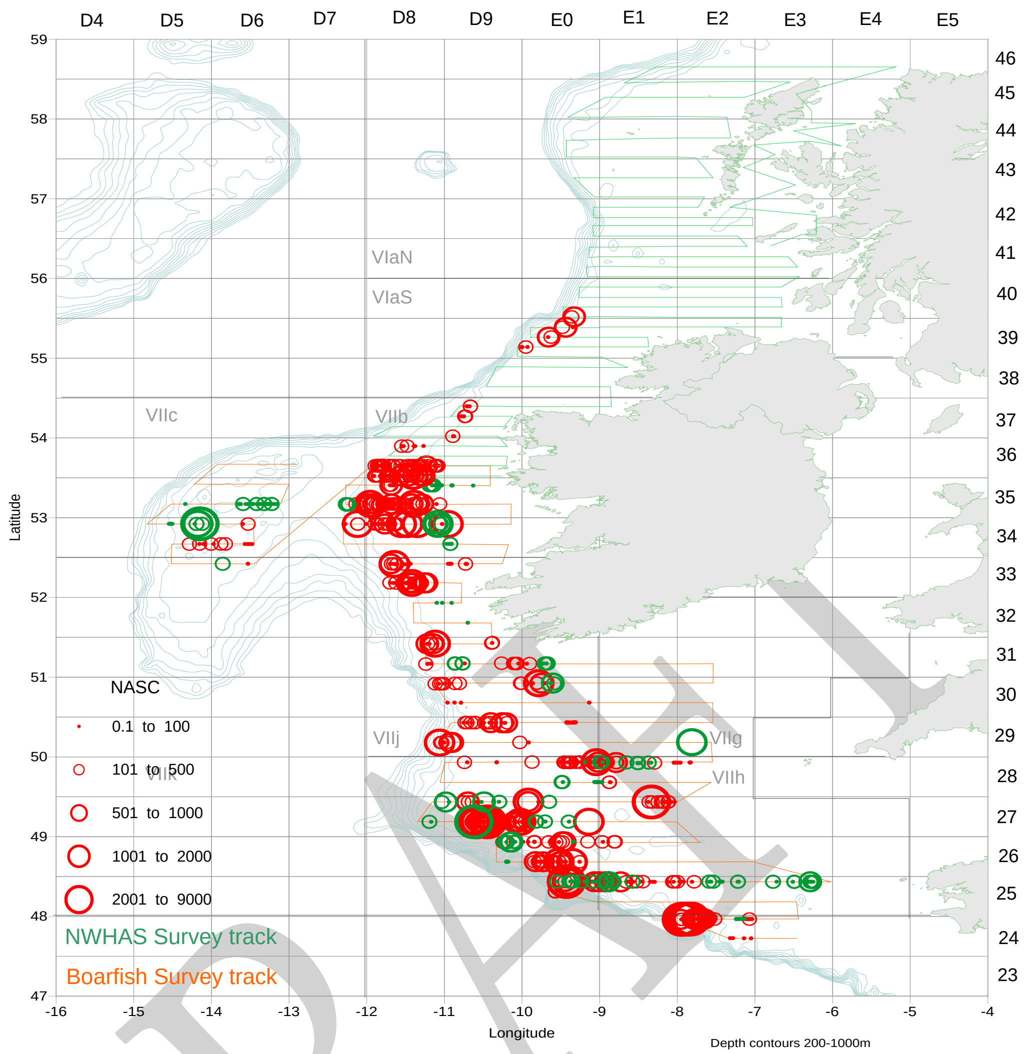
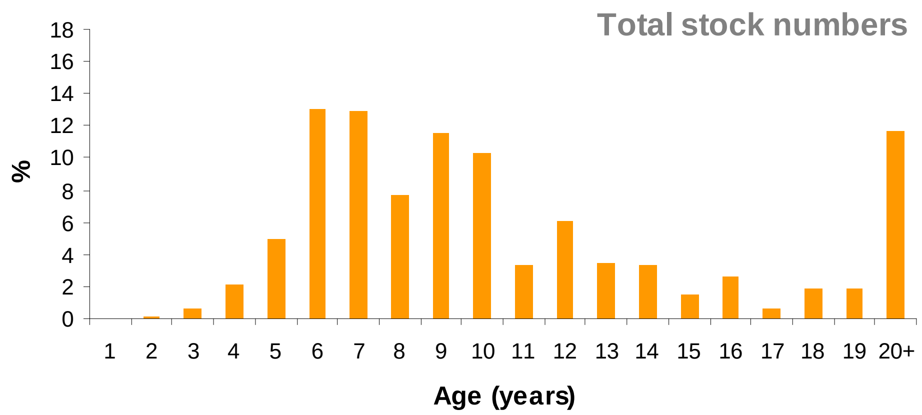


Figure 2. NASC plot of boarfish distribution. Circle size proportional to NASC value. Red circles represent 'definitely' boarfish category and green 'probably boarfish'.



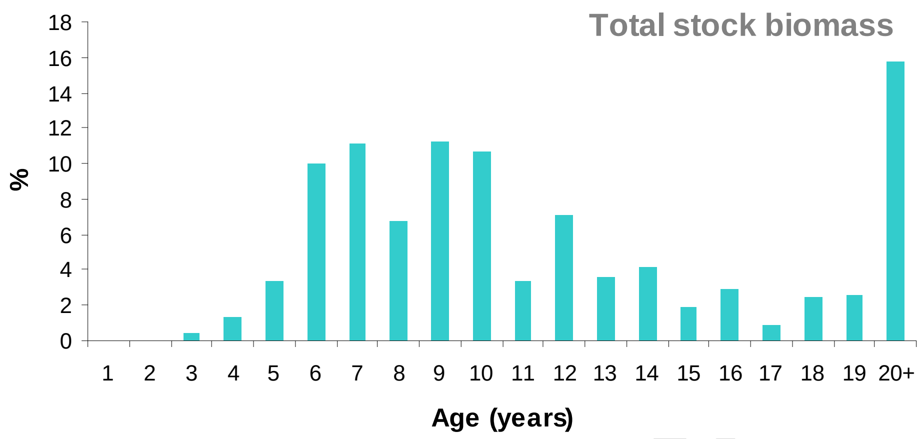
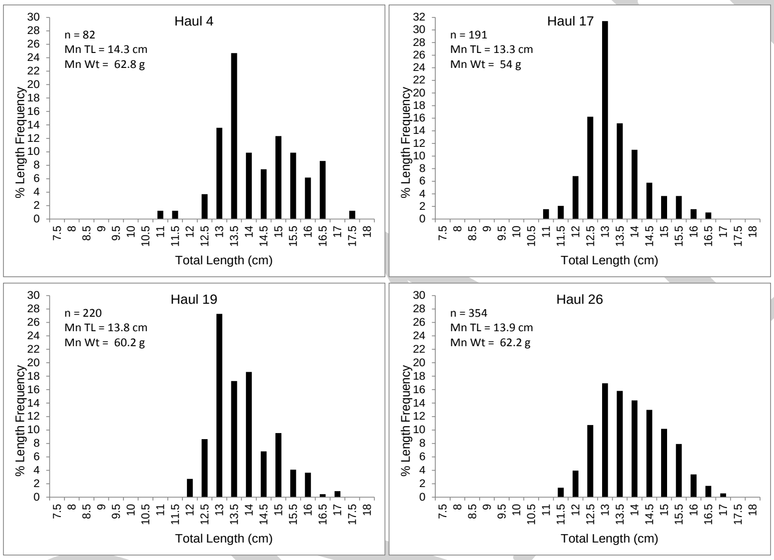


Figure 3. Percentage breakdown of TSN (top) and TSB (bottom) of survey stock.

Celtic Explorer Hauls



Boarfish Survey Hauls

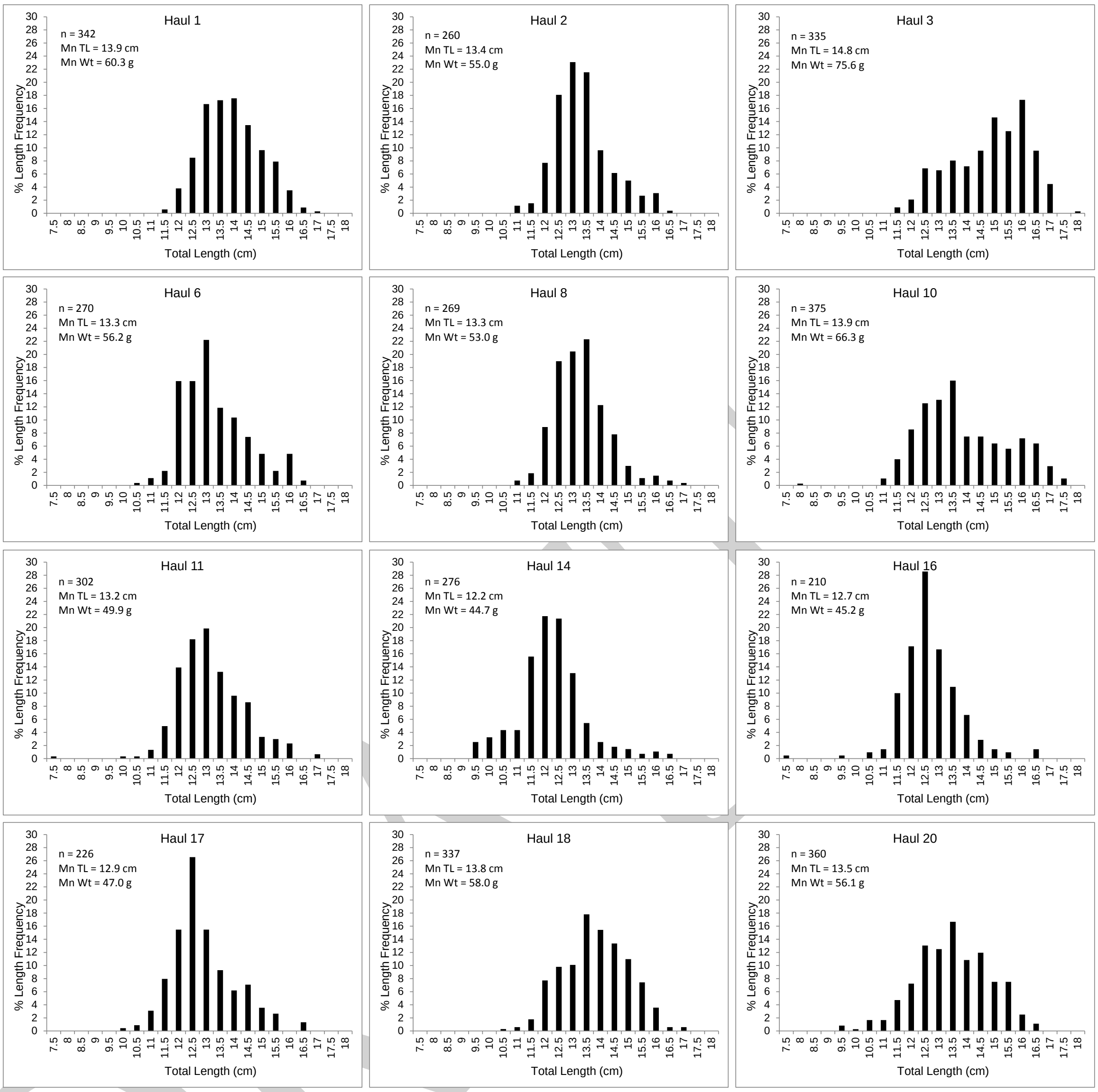
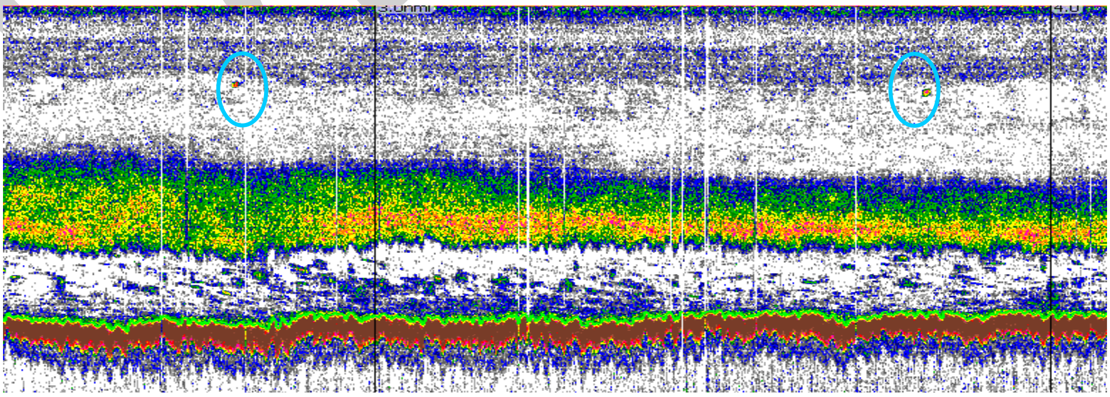
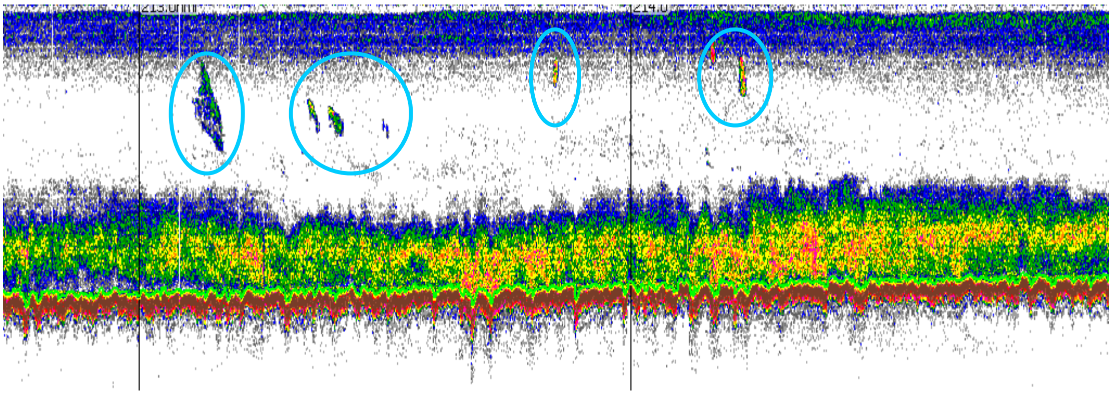


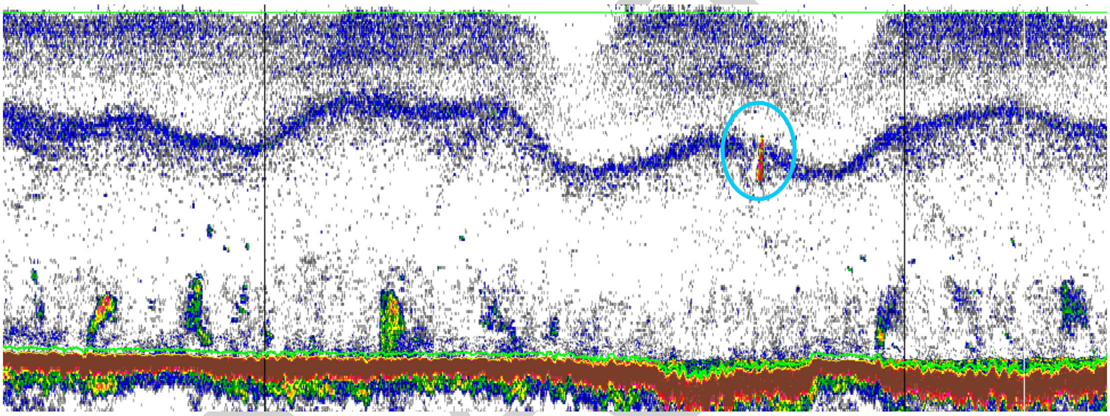
Figure 4. Percentage composition of boarfish by haul presented from north (58°N) to south (47°N).



a). *Porcupine Bank scattering layer recorded prior to* ***Haul 01****. Heavy plankton layer dominates the picture with small high density schools of boarfish occurring above this layer (circled) which were targeted during the trawl. Bottom depth is 300m with targets occurring at 100m.*

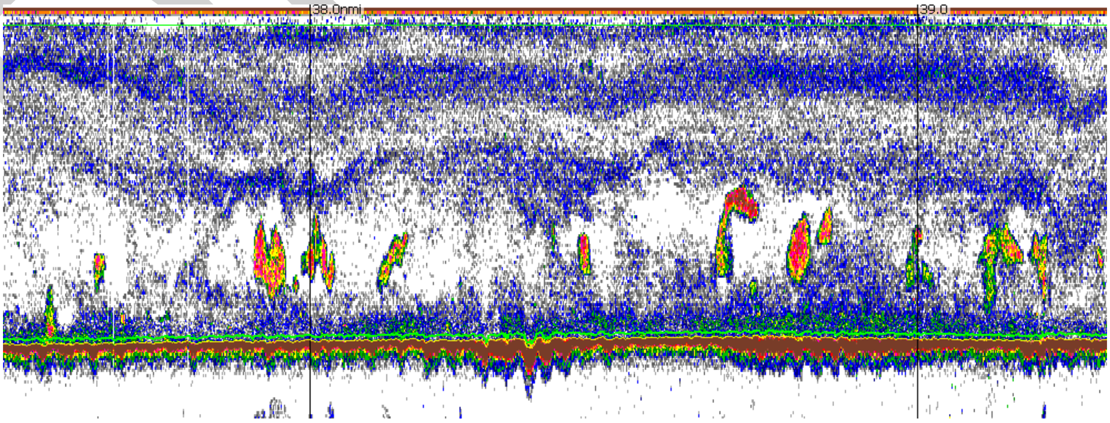


b). *High density bottom feeding layer containing boarfish and mackerel targeted during the trawl (**Haul 03**). Midwater boarfish schools (circled) clearly visible below the thermocline. This type of scattering layer was typical of those encountered between 53º-54ºNon shelf in area VIIb. Bottom depth is 184m with targets extending from 0-50m off the bottom.*

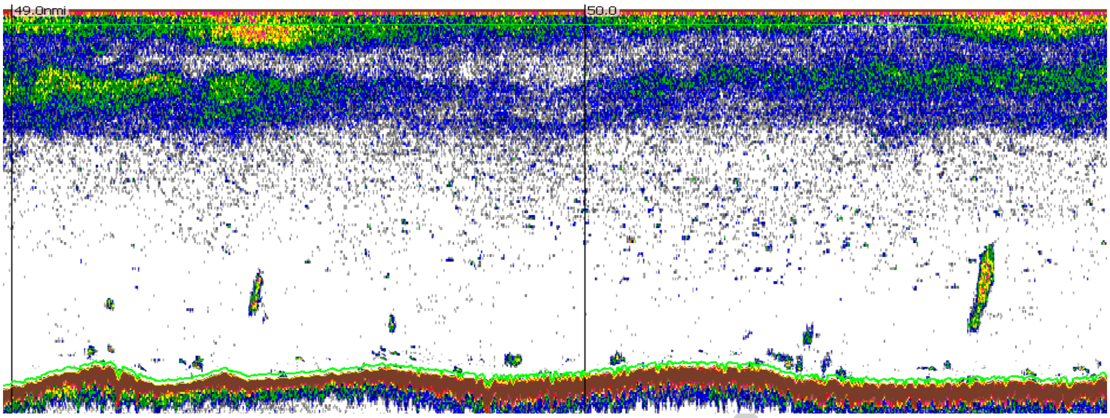


c). *Mixed bottom schools containing boarfish, mackerel and horse mackerel targeted during **Haul 06**. High density boarfish school present midwater (circled). Bottom depth is 150m with schools extending from 0-40m off the bottom.*

Figures 5a-c. Echotraces recorded prior to directed trawls. Boarfish survey, July 2011. Note: vertical bands on echograms represent 1nmi (nautical mile) intervals recorded at 38 kHz.



d). *High-density midwater boarfish schools encountered towards the shelf slope prior to **Haul 16** in an area of high boarfish abundance. Bottom depth is 137m with targets occurring 20-70m off the bottom.*



e). *High-density schools of boarfish close to the bottom, typical of those encountered along the shelf slopes south of 49ºN. Recorded prior to* ***Haul 20****, bottom depth is 191m with targets occurring 30-80m off the bottom.*

Figures 5a-d. continued.

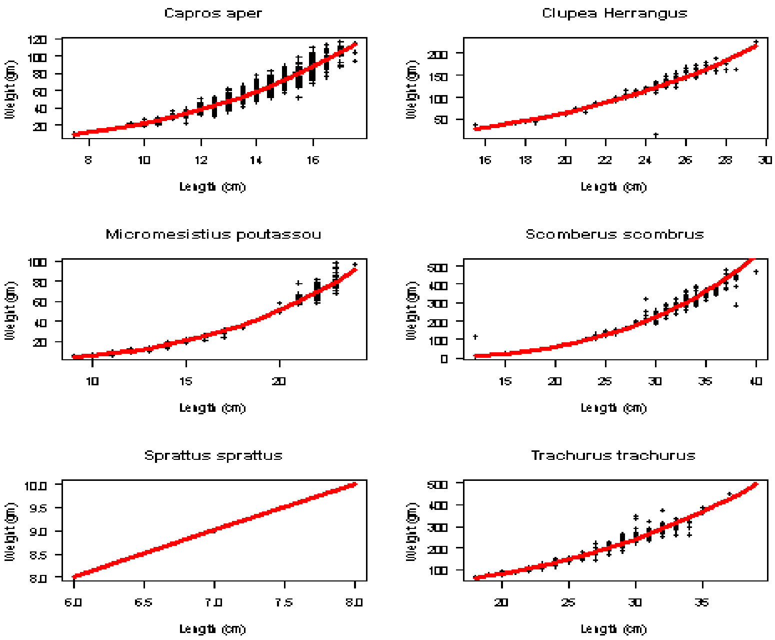


Figure 6. Length weight plots of major trawl component species used during the analysis.

Appendix 1

For fish with a gas filled swimbaldder including boarfish, the swimbladder itself may contribute up to 95% of the sound reflected sound energy (Foote 1908a). This considered the use of a species specific TS conversion coefficient is important to ensure an increased degree of precision for acoustic estimates. Boarfish are small, laterally compressed fish with a thick bony skull and thick dorsal and pectoral spines. These factors combined with the gas filled swimbladder present a complicated reflective surface for acoustic measurements. As a result the estimate of biomass and abundance are restrictive in terms of accuracy on a species level.

As no species specific target strength relationship exists for boarfish a number of scenarios are considered here. The final application of the gadoid TS coefficient presented in the report was the considered the best available from the literature as no species resemble boarfish either morpholometrically or taxonomically. When a species specific TS coefficient for boarfish becomes available it will be applied retrospectively to the survey data. A project is underway to determine a boarfish TS by means of *in situ* measurements and by theoretical modelling in the laboratory.

TS coefficients considered in this analysis were:

Gadoids TS = 20logL – 67.4 dB per individual (L = length in cm)

Herring TS = 20logL – 71.2 dB per individual (L = length in cm)

Snipefish TS = 20logL – 80.0 dB per individual (L = length in cm)

Herring was considered during the calculations as a generic, almost default TS value for pelagics (Table 1). In realty herring are not suitable as they are a physostomous species, with an open or vented swimbladder connected via the oesophagus. Snipefish were considered as they are similar in body shape and structure as described by (Carrera, 2001). However, the TS coefficient presented by Carrera is based on a non-swimbladder fish. In terms of precision, estimates by acoustic means for non-swimbladdered fish is not considered reliable, as is well documented in the case of mackerel (Table 2). The generic gadoid TS chosen in this study and determined by Foote (1980a) and is well documented (Table 3). Gadoids although very different in shape are physoclyists (closed swimbladder).

Table 1. Biomass and abundance of boarfish as determined by application of a gadoid TS.

Boarfish	Millions	Biomass (t)*	% contribution
Total estimate			
Definitely	9,322	520,985	86.4
Probably	1,495	82,024	13.6
Total estimate	**10817**	**603,009**	100
Possibly	79	3,510	
SSB Estimate			
Definelty	9,283	520,219	86.4
Probably	1,485	81,816	13.6
SSB estimate	**10768**	**602,035**	100

*Biomass derived using an gadiod TS to L conversion coefficient (-67.4dB)

Table 2. Biomass and abundance of boarfish as determined by application of a herring TS.

Boarfish	Millions	Biomass (t)	% contribution
Total estimate			
Definitely	22,363	1,249,756	86.4
Probably	3,586	196,763	13.6
Total estimate	**25949**	**1,446,519**	100
Possibly	189	8,419	
SSB Estimate			
Definelty	22,269	1,247,919	86.4
Probably	3,562	196,262	13.6
SSB estimate	**25831**	**1,444,181**	100

*Biomass derived using an herring TS to L conversion coefficient (-71.2dB)

Table 3. Biomass and abundance of boarfish as determined by application of a snipe-fish TS.

Boarfish	Millions	Biomass (t)	% contribution
Total estimate			
Definitely	169,639	9,480,367	86.4
Probably	27,202	1,492,597	13.6
Total estimate	**196841**	**10,972,964**	100
Possibly	1434	63865	
SSB Estimate			
Definelty	168,928	9,466,436	86.4
Probably	27,018	1,488,798	13.6
SSB estimate	**195946**	**10,955,234**	100

*Biomass derived using an snipefish TS to L conversion coefficient (-80.0dB)

Appendix 2

Details of the charter vessel and tow body set up used during the survey.

Figure 1. FV *Felucca* (SO 108). 54m LOA

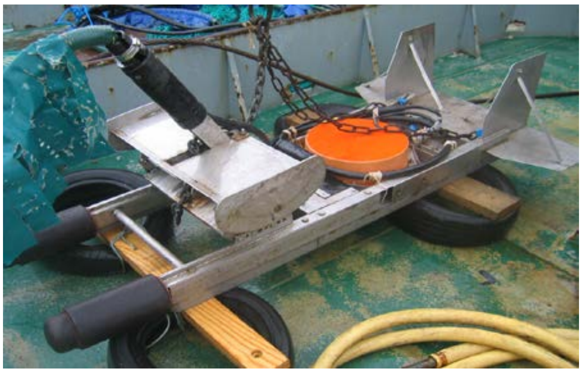


Figure 2. Tow sled with 38 kHz split beam transducer (orange centre screen).

Figure 3. Towing boom c.3m long, with support stays.

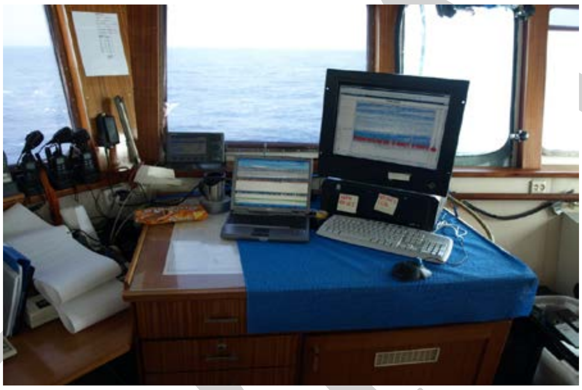


Figure 4. Top side monitoring station located on the bridge. Laptop (left) running Echoview and EK60 topside PC unit (right).

Annex 6: Terms of Reference 2011

2010/2/SSGESST00 The **Working Group on Northeast Atlantic Pelagic Ecosystem Surveys** (WGNAPES), chaired by Ciaran O'Donnell, Ireland, will meet in Kaliningrad, Russian Federation from 16–19 August 2011 to:

g) critically evaluate the surveys carried out in 2011 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;

h) review the 2011 survey data and provide the following data for the Working Group for Widely Distributed Stocks (WGWIDE):

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

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

x) hydrographic and zooplankton conditions for ecological considerations.

xi) aerial distribution of such pelagic species such as mackerel.

i) 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;

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

xii) plan and coordinate the surveys on the pelagic resources and the environment in the North-East Atlantic in 2012 including the following:

xiii) the international acoustic survey covering the main spawning grounds of blue whiting in March-April 2012.

xiv) the international coordinated survey on Norwegian spring-spawning herring, blue whiting and environmental data in May-June 2012.

xv) national investigations on pelagic fish and the environment in June-August 2012.

WGNAPES will report by 1 September 2011 (via SSGESST) 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, WGNAPES
Linkages to other Organisations	None

Annex 7: Recommendations

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

Recommendation	For follow up by:
1. This year, the temporal and spatial coverage of the stock during the IBWSS were much improved providing a higher quality stock estimate compared to 2010. In light of this WGNAPES recommends the exclusion of the 2010 survey estimate as the survey is considered incomplete when compared to this years and the previous years of the time series. The 2010 estimate was put forward as the best option from the available survey data.	WGWIDE
2. 1.Developemnt of standardised set of survey methods for the mackerle/trawl acoustic surveys in the Norwegian Sea. Methods should be developed in association with WGIPS and with input from WGWIDE. Once complete these methods should be included in the updated survey manual.	Participant countries
3. The group recommends that a dedicated blue whiting survey workshop [Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES)] be held from the 23-26 January 2012 at ICES HQ to re-evaluate the survey indices in light of the new length to target strength relationship in readiness for the species benchmark meeting in February.	Participant countries
4. The group recommends that a dedicated workshop on age reading is required for both herring and blue whiting to address discrepancies across nations highlighted for blue whiting during the EFAN otilith exchange program 2010 and during the May survey.	Participants institutes
7. WGNAPES recommends that until such a time that a fully functioning crossover database is in place within the ICES datacenter that the systems currently in place within WGNAPES (WGNAPES survey database) be maintained.	WGDIM, WGIPS, ICES datacenter

Annex 8: Terms of reference WKTSBLUES

WORKSHOP ON IMPLEMENTING A NEW TS RELATIONSHIP FOR BLUE WHITING ABUNDANCE ESTIMATES

The **Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES)**, chaired by Ciaran O'Donnell, Ireland, will be established for a single meeting and will meet in ICES, Copenhagen, 23–26 January 2012 to:

k) Review and implement the new target strength (TS) length relationship for blue whiting to the exisiting survey spawning stock abundance indices;

l) Review and evaluate the survey methods and design in readiness for the upcoming blue whiting stock benchmark (WKBENCH)

WKTSBLUES will report by the 3 February for the attention of the WKBENCH and WGWIDE.

Supporting information

Priority	The aim of the workshop is to implement a species specific TS relationship f blue whiting. The implementation will directly influence the survey abundan index and its use as the tuning series for this stock. Consequently, these activiti are considered to have a very high priority for the upcoming stock benchmark.
Scientific justification	Term of Reference a) *In situ* target strength measurements have been undertaken over serveral years during the IBWSS to formulate a species specific TS conversion coefficient not presently available. The current TS coeffcient is not species specific and so implementing the new TS will increase precision in acoustic abundance estimates. Term of Reference b) The implementation of the new TS conversion coefficient will coincide with the benchmarking of this species in early 2012 (WKBENCH). Currently the acoustic survey time series are considerably higher than those based on catch and are therefore overestimating the number of fish in the stock.
Resource requirements	The research into the species specfic TS has been undertaken over several years during the IBWSS program. Time commitments for those invovled in the data handling and processing have been secured and preparations are underway.
Participants	The Workshop will be attended by survey scientists from the IBWSS.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	ACOM
Linkages to other committees or groups	This work is relevant to the WKBENCH, WGWIDE and WGIPS.
Linkages to other organizations	None.